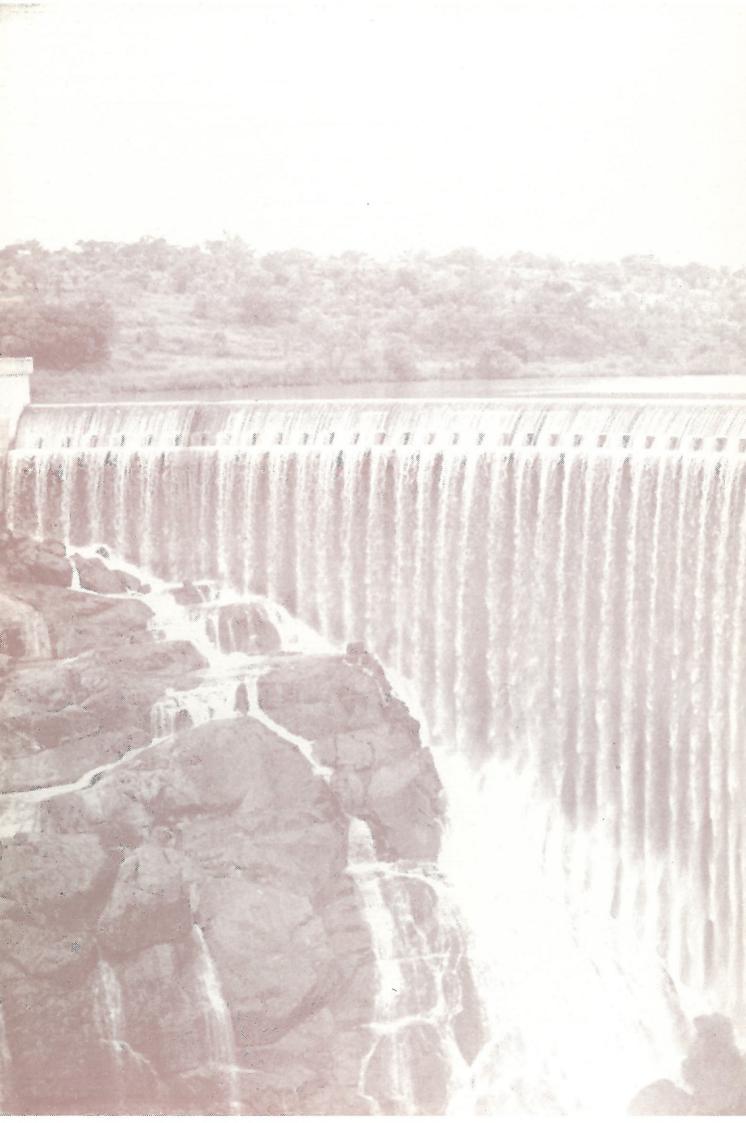
Management of the WATER RESOURCES of the Republic of SOUTH AFRICA







Department of Water Affairs



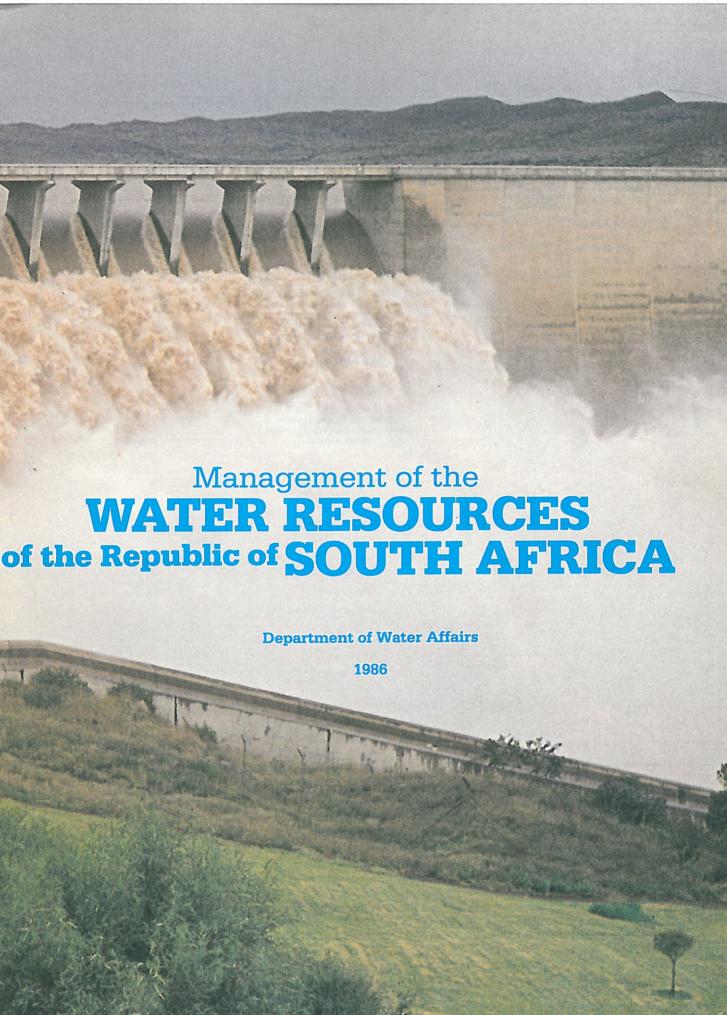
Management of the WATER RESOURCES of the Republic of SOUTH AFRICA



Department of Water Affairs

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Cover : The Blyderiverspoort Dam on the Blyde River near Hoedspruit, eastern Transvaal

Endpapers: The Roodeplaat Dam on the Pienaars River near Pretoria

Title pages: The Hendrik Verwoerd Dam on the Orange River

Preface : The Blyderivierspoort Dam on the Blyde River near Hoedspruit, eastern Transvaal

Chapter 1 : The Hartebeespoort Dam near Brits, Transvaal

Chapter 2 : Irrigated citrus orchards in the Sundays River valley, eastern Cape Chapter 3 : An irrigation canal in the Sundays River valley, eastern Cape

Chapter 4 : The Ingangwana River near Coleford, Natal

Chapter 5 : The Vaal Dam, the main source of water for the PWV area

Chapter 6: The White Mfolozi River at the Ulundi-Melmoth road bridge during the Domoina floods in 1984

Chapter 7 : Water hyacinth accumulated at the spillway gates on Hartebeespoort Dam Chapter 8 : The Beervlei Dam on the Groot River near Willowmore, Cape Province

Chapter 9 : The Kogelberg Dam on the Palmiet River near Grabouw, southern Cape Province

 ${\it Chapter~10:}~{\it The~Roode~Els~Berg~Dam~on~the~Sanddrifskloof~River~near~Worcester,~southern~Cape~Province}$

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Abbreviations and Units

Abbreviations

CP Cape Province

CSIR Council for Scientific and Industrial Research

DWA Department of Water Affairs EC Electrical conductivity

EDP Economic Development Programme EIA **Environmental Impact Assessment** Escom **Electricity Supply Commission** GDP Gross Domestic Product

GIS Geographic Information System

GNP Gross National Product

HSRC Human Sciences Research Council ICOLD International Commission on Large Dams IHP International Hydrological Programme

ISER Institute for Social and Economic Research, University of the Orange Free State

IWSA International Water Supply Association

MAR Mean annual runoff

NIWR National Institute for Water Research, CSIR NPDP National Physical Development Plan

Ntl Natal

OFS Orange Free State

PWV Pretoria-Witwatersrand-Vereeniging RDAC Regional Development Advisory Committee

RSA Republic of South Africa RSC Regional Services Council **RWB** Rand Water Board

SABS South African Bureau of Standards TRVC Transkei, Bophuthatswana, Venda, Ciskei

TDS Total dissolved solids

Tvl Transvaal

United Nations Organization UN USA United States of America VIP Ventilated improved pit WRC Water Research Commission

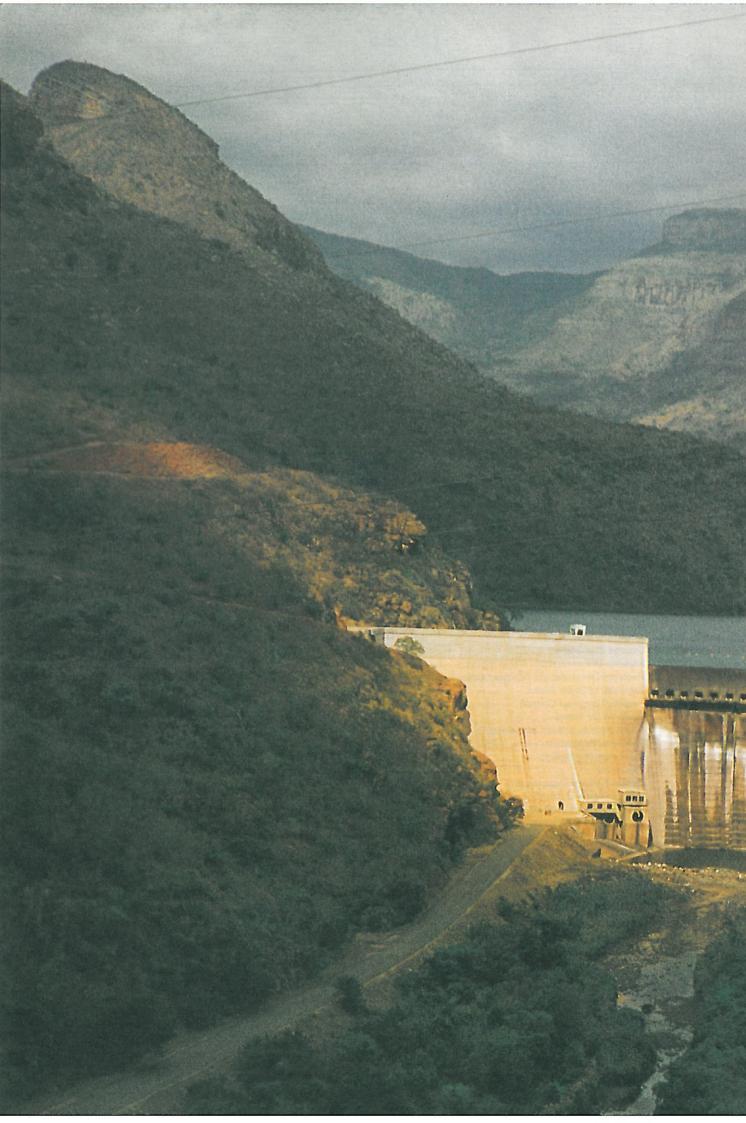
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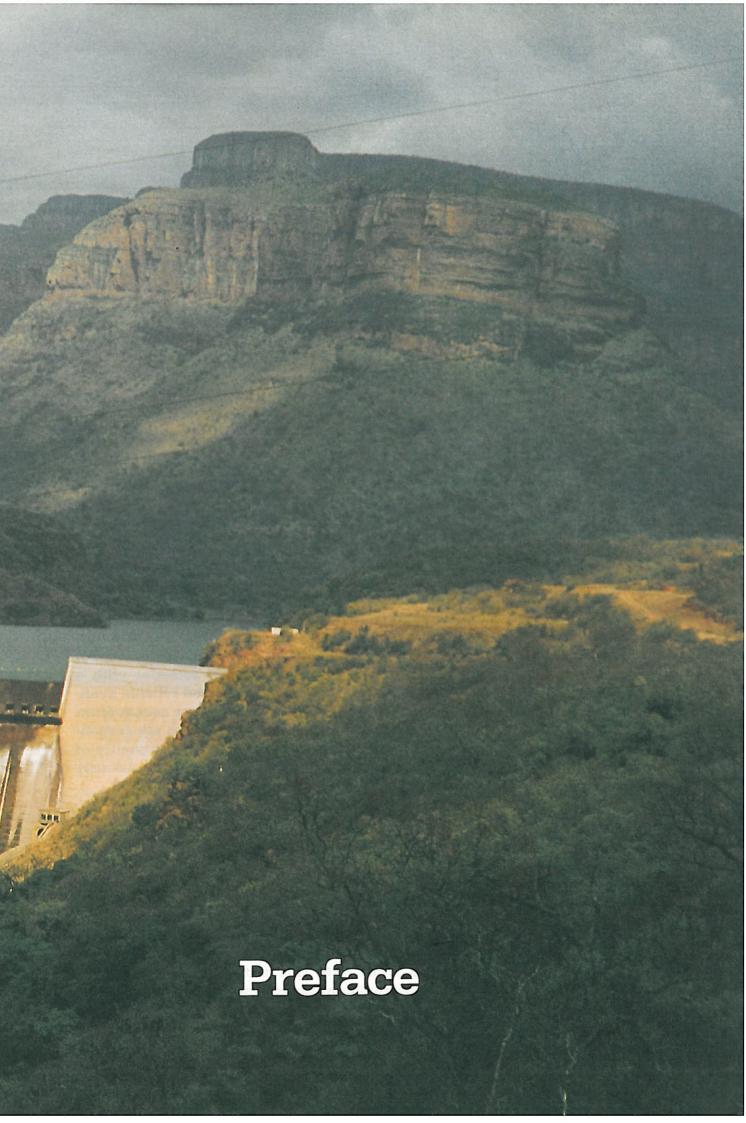
a d	annum day	m³/d m³/t	cubic metre per day cubic metre per tonne
ha	hectare	mg	milligram
km	kilometre	mg/ℓ	milligram per litre
km ²	square kilometre	mm	millimetre
ℓ	litre	s	second
ℓ/m^2	litre per square metre	mS/m	millisiemens per metre

litre per square metre mS/m m tonne

 m^2 square metre t/km²/a tonne per square kilometre per annum

 m^3 cubic metre $\mu g/\ell$ micrograms per litre m3/a cubic metre per annum





Preface

'When we build, let us think that we build for ever. Let it not be for present delight, nor for present use alone; let it be such work as our descendants will thank us for.'

John Ruskin

Water is essential to life, to social development and to economic progress. Its value is well appreciated in undeveloped communities, where many individuals experience the tedium of bearing heavy burdens of water, possibly of dubious quality, over long distances to meet their basic needs. Yet in developed societies with a higher quality of life, the convenient and reliable availability of relatively cheap, purified water seems often to be taken for granted. Should those who are responsible for its supply fail in their mission, the quality of life will deteriorate and development will be seriously impaired.

In the Republic of South Africa (RSA), the increasing demand for water arising from the growth of the population and the economy has to be met from limited resources that have to be shared by competing user groups and by other states. Within these limitations, the joint utilization of the available water and the affordable waterworks will best be achieved when users appreciate the complexity of water resource development in the RSA. This publication is aimed at increasing awareness of water management issues so as to promote an effective partnership between water users and the Department of Water Affairs (DWA).

Water is a public commodity and the actions of users and polluters generally affect others. Because the water resources of the RSA are shared with other countries and as water will have to be transferred between drainage areas to an increasing extent, only the Central Government is able to exercise overall control. The powers necessary for this control are therefore vested in the Minister of Water Affairs by the Water Act, 1956 (Act 54 of 1956), as amended.

The DWA's mission, as embodied in the Water Act, 1956, and in the recommendations of the Commission of Enquiry into Water Matters, which were accepted as Government policy in 1970, is expressed in the form of a flexible national water management strategy in which the effective management of supply, demand and quality are key elements. The DWA views its function as that of being the custodian of a limited national resource in a society with a growing, diversified and competitive economy. Its major goal is to ensure the ongoing, equitable provision of adequate quantities and qualities of water to all competing users at acceptable degrees of risk and cost under changing conditions. This will be accomplished by the judicious management and conservation of the available resources in consultation with all user groups, even across international boundaries, so as to maximize their collective utility. A climate of understanding needs to be maintained in which each user group can be coerced to accommodate the changing needs of others. In its public sector role as custodian within a system of free enterprise, the DWA's powers are used sparingly and as much autonomy as is practicable is devolved upon the non-central Government sector, particularly where interests are regional rather than national in nature.

While the DWA's activities are strongly oriented towards the public sector duties of planning and control, they also entail the optimal development and management of the national bulk water supply infrastructure, particularly in those areas, comprising more than three quarters of the country, where international and interregional transfers of water are or will be required. Unlike a rigid master water development plan, which would not be able to meet the unpredictable but reasonable demands of an expanding private sector effectively, the essential features of the national water management strategy are flexibility and resourcefulness. The DWA is keenly aware that, as success or failure in its role affects the fortunes of the private sector and the quality of life of the nation, it is essential to maintain an effective partnership with users. The public is accordingly being in-

Strategy

creasingly involved in the planning process through bodies such as the regional development advisory committees. The water management strategy is also of particular importance in international negotiations concerning the joint utilization of water resources of common interest.

In water resource management the effects of poor decisions may only become apparent decades later — perhaps to a new generation. Unfortunately, the potential for harm can build up quietly and unnoticed over a long period and a crisis could be precipitated by some climatic event that may not be unusual in itself, but may prove critical in an unfavourable combination with other prevailing factors. Accordingly, increasing co-operation between the public and the professionals in the field of water resource management is essential to sharpen collective discretion in selecting and synthesizing alternatives. The DWA trusts that the growing mutual contemplation and probing of the technical aspects as well as the social values and goals related to planning and development will be found to be a profitable learning experience.

The growing demand placed on water resources gives rise to increasingly complex problems in water management. As the costs and complexities of bringing water across greater distances and heights increase, and as the risks of undersupply from river systems approaching their yield limits rise, investigations need to be done in greater detail and to higher standards than were warranted in the past. Such investigations, which are often innovative, range from studies of how to achieve the best joint international utilization of water in common drainage basins to studies on the management of water of deteriorating quality. The formulation of optimal operating strategies for country-wide systems of facilities that have been linked or may ultimately have to be linked now forms part of the planning process. Another aspect of modern system design is the evolution of allocation and pricing structures in co-operation with hierarchies of user groups. While some users may elect to pay higher prices to reduce their risk of undersupply, others may accept greater risks of undersupply at lower cost as an economic choice. Associated with allocation and pricing structures are supply priorities which must be determined for each user group, including the provision of water for the basic human needs of people at lower levels of socioeconomic development.

Drought management

The drought that commenced in 1978, often referred to in this publication as the *recent drought*, has still not broken in some parts of the country. Long droughts not only hold serious consequences for the economy but also have a depressing effect on morale. The imposition and orchestration of severe water restrictions to counter the effects of droughts is a matter of grave concern to the DWA. Within the requirement of providing a climate in which the private sector may prosper and the quality of life may improve, the DWA's apparent emphasis on demand management techniques, including the recycling of water and restrictions on use, rather than on supply management, which increases the provision of fresh water, may seem to be at vari-

ance with the consumer-oriented requirements of a free market economy. To appear to dictate that individuals need only so much water to cook, to wash or to garden with while unused renewable supplies run to the sea may seem undesirably restrictive.

However, while the DWA may appear to some to regard consumerism in water beyond an austere minimum as a vice rather than a virtue, the DWA has never advocated austerity as an end desirable in itself. It merely stresses the need for the considered, effective use of water at all times, rather than its indiscriminate and possibly wasteful use. In fact, the relaxation of restrictions on the use of water, whenever appropriate, is essential to provide a vital measure of elasticity so that demand may be managed during crises. Attempts to gain greater utility from each unit of water must also be limited to the point at which the highest collective efficiency of all the resources associated with its exploitation is obtained and the optimal utilization of water should not be sought at the cost of poor returns from the other resources.

The recent or current stringencies in water supply in some regions of the country result from an unfortunate turn of events for which no reasonable and cost-effective provision could have been made in the supply management strategy on the basis of past experience. It is unfortunate that during the orderly expansion of facilities some factors may be at a cyclical low in their development concurrent with unpredictable lows in runoff. Without the extreme severity of the recent drought, the existing water infrastructure would have met the anticipated demand at a favourable cost and an acceptable degree of risk.

An important consideration in planning self-financing works in a heterogeneous First and Third World society is the limited capacity of a major part of the population to afford increasingly expensive facilities to provide generous quantities of water on demand, taking into account that the capital expended may also incur fruitless interest charges in times of plenty. Ideally, the tariff structures designed to recover the cost of waterworks should differentiate between the legitimate aspirations of those who desire and are prepared to pay for more generous or unrestricted supplies and those who can afford a merely adequate supply to meet basic needs only. Appropriate tariff differentials reduce the possibility of a social bias in water supply.

However, it is not easy to guarantee infallible supplies on a continuous and a cost-effective basis. Three factors in particular influence the ability to provide a desirable level of supply at all times, even during droughts. The first is the very long planning and implementation time of five to 15 years needed to obtain the design yields from most new works, during which period the demand pattern may actually change. The second factor is the very substantial sizes in which subsequent phases of waterworks often have to be built to make them economically viable. It is often difficult to time the construction of works so that completion is neither too early nor too late, and consideration must be had for the fact that financial deficits (which influ-

Financing and pricing

ence costs and therefore affordability) accumulate during the early years in the life of a project when water sales are under capacity. The third factor is the long and often unpredictable time it takes to gain international agreement on joint ventures.

The DWA is accordingly prone to finding itself walking a precarious tightrope between two extremes, both of which are of possible detriment to the consumer, namely over-capitalization and higher tariffs than necessary (in addition to placing an unnecessary burden on the limited capital market) on the one hand and inconvenience and economic risks through under-capitalization on the other. Because of this it is essential to maintain effective dialogue on the possible standards of service and the levels of risks for which the various user sectors are prepared to accept financial responsibility.

Water supply economy

Water in the RSA may be regarded as falling within the economic classification of quasi-public goods. Such goods or services lie between pure private goods (such as groceries, which are divisible and of which various quantities may be purchased or rejected by individuals according to the prices asked) and pure public goods and services (such as police protection or public education, which are indivisible, are allocated by the Government and are funded by taxation and which may not be proportional to individual benefit). The early water supply infrastructure in South Africa fell primarily within the definition of a public good. Little direct cost recovery from users was attempted. Waterworks, mainly to promote irrigation, were constructed as welfare projects and to develop the country in the face of unfavourable conditions such as irregular rainfall, unemployment and economic recession.

When the growing needs of a diversifying economy drew attention to the scarcity of water, it was realized that Government supply-side allocation should give way to allocation based on market demand. The principle that resources should be allocated among different users so that the marginal benefit is the same for all users, was accepted as Government policy on the recommendation of the Commission of Enquiry into Water Matters in 1970. However, demandside allocation through market forces requires an effective relationship between the supply authority and water users and implies that waterworks must be financed and operated on commercial principles aimed at the full recovery of the cost of services. Under this system, any public sector or non-market allocations of water that are unavoidable in the national interest require the payment of regularly reviewed subsidies to cover operating deficits. The subsidies should be paid by whatever public body, including the DWA, finds justification for such arrangements.

The issues raised in this publication indicate that water in the RSA could never move entirely into the realm of pure private goods. The DWA trusts that this publication will assist in ensuring that unavoidable public sector resource allocations in a market-oriented society do not upset the market mechanism unduly, but have as neutral an effect as possible.

This publication should not be regarded as exhaustive. Its aim is to highlight a selection of issues that are relevant at present and that require greater appreciation and understanding. Of particular importance is the DWA's approach, based on resourcefulness and flexibility, to anticipating problems and to dealing with problems that may not yet be apparent or that may not have been identified fully. In particular, much of the illustrative information that is presented in the form of tables and graphs should be seen as being provisional. The DWA is continuously upgrading its data processing techniques and the latest information is available on request.

The aims of this publication

As the DWA has a high regard for the public view, several bodies and individuals, as listed in the Acknowledgements, which represent a wide range of informed opinion, were consulted or invited to comment on parts of the draft. The DWA is very grateful for their valuable comments, which have been well considered. Some issues, such as the desirable legal status of ground water and its conjunctive use with surface water for the community, are still unresolved or open to question.

It is the intention to publish updated editions of this publication on a regular basis.

The approach of the DWA in this publication is in line with a world-wide trend over the past few decades to recognize the importance of effectively managing water resources, particularly under centralized control. The management of water is being actively pursued and it has developed into a sophisticated science, the application of which is not restricted to arid regions.

It is accordingly encouraging to note that although the DWA's approach to demand and supply management has evolved locally as a result of changing needs over many years, it is nevertheless in line with international thinking, as expressed in the most recent hydrological strategy of Unesco, known as the International Hydrological Programme III (IHP-III), which was launched in March 1984. This strategy is based on an Action Plan propounded at the largest ever world water conference, held at Mar del Plata in Argentina in 1977 under the auspices of the United Nations. Details of this plan and the goals of IHP-III are given in Appendix I.

As with the effective partnership that the DWA seeks with the public in the RSA, IHP-III also requires greater attention to be given to areas and audiences which previously would not normally have been thought of as part of a programme on hydrology. While strongly emphasizing the traditional hydrologic sciences, the IHP-III programme also stresses the increasing importance of the need for a much broader and a more rational view by water managers. Its integrated approach to water resource management requires that not only technical professionals but also planners, policy-makers, decision-makers and the general public appreciate the possibilities and the limitations of man's activities with respect to water resources.

International experience

International considerations

Some confusion has arisen in recent years with regard to geographical terminology following the achievement of independence or self-governing status by a number of states within the original territory of the Republic of South Africa. It is current practice to distinguish between neighbouring states (i.e. Lesotho and Botswana), which were never part of the Republic, independent TBVC states (Transkei, Bophuthatswana, Venda and Ciskei), which have gained independence from the RSA and have the standing of neighbouring states, self-governing national states (Gazankulu, KaNgwane, KwaNdebele, KwaZulu, Lebowa and Owaqwa), which are still part of the RSA, and the Republic of South Africa. When the term Republic of South Africa or RSA is used in this publication it normally includes the self-governing national states.

As statistics of long-term rainfall and runoff do not lend themselves to conversion according to changing territorial boundaries, and as there is a large measure of common interest in the water systems of the subcontinent, for readability the generic phrase *South Africa* is used in this publication for the territory that covers the Republic of South Africa (including the self-governing national states), the Republics of Transkei, Bophuthatswana, Venda and Ciskei (the TBVC states) and the Kingdoms of Swaziland and Lesotho. The generic phrase *Southern Africa* is used to denote the area covered by South Africa with its various constituent states as well as neighbouring and other states in the sub-continent, such as Angola, Botswana, Mozambique, South-West Africa, Zambia and Zimbabwe, that have the potential to share water resources.

Although the Government of the RSA is seeking to promote mutual co-operation in water matters with other countries, detailed information in this publication is restricted to the RSA. The portrayal of the supply and demand situations in the independent TBVC and neighbouring states in some of the tables is tentative as it is based on the limited information that is available and has been included only for the sake of completeness. This information should not be regarded as authoritative. The DWA's policies and viewpoints on water management are confined to the situation pertaining to the RSA. Should neighbouring countries wish to include information on their supply and demand situations and management policies in future editions of this publication, particularly where shared resources are concerned, this would be welcomed and could be accommodated.

Presentation of subject matter

The wide range of issues discussed in this publication could have been categorized in many ways. The rationale for the arrangement of chapters is set out briefly below. For ease of reference, where various aspects of an issue are dealt with in different chapters (for instance the *physical availability* of ground water is dealt with under water supply in Chapter 3, the *difficulties of its exploitation* under management issues in Chapter 6 and its *legal status* under water law in Chapter 8), cross-references and a major-subject index are provided.

Read consecutively, Chapters 1 to 9 provide an extensive background to water resource management in the RSA and outline the DWA's policies and how they have evolved. Chapter 10 provides a

concise summary of the DWA's main objectives, policies and views on water management.

Chapter 1 sets the scene by outlining the history of and the major difficulties encountered in water management in the RSA. The chapter commences by describing the limitations inherent in the unfavourable distribution of climatic, hydrologic and topographical conditions, relative to water demand in the RSA. Of particular importance is the high variability of runoff and its unfavourable distribution relative to regions of growth in demand. A brief review is given of the evolution of water use and water law during the transition from an agricultural economy to an economy that is more broadly based, and of the effect of this on water management. The review ends with the findings and recommendations of the Commission of Enquiry into Water Matters, which were accepted as Government policy in 1970. These findings and recommendations are interpreted by the DWA in the light of past experience, present validity and anticipated relevance to the future

Fundamental problems in managing water in its entirety are the determination of how much water is being used and is going to be used, by whom and at what required assurances of supply, as well as how much there is to manage. The ideal of being able to manage a total system with full understanding of all the effects of atmospheric precipitation, evaporation, infiltration, seepage, runoff and erosion processes is still far from being realized. The quantity of water that is and will be used directly by man and the requirements for dryland agriculture and for the preservation of the environment are not accurately known. Nevertheless, the practical application of that which is known is considered in *Chapters 2 and 3*, which deal with water demand and supply.

Chapter 2 provides a framework within which to manage the competing demands on the available supply of water. It firstly outlines the difficulties in determining the extent of these demands and how they may change. Whereas earlier DWA reports dealt primarily with direct demands supplied from waterworks, the holistic approach to the evaluation of water requirements being followed today has extended the field to include less direct and less easily quantifiable demands such as that of the ecology and determination of the types of assurances of supply they may require. The frontiers of knowledge are now being advanced even further by attempts to analyse even less certain factors, such as the effects of changing land use on runoff.

Demands for water range from those that provide for the essential material needs of man by supporting hygiene, domestic use, agriculture and industry, to those that provide psychological or spiritual fulfilment by conserving and beautifying the environment and supporting recreation. In *Chapter 2* a scarce resource allocation strategy is presented that should assist in achieving best joint utilization. When fully developed, the strategy should provide a more refined framework for demand management during droughts. It stresses the need to find optimal ways in which resources and costs should be shared by a hierarchy of user groups, ranging from those to whom interruptions of supply would not be in the national interest to those who could accommodate restrictions when necessary.

The latest information on the present demand of the major water-use sectors and projections of expected demand are presented more comprehensively than in the past in a new tabular and graphic format. Although these tables and graphs cover three-decade scenarios up to the year 2010, this is actually beyond the point at which predictions could be reasonably reliable. The information should accordingly not be regarded as being precise, but rather as being an indication of the direction in which the DWA is moving to determine and publish such relationships.

Chapter 3 portrays the quantitative geographical availability of those water resources that can be managed at present. A vital issue, which may possibly be insufficiently appreciated, is that the legitimate aspirations for development of several nations sharing the resources have all to be met concurrently. Practical compromises aimed at the best joint utilization by peoples at different levels of development and with different aspirations must be found for the common good.

The exact assessment of the quantity of water that can be managed is very difficult when the overwhelming proportion of the highly variable rainfall evaporates or sustains rain-fed cultivation and where continual development reduces runoff. Ideally, all water, including water recoverable from the atmosphere, should be taken into account, but this is not yet possible. The DWA's present classification of the available water sources into five types, namely surface water, ground water, reuse, unconventional water sources and imported water, has been chosen arbitrarily to suit the DWA's data base. Chapter 3 details the expected contribution of each to the manageable resources, as well as the interplay between sources. In addition to raising issues arising from land management practices, soil erosion and sedimentation, this chapter also illustrates the present and expected geographical distribution of water availability in tables and graphs akin to those in Chapter 2, and the information presented is subject to the limitations described previously.

Unfortunately, the unfavourable geographical distribution and the limited availability of water to meet the growing demand is only part of the problem. Water quality is also deteriorating in many regions of the RSA, particularly in urban and industrial areas. Three main factors affecting water quality, namely salination, eutrophication (or nutrient enrichment) and pollution by micro-pollutants, are dealt with in Chapter 4. By means of examples an insight is provided into the serious nature and extent of these problems, which may transcend international boundaries. The unavoidable controls that the DWA as the central authority is obliged to exercise are detailed and the nature of more stringent controls that are inevitable or likely to become necessary in the future are outlined. As the DWA's aim is to impose as few controls as are necessary at any one time, it regards it as vital to foster a good working relationship with those who may cause pollution or who are responsible for implementing the reuse of water.

Detailed project planning is continuously undertaken by the DWA to ensure that the legitimate and realistic water needs for growth can be met wherever required in the RSA. Brief details of drainage basin development plans are given in *Chapter 5*, followed by options for supplying the major metropolitan areas, the industrial development

points, the deconcentration points and larger towns in the RSA. As it is essential for planning of this nature to remain flexible, rigid adherence to the illustrative details is not guaranteed.

The development of risk analysis, sophisticated management techniques and operating rules for river systems (such as those serving the Vaal River region) is increasing in importance. Greater emphasis is being placed on the need to link river systems to obtain the increased flexibility needed for the optimal management of resources. As the water resources of the RSA approach full utilization, concepts that were adequate in the past have to be modified. For instance, in place of the former concept that a dam has a firm yield, it is now necessary to consider a range of yields within a system associated with different risks of supply at different costs. Security of a supply has to be seen in relation to pollution control programmes and the hierarchy of user sectors, ranked according to national worth, for scarce resource allocation. The DWA's strategy is geared to discussion with the various competing user groups, who need to be well informed about the nature and costs of the reasonable options that are available.

The DWA's holistic water management strategy is outlined in *Chapter 6*, which deals with a wide, but not exhaustive, range of topical water management issues. The management strategy embraces all the other issues and provides a flexible alternative to a master development plan, which would have an inherent rigidity and would therefore be unsuited to a developing free-enterprise economy. The anticipatory elements of the strategy seek to influence developments, while the reactive elements enable the DWA to act rapidly in identifying and analysing alternative compromises to best meet legitimate demands for water.

The global weather forces that mostly bring benevolent rains, but can at other times cause floods and droughts, are beyond the control of man. Within the limits of his powers, man must accordingly devise measures for the safety of life and property in the event of major floods or dam failures and he must formulate strategies for optimizing his return on investments under the strictures of variable weather conditions. Various ways of coping with severe floods and droughts, which are common in South Africa, are discussed in Chapter 6. These include new measures to safeguard the public against loss of life and property by means of dam safety legislation and flood control guide-lines, and resource and drought management strategies to obtain the maximum yield from water resources in individual and linked catchments under differing climatic conditions. In considering the vexed question of water restrictions, the improvements that are being made in developing dynamic types of restrictions aimed at causing minimal harm and inconvenience are illustrated.

Because future tariff structures aimed at the equitable recovery of costs from the various beneficiaries are expected to become more refined, the principles embodied and the problems encountered in current water pricing and subsidization policies are outlined. Of particular concern is the adequate provision of water for basic human needs at affordable tariffs, especially for people at lower levels of socioeconomic development. The role of water supply in supporting the current drive towards industrial decentralization is also considered.

It is the policy of the DWA to restrict its activities to the overall, national control of the utilization of water and its quality and to the provision of bulk supplies for distribution by other bodies. Accordingly, the devolution of authority over local industrial and agricultural waterworks is also considered in *Chapter 6*.

Although ground water is a vital resource in some regions of the country, its potential has not been fully exploited. In some cases, ground water could provide a more cost-effective alternative to the transmission of surface water over long distances and a number of development options are outlined.

Many agencies can assist in ensuring that the highest possible yields of the best quality water are made available from drainage basins, while simultaneously utilizing the water to achieve their own objectives. Legislation for the control of mountain catchments and the means of achieving the integrated management of catchments is discussed.

The environment must be protected for the benefit of future generations, to whom we owe its transfer in as unharmed a state as is practicable. The considerable attention given by the DWA to the conservation of the environment when developing and operating its waterworks is discussed, as is the provision of recreation facilities at its dams.

The possibility of increasing the protein supply by means of controlled cultivation in bodies of water through the medium of aquaculture is one of the many other subjects discussed in *Chapter 6*.

The expected rate of the country's development and the increase in water demand will soon render long-established water management methods inadequate and new approaches will have to be developed to meet new challenges. The optimal management of water cannot be maintained unless enough time and effort is invested in research to develop more sophisticated management techniques. Success with many of the concepts mentioned in this publication is entirely dependent on the achievement of this aim. The economic, socioeconomic and technical fields in which contributions of high intellectual and technical calibre are needed are detailed in Chapter 7. It is particularly in the search for improved economic and socio-economic criteria for the equitable allocation of the benefits and costs of water resource management that conflicts of interest may occur. Arrangements that appear to be in the common interest may break down because of intersectoral conflict or disagreement on what represents a fair sharing of opportunities, benefits, costs and sacrifices. In its endeavour to establish the most equitable criteria the DWA will attempt to harness the best expertise available, within and outside the DWA, at home and abroad.

Simplistic, quick-fix solutions to the water problems of the RSA by the massive, rapid development of all water resources on the subcontinent are regularly proposed by an enthusiastic public that does not always appreciate the international implications. *Chapter 8* outlines the many exacting requirements for achieving joint water management in international watercourse systems and the need for the reconciliation of these requirements with the provisions of the Water Act, 1956, of the RSA. It also reviews the evolution of water legis-

lation in the RSA and outlines the main legal provisions relating to centralized control. By considering a number of topical water management issues and open questions, it suggests the likely direction in which water legislation in the RSA will develop.

The DWA will not be able to achieve its task of ensuring optimal water management without adequate funds and staff. In *Chapter 9* past patterns of expenditure for changing needs and a number of factors relevant to the financing of future water projects are reviewed. In the last part of this chapter the aims and requirements of the DWA's staff policy are detailed. In seeking an ideal organizational structure, the DWA is attempting to concentrate its expertise in such a way as to achieve its aims through an effective combination of its own resources with those of the private sector.

Chapter 10 provides a convenient summary of the essence of the major objectives, policies and views of the DWA as outlined in this publication.

A list of dams with salient details is included for reference. It is important to note that the values shown for the capacities of reservoirs should not be interpreted as their yields. Yields are not given as they are subject to continuous revision in the light of more extensive hydrological records. Dams should also not be viewed in isolation from river systems. Dams are sized to economically optimize the yields of river systems at appropriate degrees of risk.

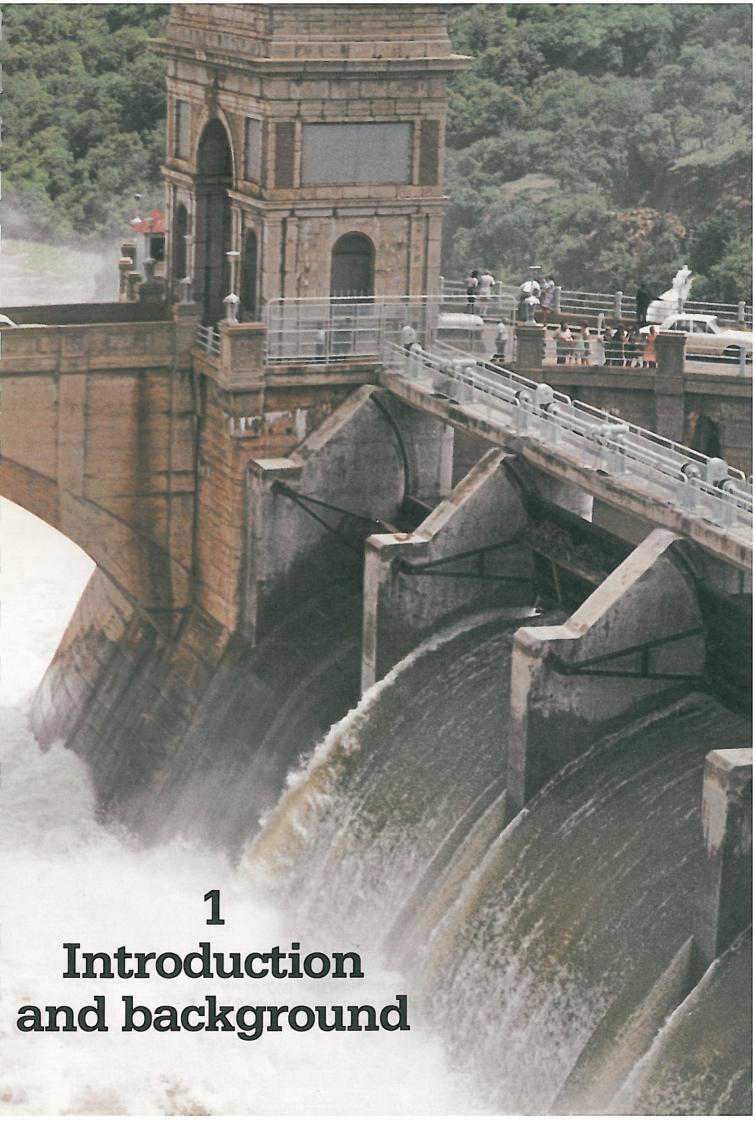
A White Paper based on information contained in this publication and detailing the DWA's policies will be tabled in Parliament in the near future.

J G du Plessis

J.G. du Plersis

Director-General: Water Affairs





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	See also Sections 5.1, 8.2 and 9.1	
1.3	Comments on the findings and recommendations of the Commission of Enquiry into Water Matters (1970)	1.13

1.1 The influence of climate and topography on water availability in South Africa

The average annual rainfall of about 497 mm for South Africa as a whole is well below the world average of 860 mm. A comparatively narrow region along the eastern and southern coastlines is moderately well-watered, but the greater part of the interior and the western portion of the country are arid or semi-arid. Sixty-five per cent of the country receives less than 500 mm of rain annually, which is usually regarded as the minimum for successful dryland farming. Twenty-one per cent of the country receives less than 200 mm.

A wide variety of rainfall-producing mechanisms occurs across the country, affecting the reliability and variability of river flow. As it gets drier towards the west the variability increases rapidly. Over most of the country the average annual potential evaporation, which ranges from about 1 100 mm to more than 3 000 mm, is well in excess of the annual rainfall. This affects surface runoff from rainfall significantly and causes high evaporation losses from water stored in dams.

The combined average annual runoff of South Africa's rivers is estimated to be 53 500 million m³. In some areas the highly variable river flow can have periods of up to 10 consecutive years of less than average flow. This must be allowed for in both the planning and the operation of water supply systems. Because of this variability and the high evaporation losses from storage it is estimated that, with the present state of knowledge and technology, only about 62 per cent or 33 000 million m³ of the mean annual runoff can be exploited economically. In addition, about 5 400 million m³/a may be obtainable from underground sources. Further supplies will have to be obtained from the importation of water or from unconventional water sources such as reuse or desalination.

Water availability is distributed poorly in relation to regions of economic growth and the cost of providing water in South Africa will rise in the future owing to the greater distances that water will have to be transported to areas of increasing demand.

Rainfall-producing mechanisms

As South Africa is situated within the high pressure belt of the middle latitudes of the Southern Hemisphere, warm dry descending air associated with high pressure systems occurs over the greater part of the country most of the time, which is unfavourable for the formation of rain. This climate is modified by the influence of the warm, southward-flowing Agulhas current along the east coast and the cold northward-flowing Benguela current along the west coast. The warmer east coast air masses tend to be less stable than

those in the west and are more likely to give rise to precipitation.

Rainfall is distributed unevenly over the country, with humid subtropical conditions in the east and dry desert conditions in the west. For instance, the mean annual rainfall on the east coast in the vicinity of Durban is 1 070 mm, while that for Port Nolloth at the same latitude on the west coast is a mere 58 mm. The highest rainfall occurs in the mountain ranges of the south-western Cape and in the Drakensberg, where the mean annual rainfall exceeds 3 000 mm in places (Fig. 1.1.1).

The factors which influence rainfall vary from region to region. At one extreme there is the east-facing Drakensberg escarpment in Natal where moisture-laden air is often present and where several different rainfall-producing mechanisms exist. At the other extreme is the desert area of the north-western Cape Province where the air is hot and dry and the topography flat and the main rainfall-producing mechanism is the occasional convectional thunderstorm.

During the summer months low-pressure troughs develop periodically over the interior. These troughs are orientated roughly NW-SE and have the effect of drawing in moist air from the north and north-east. This rising moist air cools and produces rain. These convergent systems are the source of most of the runoff-producing general rainfall in the interior of South Africa, although their influence is diminished in the western half

Rainfall is distributed unevenly over the country, with humid subtropical conditions in the east and dry desert conditions in the west. 7

of the interior.

Orographic rainfall occurs when winds force moist air up a mountain or escarpment slope. This is an important source of river flow along the southern and eastern escarpments and mountain ranges. Although the rainfall intensity may be lower than that of other rainfall-producing mechanisms, orographic rain occurs more frequently and for longer durations, with the result that river flow in these areas tends to be more reliable and less variable than that in regions which do not have a large orographic rainfall component (Fig. 1.1.2). Although mountains and escarpments create favourable rainfall conditions on their wind-

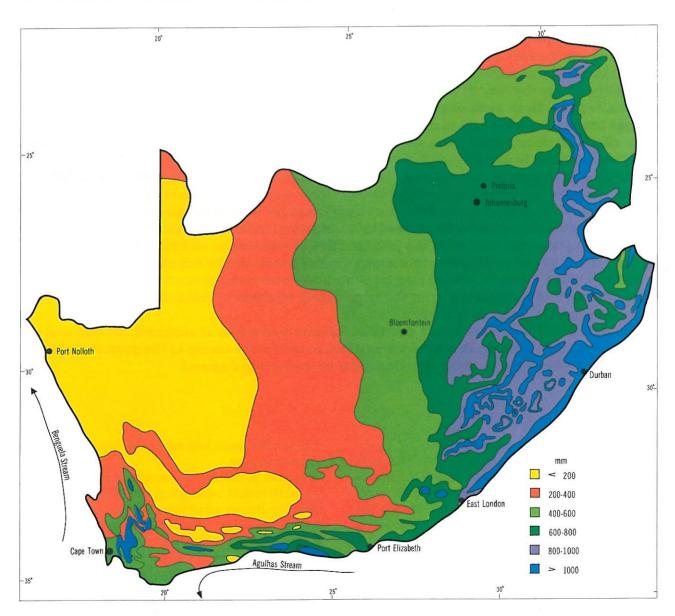


Fig. 1.1.1: Mean annual precipitation

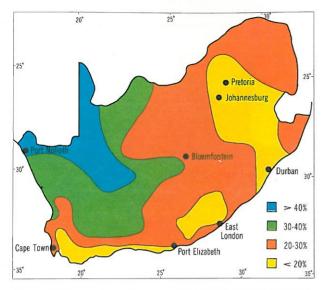


Fig. 1.1.2: Percentage deviation from mean annual rainfall

ward slopes, they also create the opposite conditions in the downwind areas, as demonstrated by the sharp difference in rainfall conditions between George and Oudtshoorn.

Cold fronts which regularly approach the country from the west and south-west during the winter months are the main source of rain in the winter rainfall region of the Cape Province.

In the drier areas occasional convectional thunderstorms are the main source of rain. These usually occur over a small area and are generally of short duration, although intensities may be sufficiently high to cause short-term flow in local streams.

South Africa is periodically afflicted by severe and prolonged droughts which are often terminated by severe floods.

The most appropriate form of water resource development for a region depends on local hydrological conditions. The winter rainfall region is a relatively narrow area along the Cape western and south-western coasts. The summer rainfall region covers most of the remainder of the country. Between the winter and summer rainfall regions lies a transitional area where rain occurs during all seasons (Fig. 1.1.3).

In the winter rainfall region precipitation results mainly from cyclonic disturbances. These rains are often of long duration and low intensity except along the mountains, where orographic effects may induce heavy showers. Snow which melts within a few days may occur on the mountains four to six times during the winter but it is not a significant contributor to river flow.

Winter snow in the summer rainfall region is confined mainly to the eastern highlands, especially the Drakensberg and the Maluti Mountains. Over most of the summer rainfall region convectional storms, frequently violent and accompanied by thunder, lightning and often hail, are the source of most of the rainfall.

Droughts

South Africa is periodically afflicted by severe and prolonged droughts. The greater part of the country was drought-stricken from 1960 to 1966, while the longest drought on record was from 1925 to 1933. The drought that commenced in 1978 introduced new cumulative lows in runoff records in many areas. Droughts are usually associated with prolonged periods of anticyclonic activity over the inland plateau and consequently are most common in the summer rainfall region, especially towards the west. Droughts are often terminated by severe floods.

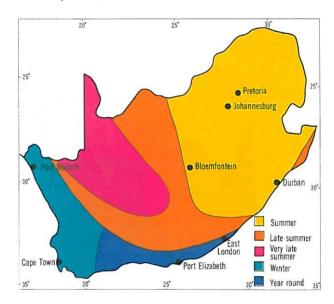


Fig. 1.1.3: Seasonal rainfall regions

Floods

South Africa is regularly subjected to floods. The major flood-producing rainfall mechanisms in the southern Cape and the Karoo are the cut-off low-pressure systems such as those which produced the severe flooding in Laingsburg and adjacent areas in January 1981 and which are responsible for frequent flooding over the south-eastern Cape.

Heavy floods in the summer rainfall region of the interior normally occur when a low-pressure system over the interior is trapped by high-pressure systems in the Indian and Atlantic Oceans. Warm moist air is drawn into the interior from the north and north-east and moderately heavy rain may last for several days, producing widespread floods such as those in the Vaal River in 1975 and in the Orange River and the northern Cape in 1978. Smaller convectional systems such as cloud mergers can produce very high intensity rainfall of very short duration (less than 30 minutes) over areas of a few square kilometres only. For example, at Nelspruit 102 mm of rain fell in 16 minutes in December 1975.

Tropical cyclones which cause heavy rain to fall over a wide area, such as cyclone Domoina in January 1984, occasionally penetrate as far south as the Transvaal Lowveld, southern Mozambique, Swaziland and northern Natal.

Evaporation

As a consequence of the low frequency of cloud over much of South Africa, the high proportion of solar radiation that reaches the earth's surface provides an abundance of energy to evaporate water from land and water surfaces and cause its loss to the atmosphere. The rate of evaporation also depends on the temperature and humidity of the adjacent air (Fig. 1.1.4). 'Potential evaporation' is the term used to define the depth of water that could be evaporated in this manner.

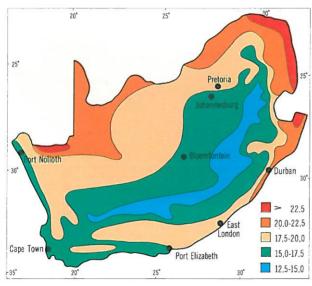


Fig. 1.1.4: Mean annual surface temperature

There are only a few isolated areas in South Africa where the average annual potential evaporation is less than the average annual rainfall. These are in high rainfall areas where the annual rainfall is generally in excess of 1 500 mm. Over the rest of the country the average annual potential evaporation varies from less than 1 100 mm to more than 3 000 mm per annum. In the north-western Cape evaporation exceeds rainfall by a factor of 25:1.

The difficulties of water resource development resulting from a generally decreasing rainfall from east to west are thus intensified by the progressively greater potential evaporation losses (Fig. 1.1.5). The loss of water from dams in areas of high potential evaporation is of great consequence.

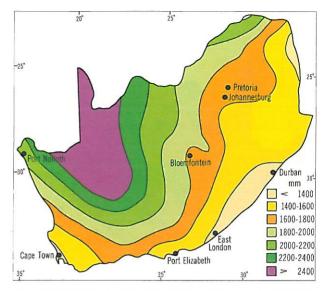


Fig. 1.1.5: Mean annual evaporation from an open water surface

Rainfall runoff relationships

The mean annual runoff is not related directly to the mean annual rainfall, but decreases rapidly with a decrease in rainfall because of the high evaporation losses associated with low rainfall conditions. In the low rainfall areas there are longer dry periods between rainfall events during which there are cloudless skies and high soil temperatures and the air is warm and dry. Evaporation of the soil moisture is high and the soil dries out to a much greater extent between successive rainfall events, with the result that most of the already meagre rainfall is absorbed by the soil and then evaporates back into the air without reaching the rivers.

There are only a few isolated areas in South Africa where the average annual potential evaporation is less than the average annual rainfall.

The relationship between rainfall, potential evaporation and river flow at representative dams (see Fig. 1.1.6) is shown in Table 1.1.1. The percentage of the rainfall that becomes river flow decreases dramatically with decreasing rainfall and increasing potential evaporation (Fig. 1.1.7).

The influence of topographic conditions

The major part of South Africa comprises a geologically warped plateau at more than 1 000 m above sea-level. The southern part of the plateau, which covers the most of the RSA, excluding the northern Transvaal, is tilted downwards to the west, while the northern part is tilted downwards to the east. The main river system of the south, that of the Orange River, accordingly flows west-

wards while the long rivers of the north, such as the Limpopo, flow eastwards. The comparatively well-watered rivers that rise at the escarpment and flow eastwards toward the Indian Ocean are relatively short and fall sharply. To conserve and convey part of their water across the divide to where it is needed demands major engineering works and high capital expenditure and involves high pumping costs.

The relatively flat topography of the plateau gives rise to shallow storage dams which have large water surfaces exposed to evaporation. Owing to the low rainfall, vegetal cover is generally insufficient to prevent soil loss by erosion and this, coupled with a surface geology prone to weathering and erosion, as well as the high inci-

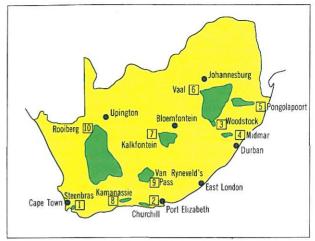


Fig. 1.1.6: Location of dam catchments listed in Table 1.1.1

Table 1.1.1: Runoff, catchment precipitation and potential gross evaporation for 10 selected dams in the RSA

Dam	Dam reference	Location and types of runoff-producing rainfall	Catchment area	Mean annual potential evaporation	Mean annual catchment precipitation	Mean annual runoff	Percentage runoff
			(km²)	(mm)	(mm)	(mm)	(%)
Steenbras	1	South-western Cape: High winter rainfall, mainly orographic and frontal	67	1 413	1 231	619	50,3
Churchill	2	Southern Cape: High year- round rainfall, mainly orographic and frontal	357	1 390	740	202	27,3
Woodstock	3	Drakensberg: High summer rainfall, orographic and convectional	1 149	1 301	1 490	635	42,6
Midmar	4	Natal Midlands: Moderate summer rainfall in mist belt, mainly convectional	928	1 386	975	198	20,3
Pongolapoort	5	Northern Natal: Moderate summer rainfall, mainly convectional with occasional tropical cyclones	7 831	1 514	871	140	16,1
Vaal	6	Highveld: Moderate summer rainfall, convergence and convectional	38 505	1 703	750	50	6,7
Kalkfontein	7	Orange Free State: Low summer rainfall, mainly convergence and convectional	10 268	1 874	452	15	3,3
Kamanassie	8	Little Karoo: In rain shadow, year-round low rainfall	1 505	1 697	463	24	5,2
Van Rhyne- veld's Pass	9	Cape Midlands: Low summer rainfall	3 681	1 996	365	10	2,7
Rooiberg	10	Great Karoo: Very low summer rainfall from occasional convergence	TO 005	0.540	140	4	0.7
		systems	72 335	2 740	149	1	0,7

dence of erosive thunderstorm rainfall, causes rivers to carry heavy sediment loads. Rock formations in most parts of the country are also unsuited to the storage of ground water.

In general, the cost of providing water in most of South Africa is high compared with that in many other countries because of the higher storage capacity required on South African rivers to achieve equivalent yields. This unfortunate natural handicap which results from the hydrological characteristics of rivers is illustrated in Fig. 1.1.8.

As an illustration, the Vaal River, which is the water source for the most important region in the country, requires a storage capacity of 200 per cent of the mean annual runoff to ensure a dependable gross yield of 75 per cent of the mean annual runoff during a 1:50-year drought. The storage requirements of some significant comparable basins in other parts of South Africa and the world, for similar yields, are as follows:

The Tugela	100%
The Upper Orange	50%
The Indus Basin rivers in Pakistan	30%
The Blue and White Niles in Egypt and Sudan	10% to 50%
The Tigris and the Euphrates in Iraq	70%
The Murray and Toulumwe in Australia	90%
The Sacramento River in the USA	100%

River basins in countries such as Australia have characteristics similar to those of South Africa. Compared with the Australian examples, the Vaal River needs twice the storage for a given yield. The comparative figures represent storage required to regulate the highly variable river flow. An additional 10 per cent to more than 100 per cent of storage capacity must be provided to allow for evaporation losses, depending on climatic con-

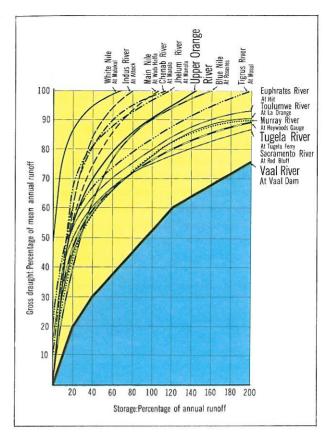


Fig. 1.1.8: Draught curves of representative rivers for different countries (50-year recurrence interval)

ditions at the specific site and on dam basin characteristics. For the Vaal Dam this amounts to an additional 15 per cent storage capacity. The choice of the most efficient storage sites, such as those of the Upper Orange and Tugela Rivers, is thus of the utmost importance in utilizing South Africa's limited runoff.

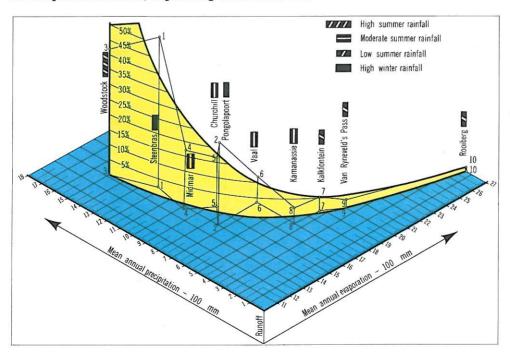


Fig. 1.1.7: Typical relationships between precipitation, evaporation and runoff

1.2 Evolution of water use in South Africa

At the end of the 19th century agriculture accounted for most of the water used in South Africa. Irrigation was generally by direct diversion from rivers, since few storage dams had been constructed. Legislation enacted in the early years of this century protected the water rights of farmers along rivers and the State concentrated on the construction of works to benefit irrigation.

This approach was incompatible with water requirements for the progressive expansion of industry. Accordingly, in 1956 a Water Act (Act 54 of 1956) was passed, which was intended to ensure equitable distribution of water for industrial and other competing users, as well as to make possible strict control over the abstraction, use, supply, distribution and pollution of water, artificial atmospheric precipitation and the treatment and discharge of effluent.

During the 1966 drought and in view of the rate of industrial expansion at the time and the limited water resources of South Africa, the State President appointed a Commission of Enquiry into Water Matters. The findings and recommendations of the Commission, accepted by the Government in 1970, are reproduced in Section 1.3, together with comment based on more recent experience of the Department of Water Affairs.

Because of increasing development, water quality is now deteriorating rapidly and the scarce, unutilized supplies are mismatched geographically in relation to demand. This is a national problem that cannot be solved at less than State level, particularly since, with the national states (Gazankulu, Lebowa, Owaqwa, KwaZulu, KwaNdebele and KaNgwane) attaining self-government and the TBVC states (Transkei, Bophuthatswana, Venda and Ciskei) gaining independence, most of South Africa's water is now subject to joint use in international drainage basins. Accordingly, the DWA is refining and implementing a national water management strategy aimed at the optimization of resource utilization and infrastructure development. Scarce resource allocation procedures with appropriate controls over use and disposal are incorporated in the management strategy.

For more than two centuries after the arrival of Van Riebeeck the responsibility for water resource development — primarily for irrigation — remained in the hands of private enterprise and the village and town authorities who had to build water supply schemes. The State played only a minor role in development. In 1875 the first impetus was given to more ordered water development by the formation of a hydraulic division under the Commissioner of Public Works in the Cape Colony. In 1904 irrigation departments were

created in the Cape and Transvaal colonies.

Irrigation development played a major role not only in the moulding of early water policy but also in the infrastructural, economic and social development of South Africa. It also contributed greatly to development by making planning data and maps available. The formation of irrigation boards, for which legislation had come into being in 1877, was encouraged and after proclamation of the Irrigation and Conservation of Waters Act, 1912, which promoted the building of storage schemes,



Poor whites employed on labour-intensive State waterworks during the Great Depression in the early 1930s

the construction of several major dams commenced. During the depression which followed the First World War, even substantial private development by irrigation boards could not provide sufficient badly needed growth to alleviate the prevailing grave social conditions. The construction of Government irrigation settlement schemes was therefore accelerated.

The great economic depression which commenced in 1929 and the coincident drought gave impetus to the construction of several labour-intensive State schemes on which destitute Whites from drought-stricken areas were employed and settled. In the mid-1930s subsidies were introduced to accelerate the development of private irrigation schemes since developers had been discouraged by adverse factors such as extreme fluctuations in runoff, high evaporation, rapid siltation of reservoirs, the occurrence of saline and sodic soils and the presence of debilitating fever in some areas.

In the years following the Second World War subsidies for municipal water schemes were introduced to improve the standards of supply, although these were subsequently modified to assist only smaller municipalities that would otherwise not have been in a position to carry out works of a satisfactory standard. Beginning with the small Saldanha Regional Water Supply Project, built as a war measure in 1943, several Government regional water supply schemes were constructed, such as the Orange Free State Goldfields Scheme to promote the exploitation of newly discovered gold. The Umgeni, Pietersburg, Vaal-Gamagara, Springbok and Caledon-Bloemfontein projects have been built since. At present comprehensive regional water supply schemes are being constructed, one example being the Komati-Usutu-Vaal Scheme supplying the eastern Transvaal Highveld.

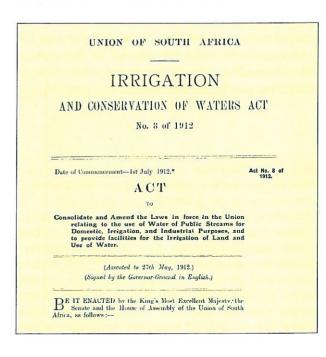
South Africa experienced rapid industrialization after the Second World War. The fast-growing needs of mining, urban and industrial development highlighted the limitations of available resources and it became evident that agricultural water use, often excessive until then, would have to be optimized.

Development of water law

South Africa was under Dutch rule from the time of Van Riebeeck to the British occupation early in the 19th century. As all land was held in leasehold, the principle that the State had ownership of all water and had absolute control over its use applied. The British introduced freehold land tenure and under English law the natural rights appertaining to the land belonged to the owner. The riparian principle, namely that all owners of land along rivers had common rights to the water in such rivers, became established.

Irrigation development played a major role not only in the moulding of early water policy but also in the infrastructural, economic and social development of South Africa.

Special water courts were created to apportion water and to determine individual rights. The Irrigation and Conservation of Waters Act, 1912, was eminently suited to promoting irrigation development in accordance with these principles. It was realized after the Second World War that the 1912 Act was obsolete in that it did not make provision for the demands of an expanding industrialized economy. As the result of a Commission of Enqu-



iry which reported in 1952, a new Water Act (Act 54 of 1956) was promulgated.

The Water Act of 1956, while recognizing the principle of private ownership and acknowledging all water court awards, reintroduced the concept of State control. This enabled the State to obtain control over water which was in excess of existing users' rights, where necessary. The State could now carry out long-term planning in the national interest through the proclamation of surface or subterranean Government water control areas in which the water courts, which did not undertake planning, had no further jurisdiction. The Act gave rise to several new divisions in the DWA to undertake the scientific, engineering and economic investigations necessary to optimize the implementation of these wide powers in the immediate short term and the long term.

The evolution of water development strategies

The economy of South Africa has developed from a rudimentary level through an agricultural phase hampered by droughts and depressions into that of a sophisticated, rapidly industrializing region. The evolution of water development strategies is intimately linked with the region's economic and socio-economic advancement. Fig. 1.2.1 and the accompanying Table 1.2.1 illustrate the contribution to the gross national product of various sectors of the economy since 1911. In common with trends in other developing countries, as the graph and table show, the contribution by agriculture has declined to about one-third of its original value, while that of manufacturing has increased sixfold. Mining has fluctuated but has recently shown an upward trend. Factors such as this will influence the direction of future planning.

South Africa experienced rapid industrialization after the Second World War and it became evident that agricultural water use, often excessive until then, would have to be optimized.

Because of the scarcity of water and the geographical mismatching of demand and supply, a recent trend has been the construction by the State of large interbasin transfer schemes, such as the Orange-Fish, Tugela-Vaal, Riviersonderend-Berg River an Usutu-Vaal projects, which involve large and sophisticated engineering works.

Meeting the needs of the future will require a reorientation of traditional social attitutes, particularly the belief that water is an abundant natural resource available at low cost, when in fact it is an essential commodity becoming scarcer and more

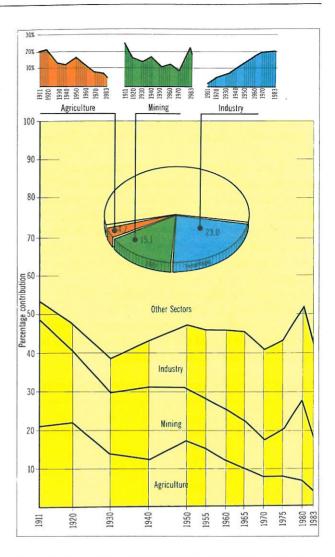


Fig. 1.2.1: Percentage contribution to gross national product

valuable through increasing competition. Increased application of the principle that each identifiable beneficiary pays the cost of providing him with an acceptable assurance and quality of supply, and of treating his effluent, will assist in achieving optimal allocation and use of water.

Users must be encouraged by suitable incentives, rewards and penalties to become actively involved in reducing costs and saving water. Co-operation with bodies able to provide data and advice, and the use and refinement of systems analysis and economic analysis to determine the direct and indirect benefits of various forms of water use are underway and will be intensified.

The trend in all water use, but particularly for irrigation, must be towards greater efficiency. A great deal of work has to be done to improve the technology for optimizing the abstraction of ground water, treating and recycling effluent, reducing evaporation and seepage losses and reducing requirements for power generation. Other aspects of water resource management that require attention are rainfall stimulation,

If The traditional belief that water is an abundant natural resource available at low cost will have to change.

desalination, interbasin transfer, optimum operation of river systems, the elimination of pollution and the improvement of irrigation and industrial techniques.

With the attainment of self-government by the national states and independence by the TBVC states, a high degree of co-operation is required to facilitate sound water management since most of South Africa's water sources are now situated within international drainage basins. Co-operation with neighbouring countries could also provide valuable sources of water.

Against a background of limited resources and rising demand it is the aim of the Department's national water management strategy to achieve optimum joint use of the available resources by all demand sectors for an indefinite period.



Scotch carts being loaded with fill for dam construction around 1918

Table 1.2.1: Percentage contribution to the gross domestic product of South Africa and South-West Africa

Year	Agriculture, forestry, hunting and fishing	Mining and quarrying	Manufacturing	Commerce, catering and accommodation services	Other	Total
1911	21,0	27,7	4,0	12,7	34,6	100,0
1920	22,2	18,3	7,3	15,6	36,6	100,0
1930	14,2	15,6	9,4	15,1	45,7	100.0
1940	12,7	18,7	12,4	13,9	42,3	100,0
1950	17,7	13,5	16,4	14,0	38,4	100,0
1951	19,4	13,3	16,1	12,8	38,4	100,0
1952	16,1	12,6	17,2	13,7	40,4	100,0
1953	17,3	11,1	18,5	14,8	38,3	100,0
1954	16,9	11,3	18,6	14,8	38,4	100,0
1955	15,5	12,6	18,4	14,4	39,1	100,0
1956	15,1	13,3	18,5	14,2	38,9	100.0
1957	14,8	13,5	18,1	14,0	39,6	100.0
1958	12,8	13,2	18,6	14,1	41,3	100,0
1959	12,8	13,8	18,3	13,4	41,7	100,0
1960	12,4	13,7	20,5	14,2	39,2	100,0
1961	12,9	13,4	21,0	13,9	38,8	100,0
1962	12,4	13,2	21,1	14,3	39,0	100,0
1963	12,2		21,8	14,4	39,0	100,0
1964	10,6	12,6 12,8	22,4	14,6	39,6	100,0
1965	10,8		23,2	14,6	39,5	100,0
1966		12,5		14,0	40,1	100,0
	10,5	12,3	22,9		40,1	100,0
1967	11,5	11,3	22,1	14,4	Section Section 1997	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1968	9,8	11,0	22,2	15,1	41,9	100,0
1969	10,5	12,6	26,0	17,1	33,8	100,0
1970	8,1	10,0	23,3	15,1	43,5	100,0
1971	8,8	8,8	22,5	14,5	45,4	100,0
1972	8,8	10,1	21,7	14,2	45,2	100,0
1973	8,2	12,0	21,9	14,3	43,6	100,0
1974	9,6	13,3	21,2	14,1	41,8	100,0
1975	8,2	12,3	23,2	14,2	42,1	100,0
1976	7,8	12,0	23,9	14,1	42,2	100,0
1977	8,1	12,7	22,5	13,4	43,3	100,0
1978	7,5	15,3	22,1	12,7	42,4	100,0
1979	6,7	18,3	22,6	12,0	40,4	100,0
1980	7,1	22,1	22,6	11,6	36,6	100,0

1.3 Comments on the findings and recommendations of the Commission of Enquiry into Water Matters (1970)

Commission's Findings

I. The water resources of the Republic: available supplies and estimated future usage

(1) The available supplies

South Africa lies in the drought belt of the globe—consequently it is a dry country. The west is drier than the east and the lower the rainfall the more unreliable it is. Although over the geological ages there have been great changes, the climate of historical times, that is for as long as reliable data have existed, has in general remained much the same. The question therefore is not how the drought problem can be solved but rather how we can make best use of the various water resources at our disposal.

The average annual runoff from the Republic (i.e. the average annual quantity of water that reaches our rivers) is put at 52×10^9 m³ (20 mil-

lion morgen feet) per annum, or 143 200 x 10³ m³/d (31 500 million gallons per day (mgd)). Because of unavoidable losses by spillage and evaporation from storage, and the fact that not all runoff can be diverted for use before reaching the sea, it has been accepted that only 40% of the runoff, or an average of 57 280 x 10³ m³/d (12 600 mgd), can be regarded as the assured proportion that can be made available for use through the provision of storage. In this estimate the position with regard to our neighbour states has been taken into account.

Several measures can be applied, however, to enhance appreciably the assured yield of our storage works. Moreover, by application of the results of further investigations, it may be possible to regulate a somewhat greater proportion of the runoff by means of storage. Indeed, it should be possible to push up the utilisable surface waters of the Republic to about 50% of the mean annual runoff, i.e. to $26 \times 10^9 \, \mathrm{m}^3$ (10 million morgen feet) per annum, or $71 \, 370 \times 10^3 \, \mathrm{m}^3/\mathrm{d}$ (15 700 mgd).

To arrive at the total usable natural water resources of the Republic, the potential groundwater yield must be added. Unfortunately, however, it is not possible at this juncture to make reliable estimates of the safe yield of our groundwater resources. It is reasonably certain, however, that present consumption could be doubled if sufficient were known about the occurrences and replenishment of groundwater. For the sake of conservatism the Commission has taken into account only the current estimated total abstraction of about 3 090 x 10^3 m³/d (680 mgd) from our groundwater resources.

It may be accepted with a measure of confidence that, given thorough investigation, research and planning together with the necessary financial means, about $27.4 \times 10^9 \text{ m}^3$ (10,5 million morgen feet) per annum, or 75 010 $\times 10^3/\text{m}^3/\text{d}$ (16 500 mgd), can be made available from natural water resources.

Note: The findings and recommendations of the Commission of Enquiry into Water Matters have been reprinted verbatim from the Report of the Commission. However, obvious typographical errors have been corrected and the form in which metric units were presented has been adapted to modern usage. Where a 'Section' or a 'Chapter' is referred to in a Comment, reference is made to this publication and not to the Commission's Report.

Comment

Based on research since 1970, the total surface runoff of South Africa is now estimated at 53 500 million m³/a, which is approximately 1500 million m³/a more than the Commission's finding (Section 3.1). The national average for the utilizable portion of this water is now believed to be about 62 per cent, but the figure varies considerably between catchments. An ongoing effort is being made to improve the estimates. The quantity of ground water which could theoretically be abstracted regardless of cost is now thought to be about 12 000 million m3/a, but the estimate for practical use is about 5 400 million m³/a. For potential availability from reuse, from unconventional sources and from possible imports see Sections 3.5, 3.6 and 3.7.

(2) Present and expected future consumption

The future consumption of water will be influenced by increasing population, rising standards of living, and growing demands for irrigation water and by industrialisation and urbanisation of the South African economy.

Rates of increase in consumption for irrigation and stockwatering have been fairly constant since the year 1910. By 1965 consumption for these purposes had reached an average of 20 985 x 10^3 m³/d (4 616 mgd), or 83,5% of the total water consumption throughout the country. Expectations are that by the close of the century, with current methods of utilisation, the total for irrigation will have become about $34\,780$ x 10^3 m³/d (7 650 mgd), of which roughly $32\,280$ x 10^3 m³/d (7 100 mgd) will have to be provided from permanently developed surface water resources.

Till recently water resources in the Republic have been developed and used chiefly for agricultural purposes. South Africa's economic development, however, is conforming closely to the standard international pattern — a pattern in which during the process of economic growth, contributions to the gross national product by the primary sectors, agriculture and mining, show a relative decline with rising per capita incomes while those of industry reflect a proportionately steep rise. This evolution will be accompanied by increasing urbanisation and rapidly rising water consumption for urban and industrial purposes.

In contrast with the use for irrigation, the increase in the use of water for urban and industrial purposes has not occurred at a constant annual rate. At 3,4% per annum up to the year 1933 the increase was comparatively slow but onwards to

1965 it accelerated to about 7%. If this growth rate is maintained, the water demand for urban and industrial use will reach about $45\,460\,\mathrm{x}\,10^3\,\mathrm{m}^3/\mathrm{d}$ (10 000 mgd) by the end of the century. If the proportion abstracted from groundwater is maintained at the present 10%, $40\,900\,\mathrm{x}\,10^3\,\mathrm{m}^3/\mathrm{d}$ (9 000 mgd) will have to be derived from permanent surface sources by the close of the century.

The adopted rate of increase in water demand for urban and industrial purposes is indeed very high. It has been projected linearly on a semi-log plot and represents a 7% per annual increase rate over the years 1940-2000. However, since there seem to be just as many factors tending to increase the water demand as there are working in the opposite direction, the Commission feels the foregoing figures should be adopted for planning purposes. Galloping water demands constitute just one of those unavoidably explosive results of incorporating a compound growth rate into an economy. For purposes of medium-term planning, actual consumption trends must be continuously re-examined to ensure that adequate water supplies for urban and industrial use are, as far as possible, provided five years in advance. Similar studies are needed also to ensure that long-term projections conform to actual growth rates. If estimated increases in demand materialise, total water needs will rise to $80 240 \times 10^3 \text{ m}^3/\text{d}$ (17 650 mgd) by the turn of the century.

Comment

Sectoral water use has been monitored over the past decade and the quality of data is improving (Chapter 2). The actual growth in industrial and domestic demand is less than the seven per cent assumed by the Commission. It averages about 4,4 per cent for the major metropolitan areas and will be slightly less for the country as a whole. Despite the growth in water use for irrigation, the use by this sector has decreased to 51,5 per cent of total water use. A national inventory of water availability and use is systematically being improved and maintained in user classifications (Section 6.1). The long-term national water management strategy being developed by the DWA, which offers a maximum of flexibility to accommodate changes in trends, is supported by this data. On a national scale there appears to be sufficient water to meet the needs in the foreseeable future, provided that sufficient capital is available to develop the water resources and that difficulties inherent in interbasin transfers can be overcome.

(3) Preserving a balance between supply and demand

Seeing that assured yields in the Republic are estimated at only 60 460 x 10^3 m³/d (13 300 mgd), with potential maximum of only 75 010 x 10^3 m³/d (16 500 mgd), the rapidly rising demands, if they materialise, will exceed maximum estimated yields even before the close of the century. If account is taken also of the facts that the available water resources are very unevenly spread geographically, that three-fourths of the runoff is derived from only one-third of the land area and that our most important metropolitan regions do not happen to be located on major rivers, it becomes evident that urgent regional problems may crop up long before the close of the century.

Solutions to the problem may be sought along three main paths. First, we must strive for improved methods of development and utilisation of our natural water sources. Secondly, we must raise the efficiency of current use of developed supplies; the most obvious methods lie in the reuse of effluents and improved efficiency in the use of water for irrigation. Finally, we must seek ways of creating new sources of water; probably the desalination of sea water would make the biggest contribution. If the efficiency of water use for irrigation could be improved to the extent that the same crop yield per morgen was maintained with a 25% reduction in water application and if municipal effluents could be reused in two cycles, the total demand from natural sources at the end of the century will be only $52\,300 \times 10^3 \,\text{m}^3/\text{d}$ (11 500 mgd) $80\ 240\ x\ 10^3\ m^3/d$ as against (17 650 mgd) without the improved utilisation techniques. Solutions along these lines are analysed in Part II of the report. If these savings materialise there will still be a surplus available in the year 2000. However, the task will make very substantial demands on our human and material resources.

Comment

Progress is being made with the improvement of methods to develop and utilize South Africa's natural water resources by carefully analysing schemes before implementation and by improving operating rules, particularly as far as these apply to the determination of restrictions during droughts (Section 6.3). Attention will be given to providing greater assurance for certain key users and to flexibility of operation through the interlinking of catchments. The development of water schemes in stages is carefully analysed with sophisticated economic discounting

techniques. Progress with water conservation has been made by industrialists and water supply authorities through the reuse of effluent and by the State throught the reduction of transmission losses on Government water schemes. Although some groups of irrigation farmers have gained notably better use of their water by using efficient irrigation equipment, there is still considerable scope for improvement in this area. Little progress has been made in developing unconventional sources of water. Although adequate desalination technology exists, in general the cost is not yet competitive with that of developing the remaining conventional supplies (Section 3.6).

(4) Food production and the use of water

In regard to most of the important agricultural and horticultural products the Republic is self-sufficient. There is every reason to believe that normal technological advances in farming, supported by research and extension services provided by state and private enterprise, will suffice to maintain at least the present degree of self-sufficiency till the end of the century without the need of any additional dryland or irrigation land for raising more of these products. In respect of a few products, such as wheat (and also rice, of which little is produced at present) it will evidently be necessary to continue to rely to some extent on importation. If State research and extension services were to lay greater emphasis on these products, however, it is possible that even in these products a greater measure of self-sufficiency could be achieved than at present. This applies particularly to wheat. On the other hand, it seems fairly certain that importation will in general be more advantageous than attemps to raise local productivity if this entails opening up new irrigation land. In regard to strategic considerations it must be recognised that emergency situations affect not only importation sources but also export channels. In such events, land normally utilised for export production would become available to overcome shortages in specific products.

In respect of some animal products used for human consumption, the Commission finds that production indeed lags behind demand and that there is therefore to a fluctuating degree dependence on imports. The outlook is moreover that dependence on imports will persist beyond the close of the century unless successful steps can be taken to improve productivity in cattle farming. In South Africa, productivity in ranching has lagged behind that in agriculture and horticulture and so

there is reason to presume the potential exists for appreciable improvement, among both White and Bantu farmers, in the local production of foods of animal origin. The State's agricultural research and extension services should therefore give particular attention to this aspect. By contrast, irrigation at present plays a relatively minor role in meat production and whether it will contribute economically in future depends, among other things, on future trends in the relative prices of beef and agricultural products and in the people's meat consumption habits. Moreover, in view of the fact that South Africa's import sources, especially of meat, seem to be reasonably assured, the costs of the additional irrigation facilities that would be needed for meeting local shortages of these products must be carefully weighed against the alternative of relying on importation. For dairy products, especially butter, it should be possible in emergency to find substitutes without undue local disruption.

On the basis of experiences of the past and fore-seeable developments of the future, the Commission finds it unlikely that either export markets or internal processing industries for agricultural products will in general offer sufficient growth potential to warrant according high priority to expansion of land areas under irrigation. Exceptions to this generalisation are to be found, however, in such products as deciduous fruits, citrus, leaf to-bacco, sugar and wine. These products, most of which can be raised under supplementary irrigation and therefore with relatively modest applications of water, contribute substantially to the gross national product and to the country's export trade.

The Commission's general finding is thus that there is no urgent need to accord high priority to the provision of additional irrigation facilities for the benefit of agriculture. On the contrary, the emphasis in agricultural production policy should be placed on more efficient use of existing production facilities and this includes existing irrigation lands. The measures needed to achieve this, such as continued research and extension of facilities, as a rule cost far less than the alternative, viz. the provision of additional irrigation land. To take care of possible emergencies, it might be desirable, if this has not already been done, to draw up emergency plans for the switching of land (both dryland and irrigation land) from raising produce of which the country has a surplus to raising produce that is normally imported.

This finding should not of course be construed as meaning that, except for the products mentioned, strictly no new irrigation projects should be tackled to the benefit of agriculture. It is meant merely to emphasise the principle that justification for such projects should, in each specific case, be based on careful socio-economic analysis, the weighing of costs and benefits against those associated with alternative allocation of funds and of the water that would be demanded.

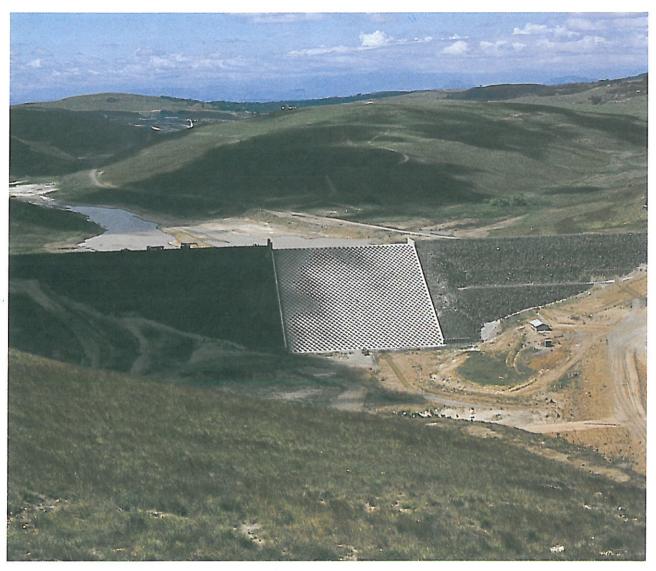
Comment

Progress has been made with genetic techniques to improve dryland farming yields with new and improved cultivars. South Africa promises to remain self-sufficient in food supply in the foreseeable future. The Commission's general finding that there was no urgent need to accord high priority to the provision of additional irrigation facilities for the benefit of agriculture has been found to be correct during the past decade. The Commission's opinion that canned deciduous fruit, sugar and wine could possibly warrant expansion of irrigation has not proved valid as these commodities are in world-wide oversupply. However, expansion of irrigation by private farmers and irrigation boards has continued since the Commission's report, indicating that expansion under private initiative is commercially viable and that participation by the State on a large scale could possibly upset established markets (Section 2.6).

During 1983 a study was commissioned by the DWA to find the means of determining the socio-economic effects of irrigation development and during 1984 an interdepartmental committee began an investigation into the probable demand for agricultural products and to what extent the demand should be met by new irrigation schemes. At present the Departments of Water Affairs and of Agriculture and Water Supply are investigating the economic need for the expansion of irrigation. The position is thus under continuous review (Sections 2.6 and 7.1). There has been no need to implement emergency plans to switch land for import substitution and this has therefore not been done (Section 2.6).

(5) Available water supplies and the future needs of the most important urban and industrial areas

Industrial activities and population are highly concentrated in specific areas of the Republic, so much so that in 1960 the four most important metropolitan regions produced no less than 80% of the country's manufactured articles and provided work opportunities for 78,5% of the indus-



Driekloof Dam, an element of the Drakensberg Project, which supplies water to the PWV area

trial labour force.

Of particular importance is the Southern Transvaal industrial complex, which is responsible for 45% of the country's industrial production. This region is dependent for its water mainly on the Vaal. The assured yield of the present Vaal Dam is $2.823 \times 10^3 \text{ m}^3/\text{d}$ (621 mgd). By means of schemes already planned, for the bringing of water from other catchments, for the provision of additional storage facilities within the Vaal basin and for the application of sound management practices, the assured yield can be pushed up to 11 820 x 103 m³/d (2 600 mgd). With two-cycle reuse of 50% of the water drawn from the system, it is estimated that the total demand in the catchment may well rise as high as $9550 \times 10^3 \text{ m}^3/\text{d}$ (2 100 mgd) by the close of the century. There will thus in fact be a slight margin for future development. Although it may turn out to be lower than indicated, predicted usage for planning purposes can be established only through careful study of consumption trends.

Neither demand nor supply can, however, be regarded as fixed quantities but rather as quantities that can be influenced by price and administrative policies. If there is a reasonable decentralisation of economic activity and the appropriation of adequate funds, sufficient water can without doubt be made available to meet the evergrowing needs of our largest metropolitan complex.

The Western Cape embraces a second important node of economic activity. Its water demand is expected to increase from the 1965 level of $245 \times 10^3 \, \text{m}^3/\text{d}$ (54 mgd) to $1\,246 \times 10^3 \, \text{m}^3/\text{d}$ (274 mgd) by the year 2000. If all available supplies are exploited and reasonable reuse of sewage effluents is introduced, sufficient water can be made available for the foreseeable future. Thereafter, the desalination of sea water will provide for future needs.

A third important industrial region is the Durban-Pietermaritzburg complex, which is expected to grow rapidly. It is estimated that water usage will rise from the present $455 \times 10^3 \, \text{m}^3/\text{d}$ (100 mgd) to about $1\,800 \times 10^3 \, \text{m}^3/\text{d}$ (400 mgd) by the close of the century. When the catchments presently being tapped have reached full development and water has been brought in from the Unkomaas, there will be sufficient water, with efficient reuse, to meet requirements till the beginning of next century and thereafter sources such as the Umzimkulu and Lower Tugela can be exploited. In regard to water the future of this region is therefore assured.

Port Elizabeth-Uitenhage is the fourth important metropolitan zone. Water demands have risen sharply during the post-war years and expectations are that usage will increase from the present $90 \times 10^3 \, \text{m}^3/\text{d}$ (20 mgd) to about $730 \times 10^3 \, \text{m}^3/\text{d}$ (160 mgd) by the end of the century. The area is assured of sufficient water for the foreseeable future and, being near the coast, can always fall back on the desalination of sea water.

Bloemfontein can draw adequate water for its future requirements from the Caledon River.

To meet its rapidly increasing demands, the Witbank-Middelburg area can obtain water from the Olifants in quantities sufficient only till about 1980. Thereafter, additional supplies will have to be derived from the Steelpoort or elsewhere.

Fortunately, the largest of the Bantu homelands are situated on the eastern escarpment, which is blessed with the country's richest water resources; water supplies for the homelands and decentralised border industries will therefore offer little difficulty. From the water supply point of view, the Tzaneen-Phalaborwa, Tugela basin, Richard's Bay-Empangeni, and East London-King William's Town regions are all extremely well suited to large-scale decentralisation.

The centres immediately to the north of the Southern Transvaal complex, such as Rosslyn, Brits and Rustenburg, will have to remain partly dependent on the Vaal. Temba can be supplied from the Pienaars River and the Pietersburg-Potgietersrust region will eventually have to draw water from the Olifants.

Comment

The present and expected water supply situation in the major metropolitan industrial areas and growth points in the country is dealt with in Chapter 5. In general, the expected medium-term demands can all be met. The Industrial Decentralization Strategy is discussed in Section 6.7 and the joint use of water by the RSA and the self-governing national states and independent TBVC states is discussed in Sections 3.1 and 8.1.

II. Measures to maintain the balance between supply and demand — efficient management and control of the country's water resources

(6) Introduction

As explained in chapter 1, unless the essential steps are taken to plan the exploitation and augmentation of our water resources, to conserve and reuse our available supplies, and to manage and control our resources in the most efficient manner, serious shortages will be suffered somewhere before the close of the century. Following on from Part I, Part II sets out the measures that must be adopted to maintain a continuous balance between the available supplies and sharply rising demands.

(7) Efficient storage of water

Attempts to raise the net assured yields of our storage works may be approached from three angles: first, the possibility of rendering a greater percentage of river flow available for use by means of suitable storage; secondly, the efficient management of available supplies and, finally, the elimination of unbeneficial water works.

Belonging to the first group are attempts to raise the yields by planned siting of dams. A purposeful programme should be launched for the investigation of all possible sites where dams can be built in order that it may be possible to determine with confidence the maximum utilisation of the runoff of our rivers. In the selection of dam sites, special attention should be given to the reduction of evaporation losses.

The second group embraces the application of advanced control systems for the management of dams to ensure improved yields. In managing a multi-purpose scheme that has to meet competing needs within a region, the aim must be the optimum yield and utilisation of the available water supplies.

To the final group belong attempts to limit the numerous small farm dams that merely lead to unnecessary evaporation losses; construction of these should be permitted only where the advantages fully compensate for the concomitant evaporation losses and runoff reduction.

The implication is that in principle there should be some control over all dam-building to ensure that in future storage of water will be beneficial to the country as a whole. Such control must, of course, be exercised in such a way that it will not be a hindrance to sound, desirable agricultural development.

Comment

A comprehensive site investigation programme which considers all factors and includes intensive geological studies is now undertaken for all dams. For the past decade the DWA has been striving to apply improvements in the analytical techniques developed for the operation of dams (Section 6.3). The Commission's recommendation that the number of small farm dams, which may cause unnecessary evaporation losses, be restricted has not been implemented. Research is being undertaken by the DWA to determine the usefulness and the influence on water resources of small farm dams (Section 3.2) and legislation aimed at controlling the number of farm dams in critical catchments is being considered (Sections 3.2 and 8.4).

(8) Reduction of evaporation losses

Although the percentage diminishes from west to east and varies considerably from place to place, on the average about 27% of the water that our existing dams can deliver is lost by evaporation. Reduction of this loss will raise the assured yield of our storage dams. Methods that have already enjoyed attention include the application of protective layers to water surfaces, the construction of larger and deeper reservoirs, the siting of dams in regions of low net evaporation, and the storage of water underground. As evaporation loss is much greater from full than from part-full reservoirs, it follows that losses will be lessened by operating reservoirs according to the variable draft procedure. The application of correct management procedures, especially where there are multiple dams in a single basin or in separate interlinked catchments where evaporation loss rates differ, can help considerably to keep losses as low as possible.

Comment

In the planning of storage, account is taken of the advantage of deep basins with a small water surface area. As the most favourable dam sites have been exploited, implementation of this principle is becoming more difficult. However, some notable successes have been achieved, for example with the Sterkfontein Dam, which augments the Vaal River system. Its high altitude and deep basin favour low evaporation.

Evaporation suppressants, normally films of chemicals sprayed onto the water surface, have proved disappointing in experiments (Section 3.6). Variable draft procedures used to reduce evaporation have been implemented where applicable and improved techniques are being developed (Section 6.3).

(9) Underground storage of water and augmentation of our water resources from ground-water sources

Where aquifers are located deep enough to avoid losses through evapotranspiration and if leakage can be eliminated, underground storage will permit us to exploit more of our available water.

Unfortunately it is not yet possible to assess quantitatively the potential contribution of our groundwater resources. It has been proved, however, that there is no question of a progressive country-wide drop in groundwater levels and gradual exhaustion of groundwater resources. It has been found that, although over-pumping is going on in a number of areas with the resultant steady depletion of stored groundwater, the underground resources of the country as a whole are not being fully exploited. It is essential that those areas where groundwater sources are being or are clearly about to be overtaxed be identified as quickly as possible and declared subterranean water control areas. Further development in such regions must then either be frozen or allowed only under permits embodying strict conditions.

Over the major part of the Republic natural replenishment of groundwater takes place every year. In some parts, especially those with dense vegetation and summer rainfall, recharge occurs irregularly but areas that enjoy no replenishment are very limited. The drying up of numerous boreholes annually is largely ascribable to the extremely limited storage capacities of the sources and to the fact that boreholes are injudiciously distributed, with the result that as a rule the sources are only partially exploited. On the other hand,

there are areas where the groundwater reservoirs are comparatively large and where total abstractions should definitely be restricted to the average annual recharge. Safe yields of such groundwater sources can, however, be increased by artificial recharge. Judicious development of groundwater sources can be achieved only on the basis of comprehensive surveys and yield determinations. Our knowledge of the groundwater resources of the Republic is unfortunately limited. Only a few groundwater compartments have been fully surveyed and the available information is thus quite inadequate for any long-term resource planning.

Comment

The storage of purified sewage effluent in the alluvial aquifers of the Cape Flats is being investigated (Section 3.5) and a pilot abstraction and recharge scheme started operating in 1985. Abstraction of ground water from the dolomitic area south of Pretoria and in the Zuurbekom and Tarlton areas is being investigated and boreholes are being drilled with a view to developing emergency water supplies for the Rand Water Board. These investigations will be extended to the rest of the dolomitic areas in the Pretoria-Witwatersrand-Vereeniging (PWV) region. If abstraction of water from the dolomites is found to be feasible, the investigations will provide the information needed for the design of storage and abstraction facilities.

Since a report on the ground water situation was produced in 1973 by the Ground Water Division of Geological Survey of the Department of Mines with the cooperation of the Water Research Commission (WRC), numerous ground water investigations have been undertaken to locate and develop water supplies for local authorities. Notable examples are Atlantis (the development of which from its inception until at least 1987 will have been based solely on ground water), De Aar, Beaufort West, Vryburg and Potgietersrus.

Since 1970 three areas, where it was suspected that the ground water resources were being overtaxed, have been declared subterranean water control areas, namely the Nyl River (1971), Saldanha (1976) and the Crocodile River (Western Transvaal) (1981). The declaration of subterranean water control areas is approached with circumspection (Sections 6.12 and 8.4).

(10) The state of preservation of catchments

There is a close relationship between soil conservation and the harvesting of water from catchment areas but the interplay is highly complex. Soil conservation is promoted by dense vegetation, which inhibits soil erosion, delays storm runoff and encourages infiltration. Nevertheless, vegetation needs water to sustain itself. Because of interception and transpiration, particularly by dense evergreen forests of plantations and by hydrophytic plants in vleis, the total water yield and low flows during the long dry seasons are diminished. Much more runoff occurs from a bare soil surface but, because of reduced infiltration, flood peaks are raised and percolation, which feeds the rivers during dry seasons, is decreased and the runoff is consequently less sustained. Increased soil erosion from bare surfaces also greatly aggravates the silting of storage works.

The ideal from the point of view of water yield thus lies between the two extremes of the complete preservation of the soil and the total exposure of the soil to erosion. Optimum treatment for each region must be decided according to local circumstances and the nature of the vegetation. Plants that thrive during the rainy season and are dormant during the dry season will have a less detrimental effect on the low flow yield. To derive maximum advantage from the available water and associated soil it is important to create a cover of useful and beneficial vegetation.

As a result of increasing water consumption, evidently in the main owing to the intensification of agriculture, some regions have, according to gaugings over the past twenty years, experienced marked reductions in runoff per unit of catchment rainfall. Large reductions, however, are confined exclusively to two-thirds of the country's area, which yields a mere 15% of the runoff, and therefore do not as yet constitute a threat to the water resources of the land as a whole. The phenomenon is nevertheless posing serious regional problems for riparian owners along the lower reaches of rivers in the arid parts of the country. In some of the mountain catchments of the Eastern Transvaal, large-scale afforestation especially of former grass-covered mountain slopes on which the vegetation used to be dormant for part of the year, has established a dense evergreen vegetal cover and reductions in runoff by as much as 30% appear to have taken place. It is important that more quantitative information be gathered on the influence of afforestation on runoff so that it may be established with certainty to what extent and in which regions the consumption of water by plantations can be regarded as a beneficial use of water from the point of view of the overall economy.



Afforestation plays a major role in the conservation of mountain catchment areas

The state of catchment conservation has an important bearing on the sediment loads in the rivers. Where rainfall is comparatively high and vegetal cover satisfactory, sediment loads are usually low. Tendencies to soil erosion, with consequent increases in sediment content of river flow, however, are in some areas aggravated by the nature of the geology.

Measurements of sediment loads in our rivers reveal that there are wide variations in the average percentage of material in suspension from river to river. As a volumetric percentage, mean silt movement seems to be 0,53% of runoff, implying a total annual average sediment load of $276\ 700\ x\ 10^3\ m^3\ (106\ 000\ morgen\ feet)$.

The deposition of sediments and manner of distribution of the silt in reservoir basins greatly affect the useful life of storage, the acquisition of land for storage basins, and the costs of measures to prevent silting.

Apart from the great expense associated with the raising of a dam to retrieve lost storage volume, in the long run the major disadvantage of silting is that deeper parts of the basin fill up the most quickly with silt. The result is that with each raising of the wall, for a given storage capacity, there is an increase in the water surface area exposed to evaporation. This means that evaporation losses increase and, with continued raising, become so large that eventually the basin is no longer of value as a storage unit. It is thus very important that silting be combated as energetically

as possible to ensure that our available water can be effectively stored for use.

There can be no doubt that the best protection against the silting of storage works is to be accomplished by arresting at source the sediments that reach our rivers. Correct land management is thus of cardinal importance in the combating of siltation.

Regarding the state of conservation of catchments, it must unfortunately be confirmed that, in spite of encouraging progress with soil conservation in limited parts of the country, the condition of many of the important mountain catchments as well as of the lower-lying parts of our drainage regions is still highly unsatisfactory.

According to the report on "Conservation of mountain catchment", which appeared in 1960, 14% of the catchments were then in good condition, 76,5% average, and 9,5% poor. Subsequent observations in 90 of these areas reveal that conditions in 16,6% of them have improved, 43,3% have remained much the same and 40,1% have deteriorated still further. The state of conservation in many of the lower-lying parts of our drainage regions also leaves much to be desired. In fact, there is scarcely a single part of the country where soil and vegetation have not to a greater or lesser extent been damaged.

The most important reasons for deterioration in the state of conservation in many catchment and drainage areas are to be found in the primitive and inefficient farming practices still being applied in large areas of the country and the continued injudicious burning of mountain slopes, especially when accompanied by mismanagement and misuse. This unsatisfactory state of affairs must be ascribed partly to the ignorance of the inhabitants, partly to tradition, especially among the Bantu, partly to lack of interest, and partly to the proliferation of sub-economic farming units.

On the question of burning in mountain catchments, the Commission's opinion is that in the arid mountain catchments and mountain kloofs the advantages are not outweighed by the disadvantages, but that a judicious rotational burning system in the higher rainfall parts — excluding mountain kloofs — may well be justified.

Clearly, as there is a general conflict between the interests of individual landowners and the broad national interest, the Commission is of the opinion that the protection of all important catchments is a matter for which the State must, in large measure, accept responsibility. It is in fact essential that the measures undertaken by official bodies to check soil erosion and to effect stability in the potential water yields of our catchments be accelerated. In this connection water-courses deserve special attention.

Comment

In the Fish and Sundays River catchments soil conservation has proved very effective and has resulted in a considerable reduction in both sediment load and runoff. An unforeseen effect was the increased salination of the base flows of these rivers (Section 4.2).

Since the introduction of the Mountain Catchment Areas Act, 1970 (Act 63 of 1970), mountain catchment areas have been defined and management committees established. The implementation of management plans has made an important contribution to the state of preservation of catchments. A permit system was instituted in 1972 to control expansion of afforestation (Sections 2.8 and 6.13). The Department of Environment Affairs is developing a catchment biosystem management model which aims at obtaining the maximum production per unit of water, the optimum preservation of the natural ecology and minimization of soil erosion.

Serious deterioration is still occurring in some catchments where the Agricultural Resources Conservation Act, 1983 (Act 43 of 1983), the Forest Act, 1984 (Act 122 of 1984), and the Mountain Catchment Areas Act, 1970, are not actively implemented (Sections 3.2 and 6.17).

(11) Hydrological planning of catchment development

From the foregoing review of the various aspects of soil and water conservation it seems that the two concepts are not always synonymous. The best management of a catchment must in fact be a compromise whereby as little as possible of the water that is not being beneficially utilised should be held back, consistent of course with avoiding soil erosion. To obviate a clash, it is important that the work on erosion control be co-ordinated with that on water conservation.

In Chapter 6 it was proved that shortages before the close of the century in any of the most important agricultural products in South Africa were highly unlikely and therefore there seems no reason why any region suitable for afforestation should be reserved for agricultural purposes or why afforestation should be restricted so that the water resources may be reserved for future irrigation purposes. Normal fluctuations of economic factors may in due course provide a decisive answer to this but, in any event, the matter can always be reviewed as and when plantations now established reach maturity and are clear-felled.

Where expansion of afforestation is endangering established irrigation or other water utilisation developments, however, restrictions should be imposed. Full consideration should in any event be given to the economic benefits of afforestation, the probable costs of storage schemes to overcome water shortages and the economic justification for expanded development.

A policy which has been applicable since 1934, namely that of State acquisition by negotiation or expropriation of mountain catchments deemed vital for water conservation, should be retained, but steps should be taken to accelerate the process so that the most important mountain catchments can become State property within a reasonable time.

In the transition period while mountain catchments are being purchased by the State, as many of these areas as possible should be declared catchment control areas in terms of the Water Act of 1956, and should be managed with a view to protecting the water sources.

To avoid clashes of interests that arise among various consumers as the result of rising demands for water it is desirable that the manner and purpose of water utilisation within each catchment be timeously determined and that planning and subsequent action accord with such determinations

The Minister of Water Affairs could with advantage invoke his powers under the Water Act to insist that, where afforestation schemes have been or are about to be established in catchment control areas, such schemes be managed in accordance with conservation directives laid down by him for each specific afforestation project. It is considered particularly desirable that the Departments of Agricultural Technical Services, Agricultural Economics and Markets, Water Affairs and Forestry should make joint recommendations for these directives.

Often referred to as "sponges" and presumed to detain stormwater during the rainy season and slowly release it during low flow periods, some vleis frequently turn out in fact to be mere consumers of water; yields would in most instances be increased if they were to be drained and such vlei vegetation as has no value replaced by useful crops. On the other hand, many vleis do indeed provide good grazing. Drainage of vleis is of course permissible only if executed in such a way as not to lead to soil erosion. The whole subject demands careful investigation.

Comment

These issues are dealt with in the sections on water demand for forestry (Section 2.8), the application of the Mountain Catchment Areas Act, 1970 (Section 6.13), the influence of land use on runoff (Section 3.2) and water for ecological considerations (Section 2.9). The concept of utilizing rainfall in situ has been included in the Forestry Guide Plan developed by the Department of Environment Affairs and in a programme by the Department of Agriculture and Water Supply to develop improved cultivars for dryland farming.

(12) Control of flooding

Although the problem has never as yet assumed major dimensions in South Africa, appreciable damage is from time to time wrought by floods.

Control of flooding is of importance in protecting and augmenting our water resources from two particular points of view. On the one hand, appreciable additional quantities of water can be retained in storage through improved flood control and be made available over an extended period; by regulating storage on a variable draft basis beneficial use can be made of the water while, on the other hand, silting of storage can be delayed.

Application of sound hydrological and hydraulic principles and promotion of soil conservation measures can contribute to the solution of flood problems. Steps should also be taken to control development within the flood plains so as to obviate the damage suffered during inundations.

Comment

Since the Commission's report, major floods have occurred in the RSA, such as the flood at Laingsburg in 1981 and the floods caused by cyclone Domoina in 1984. All dams in the RSA are now subject to a review of their flood handling capabilities. More rigorous standards of design are being implemented for new dams and new legislation relating to dam safety is being implemented (Section 6.18). Some dams have been designed with a flood protection function, in addition to their storage function, such as the Hendrik Verwoerd Dam and, to a limited extent, the recently raised Vaal Dam.

Flooding of irrigated crops along river banks, where flood plains are susceptible to occasional inundation, is a serious problem, as was demonstrated by damage to sugar cane along the Umfolozi River and on the Pongola flood plain in 1984.

A policy restricting flood damage compensation to areas above the 1 in 10 year flood line has been proposed. In accordance with the Water Act, 1956 (Act 54 of 1956), all developers are compelled to show the 1 in 20 year flood line on new township layout plans. Enforcement of this provision is vested in local authorities, who may impose restrictive conditions on development below the flood line (Section 6.5).

(13) Desalination

Desalination of sea water to augment fresh water supplies to development nodes along the south and west coasts of the Republic will become indispensable within the next two to three decades if urban and industrial development is to continue. Current research assessments of the economics of desalination hold out promising prospects for production of fresh water from sea water for urban and industrial purposes. Where economic circumstances are favourable, sea water desalination combined with power generation is being put into practice in several overseas undertakings, all of which at present use fossil fuels. It follows that the discovery of oil and combustible natural gas at the coast, as also the development of nuclear energy on an economic basis, would considerably aid the large-scale desalination of sea water.

Although on economic grounds the use of desalinated sea water solely for irrigation purposes holds little or no promise, the benefit-cost structure of a combined power generation and desalination unit of the order of 227 x 10³ m³/d (50 mgd)

capacity might well, under favourable circumstances, become attractive for indirectly assisting irrigation. In the western Cape, for instance, desalinated sea water could largely relieve the urban and industrial areas of their dependence upon the rivers and river catchments and consequently promote the profitable irrigation farming of the region.

The development of economic desalination processes would make possible the following

- (i) the unrestricted reuse of purified industrial sewage effluents in a closed water system. In an urban water economy, cumulative utilisation will lie between 1,4 m³ and 1,8 m³ (300 and 400 gallons) for every 0,5 m³ (100 gallons) of fresh water introduced into the system depending on losses in the water reticulationsewage cycle; and
- (ii) The reduction of mineral pollution of fresh water sources and consequent increase in the usage value of mineralised effluents.

Research currently being undertaken by the Council for Scientific and Industrial Research into the desalination of sea water should, in the opinion of the Commission, be intensified in collaboration with other interested organisations and placed on a feasibility basis.

Comment

The desalination techniques are now well advanced and desalination may be needed to meet the water requirements of some coastal urban areas by the twenty-first century. At present, however, desalination cannot compete economically with the development of the remaining conventional resources (Section 3.6).

(14) Reuse of water

By practising multiple internal recirculation of water and effluents in factory processes, the fresh water intake can be reduced by between 50% and 90%. Furthermore, research work carried out in practical situations has proved that factory production can be pushed up by 50% to 100% without raising the fresh water demand.

Between 60% and 100% of the fresh water intake to factories and residential areas reaches the sewage treatment works, and in a rather limited number of cases purified effluents are reused for a variety of purposes. On the Witwatersrand, for instance, only 20% is reused by industries and power stations.

As a result of the development by the CSIR of advanced techniques for the conversion of purified sewage to class A water, and the successful transfusion into the water mains at Windhoek, it is economic and practicable to establish the reclamation of sewage effluents as an integral part of the water economy within the urban and industrial areas and in major towns. It is feasible to meet 50% of the water demand from reclaimed water; two-cycle reuse is equivalent to making available an additional 75% of the original fresh water intake. It is therefore imperative that the research work of the CSIR is this field be placed on a feasibility basis in collaboratin with other interested organisations.

Comment

Noteworthy advances have been made with the internal reuse of water for industrial processes since the Commission's report. Considerable indirect reuse is also taking place as a result of effluent discharged to natural water courses being reused further downstream.

The rate of indirect reuse is increasing and the associated complications caused by salination are fast becoming a major problem. The technology for the direct domestic reuse of treated sewage effluent has been proved at Windhoek and Daspoort, and a pilot scheme for the reclamation of waste water to potable standards has been started in Cape Town. Full-scale plants to utilize reclaimed sewage effluent have been found to be both feasible and economic in investigations undertaken in the Border region (Section 4.2).

(15) Further savings in urban water use

The domestic use of water can be reduced in many ways without lowering living or health standards or unnecessarily burdening consumers. It must be brought home to them that even though squandered water can be reclaimed, this requires additional capital outlay and running costs. Substantial savings can be effected by modifications in the type and size of toilet facilities, improved water use methods, elimination of leakage, and pressure regulation at distribution points.

Experience has also proved that water consumption invariably declines when individual metering is introduced and each family pays according to quantity used. An appreciable reduction in water use can be effected by installing individual water meters for all industrial and domestic consumers, including individual flats and non-White dwellings.

Large erven and gardens, which have in the past been traditional in South Africa, also promote the excessive use of water. In areas where inordinately large quantities of water are needed to maintain gardens, plots will in future have to be restricted to reasonable size.

Comment

There has been no substantial progress with the use of water saving appliances in houses, individual metering and the fitting of meters in flats, but progress has been made with the development of water saving appliances such as toilet cisterns. Research into water saving measures for distribution systems in urban areas is being carried out by the National Building Research Institute under contract to the WRC. There has been a trend towards smaller erven but water use in subeconomic areas is often still not metered, resulting in wastage.

Too rigorous an adherence to water saving in households will however reduce the flexibility needed to accommodate water restrictions during droughts (Section 6.4). General adherence to the limit of 400 ℓ /d per household during the recent drought in the Pietermaritzburg-Durban area has shown that use can be curtailed for a time by drastic restrictions and punitive tariffs.

(16) Prevention of pollution

Pollution of the Republic's rivers, through the discharging of industrial and domestic sewage effluents and the shedding of stormwater from urban, industrial and mining areas and from cultivated, irrigated and over-grazed lands and through seepage from irrigation areas, has already, to a greater or lesser degree, detrimentally affected fresh water sources. Pollution by mineral salts, particularly those derived from irrigation seepages, industrial and mining effluents, and storm runoff from mining areas, has already created serious problems.

In some of the Republic's urban and industrial areas — for instance, the Witwatersrand region — the capacity of rivers to limit the deleterious effects of mineral pollution by dilution has reached breaking point. It has accordingly become essential to protect the Republic's fresh water sources in regions where mineral pollution has assumed serious proportions. This can perhaps best be accomplished by creating closed saline water control systems, planned in such a way that the waters are used for recreational, industrial and

other purposes that do not demand mineral-free water. Moreover, these bodies of water can be planned as sources for mass-production demineralisation plants.

The most effective means of controlling pollution by industrial and domestic sewage effluents lies in the reuse of water and the reclamation of effluents. The organic pollution load in industrial effluents can be efficiently removed if mixed with domestic sewage and the two types of waste purified in conventional sewage treatment works. In this way the reclamation of purified effluents for reuse would be promoted. It stands to reason that industrial effluents should be discharged into municipal sewers the better to control pollution and promote reuse. On the other hand, it is essential that local authorities institute strict control measures because effluents from some industries contain chemicals that detrimentally affect the reuse value of the treated effluent.

Comment

The monitoring and control of pollution by the DWA has increased greatly since the Commission's report. As the deterioration of water quality may become a more serious problem than the limited resources available, a major effort is being made to counter pollution. Effluent standards have been raised and an intensive study of the eutrophication and salination problems of the PWV area is under way. Progress is promising (Chapter 4).

(17) Water savings in power generation

The quantity of water consumed per unit sent out varies from $0,006~\text{m}^3$ (1,3 gallons) per kWh in the old stations to $0,004~\text{m}^3$ (0,9 gallons) per kWh in the modern stations.

Tests currently being undertaken by Escom hold out prospects of reducing the water consumption in "wet" cooling systems to about 0,003 m³ (0,6 gallons) per unit sent out.

If the use of "dry" cooling systems, with which Escom has already made a start, proves technically and economically acceptable, water consumption may drop to 0,00068 m³ (0,15 gallons) per unit sent out.

It is predicted that the installed capacity of power stations in the Republic at the close of the century will be 68 000 MW. If it be accepted that half the energy demand at that time will be met by nuclear power stations located at the coast and the remainder from coal-fired stations in the interior, the capacity of inland stations, allowing appropriate load factors, will be 45 000 MW. If "wet"

cooling is then still in use, the water consumption for power generation will be $1\ 227\ x\ 10^3\ m^3/d\ (270\ mgd)$, of which an appreciable proportion will be derived from the Usutu complex. On the other hand, if all new coal-fired stations beyond the first $10\ 000\ MW$ are equipped with dry cooling systems, the water consumption for power generation at the end of the century will be only $511.4\ x\ 10^3\ m^3/d\ (112.5\ mgd)$. The possibility of bringing about savings of such magnitude clearly calls for efforts in this direction to be pursued with energy and perseverance.

By making full use of the Republic's small but valuable hydro power potential, by importing power from contiguous regions, by establishing nuclear stations at the coast and by adopting water-saving measures at coal-fired power stations, much can be done to reduce water consumption. It is nevertheless evident that appreciable quantities of water will have to be reserved for power generation purposes.

Comment

Maps have been prepared showing the availability of water relative to that of coal. Where possible, power-stations are being optimally sited in relation to both.

To reduce the use of water for power generation, the DWA has requested Escom to consider using a dry-cooling process in future power-stations where this is economically feasible and where it can lead to a decrease in the consumptive use of water (Section 2.4). Each power-station will be dealt with on its own merits. Two dry-cooled stations are at present under construction and at the Grootvlei power-station near Heidelberg, where Escom decided to use drycooling before the DWA introduced this requirement, this process is already in operation. The increased capital costs for dry-cooling and the marginally lower thermal efficiency of the process will be offset by the savings on the cost of water supply.

Hydro-electric stations at the Hendrik Verwoerd and P K le Roux Dams and the Drakensberg and Steenbras Pumped Storage Schemes have assisted in balancing loads on the electricity supply grid. A pumped storage power-station is being constructed on the Palmiet River in the south-western Cape and the economic viability of building other hydro-electric power-stations is being investigated. The nuclear power-station at Koeberg in the western Cape, cooled by seawater, was commissioned in 1984.

(18) Improvement of irrigation techniques

Agriculture is by far the major consumer of water. Efficient control and utilisation of water by this sector is therefore of utmost importance in the drawing up of a national water plan for the future.

There seems little doubt that the irrigation techniques currently employed and the irrigation scheme layouts adopted often lead to waste of water. Leaky dams and furrows and faulty physical planning are also frequently responsible for wastage of water. Resultant waterlogging and brack are aggravated by the fact that in the planning and layout of irrigation schemes adequate provision has not always been made for effective drainage systems.

Among many irrigation farmers, knowledge of the basic requirements of efficient irrigation and water utilisation is lacking.

Enlightenment of farmers in the agricultural and engineering aspects of irrigation practice must enjoy high priority otherwise efficient use of irrigation water will not be achieved. Such enlightenment should be closely linked with the provision of water by the Department of Water Affairs and, consistent with good farming practices, emphasis should be laid on economic aspects in order to achieve the maximum yield per unit of water. To promote enlightenment in basic knowledge it is regarded as essential that an irrigation research institute be established where the relevant departments and other organisations can co-operate in this sphere.

The planning and development of irrigation schemes should not be over-hasty and must not precede the acquisition of essential information, such as the results of soil surveys. For rational planning it is necessary that a master plan be compiled by all interested organisations, in which all facets are gathered together to form a unit and are evolved according to plan. Success demands the closest co-operation and co-ordination among the various departments and other interested organisations. In the past this essential requirement has very seldom been met.

Thorough knowledge and evaluation of the soil forms the basis of efficient planning of an irrigation project and this can be gained only if effective soil surveys precede the planning. Because of inadequate staff, however, it has seldom been possible to complete the necessary soil surveys.

The Commission is of the opinion that, if the shortcomings referred to can be overcome, the struggle towards a 25% saving of irrigation water per unit of production can succeed.

Comment

Since 1970, the DWA has instituted a training programme for water control officers and has undertaken improvements to its waterworks, resulting in a reduction in water distribution losses. Although there have been clear improvements in irrigation efficiency there is still considerable scope in this direction. The DWA subsidizes the purchase of more water-efficient irrigation equipment by farmers and also the cost of reducing seepage from furrows and night storage dams, generally referred to as leidams.

The Soil and Irrigation Research Institute recommended by the Commission has been established and a study on means of achieving the maximum yield per unit of water is under way. In recent years the planning of irrigation schemes has been based on intensive soil surveys. A liaison committee between the Departments of Water Affairs and of Agriculture and Water Supply has been established to monitor existing schemes and to co-ordinate the planning and development of new schemes. Where uneconomic units exist, farmers are encouraged to consolidate properties, but this recommendation has not been effectively implemented because of financing constraints.

Irrigation plots allocated at the Ramah Canal on the Orange River Project were made available to candidates with the necessary acumen, but no specific training programme was undertaken. Economic irrigation units were provided at the Ramah Canal and will be provided on any future irrigation schemes. Irrigable land in excess of an economic unit was included in each plot so that the able irrigator can achieve higher yields per unit of water. Plot owners are also permitted to purchase additional plots. This policy is however being reviewed to establish whether it does in fact promote the optimal use of irrigation water (Section 2.6).

(19) Forecasting of climatological conditions

Very great advantages in the management and practical utilisation of our water resources would follow if a measure of reliability could be achieved in the long-term forecasting of climatological conditions. If rainfall for a year ahead could be predicted with some certainty, advance decisions could be taken, with the result that the available water resources could be more efficiently utilised.

For some time past, attempts have been made

to establish a correlation between rainfall and sunspot cycles, but in South Africa there seems to be little connection between sunspot activity, or changes in the intensity of sunspot activity, and rainfall.

Bearing in mind the enormous capacity for heat storage in the oceans compared with that of the atmosphere, there can be no doubt that long-term insolation changes are reflected in the sea and thus affect atmospheric turbulence. Consequently it is possible that major long-cycle fluctuations in the weather are brought about by measurable changes in the oceans. Attempts are currently being made on an international scale to acquire the necessary oceanographic data with the aid of sophisticated electronic devices.

The Commission regards it as essential that research and attempts to acquire the necessary data to make long-term weather forecasting possible be actively supported.

Comment

No reliable techniques for long-range weather forecasting have been developed in the RSA or elsewhere. The severe drought in South Africa since 1978 and the world-wide climatic disturbances during this period have underlined the need for research (Section 6.3).

(20) Extraction of water from atmospheric moisture

It is estimated that only about 5% to 10% of the moisture content of the air mass moving over a country reaches the ground surface in the form of rain or snow. Methods of extracting and using more of the remaining moisture have already enjoyed much attention but considerable research is still needed. According to tests carried out elsewhere, condensation of moisture droplets in a cloud can be triggered by the artificial introduction of suitable nuclei such as silver iodide and indications are that in favourable circumstances rainfall can be increased by as much as 20%. Another possibility is the extraction of moisture from the atmosphere by means of condensation screens. At this juncture it is not possible to say with certainty to what extent our water resources can be augmented through activities of this type. It is considered essential, however, that research in these spheres be promoted by the Department of Water Affairs in collaboration with the Weather Bureau and other suitable bodies, such as the

Analyses of the characteristics of South Africa's

climate, and the circumstances associated with the occurrence of deserts alongside oceans, inland seas and lakes, indicate that the building of dams or the creation of lakes, as envisaged by the socalled Schwarz Scheme, would have practically no influence on rainfall in South Africa.

Comment

Despite considerable incentives to achieve success and much experimentation, results in the field of rainfall stimulation and abstraction of atmospheric moisture are still inconclusive. World research has declined but a new series of experiments is being undertaken in the RSA (Section 3.6).

(21) Variable draft

Our water resources, whether underground or surface, have their origin in the rainfall. Rainfall and runoff, however, fluctuate from season to season and from year to year, and losses are suffered through evaporation. The larger the capacity of storage dams, and the lower the rate of evaporation, the greater the degree of control we can exercise over our water resources. If storage provision were to be infinite and evaporation nil, river flow could be regulated to a constant value equivalent to the long-term mean annual runoff.

The difficulty in the Republic, however, is that runoff is extremely erratic and that evaporation rates are inordinately high. If utilisation is restricted merely to the assured yield, which is fixed by the most severe drought to be expected, large quantities of water would during normal and wet years be lost by evaporation or would escape over the spillways of dams. It would be far better to use surplus waters for purposes that do not demand a very high guarantee than to allow large quantities of water to escape from storages that are held as full as possible to guarantee yield during the most severe drought. If we can categorise demands according to priority, and therefore according to the degree of assurance with which the demands must be met, storages could be so regulated as to satisfy requirements in optimal manner.

A variable draft policy is especially applicable to the management of a multi-purpose scheme or one comprising linked catchments having different evaporation rates and meeting various kinds of demands. By employing sophisticated modern techniques it is possible to predict, six months in advance, the storage reserves needed to satisfy the various uses according to the required degree of assurance. In years of normal or better than normal runoff appreciable quantities of water that

otherwise would be lost can be beneficially used for irrigation, for which a high degree of assurance is not imperative. During a year of poor runoff the supply would have to be appropriately curtailed.

Farmers can be informed prior to planting time as to the available water supply. By these means water utilisation efficiency in a multi-purpose scheme can be increased by between 10% and 20%. It must be recognised, however, that major fluctuations in the water supply to irrigation schemes may have undesirable agricultural and economic repercussions. The degree to which the variable draft policy can be employed must therefore be thoroughly investigated under guidance of the proposed Water Affairs Committee.

Comment

Variable draft techniques are now being applied and will be refined (Section 6.3).

(22) Systems analyses

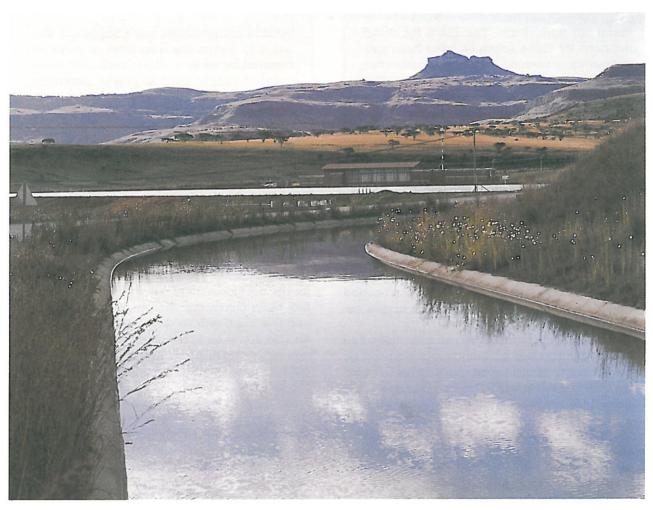
As the various centres to be supplied increase in number and become more diversified and as the water sources to be exploited multiply, so decisions as to the best sequence of development of the various resources and operational procedures to be adopted become more complex. Advanced techniques based on systems analyses have been designed to ensure the optimal management of multi-purpose multi-unit schemes. Application of systems engineering methods by experts in this field can lead to appreciable increases in the assured usable yield. The Commission considers that these methods of planning and managing our water resource developments should be adopted and that suitable personnel be recruited and trained in the techniques.

Comment

Dams operated in tandem as well as interconnected river systems are now being managed in accordance with systems analysis principles. Greater use will be made of these principles as more catchments are linked (Sections 6.3 and 6.4).

(23) Adoption of a suitable price policy

The application of a realistic price policy that reflects underlying scarcities is one of the most efficient ways of ensuring the effective exploitation of a country's resources. In a free economy it is more-



Main canal on the Drakensberg Project for transferring Tugela River water to the Vaal River system

over the best way of effecting a balance between supply and demand and preventing waste of a scarce commodity. It is therefore undesirable that the price of water, either to the urban or to the agricultural sector, be kept artificially depressed through administrative decisions.

In the past, water has largely been regarded as an asset provided free by nature, and the unrealistically low prices paid by farmers on Government irrigation schemes do not even cover the operation and maintenance costs. Such a policy has had the deleterious effect of encouraging the wasteful use of water. Farm budgeting data reveal that in the Republic water rates constitute a lower percentage of production costs than in other countries and that water costs represent a negligible proportion of the gross costs of crop production under irrigation. Moreover, it is clear that the production costs of most crops are relatively insensitive to water rates, with the result that there is little incentive for irrigators to use water sparingly. The solution to the problem is that water rates must be raised as a spur to the achievement of higher efficiency through the better use of all the factors at stake. Where water to a much

greater extent than soil, is the limiting factor for irrigation schemes, and likely always to be far more so than soil, it is essential that irrigation farmers pay much more attention to the yield per unit of the scarce factor through the optimal combination of both associated factors. It is only by prescribing realistic prices to both resources — prices that reflect the scarcity value in the national economy — that this objective can be achieved.

In general, therefore, it is regarded as fully justifiable gradually to raise water rates at existing schemes till at least the annual operating and maintenance costs are covered, and that for all new schemes this approach be adopted from commencement. In so far as possible, a contribution must also be made towards overhead expenditure.

Comment

Water for industrial and urban purposes is supplied at cost, but little progress has been made with the recovery of capital costs on Government water schemes supplying water for agriculture. The rates for water supplied by these schemes have been progressively increased to recover operating and maintenance costs, but not to an extent which has enabled the objectives to be achieved (Section 6.6). In the case of irrigation boards, a percentage of outstanding loans has been written off since the Commission's report.

(24) Transference of water from regions of surplus to regions of shortage

The provision of adequate water will in future be not only a national problem but to an even greater extent also a regional problem. The planning of catchments as geographic units will be demanded as well as the appropriate linkages of the resources of contiguous basins.

The basic aim in formulating plans for individual catchments and their mutual coupling should be the establishment of a broad directive for the optimum use, or combination of uses, of the water resources with provision for the future needs of the region.

There are, in the Republic, fortunately no legal restrictions for the transfer of water from one river basin to another. This does not, however, relieve the authorities concerned with such transfers of the responsibility for preparing very careful costbenefit comparisons, not only in the region of origin but also in the water-receiving region.

The solution of our water problems will in future entail the conveyance of more and more water over longer and longer distances. To provide for our large metropolitan regions, and some of our new industrial nodes and irrigation projects, the linking of neighbouring catchments will be an essential requirement. This demands the thorough planning of our water resources to ensure that optimum benefits will accrue to the whole country. In applying this policy, socio-economic principles that embrace the interests of the country as a whole rather than mere sentimental or geographical considerations must be decisive.

Comment

The policy of interlinking catchments is being applied to an ever-increasing extent. Examples are the Orange-Fish, the Tugela-Vaal, the Usutu-Vaal and the Riviersonderend-Berg River systems. The linking of catchments enhances water supplies, improves operating procedures and assists in countering the effects of droughts, and will

become progressively more important (Section 6.2). Increasing quantities of water are required by sectors which need high assurances of supply, such as power generation, mining and industry. During the drought that began in 1978 emergency measures had to be taken to link catchments such as those of the central and upper Vaal River and the Mooi and Mgeni River systems.

(25) Capital expenditure on the development of our water resources

Maintenance of a balance between supply and demand will in future call for huge and steadily increasing capital expenditures. Spending of funds for the development of our water resources has in fact been increasing sharply over the past years and the trend will no doubt persist. The reasons for this are to be found, first, in the industrialisation of the South African economy and the concomitant urbanisation of the population, secondly, in the fact that the more accessible and less expensive schemes have already been completed and, thirdly, in that water will in future have to be conveyed over steadily increasing distances. According to estimates, at present prices, the annual capital expenditure by the State on the development of our water resources will rise from R100 million during the 1970s to R200 million during the eighties and to R410 million by the end of the century. For the local and regional distribution of water, local authorities will have to incur appreciable additional capital outlays amounting by the close of the century to R125 million per annum.

Comment

The Commission's recommendation that public expenditure on the development of water resources be increased has not been implemented. Schemes are being built at higher than budgeted costs because construction is late in starting, relative to White Paper intentions, and because of extended construction periods resulting from cutbacks in finance. A far higher rate of inflation than expected is also a major factor. Since 1910 the proportion of State expenditure on water resource development has varied and at present it is at a major low point. South Africa's ability to withstand droughts is being severely tested at present and a considerable increase in expenditure is indicated in view of the associated risks and inconveniences (Sections 9.1 and 9.2).

III. Policy issues

(26) Planned development of the Republic's water supplies

The objective of planning is to achieve the optimal development and use of the country's water resources and this requires co-ordination with general economic and physical planning. Planning is thus an interdisciplinary process and a neverending task.

In the past our water resources have been developed 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 the optimal scale and sequence of development projects. Information provided in White Papers is usually aimed at justifying a particular scheme but is inadequate from the point of view of the cost-benefit analysis of projects generally. Frequently also the proposals are based on inadequate preliminary physical and economic investigations and analyses. The result is that the right scheme is not always tackled at the right time.

Planning of our water resources must be tho-

rough, however, not only because of the importance of providing adequate supplies to maintain life and for the advancement of the people, but also because of the enormous capital expenditure required for major waters schemes.

For the effective utilisation of our limted resources proper socio-economic evaluations of projects are indispensable. These require careful weighing of all the benefits—direct as well as indirect and intangible—against the associated costs. Only in this way can it be assured that, with the many other investments competing for the scarce financial and other productive resources of the land, a given project can be socio-economically justified.

Co-ordination of water development with general economic development is especially imperative to ensure that the scarce water resources are effectually exploited to provide for the future needs of the various sectors of the national economy.

Till now our water resources have been developed primarily for irrigation purposes. Because of the continually rising proportional contribution of manufacturing industry to employment and to the gross national product, the Commission is convinced that justifiable industrial development and the resultant future urbanisation of the population must be promoted by the fair apportionment of water among all sectors of the economy. In future allocations of water to irrigation development the same socio-economic considerations must apply



Midmar Dam, a major element in the development of the Umgeni River, Natal

as hold for the other sectors. Of the available supplies at the big schemes – the Orange and Pongola – a substantial share must also be reserved for industrial and urban development.

Neither on economic nor on strategic grounds is there any urgent need for the large-scale provision of additional water for irrigation within the foreseeable future. Emphasis should far rather be placed on raising the productivity of agriculture and animal husbandry on the already available dryland and irrigation soils and particularly on the achievement of higher yields per unit of water applied. Provided the necessary training and extension services are made available to irrigators, and layouts are improved where necessary, it seems that production on irrigation schemes can be increased by one-third without allotting additional water, in other words, the endeavour to effect a saving of 25% in irrigation allocation per unit of yield can succeed.

In the supply of water for urban and industrial use it is essential that, of the total fresh water intake, the percentage recovered for reuse be pushed up to about half over the next 30 years, that intensive research be instituted into all aspects of the conservation, utilisation, reuse, desalination and storage of water, and that in future very substantial financial resources be made available for this purpose.

Because of the regional water supply problems that already prevail, the efficient utilisation of our limited water resources requires also that catchments be planned and developed as geographic units and that contiguous catchments be linked. However, water must not be transferred from one catchment to another unless such action extends benefits to the country as a whole, i.e. when looked at from both long-term and short-term points of view and when careful consideration has been given to the interest of both the area receiving the water and the region from which it is to be taken. A greater measure of decentralisation of the Republic's economic activities can contribute much to the solution of urgent regional problems.

Comment

The national water management strategy being refined by the DWA incorporates a decision support system based on principles of scarce resource allocation using data from a water balance model which records availability and demand in each catchment (Section 6.1). Evaluation of the economic and socio-economic returns on water allocated to each user group will assist in promoting the optimal long-term use of water (Section 7.1).

(27) Financial and cost aspects

As already mentioned, capital expenditure on Government water works has risen sharply in recent years. If the Railways, the Provincial Administrations and Defence are omitted from the comparison, the envisaged expenditure by the Department of Water Affairs is in fact greater than that by any other State department.

Purchase of land associated with the construction of water works has in the past been excluded from expenditure records and, in view of the fact that land acquisition adds substantial sums, it is desirable that for each scheme this information be recorded in the Department of Water Affairs for adding accumulated capital expenditures so that the Department may be in a position to determine the total costs of its schemes more reliably. The Water Act in fact requires that this be done.

Rather conspicuous is the great difference often to be noticed between the original estimates for dam constructions and the actual amounts eventually spent. These differences are attributable, in the first place, to alterations in the nature and scope of projects between the time that initial investigations are instituted and the eventual completion of the project, the time lapse between the original estimate and eventual project completion date, and unforeseen circumstances. Secondly, differences are ascribable to insufficient preliminary investigations, incomplete cost returns and the Department's policy of step-wise completion of schemes. Finally, the differences can be attributed to the Treasury's policy of restricting the total amount that may be spent on water works in any given year.

The information presented in White Papers has frequently been insufficient to substantiate and justify the building of a scheme. This is significant in that the particulars called for by the Water Act are both searching and comprehensive.

The purpose of the Act is very clear. The data is essential to provide Parliament with a basis on which to adjudicate the large number of competing demands on the scarce financial and other resources of the country and to lay down rational priorities. The Commission subscribes fully to these requirements and considers that the data contained in White Papers should be as comprehensive as possible. Particularly important is the information needed for judging the economic justification of schemes. Adequate information in White Papers would enable Parliamentary representatives the better to make critical evaluations and to ensure that projects for which funds are granted will be in the best interests of the country as a whole.

It seems also from an analysis of the Department's vote that usually only a small part or none

at all of the capital outlay on state irrigation schemes is recovered. Frequently not even the operating and maintenance costs are covered by the rates. Most irrigation boards are also substantially subsidised. Only in the case of water schemes for municipalities and industries and in the case of some private irrigation schemes (that account for about 40% of the total irrigated area) are the full running costs and a large share of the interest on capital recovered.

The price policy for irrigation water embodies a hidden subsidy to this sector in the form of extraordinarily low prices for water received. According to data up to the year 1966/67, the subsidy to farmers on government irrigation schemes amounted to 100% on capital costs, with a further average subsidy of 69% of the annual operating and maintenance costs.

In 1961 about 29% of the irrigated area in the country was controlled by irrigation boards and, taking into account loans written-off, these boards in effect enjoyed a 60,2% subsidy on capital costs from the State but paid in full their own running costs. Private irrigators, who control approximately 40% of the irrigated land, received a subsidy of at most 331/3% of the capital outlay on their schemes. Although the irrigation board schemes and private irrigation works in general embrace the more favourable schemes, the Commission finds it anomalous that there is such a large difference in the financial assistance rendered by the State to these two classes of schemes, particularly if it is also compared with the 100% subsidy on capital costs and in addition the large subsidy on running costs that applies to State schemes.

In the Commission's opinion the ultimate goal must be to impose on all customers, whether for consumption or for processing purposes, a tariff for water supplied from Government water works such that, after taking into account all the other direct, indirect and intangible benefits of the scheme, the capital and running costs will be covered. The immediate and practicable target must be to cover at least the running costs of irrigation schemes. The subsidising of any sector, region, function or specific scheme or part thereof should in each particular instance be judged on merit and based on proposals made by the relevant State department. For the provision of water for agricultural purposes this should be the Department of Agricultural Economics and Marketing. The Commission is of the opinion that the Department of Water Affairs should report annually on the income and expenditure associated with State water schemes, with a full exposition of the extent and cause of losses sustained. In this way specific subsidies can be consciously and precisely determined for individual schemes.

In order to obtain reliable unit costs of the activities of the Department of Water Affairs and to get a meaningful classification of expenditure for purposes of economic analysis, and to meet this requirement it is in the Commission's opinion essential that the Department's cost accounting system should be expanded.

Comment

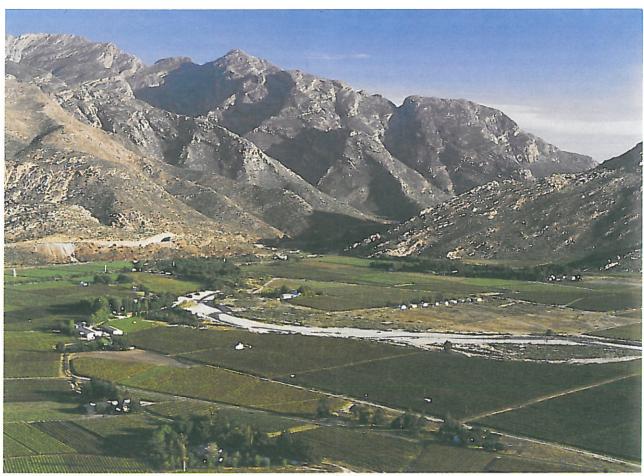
The reasons given by the Commission for construction costs exceeding estimates are still valid. A White Paper on water tariffs tabled in 1984 is reviewed in Section 6.6. A financial review of each Government water scheme is now published in the annual report of the DWA. A cost accounting division has also been established in the DWA.

(28) Water rates and allocation of land on Government irrigation schemes

In the Republic water is a scarce resource that will become continually more scarce. The price of water, however, particularly on Government schemes, is administratively kept at an artificially low level. Not only is this not conducive to the efficient utilisation of a scarce commodity but it leads also to enhanced prices of the associated production factor, the soil. The result is that an optimal combination of the two factors is hampered and, in the opinion of the Commission, the position can be rectified only by establishing realistic prices that recognise the inherent scarcity of both factors in the national economy.

From cost data for water provision at a number of Government irrigation schemes, it appears that the average water rates at present vary between 0,5% and 1,2% of the gross yields of the plots, whereas the operating and maintenance costs excluding interest on capital - vary from 1,5% to 2,5% of gross yield. Water rates currently cover on the average about 30% of the annual operating costs and make no provision for interest and redemption of capital. It is regarded as essential that rates be raised sufficiently to cover at least the operating and maintenance costs and, where possible, to make a contribution to the interest burden. Particularly where plots are small and socio-economic factors demand consideration, price adjustments must of course be gradual so as to avoid unnecessary disruption.

At present-day prices the average cost of providing irrigation water on settlements varies between R750 and R1 200 per morgen (R875 and R1 400 per hectare). Scheme construction adds a similar if not greater valuation to the land. There



Intensive irrigation of vineyards from the Greater Brandvlei Dam

seems to be no reason why the fortuitous owner of the land should have a right to exploit this enhanced valuation. The levying of water rates that cover full costs would obviate this form of increase in land prices.

An alternative way of compensating the State for at least part of the incurred costs would make irrigators pay for the increase in land value consequent upon the establishment of a scheme. The necessary capital can be loaned by the appropriate financial institutions. Such a measure would place settlers at State schemes on the same footing as private farmers.

Irrigation farming is an intensive type of agriculture that demands specialised knowledge and a high capacity for management. In the past, irrigation land has largely been allocated to persons that possess neither these qualifications nor the minimum capital necessary to develop efficient farming practices. The need to allocate irrigation land only to persons who possess the required background and knowledge cannot be overemphasised.

Indications are that there is possibly a shortage of potential irrigation farmers. This aspect should be further investigated so that timeous steps may be taken to ensure that the required persons will be available when the irrigation plots of the Orange River and Pongola-Makatini Flats projects are ready to be occupied.

Many of the irrigation plots issued in the past must by present standards be recognised as uneconomic units. It is for this reason that many irrigation farmers cannot become fully self-supporting. It is costing the State large sums of money to rectify faults of this type.

The minimum economic sizes of farming units are in fact continually increasing all over the westem world and it may be expected that the trend will persist. When determining the economic size of units in future, therefore, the norm should not be set at the minimum plot size but rather at the size that will permit the farmer to develop his farming efficiently and to maintain a reasonable standard of living. Furthermore, plot sizes should be adjusted to permit variable draft procedures to be instituted and the ideal of maximum practicable yield per unit of water to be achieved. It is of the utmost importance that these practices be encouraged, and accordingly each plot should embrace more irrigable land than is at present regarded as sufficient for an irrigation unit.

In the past, irrigators on State settlements have usually been restricted to the possession of only one farming unit. In so far as may be consistent with socio-economic requirements, able farmers should in the opinion of the Commission be permitted to consolidate several plots. This would lead to the formation of more efficient units.

Comment

See Comment on Findings 18 and 27.

(29) Nature and scope of financial support for municipal and industrial water schemes

Although water is scarce in the Republic, water rates for municipal and industrial purposes are still comparatively low. The average cost of water as a percentage of that of all raw materials used in industry is insignificant. There seem thus to be no grounds for subsidising water schemes with the object of lowering water prices for these activities other than in those exceptional cases where water prices exceed R1 per 4,5 m³ (1 000 gallons).

Subsidies for the provision of water to local authorities and industries should be aimed at creating altogether new sources rather than at promoting the development of existing natural water resources. One thinks here particularly of the reclamation of sewage. In the Commission's opinion, it would be in the national interest to render financial assistance with the object of lowering the unit cost of reclaimed water to a level onethird lower than that at which water could be obtained from any alternative natural fresh water source, or to a minimum of 20 cents per 4,5 m3 (1000 gallons), whichever is the higher. The figure of 20 cents is chosen because it is the estimated unit cost of reclaimed water in a reasonably large undertaking.

Unit costs of water are closely tied to methods of cost accounting. The usually employed methods, whereby the full annual costs - inluding interest and capital redemption - must be recovered annually, has the result that during the initial years, when consumption is low the water rates must be high, and as consumption increases the rates gradually decline. This undesirable state of affairs can be obviated by making available the necessary credit to cover losses during the initial years and to redeem the total costs and accumulated debits, as well as interest on these debits, at a constant rate over the whole useful life of the scheme. In the Commission's opinion, this would be a preferable method of financing to that of awarding an initial capital subsidy. Capital subsidies should be contemplated only where the costs of water would otherwise exceed R1 per 4,5 m3 (1 000 gallons).

Comment

Water for industrial and municipal purposes is now supplied at full cost. Present accounting methods are aimed at determining a reasonable tariff throughout the life of the scheme. Initially, deficits are carried by the State, but these are recovered from a larger body of users in the later life of the scheme (Section 6.6). Interest is charged at the Treasury rate current at the time the loan is obtained.

Subsidies to local authorities for the development of water sources other than natural sources, e.g. reclamation and reuse of sewage effluent, will be implemented in appropriate cases when the need arises. The new regulations for subsidies on sewage purification plants are aimed at providing financial assistance to the smaller local authorities which have to comply with statutory water pollution abatement and health requirements. The subsidies contain no direct incentives for water reclamation as envisaged by the Commission.

(30) The administration of water affairs

It is desirable for various reasons that the Republic's water resources should continue to be developed to the benefit of the country as a whole under the full control of the Central Government.

The centralised planned management and control of the country's water resources was made possible through fundamental amendments to our water legislation passed in 1956, whereby full control over the allocation and use of water in public streams was vested in the State. These amendments placed in the hands of the Government the instrument for so apportioning the available water resources among various sectors of the economy that they could make maximum contributions to the development of the country as a whole.

In the Republic, development, management and administration of water affairs are now strongly centralised. Only in providing for urban needs and in the distribution of water do local and regional authorities play an important, but subsidiary, role. Unfortunately, however, a policy of forward planning to provide for the rapidly expanding needs of the country in general and the quickly growing urban areas in particular has not been clearly formulated and purposefully pursued nor has there been adequate co-ordination between the Department of Water Affairs and other State departments. As the Department of Water Affairs concentrated in

the past mainly on the supply of water for irrigation, the only outside organisations regularly consulted, and from which data were obtained, were the Departments of Agriculture and the former Department of Lands (now Agricultural Credit and Land Tenure).

The result has been that although the Department of Water Affairs has executed works of technical excellence there are some important shortcomings in its planning of the country's water resource development, in its apportionment of water among various sectors of the economy, in the financial control exercised over water projects and in the policy it has pursued in the pricing of water.

The Commission is convinced that the apportionment of water among the various sectors of the economy, the study and application of methods of saving water, the consideration and determination of a suitable price policy, and the general integration of water development within the overall physical and economic development of the country cannot remain the function of a single department but must become the responsibility of a broader state body having an overall interest in all facets and sectors of the country's development.

The comprehensive planning of the country's physical resources has been entrusted to the Prime Minister's Planning Advisory Council. It is the considered opinion of the Commission that the Department of Water Affairs must in future remain in close contact with this Council in the planning of all new projects, in planning the development of river basins, and in the regional planning of the country's water resources, and that there should be regular consultation between these two bodies with the object of co-ordinating water resource planning with the general planning of the country's development.

The Commission is further of the opinion that the Planning Advisory Council should establish from among its members a special Standing Committee for Water Affairs. The functions of this Committee would be to co-ordinate the plans of the Department of Water Affairs with the general economic and physical planning for the country, to report in co-operation with the Department of Water Affairs to the Minister of Water Affairs on the evaluation and priority rating of all new projects, to effect close liaison and co-operation between the Department and organisations concerned with the conservation and utilisation of and research into the country's water and associated resources, and to serve as a co-ordinating body for recommendations concerning the application of suitable pricing policies to all sectors of the economy.

It is also of the utmost importance that pro-

posed water schemes be critically examined and evaluated by the country's parliamentary representatives to ensure that they benefit the Republic as a whole.

The organisational structure of the Department of Water Affairs is deemed to be basically sound, although there are some defects attributable mainly to staff shortages. In view of the great demands on those responsible for the efficient development and utilisation of our water resources, it has become essential to draw upon expert knowledge in a wide sphere. It is the Commission's view that the Department should take the lead in enlisting the full co-operation of all who can help to solve our water problems.

The Commission heartily endorses the steps already taken by the Department to improve its cost accounting system and the effectiveness of its liaison with the public. The Commission feels that a qualified cost accountant should be appointed in the Department without delay.

Comment

Under conditions approaching full utilization of water resources and increasing competition between various classes of users, it is imperative that control be maintained by the State as was recommended. Forward planning has greatly improved since the recommendation and the DWA is now actively engaged in the determination of future demands and economic and social studies. Financial planning is done eight years in advance.

The DWA liaises closely with various specialist bodies and experts such as the Water Research Commission, the National Institute for Water Research of the CSIR, various research institutes of the Department of Agriculture and Water Supply, several universities, specialist consulting engineers, engineering geologists, geohydrologists and consulting economists. Investigations are now carried out far more intensively than in the past, as is reflected in recent White Papers, which provide information needed to judge the economic justification of schemes.

A Liaison Committee for Water Affairs has been established in collaboration with the Department of Constitutional Development and Planning at a level where co-ordination on issues of Government policy on decentralization can be addressed and the DWA has direct contact with the Regional Development Advisory Committees. A liaison com-

mittee on water affairs with representatives from the Department of Development Aid also meets regularly.

Since the Commission's recommendation a qualified cost accountant has been appointed to the staff of the DWA and a new cost accounting system has been introduced. Information on the apportionment of capital expenditure, running costs, water rates and sales is now collected on a regular basis and the unit cost of water is calculated on schemes where costs are recovered. Considerable improvements are being made in the DWA's cost estimation techniques. The DWA itself keeps a record of land purchased for individual Govemment water schemes. The income and expenditure on State water schemes is now reported annually and a White Paper setting out procedures for calculating costs was published in 1984 (Section 6.6).

In terms of a recent decision a policy advisory committee is to be established under the chairmanship of the Minister of Water Affairs. The interests of the State, public sector bodies and the private sector will be represented on the advisory committee.

(31) Research

In the light of new developments in water technology, water research will undoubtedly play a key role in the optimum utilisation of the Republic's water resources. Several organisations in the Republic are concerned with research projects, and the Commission feels that to gear modern knowledge to water resource development and utilisation there must be effective co-ordination of the research being undertaken by the various organisations.

The management and development of the country's water resources is directed by the Minister of Water Affairs whereas the comprehensive planning of physical resources falls within the jurisdiction of the Prime Minister's Planning Advisory Council. For effective co-ordination of these functions the Commission envisages the establishment of a Standing Committee under the auspices of the Planning Advisory Council.

The co-ordination of research is handled by the Prime Minister's Scientific Advisory Council under which three permanent National Committees have been established, namely:

- (a) The National Committee for Pure and Applied Natural Physical Sciences,
- (b) The National Committee for Biological Sciences,
- (c) The National Committee for Medical Sciences.

In view of the key importance and interdisciplinary requirements of water research, the Commission deems it essential that a specific committee for water research be established under the auspices of the National Committee for Pure and Applied Natural Physical Sciences and that care be taken to ensure that the work of this committee be properly integrated with that of the Standing Committee for Water Affairs.

In view of the particular interest of the Department of Water Affairs in water research it could be beneficial if, in consultation with the proposed Coordinating Committee, a branch of the Department were to be expanded to undertake, besides its own research, liaison with other scientific investigators and researchers in all fields affecting water supply.

Comment

The Water Research Commission was established in terms of the Water Research Act, 1971 (Act 34 of 1971). Apart from extensive applied research by various directorates of the DWA, research is also undertaken by other bodies (Chapter 7).

(32) The relationship of the Republic to her neighbour States in regard to water supply

In its investigations into water supply and utilisation within the Republic, the Commission was required by its terms of reference to take into account arrangements with its neighbour States concerning common water resources. Accordingly it was stated in Chapter I that, in assessing the Republic's water resources the Commission also kept in mind the Government's treaty obligations and the principles upon which those obligations were based.

In that chapter reference was also made to opinions frequently expressed in the past about the possibility of drawing substantial quantities of water in future from certain of our neighbour States. As explained, however, although such schemes may be technically feasible, they can be undertaken only in consultation with the relevant foreign interest. Moreover, for some of these schemes, the unit costs of the water may be a limiting factor.

Concerning use of water from rivers in which other riparian countries have interests, it seems that international law affecting use of the waters of such rivers is very loose. The use of such waters is generally fixed by agreement.

The Republic is currently negotiating with the authorities in Swaziland, Portugal, Botswana and

Lesotho, and discussions have also been held with Rhodesia. The Commission has taken note of these and recommends that, whenever the opportunity arises, all feasible steps be taken to ensure that the Republic's shares of the relevant waters be defined and ratified, so that appropriate account may be taken of them in planning. In this context it is appreciated that often other factors must be considered and that the development of the relevant rivers to optimum mutual benefit necessarily depends also on a good neighbour policy.

Comment

Since the Commission's recommendations, the TBVC states have gained independence and the national states have gained self-governing status within the borders of what was formerly the RSA. International drainage basins and co-operation on water projects are discussed in Sections 3.1 and 8.1. Permanent water commissions have been established with the independent TBVC states and the Cabinet has approved the establishment of similar commissions with the self-governing national states.

The importation of water from South Africa's northern neighbours and further afield cannot yet be justified on economic grounds, but could be desirable in the future, provided the political climate is favourable. Joint technical committees have been established with Swaziland, Mozambique and Botswana to consider water matters of common interest. A similar body involving Mozambique, Botswana and Zimbabwe has been established to study the Limpopo basin. Studies and negotiations on a joint scheme with Lesotho are currently in progress (Section 3.7).

(33) Conclusions

Part I of the report indicates that unless effective measures are applied in the planning and development of the Republic's water resources there may be serious shortages of water before the close of the century.

Part II explains the steps that must be taken to effect and preserve the future balance between supply and demand. These steps include not only physical measures, but particularly also measures concerned with the necessary management, control and research, and the allocation by the State of the requisite funds.

The policies that should be adopted in developing, allocating, financing and administering our

water resources are discussed in Part III.

The expected safe yields at the end of the century if current standards are still in force and the probable maximum yield if the suggested measures are applied, are reproduced below to reflect the globular position as at the year 2000.

Comparison between yield and anticipated demand at the end of the century

	Situation with safe yield from natural water resources according to standards at present in force $10^3 \mathrm{m}^3 / \mathrm{d}$ (mgd)	Situation with probable maximum potential yield of natural water sources 10 ³ m ³ /d (mgd)
(1) Water available from natural resources	60 460 (13 300)	75 010 (16 500)
(2) Water demand with total consumption provided from natural resources	80 470 (17 700)	80 470 (17 700)
Shortfall	- 25%	- 9,4%
(3) Water demand with 25% saving in irrigation water and two cycles of 50% reuse of urban effluents	52 280 (11 500)	52 280 (11 500)
Surplus	+ 16%	+ 44%

Water intake by the various sectors as at present and as at the end of the century, as reflected in item (3), will be as follows:

	1965	2000
	10 ³ m ³ /d (mgd)	10 ³ m ³ /d (mgd)
Consumption by agriculture Urban and industrial	20 985 (4 616)	26 049 (5 730)
consumption	4 828 (1 062)	26 231 (5 770)
Total	25 813 (5 678)	52 280 (11 500)

"Maximum potential yield of natural water sources" does not include the following possible additional sources of water supply –

- (i) desalination, particularly of sea water, which will in large measure have to provide for the future needs of coastal cities;
- (ii) water that can be obtained from the stimulation of rainfall or schemes to condense moisture from the atmosphere;
- (iii) water that may be obtained from the northern



Rhenosterkop Dam on the Elands River in the South Ndebele Government Regional Water Scheme

neighbour States and which may be of importance in supplying possible future industrial nodes in the north-western Transvaal:

- (iv) further exploitation of groundwater; and
- (v) improved utilisation through long-term weather forecasts.

It must be reiterated that the combined growth rate in urban water consumption employed in the prediction is in fact very high. Should this rate of increase not eventuate, additional water, in quantities depending on the degree to which the growth rate falls short of the estimate, will become available.

Offsetting these possible additional supplies, however, is the fact that for a long time into the future it will probably not be possible to use economically all the waters of the eastern escarpment—and particularly those of the Transkei rivers, which yield no less than 15% of the Republic's water.

The water resources of the Republic are thus adequate to meet our rapidly growing needs till the close of the century and for a considerable time beyond. Our population is growing at present, however, at a rate conservatively estimated at 2,35% a year, representing a doubling of the population every 30 years, and is expected to reach 45 million by the end of the century. During the following century sufficient additional water could probably be developed in the interior to meet water needs to the extent of a further increase of 45% in the calculated requirements. But it must be stressed that a further increase in our

sharply rising population, which will demand a corresponding increase in agricultural, mining, and industrial development, if existing standards and indeed improved living standards are to be assured, will make continually increasing and exacting demands not only on our water resources but also on our administrators, entrepreneurs, planners, engineers, and scientists, as well as on our financial means.

Comment

The growth in demand for water has been lower than predicted, thereby extending the date until which conventional sources can meet the demand to nearer the middle of the next century (Chapters 2 and 3). The increase in population is the major factor influencing demand, which, if not met, must lead to a deterioration in living standards. Constitutional development has introduced the division of water resources between states as a major factor, in addition to the difficulties associated with inter-basin transfers (Sections 3.1 and 8.1). So far, earlier indications that the RSA could rely on unconventional sources have proved less promising than was hoped (Section 3.6). Although the DWA is making every effort to avoid serious water shortages, the most important limitation is not the availability of water, but finance (Sections 9.1 and 9.2).

Recommendations of the Commission of Enquiry into Water Matters (1970)

1. Utilisation of water resources to meet all needs in the Republic

The Commission has come to the conclusion that, because of the limitations of our natural water resources, South Africa has reached the stage of development where it has become of cardinal importance to develop the remaining resources with the utmost care and to utilise them as efficiently as possible. Existing schemes must also be managed as effectively as possible.

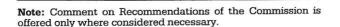
The Commission therefore recommends that water projects be soundly planned to suit the water needs of the country as a whole and to ensure that optimum benefit can be derived from the water yielded.

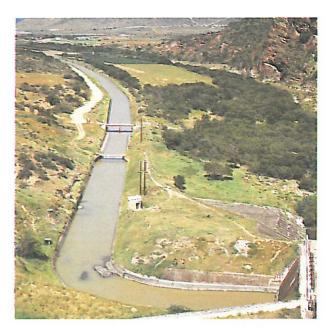
2. Water conservation

Water conservation is not an end in itself but merely a means of making water available for beneficial use. It is recommended that this dictum be kept continuously in mind and that the benefits to be derived from water conservation always be weighed against the concomitant expenditure on other resources. When water is conserved, it must be possible to use it beneficially; it must not be possible to store it or use it more effectively elsewhere; and established development dependent upon water must not be detrimentally affected by storage or other uses of the water.

3. Efficient utilisation of water

The elimination of waste would release a substantial hidden reserve of water for beneficial use, and the Commission accordingly recommends that there be a continual striving towards the highest possible yields per unit of water and towards the elimination of excessive use of water in so far as this is consistent with the maintenance of an effective combination of all input factors, efficient production, manpower control, satisfactory health standards, civilised living standards and aesthetic considerations.





Irrigation canal in the Sundays River valley, eastern Cape

4. Stage development of water schemes

Many water projects can be planned to be efficiently executed in stages, but care should be taken that subdivision into stages, particularly in regard to the possible future raising of dams, does not lead to the over-deployment of scarce manpower and to increases in the present value of the ultimate outlay.

5. Efficient planning of water resource development

Because the availability of adequate water is indispensable to the economic advancement of the country and the welfare of its peoples, the advance planning of water resources is a matter that must enjoy the highest priority. For this the following steps are necessary:

(i) Data on water consumption and water requirements

It is essential to South Africa's continued progress that the work necessary for the provision of water to various sectors of the economy be timeously planned and built. To achieve this, reliable data on actual consumption and anticipated requirements are necessary. It is accordingly recommended that steps be taken to establish and keep up-to-date a reliable record of water consumptions and growth rates subdivided according to consumer class.

(ii) Yields of water schemes

Because of the variable nature of runoff in South Africa, and the fact that it can never be stated with certainty that a drought more severe than any experienced during recorded periods will not occur in the future, it is recommended that every scheme in which continuously rising consumption is expected should be designed for a final yield capacity such that there is a reserve to cope with eventualities such as a more rapid growth rate than anticipated. At the same time, it must be remembered that sound planning and execution of a major project may last from five to ten years.

(iii) Timely provision of water

A programme for water provision should be drawn up to ensure that adequate supplies of water for urban and industrial use can be made available, in so far as economically feasible, five years in advance of requirements, so that reasonable reserves will be on hand to cope with contingencies related to increased consumption or the incidence of drought more severe than previously experienced.

(iv) Fixing of priorities

Limitations of water resources and of qualified manpower, rapidly growing water demands and large requirements of capital for a wide variety of developments all point to the utmost importance of the correct fixing of priorities. The Commission therefore recommends that new schemes be not undertaken before a thorough cost-benefit investigation has been performed. The analysis must moreover be based on socio-economic and not merely on financial grounds. No project for which the benefit-cost ratio is less than unity should be constructed and, in general, a scheme for which the ratio is high should take preference over one for which the ratio is low. Such a policy will ensure that only schemes that are socio-economically sound and which will be of ultimate benefit to the country and will make positive contributons to national development will be constructed.

(v) Composition and presentation of White Papers for motivation of new projects

The Commission recommends that the advance planning and allocation of priorities be placed on a sound footing with the aid of careful long-term estimates of development of the various regions coupled with preliminary investigations of cost and yield aspects set in rational economic relationship. As such preliminary investigations have to be performed by a number of different departments, the Department of Water Affairs should, in consultation with the proposed Standing Committee for Water Affairs of the Planning Advisory Council, undertake the final compilation of White Papers, as well as the original selection

of all proposed schemes for which formal reports are to be prepared for submission to Treasury and Parliament.

Comment

- (i) Data are being assembled in the national water inventory and will be maintained in user classifications as recommended (Section 6.1).
- (ii) and
- (iii) Lack of finance has limited the systematic implementation of this principle, although it may have been achieved on occasion. The principle has to be implemented judiciously as the increasing burden of interest on schemes built too far ahead of time can raise water tariffs unnecessarily in terms of the risk which can be tolerated by some users (Sections 2.2, 5.2, 6.6 and 9.1).
- (iv) Benefit-cost analyses have been carried out for all irrigation schemes proposed since the Commission's recommendation and they have been ranked in order of viability. A study has been launched to determine a method to quantify secondary and socio-economic benefits (Sections 2.6 and 7.1). Schemes for urban and industrial supply have not been analysed for their socio-economic benefit since the full costs are recovered in the tariffs and such studies are complex, but the most favourable solutions are always chosen from a range of alternatives.
- (v) There is close liaison between interested bodies and the DWA in the compilation of White Papers which are submitted to Parliament as required by the Water Act, 1956. No White Papers are prepared for water projects in the self-governing national states.

Allocation of water to various sectors of the economy

In view of the limited supplies of water that can still be brought into use, the utmost care and circumspection must in future be exercised in apportioning the country's water resources. The sectors are dealt with in turn:

(i) Irrigation

According to estimates, 93% of the Whites, 92% of the Asiatics, 86% of the Coloureds and 75% of the Bantu in the Republic will be ur-

banised by the end of the century. About 90% of the gross national product will by that time be contributed by the secondary and tertiary sectors of the economy, compared with only 6% by agriculture. As 83,5% of our fresh water intake was used for irrigation in 1965 and an increase by 24% in this quantity has already been planned, the Commission recommends:

- (a) that no new water scheme for irrigation purposes be tackled in future unless it has been preceded by a thorough and comprehensive investigation into costs and benefits and a weighing of these against possible alternative ways of utilising not only the funds entailed but also the water demanded and unless such examinations show that the socio-economic benefits of the scheme exceed the costs;
- (b) that in the aforementioned investigations careful account be taken of both current and future means of marketing of the produce, at home or by export, as well as of the availability of suitable persons to occupy the scheme and of the need for the optimum utilisation of the latest scientific knowledge;
- (c) that even though a scheme may comply with the conditions set out in (a) and (b), there should be reasonable assurance that the same results could not be achieved by another route such as importation or the enhancement of productivity on existing irrigation or dryland farms;
- (d) that, in the execution of its research and extension functions, the Department of Agricultural Technical Services devote particular attention to food products in which the Republic is not at present, but on economic grounds should be, self-sufficient;
- (e) that the Departments of Agricultural Economics and Marketing and of Agricultural Technical Services carry out the necessary precautionary planning to enhance the Republic's defensibility against any emergency affecting her food requirements.

(ii) Stockwatering

In some regions, such as the South Western Districts of the Cape Province, the carrying capacity of the veld, either in its natural state or when supplemented with artificial pastures, is adequate but supplies of water of satisfactory quality are insufficient to permit the stock carried to be increased. The Commission recommends that in such situations the provision of stockwatering schemes be investigated and consideration be given to the establishment of such schemes where they compare favourably

with alternative local supplies from boreholes or the desalination of brack waters. It is essential, however, that appropriate steps be taken to avoid overgrazing, tramping and deterioration of the veld.

(iii) Urban and industrial purposes

It is recommended:

- (a) That steps be taken in good time to ensure that the most important urban and industrial areas of the Republic are provided with adequate water supplies for future development and that the State place the financial and other means necessary for the task at the disposal of the Department of Water Affairs;
- (b) that, since decentralisation of economic activity offers one of the most important means of resolving regional water supply problems, the establishment of decentralised industrial centres on a large scale be encouraged in those areas where adequate water supplies are available or can be economically created;
- (c) that industries requiring large quantities of water be discouraged from establishing themselves in the Southern Transvaal industrial complex or the Witbank-Middelburg region;
- (d) that, after making provision for the existing riparian use of water downstream of the Klipvoor Dam in the Pienaars River, all the available water supplies should be reserved for urban and industrial development, especially within the Bantu area in which the dam is situated;
- (e) that adequate water be reserved from the Magol River for future development of the Ellisras coalfield;
- (f) that investigation into the provision of water for the Witbank-Middelburg region be instituted;
- (g) that water for the efficient development and exploitation of the Eastern Transvaal coalfields be made available;
- (h) that, of the water made available by developing the resources of the lower Olifants River, after provision for present consumption by riparian owners, the Kruger Park and Phalaborwa, a generous supply be reserved for the future development of the Pietersburg and Potgietersrus regions¹;
- that at least 20% of the potential yield of the Crocodile River in the Eastern Transvaal be set aside for urban and industrial development;

^{1.} Our treaty obligations must also be borne in mind.

- (j) that adequate water from the Berg-Sonderend River complex be reserved for urban and industrial development in the Western Cape;
- (k) that initially at least 25% of the water that will become available from the Orange River and Pongola projects be held in reserve for possible urban and industrial use.

(iv) Recreation

The use of water for recreational purposes is both necessary and warranted. Fortunately recreation can be promoted at dams built for other purposes and the quantities of water used consumptively are small. It is recommended that use of the large bodies of water at our dams for recreation be carefully planned and encouraged and that the intangible benefits associated with recreational uses be taken into consideration in the study of the results of benefit-cost ratios for assessing proposed water schemes.

(v) Nature conservation

It would be disastrous both for nature conservation and for our tourist industry if too little water were to be made available for wild life in the Kruger Park. Other nature conservation areas, such as the St. Lucia Lake, require fresh water for the protection of natural assets. The Commission recommends that, in the utilisation of our water resources, provision 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.

Comment

- (i) (a) Extensive benefit-cost analyses have been made since the Commission's recommendation and the construction of new uneconomic irrigation projects has been phased out. A study has been commissioned to determine methods of effectively evaluating the socio-economic benefits of future irrigation projects and an interdepartmental committee of the Departments of Water Affairs and of Agriculture and Water Supply is investigating the economic need for the expansion of irrigation (Sections 2.6 and 7.1).
- (i) (b) These factors are carefully evaluated during investigations.
- (i) (c) There is promising evidence that improved dryland production with new cultivars and greater efficiency on

- existing irrigation schemes can meet much of the medium-term needs without further large-scale irrigation development. Monitoring and research is being undertaken by the Department of Agriculture and Water Supply.
- (i) (d) This is being done by the Department of Agriculture and Water Supply.
- (i) (e) This is being dealt with by an interdepartmental committee representing the Departments of Water Affairs and of Agricultural Economics and Marketing (Sections 2.2, 2.6 and 7.3).
- (ii) Since these recommendations the Duivenhoks rural water supply scheme, the Kalahari West scheme and the Rûensveld East scheme have been built. The Kalahari West scheme was built by a water board. The schemes have proved to be very costly and the economics are questionable. The building of further stock-watering schemes will require careful consideration (Section 2.7).
- (iii) Within the limits of the severe financial restrictions, planning for foreseeable circumstances in urban and industrial areas has been carried out and is revised continuously. Droughts as severe as the one that began in 1978 cannot reasonably be fully provided for. Because of the erratic nature of South Africa's runoff, adequate finance will have to be made available for the implementation of the Commission's proposals.

Since the Commission's report, the DWA has endeavoured to meet only proven demands in order to avoid fruitless expenditure. Experience has shown that the provision of water alone, without the availability of skilled labour and adequate supporting infrastructure and markets, does not stimulate development. A permit system is used to limit the establishment of industries in water scarce areas (Section 4.3). The industrial decentralization strategy is discussed in Section 6.7. The allocation of water to industry is dealt with in Section 2.3 and in Chapter 5.

(iv) In most cases the recreational aspects of water surfaces are now administered by the provincial administrations. Recreation is considered in Sec-

tions 6.14 and 2.9, which cover water to maintain the ecology in the Kruger National Park and at Lake St Lucia and for environmental management.

7. Apportionment of water to various regions

Water shortage becomes a regional problem before it is discerned as a national problem. Where the resources of one catchment are insufficient to meet all needs, water must be transferred from another catchment. The development of local sources, however, is usually cheaper and more efficient than transferring water from elsewhere. Accordingly the Commission recommends -

- (i) that the development of all water resources, including groundwater, within a catchment be first thoroughly investigated before a decision is taken to transfer water from another basin;
- (ii) that the limited water resources of the Republic be utilised where the greatest socio-economic advantage to the country as a whole will result. Claims founded merely on geographic or sentimental reasoning cannot be regarded as justifiable. Water should be transferred from one catchment to another, however, only if the short-term, as well as the long-term, advantages of using the water in the receiving catchment exceed the disadvantages to the bereft catchment;
- (iii) that priorities in water resources development should be decided according to the relative importance of new projects to the development of the country as a whole and not merely by the forcefulness of interested pressure groups;
- (iv) that in planning the transfer of water, future as well as present development possibilities, be taken into account, as well as technological developments, such as, for example, the possibility of desalination;
- (v) that the use of water for domestic purposes and stockwatering should invariably take preference over other uses but only in so far as such use is reasonable and does not lead to waste:
- (vi) that the Government continue to encourage the decentralisation of economic activities as one of the most effective ways of achieving the efficient utilisation of the country's water resources; and
- (vii) that for social and strategic reasons the lower Orange River be developed, with the reservation, however, that development be held within reasonable economic bounds.

Comment

- These recommendations are being attended to as a matter of routine (Sections 6.3 and 6.7).
- (ii)

and

- (iii) The economic and socio-economic criteria used to determine the value of projects to the country will improve progressively with the refinement of the national water management strategy (Section 2.2, 6.1 and 7.1).
- (iv) The national water management strategy considers a series of time scenarios well into the future (Section 6.1) and desalination is being studied intensively (Section 3.6).
- (v) The highest degree of assurance will be given to those users upon whom restrictions would have the most detrimental effect on the country (Section 2.2). At present these users are identified as being power generation, fuel production, mining and industry, while primary use for stock-watering and basic domestic use also falls in this category.
- (vi) Water can be supplied at actual cost to meet the objectives of decentralization in any part of the country (Section 6.7). However, in certain cases this cost could be very high. The withholding of water in one region to encourage growth in another is a very drastic measure which should be avoided.
- (vii) Investigations since the Commission's report into the potential of and the need for extensive agricultural production in the Lower Orange River region have indicated that development of high-lying irrigation land is not economically justifiable.

8. Conservation and use of groundwater re-

As it is essential that groundwater be fully utilised within the limits of safe yields, the Commission recommends -

- that, in collaboration with the Department of Water Affairs and other interested organisations, the Geological Survey should undertake the following
 - (a) conduct research into groundwater occurrences and into techniques for siting boreholes, for delineating groundwater compartments and for determining the

- characteristics and safe yields of aquifers, and as far as possible to accelerate detailed field measurements for quantitative evaluation of the more important groundwater supplies;
- (b) accord highest priority to the survey of Subterranean Water Control Areas to determine their safe yields;
- (c) extend the scale of research into the artificial recharge of groundwater compartments and sources; and
- (d) conduct a thorough geo-hydrologic study of all groundwater supplies in dolomitic areas, such study to embrace not only the compilation of water balances in the various compartments but also the following aspects –
 - (1) quality of supplies and the influence thereon of mining activities;
 - (2) the possibility of exploiting certain compartments as emergency storage, and subsequent artificial recharge; and
 - (3) the possibility of utilising the normal replenishment of groundwater in the worked-out mining areas, e.g. of the East Rand;
- (ii) that an Inter-departmental Committee be appointed by the Minister of Water Affairs with the following functions
 - (a) to identify areas that are being, or possibly soon will be, overpumped, and to make recommendations for such areas to be declared Subterranean Water Control Areas;
 - (b) to be responsible for co-ordinating geohydrological surveys and research; and
 - (c) to make recommendations concerning the maximum allowable development of water sources;
- (iii) that the long-term planning of development and use of dolomitic groundwater supplies be closely linked with the planning of urban and industrial developments in the general region and that control of dolomitic water resources in accordance with the resulting approved plans enjoy high priority;
- (iv) that investigations be instituted leading to recommendations concerning precautionary measures to be taken by the mines in dolomitic areas to ensure that the dolomitic compartments will remain as separate, watertight, groundwater units available for the underground storage of water after mining activities are discontinued. Special attention must be given to sealing of the drives and to ensuring the adequate thickness of pillars at depth to obviate fracture of the dolerite and

- syenite dykes. In view of the valuable role that the separate compartments may play in the future water economy of the Republic, the financial aspects should also be examined. Specific recommendations should be made regarding the conditions to be incorporated in mining leases or in permits issued for the dewatering of compartments; and
- (v) that investigations be instituted into the possibility of developing the dolomitic compartments of the East Rand and Far West Rand to serve as reserve water storages to be overdrawn during times of water crisis and afterwards artificially recharged.

- (i) The Ground Water Division of the Geological Survey was incorporated into the Division of Geohydrology of the DWA in 1977. Since then this division has been responsible for implementing the recommendations set out in subparagraphs (a), (b), (c) and (d). In this task it enjoys the co-operation of the WRC, which has contracted various bodies to carry out specific research (Sections 3.4, 6.12 and 8.4).
- (ii) This has been done. A report on the ground water situation was produced in 1973.
- (iii) This recommendation has not been implemented since it requires specific information on those dolomitic areas which should be reserved for ground water development. Results of investigations into the occurrence of dolomitic ground water in the PWV area are expected to yield the necessary data (Section 5.3.6).
- (iv) This recommendation has not been implemented.
- (v) Investigations into the utilization of dolomitic ground water as an emergency supply are in progress (Section 5.3.6).

9. Water savings through improved irrigation techniques

As by far the greatest share of the water presently in use is that allocated for irrigation and as the techniques employed are sometimes very unsatisfactory, it will be from this sector that the biggest contributions to reduced water consumption can be expected at this stage. The Commission therefore recommends –

 that steps be taken to promote the efficient use of water on irrigated land, particularly by so improving irrigation techniques that over

- as well as under-irrigation can as far as possible be avoided, including attempts, in so far as economically warranted and not yet applied, to prevent leakage from furrows and leidams;
- (ii) that appropriate and systematic guidance be given to irrigation farmers on a much more intensive basis than heretofore;
- (iii) that timely steps be taken to select and train the persons to whom irrigation plots are to be allocated;
- (iv) that high priority be accorded to research into irrigation problems including studies aimed at distinguishing the relative merits of surface as opposed to sprinkler irrigation for specific crops in given circumstances. In carrying out this research and formulating future policy, there must be close liaison and co-operation between the Agricultural Departments and the Department of Water Affairs. Irrigation research must, within the limits of economic considerations, be purposefully concentrated on achieving maximum yield per unit of water; and
- (v) that serious attention be paid to the establishment of an Irrigation Research Institue where officers of the Departments of Agricultural Technical Services and Water Affairs can cooperate with persons from other organisations towards the solution of urgent irrigation problems of which our present knowledge is defective.

- (i) Although there has been a considerable increase in the use of capital-intensive, water-efficient irrigation equipment in the RSA since this recommendation, there is still considerable scope for improvement in irrigation efficiency.
- (ii) The DWA has instituted a training course for private sector suppliers of irrigation equipment to upgrade the design standards in the public interest, but direct guidance by the Department of Agriculture and Water Supply is being hampered by a lack of staff.
- (iii) The plots allocated at the Ramah Canal on the Orange River Project were made available to candidates with the necessary skills, but no specific training programme has been undertaken.
- (iv) Irrigation research to achieve maximum yields per unit of water is being undertaken under the auspices of, and is being financed by, the Water Research Commission.
- (v) The Soil and Irrigation Research Institute was established by the Department of Agriculture and Water Supply to undertake this research.



A greater yield per unit of water is achieved with efficient irrigation equipment

Attainment of maximum yield of irrigation crops per unit of water

The maximum yield per unit area of irrigated land results from a fairly generous application of water, but a further increase in water applied is usually accompanied by a reduction in yield. Maximum yield per unit of water, on the other hand, is achieved at an appreciably lower annual application of water than that required for maximum yield per unit of land although, to accomplish this on a continuous basis, a slight increase in land area is needed. Since water is relatively scarcer in the Republic than irrigable land, the Commission recommends that the endeavour should be towards the maximum yield per unit of water, but that consideration should be given to the need for achieving an optimum combination of production factors by fixing realistic prices for all the input components.

Comment

On the plots allocated at the Ramah Canal 20 ha of non-scheduled land was provided in addition to the 60 ha scheduled to receive water as an incentive to use water more efficiently by irrigating a larger area with a fixed quota. To achieve this aim, realistic tariffs must be charged for water (Section 6.6). This policy of providing additional but non-scheduled land is under review because it does not necessarily achieve the optimal utilization of all farming inputs.

11. Planning and development of irrigation schemes

(i) Planning of irrigation schemes

Apart from water supply, numerous other factors play important roles in the successful development of irrigation schemes, and the Commission recommends that the co-operation of all interested organisations be mobilised to unify all the relevant facets in a final development plan according to which schemes may evolve.

(ii) Soil surveys

Careful soil surveys to determine the suitability of soils for irrigation form an essential basis for designing the layout of irrigation plots and water distribution systems. In the past the relevant information has not always been adequate during the early stages of planning. The Commission, therefore, recommends that steps be taken to expedite comprehensive soil surveys of all possible irriga-

tion projects so that there need be no conjecture in this important aspect of water use for agricultural purposes.

(iii) Planning of economic irrigation units

Numerous factors have to be taken into account in establishing the economic size of an irrigation unit, e.g. the nature of the soil, the crops to be grown, the crop production costs, the incomes to be derived, the social conditions, and so on. The Commission recommends that the size considered adequate for the average irrigator to make a reasonable living shall be fixed by the Department of Agriculture in consultation with the Department of Water Affairs, and that such size shall be adopted as the economic unit to be scheduled for water allocation and for the levying of water rates.

(iv) Size of farming units

The efficient irrigation farmer will be able to irrigate with his water quota more than the average area of land, and the Commission accordingly recommends that irrigation plots under Government irrigation schemes should include more irrigable land than that determined as the economic unit in order that the able irrigator may achieve higher yields per unit of water and practise efficient crop rotation.

(v) Number of irrigation plots that a person may possess under a Government irrigation scheme

The Commission regards it desirable that a progressive farmer on a Government irrigation scheme should be given the opportunity to improve his position by being allowed, as and when he can afford to do so, to purchase additional plots up to a predetermined maximum. Should an owner come into possession of more then the determined maximum number of units, the principle of de-scheduling should be brought to bear.

(vi) Payment for irrigation land

Owing to the fact that the building of an irrigation scheme imparts to the irrigable land a greatly enhanced value and that such an increased value is directly related to the cost of providing water, it is recommended that all irrigators, including settlers that draw water from such schemes, should pay for the water rights they acquire according to the enhanced value of the land for which they are being scheduled and that, where necessary, financial assistance should as far as possible be rendered through State financing institutions to enable landowners to meet their obligations in this regard. The Commission be-



The Vaalharts Irrigation Scheme

lieves that the implementation of this recommendation would go a long way towards preventing unfair speculation and would allow the State to recoup a reasonable share of the costs of irrigation schemes.

(vii) Allocation of water to irrigation units

The principle currently applied by the Department of Water Affairs, whereby part of the predetermined water quota is supplied at a fixed tariff, after which the water rate rises with consumption up to the limit of the quota, and is calculated according to the total quantity used, is regarded by the Commission as basically sound and it is accordingly recommended

- (a) that, after deliberation with the Department of Agricultural Economics and Marketing, the aforementioned system be extended to all irrigation schemes; and
- (b) that, when water is available over and above the quota and can be delivered, the opportunity to purchase additional water should be given subject to a maximum per morgen scheduled, as is at present the practice.

(viii) Consolidation of uneconomic units

Owing to the fact that at some irrigation schemes there are plots that cannot these days be regarded as economic units, the Commission recommends that all feasible steps be taken to consolidate such pieces of irrigation land into economic units, thereby to ensure that the available water supply is used to the best advantage of the country as a whole, even though this may entail finding a refuge elsewhere for inefficient irrigators. In making this recommendation the Commission emphasises that the country simply cannot afford the wasteful use of water.

Comment

- (i) The DWA is researching the socio-economic impact and economic desirability of irrigation development in consultation with all interested organizations (Section 2.6 and 7.1).
- (ii) Comprehensive soil surveys of areas being considered for irrigation have not always been carried out in good time because of a staff shortage in the Department of Agriculture and Water Supply. Serious consideration should be given to involving the private sector in this area.
- (iii) This recommendation was implemented in determining the plot size at the Ramah Canal and will be implemented on any future irrigation scheme.
- (iv) This recommendation has been implemented.
- (v) This recommendation has been implemented.

- (vi) This recommendation has been partly implemented in that the prices of plots sold by auction on new schemes are regulated by market forces. The land for new irrigation projects will be bought at unimproved prices, subdivided into viable irrigation holdings and resold at market-related prices. Appropriate limited concessions regarding choice of property and prices will be extended to original owners.
- (vii) (a) Sliding-scale tariffs have been found to be counter-productive since farmers do not understand the implicasophisticated of management to regulate crop production. They have tended to use less water than allowed by their quotas, achieving suboptimal production while the State lost revenue. Sliding-scale tariffs are being replaced by constant tariffs (Section 6.6).
 - (b) This is being implemented (Section 6.6).
- (viii) The Agriculture Water Affairs Liaison Committee, representing the Departments of Agricultural Economics and Marketing, of Water Affairs and of Agriculture and Water Supply, has investigated irrigation schemes where uneconomic units exist and has recommended that farmers be encouraged to consolidate properties with financial assistance from the Land Bank. Requests for consolidation by expropriation by the State cannot be acceded to for financial reasons.

12. Reuse of water

The reuse of water will in future assume an increasingly important role in augmenting the country's limited water resources. The Commission therefore recommends —

(i) that the Department of Water Affairs, in administering the Water Act, place the internal water use by industry and the reclamation of effluents for reuse on a practical footing, first, by issuing the necessary policy directive for the execution of a long-term water plan and, secondly, by defining the administrative procedure and instructions for the planning and erection of water reclamation schemes as integrated parts of the water economy of the areas to be served by them;

- (ii) that, to promote sewage reclamation as an essential part of water supply on a national basis, consideration be given to subsidising water reclamation schemes for local authorities where consumption exceeds 1 137 m³/d (250 000 gallons per day). (The cost of water reclamation already falls within the price limits of the fresh water supply of some towns and cities); and
- (iii) that adequate financial support be given to ensure that research work into water reclamation and the internal reuse of water in industry can be placed on a practical footing and substantially intensified. The importance of such studies is reflected by the fact that the total reclamation of effluents in some areas is already more economic than the development of new water sources. It is important that feasibility studies be extended as quickly as possible to development centres such as the Witwatersrand, Cape Town, Durban, Port Elizabeth, East London and Bloemfontein.

Comment

- (i) The refinement of a long-term water plan in the form of a national water management strategy has commenced. (Section 6.1). Reuse, with associated salination problems, is increasing (Section 3.5 and Chapter 4). Apart from internal recycling for certain industrial processes, all present reuse is indirect, i.e. effluent is first returned to public streams before being abstracted for reuse lower down. Because of a lack of public acceptance. direct reuse of reclaimed sewage effluent for domestic purposes will not normally be required by the State while conventional supplies are still available. The technology for reuse is well established, however, and can be implemented by local authorities as an economic choice. Subsidization of the differential costs of tertiary treatment to produce water to potable water standards will be considered on an ad hoc basis.
- (ii) In Cape Town a pilot scheme for the reclamation of sewage effluent has been commissioned. Such schemes have not yet been subsidized.
- (iii) The reclamation of sewage effluent has been studied in the Witwatersrand, Cape Town, Port Elizabeth and East London areas for possible implementation when warranted.

13. Prevention of pollution

- (i) Pollution of some of the Republic's most important rivers by mineralised industrial and mining effluents and the return flow from irrigation schemes has already reached such proportions that energetic investigation and action on a national level is imperative. It is accordingly recommended that an Investigational Committee composed of representatives of the Department of Water Affairs and other interested organisations be convened with the following terms of reference
 - (a) to define the scope of the problem and ascertain what is being done about it;
 - (b) to recommend possible solutions or longterm measures to control the problem; and
 - (c) to make recommendations for the manner of implementing and financing control measures.
- (ii) It is further recommended that local authorities be directed to exercise strict control over the discharging of industrial effluents into municipal sewers, particularly chemicals that are not broken down or removed in the sewage purification plant or which detrimentally affect the treatment processes. Undigested chemical residues in purified effluents or in river waters into which the effluents are discharged tend to build up to undesirable concentrations through repetitive reuse, with consequent reduction of the reuse value.

Comment

- (i) A hydro-salinity model of the PWV area has been developed under the auspices of the WRC. An advisory committee consisting of representatives of the DWA, the Rand Water Board, the Johannesburg Municipality, the CSIR and the WRC has been formed to direct further investigations into hydro-salinity. The scope of the problem has been defined and progress is being made in the implementation of a proposed solution. Investigations are being continued by the DWA (Sections 4.2 and 4.3).
- (ii) Increasingly strict control over pollution is being applied under the guidance of the DWA (Section 4.3).

14. Evaporation losses from storage

As evaporation causes such substantial losses from storage reservoirs the Commission recom-

mends that everything feasible and economically justifiable be done to limit these losses, the following steps to be included –

- (i) planning of storage should take account of the advantage of deep basins that offer relatively small water surface areas and where economically justifiable such sites should take preference;
- investigational work on evaporation suppression by the application of protective coverings on water surfaces should be continued;
- (iii) in so far as practicable, variable draft regulation procedures should be implemented; and
- (iv) water should be stored underground where favourable aquifers are available and can be tapped according to requirements.

Comment

- (i) Where possible this recommendation is being implemented, but as all the favourable dam sites have already been exploited this is becoming progressively more difficult. Some notable successes have been achieved.
- (ii) The results of experiments carried out about a decade ago were disappointing (Section 3.6).
- (iii) These recommendations have been implemented where applicable and improved techniques are being developed (Section 6.3).
- (iv) Practical solutions have not yet been developed. The implications are dealt with in Sections 5.2 and 3.4.

15. Long-range weather forecasting

Long-range weather forecasts, if reliable, can provide valuable information for the operation of storage works and for the planning of irrigation programmes and can aid in improving the efficiency of water utilisation. The Commission recommends, therefore, that thorough investigations and research be promoted by the Weather Bureau and other interested organisations into the possibilities of making reliable long-range weather forecasts up to a year or more ahead.

Comment

See comments on Finding 19.

16. Unbeneficial water works

There are in the Republic numerous dams holding back water that is put to no use worth mentioning and in the main they serve merely as evaporation basins. The Commission recommends that the State acquire powers to prevent the building of such dams and similar unbeneficial water works in future and in due course to eliminate existing works of this kind.

Comment

The recommendations are being implemented by the judicious application of the permit system within Government Water Control Areas (Sections 3.2 and 8.4).

17. Sizing of storage works

Studies have shown that in regard to cost, evaporation loss and replacement of space lost by silting per unit of stored water, and in regard to the efficient use of manpower, large storage units have important advantages over relatively small units. Accordingly it is recommended that, unless rendered impracticable by other considerations, water conservation be accomplished by means of large dams rather than by a multiplicity of small storages.

Comment

This general recommendation is taken into account during planning but the actual size and siting of storage works are determined by economic considerations and the availability of dam sites (see comment on Recommendation 16).

18. Variable draft regulation of storage

By drawing from storage at a rate considerably higher than the assured yield during years of normal runoff, but restricting draft for a limited period during drought to a value somewhat lower than the safe yield but consistent with essential requirements, it is possible to utilise beneficially more water from storage than if draft is held at all times to the assured yield. The extent to which variable draft procedures can be implemented depends upon the degree, frequency and maximum duration of restrictions that are acceptable to different consumers. In view of the need to put as much as possible of our water resources to beneficial use and the fact that the system has to some extent already been operative for some time, it is

recommended that variable draft regulation of all our storage works be examined and, where practicable, implemented. It is recommended also that, where the general benefits to be obtained from variable draft operation are increased by the application of discriminating restrictions among the several consumer sectors for small percentages of the time, consideration be given to the payment of compensation to the group or groups against whom the discrimination is applied, on condition that the national benefit substantially exceeds the amount of compensation paid out.

Comment

Variable draft techniques have only been practised on dams supplying irrigation schemes and improved techniques are being evolved. By employing these techniques an increase in overall supplies has been brought about and no compensation has thus had to be paid to disadvantaged groups (Section 6.3).

19. Systems analyses for linking of water sources

The Commission is impressed by the advantages to be derived from thorough analyses to optimise the linking of several water sources as indicated for example in White Paper WP U-'69 for the Tugela-Vaal project and recommends that advanced systems engineering techniques be applied in all such studies.

Comment

See comments on Finding 22.

20. Sediment loads in rivers

Although the data are sufficient for reasonable estimates of the useful lives of storage dams, there are still large gaps in our knowledge of the exact quantities and nature of the sediments conveyed by our rivers. It is therefore recommended that measurements of silt in riverflow be improved and extended by the Hydrological Division of the Department of Water Affairs and that the grading of suspended sediments be also determined.

Comment

This recommendation has been implemented. All State dam basins are surveyed regularly (Section 3.2).

21. Effect of river sediment load on storage reservoirs

Millions of rands are paid out for purchasing land within storage basins and the flood mark boundary within which servitudes of storage have to be acquired is affected by the pattern of sediment deposition within the basin. The Commission recommends that the research already undertaken in the Department of Water Affairs in this respect be followed up and appreciably extended so that the reliability of data for the delineation of purchase boundaries in dam basins can be improved and also that observations for determining silt retention capacity be extended.

Comment

This recommendation has been implemented.

22. Storage possibilities

As it is essential that the best use be made of our surface water resources, both now and in the future, the Commission recommends that intensive investigations into possible dam sites throughout South Africa be made so that all sites where dams would be practicable and economic may be located timeously with the object of establishing more precisely our water utilisation potential and facilitating the orderly development of our surface water resources. For this task the services of large numbers of experienced staff will be needed — engineers, geologists with specialist knowledge of dam foundations, technicians and others — and the necessary hydrological data will also have to be obtained.

Comment

Intensive routine investigations of possible dam sites are under way, but are still hampered by the lack of experienced staff and the finance to employ suitable consultants.

23. Water yield of catchments

Maximum runoff from a catchment is obtained when it is bare, but this is no criterion because of the resulting soil erosion and high sediment yield. By contrast, a fully protected catchment will yield the least runoff because of the water consumed by the vegetation and lost by evaporation from works established to combat erosion. In view of the scarcity of water in the Republic the Commission recommends that in catchment planning the endeavour should be to strike an optimum bal-

ance whereby the water yield can be as great as is consistent with economic farming practices and with the necessary protection against soil erosion.

Comment

The DWA is constructing catchment management models which promise success in optimizing the water yield of catchments (Sections 3.2, 6.13 and 6.17).

24. Vegetal cover in catchments

The vegetation needed to protect catchments against soil erosion consumes water to remain alive. With a view to the need to strive towards maximum yield per unit of water, the Commission recommends that thorough investigations be undertaken into the feasibility of replacing worthless vegetation wherever possible by plants that can contribute to the national economy, either as grazing or as agricultural crops but that can at the same time inhibit soil erosion effectually.

Comment

In mountain catchments the possible advantage of block burning is being studied. It is already being applied in State forests in the Southern Cape (Section 3.2).

25. Afforestation

Appreciating that forests make efficient use of rainfall and that forestry products are of national economic value, the Commission recommends –

- (i) that, except in regions where water supplies are already being efficiently utilised, afforestation be permitted to develop freely until such time as natural or economic limitations arise, and that forest plantations be not regarded merely as water consumers but also as sources of useful products and as soil conservation measures;
- (ii) that, where water supplies, particularly during low flow periods, are detrimentally affected by afforestation, investigations be instituted into the possibility of eliminating downstream water shortages through the provision of storage;
- (iii) that, where afforestation may result in diminution of streamflow to the detriment of established development, the relevant catchments be not afforested, and that control be exercised over existing afforestation with a view to the protection and improvement of water sources;

- (iv) that, as recommended by the Inter-departmental Committee of Investigation into Afforestation and Water Supplies, the possibilities and implications of encouraging, on individual farming units, the selective utilisation of land for both agriculture and forestry be examined; and
- (v) that hydrological research into catchment management be expedited in order to close the gaps in current knowledge and that such research be aimed particularly at regional determinations of the influence of afforesation on the relationship between average rainfall and mean annual runoff and between dry season runoff and annual runoff. High priority should be accorded to these two aspects, which should be studied by the Department of Water Affairs in collaboration with the Department of Forestry.

An afforestation permit system has been established and a Forestry Guide Plan published (Section 2.8).

26. Catchment conservation

The Commission recommends:

- (i) That control over mountain catchments be placed under the jurisdiction of the Department of Forestry, coupled with which should be created an inter-departmental committee composed of representatives of the Departments of Forestry, Agricultural Technical Services, Agricultural Credit and Land Tenure, Water Affairs, and, if necessary, Bantu Administration and Development;
- (ii) that the Departments of Agricultural Technical Services and Forestry take vigorous action against those who disregard the measures introduced in terms of the Soil Conservation Act and the Forestry Act to implement the judicious use and management of mountain catchments, and that, in this connection, the broader national interest take precedence over the interests of the individual, but that, where the implementation of this principle adversely affects established individual rights, appropriate compensation be paid;
- (iii) that, in the event of conflicting claims arising from the apportionment of water in specific catchments, a determination should be made as to how the disputed water can best serve the broad national interest, and apportionment effected exclusively on this basis but that, if apportionment should infringe vested

- rights, consideration be given to suitably compensating the affected owner;
- (iv) that the rate at which measures to combat soil erosion are being implemented be accelerated, with particular concentration on the prevention of misuse and mismanagement of mountain catchments and agricultural land, by eliminating injudicious farming practices, by obviating the cutting up of farming land into uneconomic units, by encouraging the consolidation of land subdivisions to create economic units, and by substantially improving the extension services to farmers;
- (v) that catchments be comprehensively planned and protected against erosion and that effective steps be taken to intensify the reclamation and preservation of the bottom lands by implementing appropriate biological as well as mechanical measures, and that for these purposes the closest co-ordination and collaboration between the Departments of Agricultural Technical Services and Water Affairs be established; and
- (vi) that the Department of Bantu Administration and Development be afforded all the help and support needed to bring about as quickly as possible those land-use reforms in the Bantu homelands that are so essential to protect important parts of river catchments from further deterioration and, where possible, to improve them.

Comment

- This recommendation has been implemented (Section 6.13).
- (ii) The Conservation of Agricultural Resources Act, 1983, the Forest Act, 1984, and the Mountain Catchment Areas Act, 1970, are not actively applied in the self-governing national states and in the independent TBVC states (Sections 3.2 and 6.17).
- (iii) This recommendation will be dealt with in terms of the principles of scarce resource allocation (Section 2.2).
- (iv) The position has deteriorated greatly in the self-governing national states and in the independent TBVC states, but considerable efforts are being made to improve the situation.
- (v) Satisfactory results have been obtained where this has been implemented.
- (vi) It has not been possible to implement this recommendation because of sociopolitical problems in the self-governing national states.

27. Using the rain where it falls

Direct use of the rainfall by vegetation is usually a highly efficient form of water-use and it is accordingly recommended that, after due allowance is made for the interests of other water users, the possibilities of this idea be thoroughly examined and, where found possible and economically justified, the concept be propagated.

Comment

This concept has been included in the Forestry Guide Plan and in the programme to develop improved cultivars for dryland farming (Sections 2.8 and 7.1).

28. Decline of runoff

As consumption within a catchment increases, runoff is bound to decrease. If increased consumption is economically justified and conforms generally to the national interest, there can be no objection but the implications of increased consumption to the possible disadvantage of established consumers downstream must be thoroughly examined. The Commission recommends that in the planning of water schemes, possible future reduction in runoff through increased upstream water use be taken into account, but that, if such usage within the catchment is of smaller economic benefit than that under a proposed or existing scheme, it must be prevented and schemes should be protected against less beneficial upstream usage.

Comment

This recommendation could not be implemented because of difficulties in establishing whether or not a particular water usage is beneficial.

29. Flood control in areas subject to inundation

There have in the past been great floods that have caused appreciable damage. Although the building of dams can reduce the frequency of floods of given downstream magnitude, it would be a mistake to rely too implicitly on the reduction of flood peaks in low-lying areas without examining the actual potentialities for flooding and resultant damages. It is recommended that areas susceptible to flooding be carefully delineated and that these be not available for general development unless the benefits to be derived from such development.

opment exceed the costs of protection works and compensation for flood damages; in other words, unless the benefit-cost ratio exceeds unity.

Comment

See comments on Finding 12.

30. Water savings in power generation

Appreciable quantities of water are used in power generation; it is essential that all possible efforts be made to reduce the use per unit of electricity. It is recommended:

- (i) that, as most of the energy needed at present and for a long time to come will, for economic reasons, be generated in power stations located on the coalfields of the interior, every effort be made to keep the water consumption in the inland power stations as low as possible;
- (ii) that, as soon as the necessary practical experience with dry-cooling has been gained and as soon as the process appears to be economic, it be applied in future inland power stations;
- (iii) that Escom make its information on watersaving processes available to those local authorities which generate power;
- (iv) that, where economically warranted, power generation be incorporated in dam construction and other water schemes; and
- (v) that if nuclear power stations are erected they be located, in so far as warranted by economic considerations, including possibilities for the desalination of sea water, at the coast, so that sea water can be used for cooling, and that earnest consideration be given to the incorporation of desalination plants for the provision of industrial and municipal water supplies.

Comment

See comments on Finding 17.

31. Hydro-electric power generation

Investigations over the past few years have revealed that there are indeed attractive possibilities for the development of hydro power in South Africa, particularly between the eastern escarpment and the sea. The Commission recommends that these potentialities be carefully examined by Water Affairs and Escom, with due consideration to the water needs of agriculture as well as domestic and industrial users.

See comments on Finding 17.

32. Water consumption in households

There are many ways of saving water in the household without lowering health or living standards and without imposing a burden on the housewife or wasting the time of home dwellers. Even though surplus water discharged to the sewers can be reused after purification, excessive use entails unnecessary capital expenditure. The Commission therefore recommends that the following possible ways of reducing household water consumption be carefully investigated —

- (i) reduction of quantity of water needed for toilet flushing;
- (ii) regulation of pressure within reasonable limits;
- (iii) elimination of leakage or other wastage of water in the mains or in household fittings;
- (iv) promotion of water usage methods that obviate unnecessary losses; and
- (v) use of household fittings that immediately disclose any leakage that may occur.

These investigations should be piloted and followed up by the Department of Water Affairs, but should preferably be carried out by municipal officials, plumbers, manufacturers of household water fittings, and by other competent organisations such as the Bureau of Standards.

Comment

Research is being carried out under the auspices of, and being financed by, the Water Research Commission. The DWA is of the opinion that too rigorous an adherence to this principle will reduce the flexibility needed to accommodate water restrictions during droughts. General adherence to a limit of $400~\ell/d$ per household in the Pietermaritzburg-Durban area in 1985 has shown that water use can be curtailed.

33. Measurement of water consumption in towns and cities

Experience has revealed that water consumption practically always declines as soon as individual meters are installed and consumers pay according to the quantity used instead of paying a general water rate and using water freely. The Commission recommends, therefore, that all feasible steps

be taken to have all domestic and industrial consumers individually metered and charges levied according to the quantity used. The practical implications of this recommendation should be examined by the proposed Standing Committee for Water Affairs in consultation with local authorities. The recommendation applies also to Bantu and other non-White townships where water supplies are connected to houses and other buildings.

Comment

The proposed standing committee involving local authorities has not been established. The water use in subeconomic areas is often still not metered, resulting in wastage.

34. Water meters in flats

The usual current practice is that the apartment house owner pays for water. There is thus no incentive for flatdwellers to conserve water. The Department of Water Affairs has already recommended to the United Municipal Executive that meters be fitted to individual apartments and that each flatdweller be responsible for his own water rates. Such an arrangement would require a rental adjustment in favour of the flatdweller and would result in a general saving in total expenditure for water. The Commission fully supports the principle of this recommendation and suggests that the necessary investigations into its economic justification and practical implementation be actively pursued.

Comment

The DWA is aware of great success with the metering of old and new flats in Bloemfontein and East London, but the rate of fitting meters to existing blocks of flats in other metropolitan areas and in the PWV area is believed to be low.

35. Erf sizes in urban areas

In South Africa it is traditional for householders to maintain gardens on their plots and this inclination is regarded as sound. However, the quantity of water needed to maintain a garden increases rapidly with the size of the erf. It is doubtful whether water provision for large gardens around individual houses can be justified in future, and the Commission recommends that in future a reasonable size limit be imposed in those areas where large quantities of water are needed to keep a garden in good condition.

There is a trend towards smaller erven.

36. Desalination

- (i) The Commission is convinced that current progress in the development of economic processes for desalting sea-water are promising and recommends that funds be set aside for placing research work in this field on a feasibility basis.
- (ii) The Commission's considered opinion is that the availability of desalinated sea-water for urban and industrial use in the Cape Peninsula can relieve the continually rising water demand to the advantage of the profitable irrigation farming in the Western Cape as well as the advancement of urban and industrial development. It is therefore recommended that the Department of Planning, the CSIR, the Department of Water Affairs, the Department of Agricultural Economics and Marketing, and Escom undertake investigations into the benefit-cost structure of an integrated power station and desalination plant. The present production costs of 30 cents per 4,5 m³ (1 000 gallons), according to overseas contentions for a 227 x 10^3 m³/d (50 mgd) unit, could fall within the economic limits of such an undertaking because of the particularly favourable agricultural and industrial potential of the Western Cape/Cape Peninsula complex. The anticipated lowering of these costs with continued technological development can but improve the position.

Comment

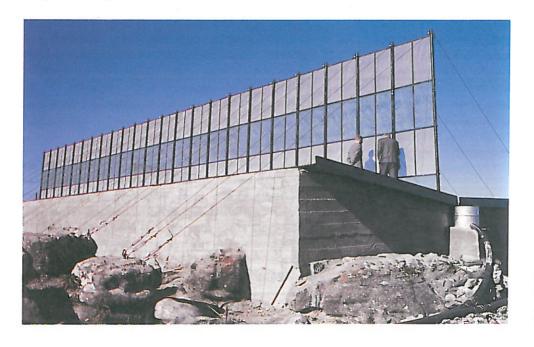
- (i) Current sea-water desalination techniques are viable but not yet competitive with the development of the remaining alternatives. However, desalination may become necessary in some coastal urban areas by the twenty-first century.
- (ii) The water supply to the Cape Peninsula may need to be augmented by desalination early in the next century and the viability of using surplus heat from the Koeberg nuclear power-station for the desalination of sea-water has been examined. Water supply options for the Cape Peninsula are described in Section 5.3.2

37. Moisture from the atmosphere

Indications are that but a small percentage of the moisture content of the atmosphere over South Africa is precipitated as rain to replenish our water resources. The Commission recommends that the Department of Water Affairs, in co-operation with the Weather Bureau and other interested and competent organisations, take steps to mount an investigation into the possibility of extracting more of the atmospheric moisture by means of condensation screens, cloud treatment or other methods and that research in this regard be actively promoted.

Comment

See comments on Finding 20.



Precipitation screens on Mariepskop, eastern Transvaal, for the extraction of water from the atmosphere

38. Adoption of a realistic price policy

Economic activities within a free economy are coordinated through price determination in a series of mutually dependent and integrated markets. As soon as the price of any input factor is maintained at an artificial level through administrative decisions, two disadvantages arise. In the first place, the optimum combination of the various inputs is prevented; e.g. excessive consumption of the commodity of which the price is set too low is promoted while consumption of the over-priced commodity is discouraged. Secondly, the artificial price of any one input influences the price paid for the other production factors, which in turn artificially encourages or discourages consumption of this commodity. To promote an optimum combination of all inputs it is essential that prices attributed to all these factors must be realistic, that is, the prices must reflect the scarcity value of the relevant factors in the national economy. This is particularly desirable in the case of water, which is a scarce commodity in this country and which must, therefore, be developed and used in such a way as to yield optimum benefits to the economy and the community.

The Commission is accordingly of the opinion that, in principle, water from Government water schemes should be supplied to all consumers, whether for consumption or for processing, at a tariff such that after taking account of all direct, indirect and intangible benefits, as well as assurance of supply, is sufficient to cover capital and operating costs. This presupposes that unit prices will be scheme-related, as is currently the practice, i.e. that a unit price will continue to be determined for each scheme.

It is therefore recommended -

- that, for each specific scheme of the Department of Water Affairs, water intended for domestic or industrial use be supplied at a price that covers the full costs and that the artificial lowering of prices to industries and other urban consumers be not permitted by the Department, local authorities or other distributors;
- (ii) that water rates on new irrigation schemes cover the full running costs as well as a percentage of the interest and redemption costs, bearing in mind the share of capital costs, of the scheme recoverable through raised land prices in accordance with recommendation 11(vi);
- (iii) that in so far as is consistent with socio-economic conditions, the water rates on existing Government irrigation schemes be gradually raised to cover at least the operating costs;
- (iv) that water rates for each irrigation scheme be

- determined by the Department of Water Affairs after investigation by and consultation with the Department of Agricultural Economics and Marketing; and
- (v) that an annual financial review for each Government water scheme be published.

Comment

At present all unit tariffs are scheme-related but do not necessarily reflect the scarcity of water

- (i) As recommended all water intended for domestic or industrial use is supplied at full cost (Section 6.6)
- (ii) It has not been possible to implement this recommendation (Section 6.6).
- (iii) Rates for irrigation water on existing Government water schemes have been gradually increased and some now cover the operating costs, but the process has been hindered by the high rate of inflation and has been too slow to achieve the desired objectives (Section 6.6).
- (iv) This is being done (Section 6.6)
- (v) This is now published in the annual report of the DWA.

39. Establishment of an effective cost accounting division in the Department of Water Affairs

To provide the reliable unit cost figures for the Department's activities, so essential to the meaning-ful allocation of expenditures for purposes of performing economic analyses, the Commission recommends that cost accounting procedures in the Department be improved. The intended expansion of the cost accounting section of the Department is therefore strongly endorsed. The Commission regards it a matter of urgency that provision be made for the appointment of qualified cost accountants. The activities of the cost accounting section, in collaboration with the engineering division, would embrace, inter alia, the following:

- (i) formulation of an improved appropriate cost accounting system for determining of unit costs at the Department's works and adaptation of existing systems to the new, so that complete background information can be made available for estimating the costs of proposed works and so that more efficient financial control can be exercised over works in construction;
- (ii) collection and apportionment of capital expen-

- ditures, running costs, receipts from water rates and water sales, for each existing and approved Government water work under respective designations and according to consumption and yield categories;
- (iii) calculation of suggested unit costs of water for project design and desirable adjustments according to actual expenditures and consumption growths at existing schemes, particularly regional schemes for industrial and municipal water supply; and
- (iv) assistance with cost estimates and anticipated monetary yields and benefits for feasibility studies and the preparation of White Papers.

A qualified cost accountant has been appointed to the staff of the DWA.

- (i) A new cost accounting system has been established. Unfortunately the objectives are rarely being achieved because cutbacks in funds result in prolonged construction periods with accompanying increases in total overhead costs.
- (ii) This information is now collected on a regular basis.
- (iii) This is now carried out on schemes where full costs are recovered.
- (iv) This is now being carried out.

40. Procedures for land purchase

It is recommened -

- (i) that within the Department of Water Affairs itself a record be kept of the costs of land actually found necessary for individual Government water schemes, which costs to be added to other accumulated expenditures so as to yield a more realistic total cost figure for each scheme; and
- (ii) that closer co-operation be maintained between the Department of Water Affairs and the Department of Agricultural Credit and Land Tenure so that a satisfactory basis may be found for estimating the costs involved in land acquisition.

Comment

- (i) This recommendation has been implemented
- (ii) This is being done.

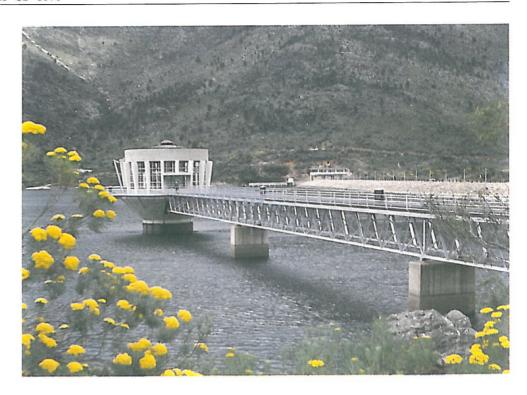
41. Procedures for calculating anticipated costs and yields

It is recommended -

- (i) that, as cost figures submitted in the past have often not been easy to compare and could not therefore provide reliable criteria for cost estimates the method of calculation of various unit costs of water schemes be standardised according to the nature of the scheme, that components be accurately described and that the method be meticulously adhered to. Among the relevant unit costs are the capital costs per unit volume of storage and per unit of assured yield from storage, the cost per unit of water yielded over the life span of a water supply scheme and the capital cost and annual charges per unit of area of an irrigation scheme;
- (ii) that the engineers be afforded opportunity for proper preliminary investigations on which to base their estimates;
- (iii) that, since there must be a direct connection between costs incurred and the products delivered or services rendered, on which the outlay can be recovered, the total costs of schemes should in all relevant instances be presented in such a way as to reveal the cost price per unit of anticipated water consumption;
- (iv) that the basic data upon which benefit-cost ratios of proposed water schemes be calculated in such a way as to enable an independent adjudicator to form his own opinion as to whether or not the proposed expenditure is economically justifiable, and it is consequently desirable that this information be provided;
- (v) that, whereas it is the function of the unit cost to distribute costs over the delivered products or services rendered and whereas the function of the unit price or tariff is to recover the total financial outlay over the useful life of the project, water rates should, subject to the reservation that they must be related to anticipated long-term consumption, take into account the causal connection between total incurred costs and income-earning outputs.

Comment

- (i) Considerable improvements have and are being made in the DWA's cost estimating techniques in the spirit of this recommendation (Section 6.6).
- (ii) The quality of investigations has improved markedly since this recommendation, but the DWA still suffers from a



Intake from Wemmershoek Dam for water supply to the Cape Town metropolitan area

shortage of experienced staff.

- (iii) This relationship is now shown more clearly in White Papers.
- (iv) Better information is now provided in White Papers and is backed up by extensive reports in departmental files.
- (v) This is still the aim (Section 6.6).

42. Funds needed for water schemes

Because the cheaper schemes have already been constructed and water must be conveyed over longer and longer distances, the costs of supplying water are rising continuously. For these reasons and because of sharply rising consumption, as indicated in Chapter 5, it can be expected that annual State expenditure on water schemes will increase, on present money values, to R100 million in 1975, to R200 million in 1987 and to R400 million by the turn of the century. Since adequate water supplies are indispensable to the country's advancement, it is recommended that the necessary appropriations of State funds be made and, besides this, that provision be made for the acquisition by regional and local authorities of the necessary capital to take care of the regional and local distribution of water, which may demand a further R125 million per annum by the close of the century.

Comment

See comments on Finding 25.

43. Development of municipal and industrial water schemes

(i) Water rates

The Commission recommends that tariffs for municipal and industrial water be such as to promote the efficient utilisation of water.

(ii) Subsidisation of municipal and industrial water schemes

The Commission finds that in South Africa water rates are in general relatively low and as a rule constitute an extremely small proportion of production costs in industry. Accordingly it recommends that no subsidisation of municipal and industrial water schemes for the development of natural water sources be contemplated unless the unit cost to the consumer rises to about 22 cents per cubic metre (R1,00 per thousand gallons), and that this figure be periodically adjusted.

(iii) Financial support for municipal and industrial water schemes

Unit costs of water are strongly influenced by methods of cost accounting and since it is desirable that a reasonably constant price level be maintained throughout the useful life of a water scheme, the Commission recommends the adoption of cost accounting methods having this approach, which is explained elsewhere in the report. The Commission recommends further that financial assistance be extended in the form of loans to cover deficits accumulated during the initial

years when consumption and therefore income are low.

(iv) Schemes for creation of new water sources

The Commission recommends that subsidies be considered for demineralisation schemes and schemes to reclaim municipal sewage effluents for reuse, with the proviso that financial assistance granted in this way be restricted in such a way that unit costs of reclaimed water be not lower than two-thirds of the cost of water from an alternative source, or not lower than 20 cents per thousand gallons (4,4 cents per kilolitre) whichever is the higher. The figure of 20 cents per thousand gallons is based on the estimated costs of complete reclamation and must in due course be adjusted.

Comment

- (i) Tariffs for water intended for municipal and industrial use are calculated at the full cost of supply. The objectives will automatically be achieved by the market mechanism as water becomes scarcer if this economic principle is followed (Section 6.6).
- (ii) Water for municipal and industrial purposes is supplied at full cost (Section 6.6). The recommendation regarding 22 c/m³ was applied and the figure has been adapted to keep pace with inflation. An interdepartmental committee has been appointed to investigate the desirability of subsidizing domestic water tariffs in areas where affordability is a problem (Section 6.16).
- (iii) Cost accounting methods having the recommended approach are now in use. Where the State constructs the projects, deficit loan funds are provided by the Treasury. In the case of schemes built by municipalities, loans must be negotiated by them to cover initial deficits (Section 6.6).
- (iv) Payment of subsidies on schemes for the reclamation of sewage effluent or for the desalination of effluent has not yet been necessary. Present regulations for subsidies for sewage purification plant do not provide for the payment of subsidies on reclamation schemes. Subsidies on the latter could however be considered on an ad hoc basis.

44. Co-ordination of water planning and general economic and physical planning and establishment of a Standing Committee for Water Affairs

It is essential that planning and development of the country's water resources be co-ordinated with general economic and physical planning. Since the comprehensive planning of physical resources falls under the direction of the Prime Minister's Planning Advisory Council, the Department of Water Affairs must remain in close touch with the Advisory Council in regard to all new individual projects, plans for the future development of river basins, and the regional development of the country's water resources, and there must be regular consultations between these two bodies with a view to the co-ordination of water resource planning with overall planning.

To effect this co-ordination and co-operation, the Commission recommends that the Planning Advisory Council establish from among its members a Standing Committee for Water Affairs. The Committee shall be entitled to co-opt representatives of other official bodies interested in water development.

The functions of the Committee will be:

- to co-ordinate the schemes of the Department of Water Affairs with the country's general economic and physical planning and to determine priorities;
- (ii) to promote firm liaison and co-operation among State departments and other organisations concerned with the conservation and utilisation of water and with research into the country's water and affiliated resources; and
- (iii) to give advice on the implementation of a suitable price policy.

The functions and tasks allotted to the Standing Committee must impose specific obligations on its individual members; in other words, it must be an active committee which should:

- (1) meet regularly also in various centres of the country;
- be able to allocate tasks among its members, with the necessary authority to ensure their execution;
- (3) have powers to appoint working sub-committees and task groups;
- (4) be able to collect and consider project reports by its members, working sub-committees and task groups; and
- (5) regularly submit progress reports on its activities.

The Chairman of the Committee must be a member of the Prime Minister's Planning Advisory Council.

An interdepartmental liaison committee with representatives of the DWA and the Chief Directorate of Physical Planning of the Department of Constitutional Development and Planning has been established for coordination on issues of common interest. The DWA is also in contact with the Regional Development Advisory Council and the Regional Development Advisory Committees. A water policy advisory committee under the chairmanship of the Minister of Water Affairs is to be established to consider policy issues and priorities for development projects.

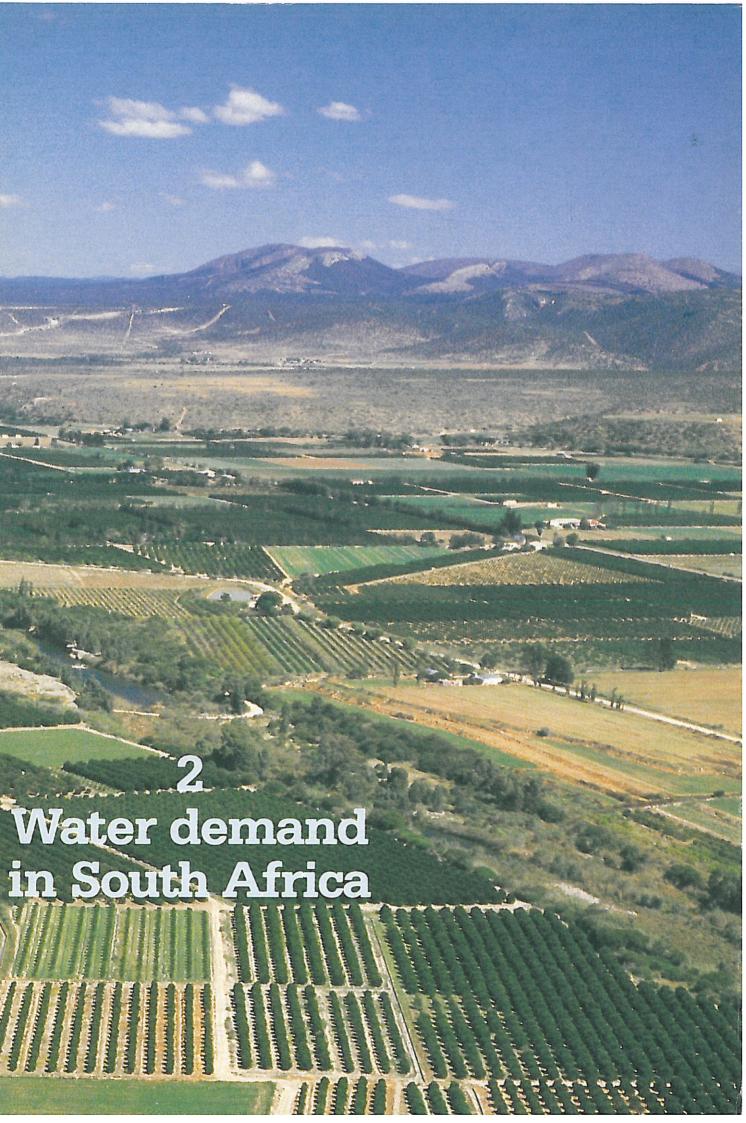
45. Research

The Commission recommends that for incorporation of the latest knowledge in water resource development and utilisation there must be effective co-ordination of the research being carried out by the various organisations and that, to accomplish this, a Co-ordinating Committee for Water Research be created by the Prime Minister's Scientific Advisory Council and that, as proposed in recommendation 44, effective liaison be established between the Co-ordinating Committee and the Standing Committee for Water Affairs.

Comment

See comments on Finding 31.





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In resource management and development it is important that a careful concentration be maintained on conflict resolution.

2.1 Estimation of water demand

In the past, the total national water demand was expressed as the sum of direct uses that were physically supplied, that is to say, water supplied directly from waterworks. However, in 1970 the Commission of Enquiry into Water Matters also took the reduction of runoff by afforestation into account as an indirect water demand. Subsequently water required to maintain ecological equilibrium in estuaries and lakes has been identified as a further major indirect demand that influences the available water supply.

The reduction in runoff as a result of dryland farming represents a further indirect demand that is not easily quantifiable. However, changes in land use are being studied to determine the effect this will have on indirect demand. As full utilization of all the available water is approached, the role of indirect demand becomes increasingly important. In future the more comprehensive total demand relationships including indirect demand will be reported.

The national use of water by the various sectors in 1980, as well as the expected growth to the year 2010, are illustrated in Fig. 2.1.1. Similar graphs are given for each of the primary drainage areas in Fig. 2.1.2.

The total demand relationships are dynamic since they are affected by the rates of industrialization and urbanization, by the growth rates of stratified population groups which should be influenced by the population development programme, by changes in living standards and by technological development in most sectors. This applies particularly to agriculture, power generation, domestic use and industry. The relationships will also be affected by improved efficiency in use, increased recycling and changes in salination and eutrophication patterns. As the relationships differ greatly from catchment to catchment, the regional situation is given in the tables in Section 2.10.

The differentiation between consumptive use, which removes the water from the system, and non-consumptive use, which produces effluent that is available for reuse, is becoming an important consideration. Criteria for the allocation of water and for fixing an appropriate tariff will take cognizance of the degree to which water is used consumptively.

The present and expected patterns of use are difficult to determine accurately. In many cases water users keep no records. In others the nature of possible changes is unknown and projections from past performances may be inappropriate. All values given in this report are the best estimates available at present and will be subject to regular revision. In due course water use will also be categorized according to water quality.

Table 2.1.1 shows that the relative uses by the municipal, domestic and industrial sectors, all of which require a high assurance of supply, are increasing. This indicates the importance of linking catchments or providing additional storage so as to secure the necessary assurance of water supply.

The relationships between the demands in 1980, expressed in the form of both direct demand ratios and more comprehensive total demand ratios, are illustrated in Fig. 2.1.3.

4Small savings in the large amounts of water used for irrigation can release significant quantities of water.

As irrigation is the largest single water user in South Africa it is unfortunate that accurate statistics on the quantities used by this sector are generally unavailable. There are three classes of irrigation users, namely those on Government water schemes, those supplied by irrigation boards (or other statutory bodies formed to promote communal interests) and private farmers. Approximately 19 per cent of the existing irrigated area, which is believed to be about 1,0 million ha out of the estimated irrigable potential of 1,4 million ha, falls under Government schemes, 22 per cent under irrigation boards and the major portion, namely 59 per cent, under private schemes.

Between 1965 and 1978 the three classes of irrigation users expanded the area under irrigation by an average of 1,55 per cent, 1,47 per cent and 3,43 per cent per annum respectively. Private irrigation has therefore been expanding at more than twice the rate of the other two. Government water schemes have the most accurate records of water use and recording procedures are being improved constantly. Many irrigation boards have works with no metering facilities and the amount

of water they use is simply estimated. Use on private farms, particularly those with small individual water schemes, has almost invariably to be estimated, since there is seldom any metering or control. Assessments are made on the basis of crop and soil types, evaporation rates and cultivated areas in different climatic regions. As considerable quantities of water could be made available from underground sources it is imperative to improve the understanding of the use of ground water, particularly for irrigation.

Remote sensing through the use of satellite imagery has already proved highly successful for determining areas that are under irrigation and is now considered to be the only technique by which a regular, country-wide survey of such areas can be made economically and in good time. The Department of Water Affairs has invested in the image processing facilities that are essential for the effective handling of the mass of information that is obtained by means of this technique. These facilities make it possible to extract a wide range of information on plant stress, irrigation efficiency, seasonal distribution of water use and crop type, all of which is required for good irrigation management.

Major improvements in irrigation techniques as well as improved management and greater use of improved cultivars for dryland farming may lead to considerable water savings and a change in the growth patterns of water use. Small savings in the large amounts of water used for irrigation can release significant quantities of water, but in practice irrigation quotas are not adjusted as irrigation techniques improve. This is because crop patterns are changed or the farmers who have the necessary land, use the saving in water to extend the area under irrigation. The possibility of expansion serves as a major incentive for the improvement of management and irrigation techniques. As a result of training programmes for water control offi-

Table 2.1.1: Expected total use and percentage of total demand

Demand sector	1980		1990		2000		2010	
	(million m³/a)	(%)						
Direct use								
Municipal and domestic	1 516	9,3	2 281	12,0	3 220	14,4	4 477	17,3
Industrial	1 031	6,3	1 448	7,6	2 043	9,1	2 961	11,4
Mining	466	2,9	511	2,7	582	2,6	649	2,5
Power generation	282	1,7	444	2,3	779	3,5	900	3,5
Irrigation	8 504	52,2	9 695	50,9	10 974	48,9	11 885	45,9
Stock-watering	262	1,6	288	1,5	316	1,4	358	1,4
Nature conservation	178	1,1	182	1,0	187	0,8	191	0,7
Indirect use								
Forestry runoff reduction	1 284	7,9	1 427	7,5	1 570	7,0	1 700	6,6
Ecological use, estuaries and lakes	2 768	17,0	2 767	14,5	2 767	12,3	2 767	10,7
Total	16 291	100,0	19 043	100,0	22 438	100,0	25 888	100,0

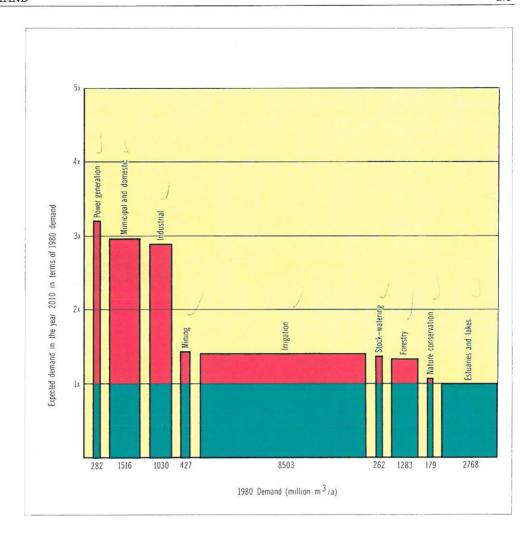


Fig. 2.1.1: Expected growth in water demand from 1980 to the year 2010 per sector of

cers substantial advances have been made in the elimination of distribution losses on Government water schemes in the past decade.

The water required for stock-watering has to be estimated from animal counts and typical unit consumption figures. Although demand by this sector is small, the local assurance of supply is generally critical and is non-elastic unless stock numbers are reduced.

The assessment of municipal and industrial water use is a laborious task. Municipalities with less than 5 000 inhabitants often have very poor records, if they have any at all, and consumption has to be estimated from population counts and typical consumption elsewhere. In larger municipalities discrepancies occur between the totals of individual and bulk meter readings. As industries that require more than 150 m3 of water per day are obliged to have permits from the DWA, their consumption is better known, but the requirements of smaller industries within local authority supply areas are difficult to establish. An additional problem in trying to ascertain use is that many municipalities suffer large distribution losses possibly up to 35 per cent of bulk draw-off.

Urban and rural domestic use patterns depend

on the rate of growth of different strata of the population and on the changes in their living standards. Future sociological and economic influences are difficult to predict. Changing trends in housing and in erven sizes, the growing use of automatic appliances that utilize water, the rate of urbanization and the influence of tariff structures on future demand are all unknown factors.

Water use by mines is fairly well documented but the proportions required for mining processes, domestic use and the watering of gardens and of recreational grounds are difficult to ascertain. Some mines pump large quantities of low-grade water from underground workings, part of which is used in mining processes. The remainder is disposed of either by evaporation in pans or by irrigation when the quality is too poor for the water to be allowed to return to a public stream. The extent to which mines may become self-sufficient in using this water through improved treatment processes and the viability of reclaiming it for future public use is being determined.

Many industries are improving their internal recycling processes. The influence this could have on demand by various types of industry has to be established.

Although water use for power generation as a percentage of the total national demand is low, it may significantly affect the availability of water to other users at a local level. The quantity of water used for power generation is well known but there is uncertainty as regards the future increase

in requirements. To reduce water use the DWA has requested Escom to consider employing the dry-cooling process in its power-stations where economically feasible in future. Only about 22 per cent of the water used by wet-cooled power-stations is needed in a dry-cooled station, but at

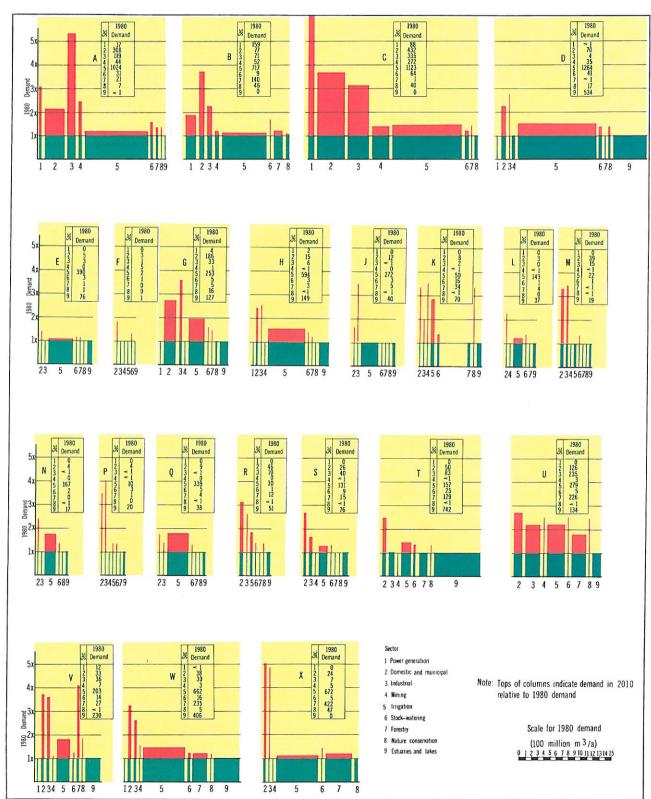


Fig. 2.1.2: Expected growth in water demand from 1980 to the year 2010 per sector of use and per primary catchment area

greater capital and running cost which could be offset by savings on water costs. Present technology is untried on the required scale and each power-station will be dealt with on its own merits.

The reduction in runoff as a result of forestry has been the subject of research for several decades. Since 1972 new afforestation has been controlled by a permit system and the Forestry Branch of the Department of Environment Affairs has a catchment management programme that aims at integrating afforestation with water resource development in suitable areas in order to maximize production and minimize sediment generation and the reduction in runoff.

The effect that industrial decentralization incentives will have on the geographic distribution of water use is also indeterminate and the resulting changes will have to be monitored.

During the past decade research into the water requirements for the maintenance of ecological equilibrium in estuaries and lakes and for nature conservation has indicated that rather larger quantities than were previously believed to be necessary may be required for this purpose. These quantities should be regarded as first estimates and additional research is necessary to determine

the minimum water requirements for this purpose. It is possible that peak flows that cannot be stored economically will be adequate to flush estuaries. Releases from storage may however also be required. The extent to which water will be made available for the management of estuaries and lakes will depend on the relative merits of the competing uses. The figures shown in the various tables are based on the assumption that demands are fully met and they can therefore be considered as the upper limit of requirements.

Since the DWA is progressively giving greater attention to strategic and long-range planning, it is essential that the quality of the necessary data be upgraded. In order to monitor the situation continuously the DWA has created a national water inventory, categorized by drainage area, in which all known and estimated information on demand and availability is being stored. This will enable interrelationships to be assessed for optimum decision-making and it is intended to institute regular user surveys to update the inventory. Provisional data from the system are given in the tables and graphs in Section 2.10 and are summarized by drainage area and by country in Tables 2.10.13 to 2.10.18.

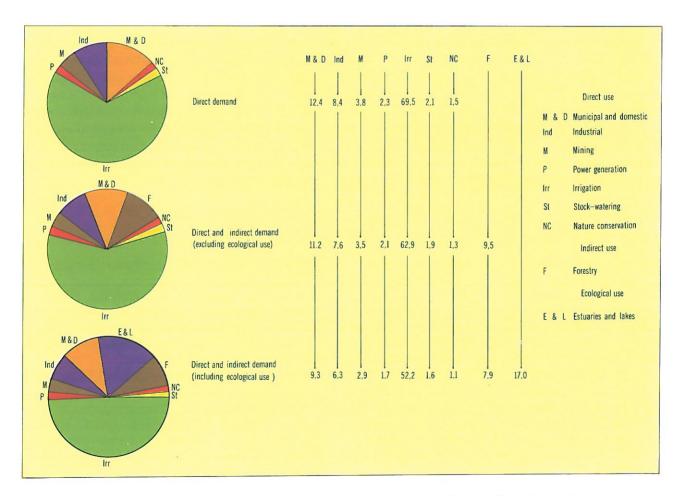


Fig. 2.1.3: Percentage use in 1980 by various sectors expressed as direct, direct and indirect, and total demand

2.2 Allocation of water as a scarce resource

The Commission of Enquiry into Water Matters (1970) recommended the fair apportionment of water among all sectors of the economy. The rapid urbanization and industrialization of South Africa has given rise to a hierarchy of water users ranging from those who require a high assurance of supply and quality in the national interest to those who can accommodate limitations of supply and degraded water qualities when necessary. With the increasing scarcity of water, the hierarchy of priorities for allocation must be further refined by means of appropriate benefit-cost and other economic and socio-economic studies. Within the requirements of contributing to the quality of life, the allocation of water must be based on the economic interests and the social demands of the country as a whole. The optimal utilization of resources, balanced growth and the minimal disruption of the economy are the most important criteria in this regard.

Water is one of the most strategic resources in the country and because of its unfavourable distribution, both geographically and in relation to other resources, it is often necessary to transfer water from areas of relative abundance to areas experiencing water shortages. The Department of Water Affairs does, however, endeavour to provide for all rightful and reasonable demands within a particular catchment area before considering exports to other areas. The fairness of demands within catchment areas will, however, always be weighed against national requirements. The possibility of a temporary allocation to a user or an area is not excluded. The export of water from a catchment area will be reconsidered as soon as the priority of use within the supply area exceeds that of the receiving area.

Economic considerations play an important role in the allocation of water to the different user sectors and for this purpose techniques for economic analysis are already well developed. At present, efforts are being made to extend the techniques further, for example to quantify the economic effects of possible water shortages. Socio-economic benefits are exceedingly difficult to assess and in spite of many attempts world-wide no completely satisfactory methodology has been developed. As is described in Section 7.1, efforts are being made at present to develop an appropriate methodology to facilitate decision-making under South African conditions.

It is generally accepted that the supply of water to power-stations, liquid fuel installations and

strategic industries and mines must be accorded the highest priority and that complete assurance of adequate water supply in these instances should be aimed at. Assurance to industries of lesser strategic importance can be somewhat reduced, but should be relatively high to avoid disruption of the national economy.

Water supply for primary domestic demand is also accorded a high priority. In normal times it is appropriate that the full demand is met, but the amount of water used for gardens and parks can be considerably restricted during periods of drought without this having a detrimental effect of critical proportions. For this reason the desirable assurance of water supply to the urban sector is determined provisionally at a two per cent risk



Main canal on the Fish-Sundays River Scheme near Cookhouse

of not maintaining full supply. This is a theoretical approach and as a result of uncertainties in hydrological analysis a more pragmatic approach is adopted and appropriate levels of restrictions are introduced to overcome the most severe consequences of an exceptional drought.

Irrigation farming is water-intensive and the very high actual cost of water supply is not reflected in the highly subsidized water tariffs applicable to Government water schemes and many irrigation board schemes. New irrigation schemes being proposed are therefore subjected to benefit-cost studies. On the recommendation of the Commission of Enquiry into Water Matters (1970) the development of such schemes can be

The national water management strategy being persued and refined by the DWA is based on a scarce resource allocation philosophy. Allocation criteria to serve the best interests of the population are being developed further.

considered only if it can be proved that the socioeconomic benefits exceed the costs. Schemes that meet these requirements are listed according to their benefit-cost ratios and recommended for development when circumstances permit. At present, socio-economic factors are being considered as thoroughly as possible and improvements in techniques of socio-economic analysis are directed towards optimizing decision-making.

Until recently it was held that a 30 per cent risk of up to 30 per cent restrictions for irrigation farming would be generally acceptable, but now the required assurance is related to the type of crop being cultivated and the economic damage that shortages could cause. Some crops may require an

assurance of as high as 90 per cent but values will differ from place to place in the country. A large number of studies still have to be done in connection with the water demands of different crops.

Although forests do not draw water directly from rivers, afforestation reduces the runoff considerably and additional afforestation contributes to the water allocation problem.

The national water management strategy being pursued and refined by the DWA is based on a scarce resource allocation philosophy that takes account of the factors previously discussed. Appropriate national, regional and sectoral criteria must be developed further to serve the best interests of the population as a whole while causing minimal harm to individuals. In the process of water allocation a healthy balance between the different user sectors must be pursued at all times. Factors such as self-sufficiency, strategic importance and social justice play an important role, although it is not always easy or possible to take them into account quantitatively.

Escom has shown that in a specific case the difference in capital and discounted operating costs between a modern wet-cooled 3 600 MW power-station using 150 000 m³ of water per day and a similar dry-cooled station using only 25 000 m³/d is R300 million. However, the higher cost of a larger water supply scheme must be subtracted from this amount. To transfer the difference in water allocation to another user would require that user to generate a direct and indirect increase in wealth of at least R300 million, less the cost of water supply.

Benefit-cost studies of proposed irrigation schemes have seldom demonstrated high direct benefit-cost ratios. The reason must be sought primarily in the relatively high cost of water supply and drainage and in the limited demand for products. Although it is generally accepted that the demand for food will increase as the population increases and standards of living rise, it is expected that in most cases this demand could be met more advantageously by expanding and improving dryland farming. This expectation will have to be proved by ongoing research, however.

2.3 Water for domestic and industrial use

The long-term estimates of domestic and industrial water demand are influenced by many factors that may cause substantial variations in use. Rates of change in population and economic growth, conservation consciousness, housing and living standards, sizes of erven, water metering, use of appliances and water-borne sewerage, industrial technology and the effects of water pricing policies and water restrictions are probably the most important direct factors.

South Africa has a high population growth rate in most population groups. There is, however, a growing awareness of the need to limit population growth and this should be enhanced by the population development programme. Census statistics have indicated significant reductions in population growth rates amongst most population groups. Although improved living standards generally lead to reduced birth rates, they also lead to increasing water demand.

Changing living standards will have a pronounced effect on domestic demand. The major part of the population consists of low-income users with a high potential for substantially increasing their living standards. The smaller part lives under developed-world conditions and has far less potential to increase living standards. The greater use of automatic appliances and the increasing provision of water in homes and of water-borne sewage schemes is causing an increase in water demand per head. This increase may be partially offset by the tendency towards smaller erven, individual metering of users, improved technology in water-using appliances and the implementation of pricing policies.

Pricing policies include sliding water tariffs where punitive rates are introduced for use above predetermined limits. For such policies to be effective the metering of individual users is essential. During the time that water was cheap and freely available the economics of individual metering

was questioned but as the price of water rises to reflect its scarcity value, more meters are likely to be installed. Where meters have been introduced, significant reductions in water use have occurred.

The strategy to be followed under the new urbanization policy will affect the rate and locality of urban development. As with the decentralization policy, urbanization will not affect the country's overall growth rate of water consumption, but will cause changes in the natural growth rates in those areas which are affected.

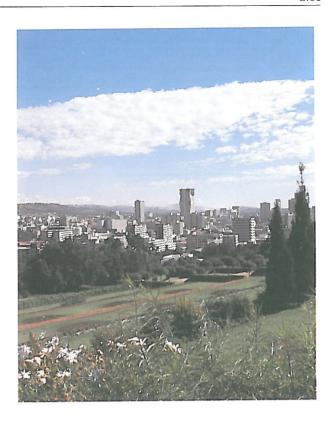
Water restrictions during droughts reduce long-term demand by making users more conservation conscious, but they also have the effect of making savings more difficult to achieve later.

Internal political stability aids industrial growth by creating favourable investment opportunities. Political stability on the subcontinent and cordial political relations with neighbouring states would create additional growth incentives. Industrial growth, and thus water consumption, is also affected by overall economic growth and by changes in technology.

Water restrictions during droughts reduce longterm demand by making users more conservation conscious, but they also have the effect of making savings more difficult to achieve during later periods of restriction as elasticity is removed from the system. Drastic water restrictions applied in Natal in 1983 during the critical drought showed to what extent water savings could be achieved. The restrictions caused water use to drop below the projected long-term average demand curve and it is expected that it will take a number of years before the demand recovers to the projected levels. This is shown in Fig. 2.3.1, which also illustrates a 20 per cent reduction in demand during the 1966 restrictions in the Pretoria – Witwatersrand – Vereeniging (PWV) metropolitan area, which is supplied by the Rand Water Board. Subsequently there was a return to the long-term average growth rate.

In addition to projections from census statistics and other official studies such as the Report of the Science Committee of the President's Council on Demographic Trends in South Africa, the Department of Water Affairs has requested several research bodies to determine expected growth rates for major metropolitan and industrial areas.

The current best estimates of present and expected future demand are shown in Table 2.10.1 and Fig. 2.10.1. These estimates are subject to continual review.



Pretoria - a major water user

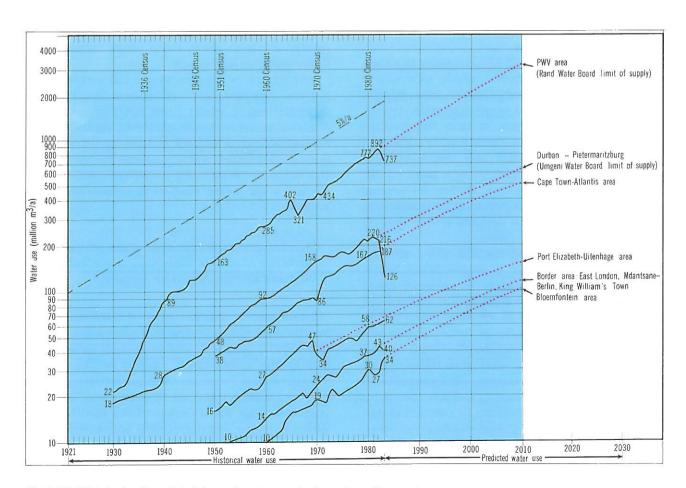


Fig. 2.3.1: Historical and predicted domestic water use in the metropolitan regions

2.4 Water for power generation and strategic industries

The user groups with the highest priority of supply will be determined on the basis of studies such as those described in Chapter 7. They are presently deemed to be those users responsible for strategic activities such as power generation and liquid fuel production. As with all other users, they are expected to achieve the most efficient use of water practicable within the limitations imposed by economic and technical considerations. Escom expects to achieve a significant reduction of about 28 per cent in the average specific water consumption by its coal-fired power-stations, from 2,5 ℓ per unit sent out in the early 1980s to about 1,8 ℓ per unit sent out in the mid-1990s.

Thermal power-stations

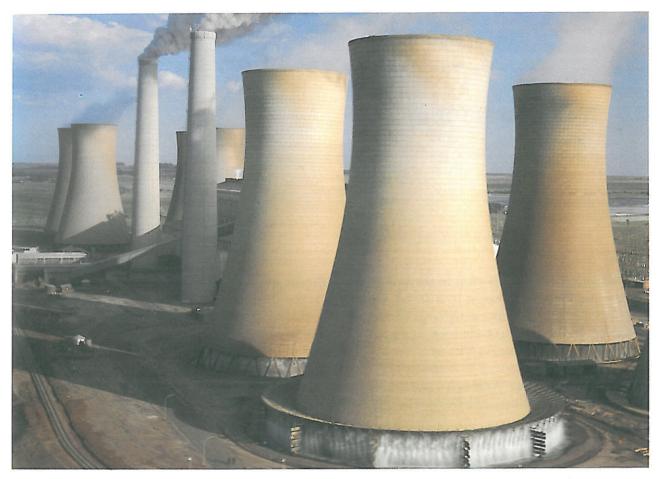
In 1984 Escom supplied 93 per cent of the electricity used in South Africa, which was nearly 60 per cent of the electricity used on the entire African continent. Installed generating capacity was 25 514 MW and Escom was constructing five additional coal-fired power-stations with a planned capacity of between 3 600 MW and 4 000 MW each, as well as a pumped-storage plant of 440 MW. Installed capacity has shown an annual growth of eight per cent between 1950 and 1981 and growth in long-term demand is expected to be five to six per cent per year.

The siting of coal-fired thermal power-stations is dictated by the location of coalfields and water is very often in short supply in precisely these areas. For this reason the Department of Water Affairs has asked Escom to consider using a drycooled generation process in future power-stations where this is economically feasible and where it will lead to a saving in consumptive water use. Each power-station will be considered on its own merits. Dry-cooling reduces the water use per unit generated to about 22 per cent of that of the latest wet-cooled power-stations. However, apart from higher capital costs, turbine efficiency does fall somewhat and more coal is required for the same power output, resulting in increased operating costs for the equivalent generating capacity, although these costs could be offset by lower water supply costs.

Although it is possible to use effluent for cooling, its large-scale use has not been found viable in actual cases which have been investigated. Power-stations are generally too far removed from adequately sized effluent sources and the use of poor-quality intake water results in problems with the disposal of polluted blowdown water. The matter is still being studied in conjunction with Escom.

The effect on the economy of the RSA of an inability to supply water to certain critical demand sectors would be serious.

The effect on the economy of the Republic of South Africa of an inability to supply water to certain critical demand sectors would be serious. During the most critical stages of the recent drought it cost Escom an additional R100 million in fuel to transfer the load to older, less efficient power-stations for a period of six months. The threat of water shortages also warranted emergency measures such as the construction at an estimated completion cost of R33 million of an emergency scheme to pump water from the Vaal Dam to the Grootdraai Dam.



A coal-fired power-station on the eastern Transvaal Highveld

The distribution of expected water consumption by thermal power-stations is shown in Fig. 2.10.2 and Table 2.10.2. The Koeberg nuclear power-station, which is cooled using sea-water, is not included.

Hydro-electric power-stations

Whereas thermal power generation gives rise to a substantial consumptive use of water, hydropower generation is non-consumptive, except for evaporation losses from storage reservoirs which are often required for other purposes too. Hydroelectric power-stations may be used either for base-load generation or, as is more common in the RSA, for efficient, intermittent, peak-load generation, as against thermal power-stations which are better suited to constant-load generation. Hydro-electric power-stations, operated in conjunction with thermal power-stations, therefore improve the efficiency of the entire generating system.

Peak-load generation may be achieved by the release of stored water through turbines, as at the Hendrik Verwoerd and P K le Roux Dams in the Orange River. Alternatively, peak-load generation may be achieved with pumped-storage schemes such as the Drakensberg and Steenbras schemes.

Whereas thermal power generation gives rise to a substantial consumptive use of water, hydro-electric power generation is non-consumptive, except for evaporation losses from storage reservoirs.

In these, base-load power is used to pump water from a low reservoir to a high reservoir during off-peak periods and the water is released to the low reservoir through turbines to meet peak power demands.

The main considerations that affect the siting and operation of hydro-electric power-stations are the effects of intermittent releases on the efficient operation of river systems and on river regimes and the evaporation loss from the storage reservoirs. The operation of hydro-electric power-stations also has a significant environmental impact in that large areas of the reservoir basins are intermittently exposed and inundated, resulting in the denudation of plant life and the creation of mud flats.

Under the hydrological conditions and in view of the availability of fossil fuel reserves in South Africa, the construction of hydro-electric power-stations has not been found to be economically viable unless associated with water supply works.

2.5 Water for mining

The mining industry is vital to the economy of South Africa. Its contribution to the gross national product is illustrated in Fig. 1.2.1. Owing to the importance of the mining industry, the supply of water to this sector will receive high priority. The demand by mining on the total national water resources is relatively low. Strenuous efforts are being made by mines to conserve and recycle water. The achievement of savings of some 30 per cent on the 1982 usage by the mines operating in the supply areas of the Rand Water Board, the OFS Goldfields Water Board and the Western Transvaal Regional Water Company has been mainly the result of the recycling of tailings decant water and purified sewage effluent.

The Republic of South Africa ranks as one of the five major mineral-producing countries in the world alongside the United States of America, the Soviet Union, Canada and Australia. It is the Western World's largest supplier of gold, platinum, gem diamonds, chrome, vanadium, manganese, andalusite-group minerals, vermiculite and certain asbestos fibres, while it is the second largest producer of the platinum-group metals, fluorspar, coal and antimony, the third largest producer of uranium and titanium minerals and among the 10 largest producers of lead, iron ore, nickel, copper, tin and silver. In 1983 the mineral industry employed more than 700 000 persons and paid out R3 565 million in salaries and wages.

Since the early 1870s the RSA, with an estimated 51 per cent of the world's known gold reserves, has dominated the world's gold supply. Recent advances in the recovery of gold, uranium and pyrites from old slimes dams have been made possible by improved technology and economic factors. These undertakings may well be termed the largest surface gold and uranium operations in the world. The RSA is the world's largest producer of gem diamonds and in 1982 was responsible for 20 per cent of world production of rough diamonds.

South Africa's reserves of the platinum-group metals are estimated at 83 per cent of the known

reserves in the Western World. These resources together with equally vast resources of chromium and vanadium in the uniquely mineralized geological structure known as the Bushveld Igneous Complex probably represent the most important single regional concentration of strategic metals known. South Africa is the largest producer of chrome ore after the Soviet Union. The production capacity of the chrome mines can be expanded to meet any increase in local and world demand.

The mines provide employment for large numbers of workers and contribute considerably to the generation of foreign exchange. It is therefore imperative that this sector be given high priority in the allocation of water.?

Manganese reserves are believed to be more than 75 per cent of known world reserves. South Africa possesses 50 per cent of the Western World's vanadium reserves, is the largest producer and exporter of vanadium in the world and is also a significant exporter of iron ore. The country also produces lead and zinc from the deposits discovered in the early 1970s in the highly mineralized north-western part of the Cape Province.

With the exception of oil, South Africa is very



Coal mining in the eastern Transvaal - a strategic water use sector

well endowed in the field of critically important mineral energy resources. Uranium production increased by 250 per cent between 1975 and 1980 but levelled off after 1980 because of a decline in world demand. Since coal is used to generate almost 92 per cent of the country's electricity, it is a vital national resource. Over the past decade, coal export tonnages have increased by about 31 per cent per annum on average. This has been made possible by the construction of a special deep-sea harbour and modern coal loading facilities at Richards Bay, which were commissioned in 1976.

The mines provide employment for large numbers of workers and contribute considerably to the generation of foreign exchange. The mineral industry is essentially export-oriented and on average some 85 per cent of its total revenue is earned abroad. It is therefore imperative that this sector be given high priority in the allocation of water. Any enforced water rationing to the gold mines, which need large quantities of water for their metallurgical extraction processes, for ventilation

and refrigeration and for water-cooled underground machinery, could cause severe economic loss to the country.

Strenuous efforts are being made by mines to conserve and recycle water and savings of some 30 per cent have been achieved.

Owing to the depth of mineral deposits, mines are generally forced to dewater underground workings and to discharge this mineralized water to surface sources. Advanced technology such as desalination and biological sulphate removal offers potential for the integration of surplus mine water into fresh water resources.

Because of improvements in efficiency and a possible levelling off in activity, it is expected that the growth in the demand for water for the mining sector will be limited. The distribution of the present and expected use of water for mining is shown in Fig. 2.10.3 and Table 2.10.3.

2.16 WATER DEMAND

2.6 Water for irrigation

Irrigation farming plays an important role in the socio-economic dispensation in the Republic of South Africa, but at the same time it is also the largest consumer of water. The economic justification for further irrigation development will depend to a large extent on the demand for agricultural products but especially on the availability of water. The availability of capital and managerial skills is also an important factor, however. In assessing irrigation schemes great emphasis is placed on the socio-economic impact of such development and the risk of water shortages, taking into account the crop being cultivated. The viability of farming enterprises is of great importance in this assessment.

A moderate but stable rate of development, in keeping with the needs of the country, is envisaged, with the emphasis on private and irrigation board schemes. Irrigation development is however a very slow process and is also highly capital intensive. Consequently, care should be taken that the rate of development keeps pace with the increasing demand for agricultural products, but at the same time over-development at any stage must be avoided. The interest of the Department of Water Affairs will be limited mainly to the development of infrastructure, such as large storage dams and main supply systems. Large-scale irrigation development will probably be restricted to the areas where water is still reasonably freely available.

Irrigation development is often seen as an important first step in uplifting relatively undeveloped communities, but irrigation development is only one, and not necessarily the most effective, means of achieving socio-economic objectives. Besides the claims made on water of common interest and capital resources, the influence of irrigation on the balance between the demand and supply of agricultural products should also be taken into account.

In 1970 the Commission of Enquiry into Water Matters found that there were no economic or strategic reasons to justify urgent large-scale irrigation development in the RSA in the foreseeable future. In its Finding I (4) the Commission emphasized that the justification for new irrigation projects should, in each specific case, be based on careful socio-economic analysis of the benefits and costs of the projects and the evaluation of these projects against possible alternative applications of the necessary funds. In Recommendation 10 the Commission also commented that 'since water is relatively scarcer in the Republic than irrigable land . . . the endeavour should be towards

the maximum yield per unit of water, but consideration should be given to the need for achieving an optimum combination of production factors by fixing realistic prices for all the input components'.

The recommendations of the Commission, which were submitted to Parliament and accepted as policy by the Cabinet, have been applied with great circumspection. Proposed new Government irrigation schemes were ranked in order of priority on the basis of benefit-cost studies. It was found that the supply of most products grown under irrigation could satisfy demand, with the result that a net economic benefit for new Government irrigation schemes could seldom be

demonstrated. The studies also indicated that emphasis should rather be placed on the efficient utilization of all production factors of the existing schemes, such as managerial skill, irrigation technique, marketing and export promotion. The acceptance of these findings and a serious shortage of development funds resulted in a rapid decline in State expenditure on irrigation development, as shown in Fig. 9.1.5.

Since the importance of agriculture in the South African economy and the strategic value of food production cannot be ignored, the Department of Agriculture and Water supply has launched an indepth study of the long-term demand for agricultural products and the extent to which this demand can be satisfied by vertical and/or horizontal expansion of dryland and irrigation farming. The result of this study will greatly influence the trend of irrigation development in the long term.

The recent drought again focused attention on the management and use of the available water resources. The current guide-line, which is based on existing records, is to provide for 100 per cent of a quota for 70 per cent of the time and 70 per cent of the quota for 30 per cent of the time over the long term. During short periods of critical drought there may even be no irrigation water available.

The profitability of farming enterprises and their survival during critical water shortages can to a large extent be assured by making specific provision for risks in the water supply.

In consultation with those concerned, consideration will have to be given to providing for local conditions by associating different levels of security of supply with specific crops, for example with permanent crops such as fruit, which require a high security, at one end of the risk spectrum and annual cash crops at the other. Maximum benefit can be obtained from the available water if a certain percentage of the crops is adaptable to variation in irrigation in accordance with the quantity of water that is available from season to season. Lucerne is a good example of a crop where production is related to the quantity of water available.

The profitability of farming enterprises and their survival during critical water shortages can to a large extent be assured by making specific provision for risks in the water supply. The farmer's capacity for adapting to a variable water supply is limited, however, by the fact that many farming expenses are fixed from year to year.

It must be emphasized that the variability of

rainfall and runoff in the RSA precludes the possibility of eliminating the risk of water shortages and that a lessening of risk will result in increased costs and greater water losses. To decrease the risk of shortages, larger dams will be required to carry over larger volumes of water for longer periods, with consequently higher costs and evaporation losses.

The acceptance of greater variability in water supply will as a rule make more water available at a lower cost. The possibility of carrying over products and capital reserves instead of scarce and expensive water for periods of shortage must always be considered as an alternative.

Since economic advantage is the decisive criterion for successful irrigation, the actual cost of all inputs must be taken into account and proposed projects must be tested against strict efficiency norms.

Water pollution is a growing problem for agriculture. The pollution is caused by salination and eutrophication of runoff and stored water by seepage from formations containing soluble salts and from irrigated lands, and by runoff from urban and industrial areas. The former is a natural phenomenon aggravated by increasing water and land use. The latter is a direct result of a growing population and its concentration in the metropolitan areas (Chapter 4).

Mathematical models developed by the Hydrological Research Unit of the University of the Witwatersrand with financial aid from the Water Research Commission are used by the DWA in cooperation with the National Institute for Water Research of the CSIR and the Department of Agriculture and Water Supply, among others, to test the effect of planning and operating options on water quality. The effects of pollution on irrigation in agriculture and possible countermeasures are also being investigated. In the Pretoria-Witwatersrand-Vereeniging (PWV) area, for instance, rigorous effluent standards are already enforced, whilst an appropriate operating rule contributes much to the improvement of water quality in the Fish-Sundays River system.

The desirability and cost of using irrigation development to achieve socio-political aims are also being investigated. In the past, the construction of several large Government irrigation schemes was successful in achieving social aims, mainly the combating of the poor-White problem at a time when there was a need for the rapid development of a non-industrialized South Africa and when there was little competition for water. A need for similar solutions in certain sectors of the popula-

tion still exists today.

Since economic advantage is the decisive criterion for successful irrigation, the actual cost of all inputs must be taken into account and proposed projects must be tested against strict efficiency norms. For instance, water tariffs on Government schemes are a fraction of the real cost of supply and the Government subsidy on such schemes must be taken into account in the evaluation of schemes

The demand for agricultural products and the subsidies on them as well as alternative methods of production and the time value of money are other equally important considerations in the evaluation of irrigation development. The need for intensive drainage works can seriously prejudice the economy of an otherwise viable irrigation project and this factor must of necessity be taken into account.

It is essential that new irrigation development be assessed on a basis that takes cognizance of competing present and future water demands.

Irrigation farming is considered to be an industry that is of both economic and strategic importance to the country. It is therefore essential that new irrigation development be assessed on a basis that takes cognizance of competing present and future water demands and South Africa's limited water resources. Economically viable projects will have to be identified for the investment of scarce water, capital and managerial expertise so that the available water can be used to the best advantage.

The sum of all estimated irrigation water demands per country and per drainage region in South Africa for 1980, 1990, 2000 and 2010 are given in Tables 2.10.7 and 2.10.19 to 2.10.22 and in Fig. 2.10.7.

At present about 1,0 million ha out of a potential area of about 1,4 million ha are irrigated in South Africa, with 59 per cent under private schemes, 22 per cent under irrigation boards and 19 per cent under Government water schemes. The compounded annual growth rates of irrigation between 1965 and 1978 were 3,43 per cent for private schemes, 1,47 per cent for schemes under irrigation boards and 1,55 per cent for Government water schemes. Private irrigation therefore expanded at more than twice the rate of the other irrigation sectors. Whereas in the past the State developed irrigation for specific social objectives, the management of these projects is now, wherever possible, being transerred to local communities by the establishment of irrigation boards.

Of the land at present under irrigation, the largest proportion is distributed approximately as shown in Table 2.6.1. As can be expected, irrigation is concentrated in catchment areas with above-average rainfall or along rivers that drain such catchments.

The development of irrigation board schemes and private

Table 2.6.1: Distribution of land under irrigation

Catchment area	ha		
Vaal River	155 000		
Orange River	137 000		
Olifants River (Transvaal)	103 000		
Breede River	100 000		
Limpopo River	95 000		
Berg and Palmiet Rivers	84 000		
Komati River	68 000		
Gouritz River	66 000		
Natal	158 000		
Various smaller areas	± 34 000		

schemes depends primarily on private initiative and to some extent on the availability of State financing. No reliable predictions can therefore be made as to progress with the development of such schemes, although it is expected that irrigation boards and private owners will undertake development as far as is possible. Where the State does undertake development, it is the intention that projects are transferred to irrigation boards. Consideration is at present being given to the establishment of schemes with a total value of approximately R900 million at ruling prices. These proposed schemes are mainly irrigation schemes, but a few multi-purpose schemes are included.

The agricultural sector is by far the largest user of water and policy relating to the effective control and utilization of water by this sector is therefore of paramount importance. The following objectives must be persued by research bodies and extension services and in practice to promote efficient water use:

- Maximum yield per unit of water, taking all inputs into account.
- 2. Improved irrigation techniques.
- Effective irrigation scheduling, drainage and prevention of brack formation.
- 4. Accurate scheduling of irrigated land.
- The combating of water losses on farms by, for example, the sealing of dams and irrigation furrows.
- 6. Improved methods of cultivation for moisture preservation.
 7. Higher production by effective fertilization, pest control
- and the development of new cultivars.

 8. The consolidation of uneconomic units into economic units.

 Units of uneconomic size are the greatest single cause of
- problems on irrigation schemes and can be eliminated only by the granting of credit to facilitate consolidation. Landowners do, however, have to take the initiative in this regard.

 9. Determination of the benefit-cost ratios of new irrigation
- 9. Determination of the benefit-cost ratios of new irrigation schemes so that the most attractive schemes can be undertaken and the allocation of priorities to irrigation schemes that compete for funds with other development.
- 10. Evaluation of the future marketing possibilities of crops that can be cultivated domestically in competition with overseas crops. Research into the future demand for food and other needs based on agricultural production should continue. The need for the production of certain crops for strategic reasons should be given special attention.
- Evaluation of the possibility of increasing dryland production as an alternative to irrigation development.
- 12. Increased productivity in agriculture and stock-farming on the already available dryland and irrigable soil by shifting the emphasis of agricultural policy as necessary.
- 13. Adaptation of farming practices to the operation of dams on the variable draft principle so that areas under permanent crops are limited to those which can be irrigated from a low yield with relatively high security.
- 14. The setting of realistic prices for State land allocated to irrigation with allowance for capital appreciation resulting from the establishment of a State scheme. When irrigation plots are allocated on State schemes, applicants should be strictly selected to ensure that irrigators with a high managerial potential are chosen.
- Determination of the extent to which irrigation development must be expanded to supplement or stabilize dryland production.

2.7 Water for stock-watering

In some regions such as the south-western districts of the Cape Province the stock carrying capacity of the veld in its natural state or when supplemented with artificial pastures is limited by the availability of water of a satisfactory quality. The Commission of Enquiry into Water Matters (1970) recommended that in situations such as these consideration be given to the establishment of stock-watering schemes, which compare favourably with the development of alternative local supplies from boreholes or with the desalination of brackish water. As a result of this recommendation the Duivenhoks Stock-watering Scheme and the Kalahari West Scheme were built and the Rûensveld East Scheme is under construction. These schemes have proved to be very costly. Consequently, the implementation of further stockwatering schemes will be considered only after thorough evaluation.

Stock-watering represents an inelastic demand, which requires a stable water supply of acceptable quality. In large areas of the country stock-water requirements can be provided from underground sources, particularly in sparsely populated areas.

Fig. 2.10.8 and Table 2.10.8 show estimates of the present and expected demand for stock-watering. The values were generally derived from animal counts and typical unit consumption figures. It

should be noted that as stock-watering is a relatively small demand, the scale of its bar chart is larger than for other demands illustrated in the figures in Section 2.10.



Stock-watering represents an inelastic demand

WATER DEMAND

2.8 Water for forestry

Forestry, a major water user, sustains the valuable timber, pulp and associated industries in South Africa and is the primary agency for the conservation of mountain catchments and natural forests. It also plays an important role in the management of sand-dune areas. In view of its significant contribution to the national economy and the fact that it does not incur direct water supply costs, forestry has an important and legitimate claim to water in competition with other users, particularly agriculture, in climatic regions where forestry is viable.

To achieve orderly development, an afforestation permit system was introduced in June 1972 by the promulgation of the Forest Amendment Act, 1972 (Act 46 of 1972). This was done after a thorough investigation of the effects of afforestation on water supply was made by an interdepartmental committee using the results of intensive forest hydrological catchment research dating back to 1940 in the western Cape, Natal and the Transvaal.

Permits are now issued or withheld according to the expected influence of proposed afforestation on runoff and taking into account existing and expected demands for water by all users in each catchment. The position is evaluated continually and research on the effects of unplanted strips that have been left in riparian zones, vleis and sponge areas is being conducted. The permit system and the criteria adopted will be reviewed if improvements are justified in the light of ongoing experience and results of research.

The contribution of the forestry industry to the gross national product averages as much as 25 per cent of the contribution of the agricultural sector. For instance, in 1981/82 the comparative figures for forestry and agriculture were R1 050 million and R4 300 million respectively. Large additional investments have recently been made by the wood-processing industry, including that for the erection of pulp mills at Ngodwana in the eastern Transvaal and at Richards Bay in Natal. Of the total area under commercial timber plantations in the RSA, 803 284 ha or 71 per cent is privately owned while 328 638 ha or 29 per cent is Stateowned. At present the forestry industry employs more than 121 000 people and administers about 1,1 million ha of plantations, 145 sawmills, 12 pulp, paper and board mills, 34 mining timber manufacturing plants, 30 timber preservation plants and three match factories, as well as more

The contribution of the forestry industry to the gross national product averages as much as 25 per cent of the contribution of the agricultural sector and amounts to more than R1 000 million per annum.

than three million ha of mountain catchments, natural forests and sand-dune areas.

The extension of the area under afforestation has been curtailed to limit reduction in runoff to nil per cent, five per cent or 10 per cent of the mean annual runoff (MAR) as measured in 1972, depending on the category of the catchment under consideration. The following example illustrates the effect this has on employment and investment. It was decided to curtail 50 000 ha of new afforestation in the Komati and Crocodile River catchments. This has resulted in 3 300 fewer jobs

in the plantation sector and 5 000 fewer jobs in the primary timber-processing industry. The plantation and primary sectors lost a possible additional income of R24 million and R35 million per year respectively and capital investments of around R32 million were not made.

According to the Forestry Guide Plan drawn up by the Directorate of Forestry of the then Department of Environment Affairs in 1982, the afforested area will have to be increased by 39 000 ha per annum to approximately 1,8 million ha by the end of the century in order to meet South Africa's projected demand for timber in all its forms, including fibre, board and paper.

Most parts of South Africa have only a low rainfall, in contrast with countries such as Brazil, the USA and New Zealand where forestry is also practised commercially. A closed forest canopy, whether natural or artificially established, can exist only in areas with a regular and reliable average annual rainfall of more than 800 mm. In South Africa these favourable conditions occur only in the narrow coastal belt that stretches from the Cape in the south to the Soutpansberg area in the north. The productivity of this limited forest area is exceptionally high (i.e. 15 m³ to 25 m³ of wood growth per hectare per annum as against the world average of 2 m³ per hectare per annum). This can be attributed to a combination of factors including rainfall, temperature, humidity and soil, as well as to the locally developed silvicultural techniques and local tree breeding research for fast-growing poplar, pine, gum and wattle species.

The afforsted area will have to be increased by 39 000 ha per year by the end of the century to meet South Africa's projected demand for timber in all its forms, including fibre, board and paper.

A committee consisting of two members each from the Departments of Water Affairs and of Environment Affairs adjudicates applications for the allocation of forestry permits for commercial afforestation on land that has not been used for this purpose for at least five years.

Fig. 2.8.1 is used to calculate the additional water use by forestry plantations in specific catchments. This diagram was drawn up by the then Department of Forestry and the DWA in close consultation. It was based on local and foreign research results which are not conclusive. Despite extensive forest hydrological research in South Africa since 1940, methods to predict accurately the influence of afforestation upon runoff and low-flow conditions and the effect on other users are

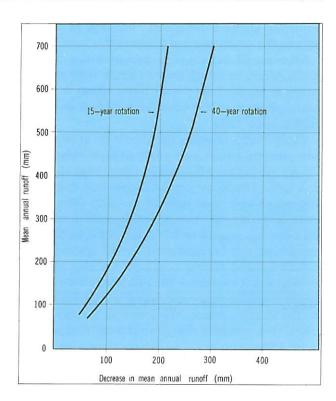


Fig. 2.8.1: Influence of forestry on the mean annual runoff

still imperfect since the variability of local factors such as topography, cultivation practices, types of crops under cultivation and soil permeability plays an important role. Until knowledge can be improved by additional research, the permit system provides the best practical policy available.

The country's catchments have been divided into three categories to maintain the balance between water availability and afforestation.

Category I catchments are those areas in which no new afforestation has been permitted since 1972 as water was already scarce at that time and is needed for higher priorities such as existing irrigation, power generation and domestic and industrial use. These areas are the White River catchment and the catchment above the Witklip Dam, the Luvuvhu and Letaba River catchments and the Usutu River catchment above the Morgenstond and Jericho Dams.

Category II catchments are those in which competing water demands limit new afforestation to such an area as will reduce the catchment's MAR as measured in June 1972 by not more than five per cent. These catchments are those of the Buffalo River near East London above all existing dams, the Mgeni River near Pietermaritzburg (divided into three subcatchments), the Mlazi River near Richmond in Natal (two subcatchments), the Tugela River above Colenso, the Komati River (five subcatchments), the Crocodile River in the eastern Transvaal (10 subcatchments) and the Great Usutu River above the Westoe Dam and the Mpu-

luzi River above a proposed dam site at Busby, both in the south-eastern Transvaal.

Catetory III catchments comprise the rest of South Africa, in which only as much new afforestation is allowed as would bring about a 10 per cent reduction in the catchment's MAR as measured in June 1972.

Table 2.8.1 illustrates the allocation of afforestation permits since June 1972, both in relation to the afforested area before the system was applied and to the biological potential over and above the afforested area that existed in 1975. Where the biological potential exceeds the permit maximum area (ref. columns 6 and 7 of Table 2.8.1), forestry expansion will be restricted by the afforestation permit system. However, where the area allowed by the permit system — the permit maximum — is larger than the biological potential, the latter will be the limiting factor. The lower of the figures in these two columns therefore indicates the maximum expansion possible beyond the area under afforestation in 1975.

It is clear that much less than 10 per cent of the MAR in 1972 has been used by new afforestation since 1972 or will be used in future.

It is clear that much less than 10 per cent of the MAR in 1972 has been used by new afforestation since 1972 or will be used in future. An example is the catchments of the Breede and Kafferkuils Rivers and of the rivers between them (H10 - H90) where only 0,325 per cent of the MAR $(10\ 000/306\ 800\ x\ 10\ per\ cent)$ will be used.

Where extension of the afforested area is still permissible, permits valid for implementation within five years after allocation are given per farm in order of application. The permit normally limits afforestation to 75 per cent of the area of any property and prohibits the planting of trees within 20 m of any perennial stream, spring or marsh. The Forest Act, 1984 (Act 122 of 1984), provides for the 20 m distance to be replaced by a distance decided on an ad hoc basis and imple-

Table 2.8.1: Afforestation permits allocated from June 1972 to October 1986 in relation to area planted before June 1972 and to the biological potential after 1975

Catchment	Description (and area allocated)	Planted area in March 1975	Total allocated after 1972	Catchment category	Permit maximum (in addition to area planted)	Biological potential
		(ha)	(ha)		(ha)	(ha)
A10 – A80	Pienaars (17); Matlabas and Mogol (50); Sterk and Magalakwin (153); Sand, Hout and Brak (200)	5 753	420	Ш	31 875	30 000
A90 (part)	Luvuvhu above Albasini Dam	1 000	69	I	0	3 000
A90 (part)	Luvuvhu below Albasini Dam (allocated before category was established)	12 223	281	I	0	37 500
B10 – B90 (excl. B80 + B60 part)	Olifants up to confluence with Wilge (1 396); Wilge (8); Steelpoort (10 269); Middle Olifants (2 068); Ohrigstad below Ohrigstad Dam up to Blyde (1 032); rest of Blyde (4 238); Selati, Klaserie and Lower Olifants (2 120)	72 533	21 131	ш	60 867	59 500
B60 (part)	Ohrigstad above Ohrigstad Dam	0	1 146	П	868	2 500
B80	Great Letaba above Dap Naudé Dam (80); Great Letaba between Dap Naudé and Ebenezer Dams (479); Great Letaba between Ebenezer and Fanie Botha Dams (353); Letsitele and Thabina (0); Middle and Little Letaba (110) and rest of Letaba (120) (allocated to replace wattle jungle and for consolidation purposes)	44 513	1 142	I	0	17 500
C20 - 80	Vet and Sand up to confluence with Vaal	2 523	154	Ш	1 000	1 000
C10	Vaal up to confluence with Klip (allocated before category was established)	0	47	I	0	72 500
E10	Olifants up to confluence with Doorn	1 340	247	Ш	51 000	5 000
G10 - 50	Great Berg (125); Steenbras and Cape Peninsula (662); Bot, Boesmans, Klein and Hartbees (285)	20 205	1 072	Ш	306 600	25 000
H10 – H90	Breede up to Brandvlei Dam (847); Sonderend (490); Breede below confluence with Sonderend (127); Duivenhoks (500) and Kafferkuils (1 257)	7 281	3 221	Ш	306 800	10 000
J40	Groot between Buffels and Dwyka (75); Olifants between confluence with Dwyka and Kamanassie (100) and Gouritz (60)	9 174	235	ш	1 000	500
K10 – K90	Klein Brak (630); Groot Brak (5); Swart (44); Touw (5 290); Knysna (4 269); Keurbooms (5 272); Groot (937); Storm, Elands, Tsitsikamma and Klipdrift (2 014) and Kromme (2 034)	63 798	20 495	Ш	244 600	40 000
L70 - L90	Couga (southern tributary) (40) and Gamtoos (1 653)	11 351	1 693	Ш	7 000	3 000

Table 2.8.1 (Continued)

Catchment	Description (and area allocated)	Planted area in March 1975	Total allocated after 1972	Catchment category	Permit maximum (in addition to area planted)	Biological potential
		(ha)	(ha)		(ha)	(ha)
M10	Van Stadens above Groendal Dam (3 100) and rest of Van				7,000	E 000
	Stadens (1 306)	522	4 406	ш	7 200	7 000
P10 - P40	Riet, Kaffirskraal and Kowie	949	40	Ш	1 300	500
Q90	Great Fish (north-eastern tributaries)	2 163	514	Ш	10 500	2 000
R10, R30, R50	Keiskamma (194); Buffels below dams (0); Roux, Mtati and Mgwalana (80)	2 880	274	ш	21 714	25 000
R20	Buffels above all dams	1 534	561	п	1 242	2 500
S10 - S70	Black Kei up to confluence with White Kei (5 756); Black Kei between White Kei and Tsomo (195); Great Kei (Stutterheim tributary) (2 793) and Great Kei (coastal portion) (15)	10 870	8 759	ш	21 813	40 000
T10-T90	Umzimvubu (1 054); Umtamvuna (1 589) and Umzimkulu	10 070	0.755		21 010	10 000
	(11 840)	47 428	14 483	Ш	231 238	105 000
U10, U30, U50, U70 U80	Mkomanzi above proposed Mpendle Dam (1 751); Mkomanzi below proposed dam (18 396); coastal rivers between Mgeni and Mvoti (220); coastal rivers between Mvoti and Tugela (40); Illovo above Richmond (854); Illovo below Richmond (5 523); coastal rivers between Umzimkulu and Mkomanzi (4 703)	74 764	31 487	ш	166 852	100 000
U20, U40, U60	Mgeni between Midmar and Albert Falls Dams (6 031); Mgeni above Midmar (7 439); Mgeni below Albert Falls (2 852); Mvoti above Umvoti Poort (7 952); Mvoti below Umvoti Poort (3 994); Mlazi above Umlaas Poort (5 587) and Mlazi below Umlaas Poort (248)	118 432	34 103	п	81 147	80 000
V10 (part) — V70	Tugela below Colenso (348); Mooi tributary above Craigie Burn Dam (1 968); rest of Mooi (2 301); Buffalo up to Tugela (55); Tugela (411); Tugela and Mpisi (438); Sundays and Nadi (624) and Tugela (Estcourt) (3)	18 308	6 148	ш	312 670	90 000
V10 (part)	Tugela above Colenso	423	182	П	41 951	25 000
W10 – W70 (W50 part)	Matigulu (1 076); Mhlatuze (17 932); Mkukuze (68); White Mfolozi (14 734); Black Mfolozi (5 557); Mfolozi (2 258); Mkuzi (St Lucia) (6 140); Bivane up to Pongola (2 695); Pongola up to and including Spekboom (11 984); Assegaai above Heyshope Dam (3 127); Assegaai below dam (14 121); Hlelo above proposed Ishlelo Dam (8 505); Hlelo below dam (200); Usutu below Westoe Dam (2 208); Bonnie Brook up to Usutu (1 093); Umpuluzi below proposed Busby Dam (12 200); Lake Chrissie and pans (532), Metula (310) and Little Usutu (2 848)	307 609	107 520	ш	447 167	280 000
W50 (part)	Ngwempisi above Morgenstond Dam (242); Ngwempisi above Jericho Dam (210)	4 000	452	I	0	1 000
W50 (part)	Ngwempisi between Morgenstond and proposed Merriekloof Dams (4 804); Ngwempisi below Merriekloof Dam (5 580); Usutu above Westoe Dam (3 497) and Umpuluzi above proposed Busby Dam (2 985)	12 500	16 866	п	18 775	20 000
X30 - X40	Sabie and Sand (5 514) and Massintonto (0)	66 039	5 514	Ш	50 284	35 000
X10 X20 (part)	Komati above Nooitgedacht Dam (110); Komati between Nooitgedacht and Vygeboom Dams including Gladdespruit (20 397); Buffelspruit and Seekoeispruit up to the proposed Boekenhoutrand Dam (8 931); Komati between proposed Boekenhoutrand Dam and Swaziland including Theespruit (16 041); Komati between Swaziland and Komatipoort (1 605); Elands up to Crocodile (20 109); Crocodile above Braam Raubenheimer Dam (4 369); Houtbosloop up to Crocodile (4 724); Queens and Suidkaap up to Noordkaap (3 290); Noordkaap and Kaap (4 783); Rest of Kaap (0); Sand above Witklip Dam (0); Sand below Witklip and Nelspruit up to Crocodile (2 621); rest of Crocodile (9 284) and Ngodwana up to Elands (7 783)	177 262	104 047	п	102 100	145 000
X20 (part)	White above Longmere Dam (0) and rest of White (0)	13 510	0	I	0	10 000
Total		1 097 150	386 709		2 527 563	1 275 000
Sub-totals:	Category III	711 753	227 813	Ш	2 231 196	823 500
	Category II	310 151	156 905	П	294 466	310 000
	Category I	75 246	1 991	I	0	141 500

mented by notice in the *Government Gazette*. Similar control systems are not applied in the self-governing national states or the TBVC states.

In hydrological experiments carried out in small catchment areas in the western Cape, Natal and the Transvaal where afforestation covers between 58 per cent and 100 per cent of the catchment area, a reduction in the MAR of between 65 per cent and 90 per cent was recorded (see Table 2.10.9). This indicates the necessity for close cooperation between the Departments of Water Affairs and of Environment Affairs and for the development of such catchments to ensure the optimal use of all available resources. Whilst using significant quantities of water, forestry is able to reduce flood peaks, soil erosion and the sediment content of runoff. Often the reduction in water available to downstream users can be offset by establishing or extending a storage system in the river basin.

The Forestry Branch of the Department of Environment Affairs has estimated that South Africa's need for wood will increase from 12,4 million m³/a during the period 1971 to 1975 to 31,4 million m³/a during the period 1996 to 2000, representing a growth of approximately 253 per cent or 3,75 per cent per annum. It is encouraging to note the private sector's initiative in

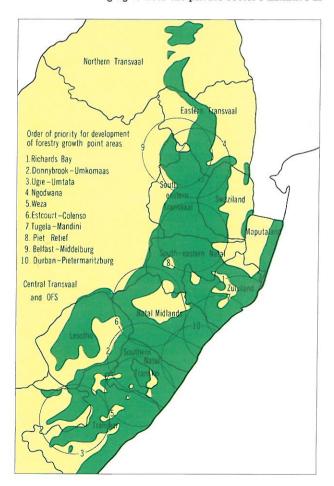


Fig. 2.8.2 Location of the 10 most important forestry development areas



Forestry plays a major role in the conservation of mountain catchments

meeting this demand but the State will have to play an important role in augmenting afforestation, particularly in water-sensitive areas in which critical catchment control is required and on marginal land that the private sector does not regard as viable at present. The Forest Act, 1984, will assist considerably in achieving many of these multi-use objectives.

The Forestry Guide Plan is intended to co-ordinate the development of the forest and timber industries in South Africa through the formulation of broad planning directives and the identification of forestry development areas with a view to the optimal utilization of resources. Ten areas have been identified for priority development, as indicated in Fig. 2.8.2. This development is subject to political, institutional, social and physical limitations with rainfall, water, soil and suitable areas being crucial. Proposed development of afforestation will require active co-operation between five main parties, namely the Governments of the RSA, Transkei and KwaZulu, the private timber growers as a whole and the group of timber growers-cumprocessors. Their water needs must be successfully integrated with those of other users.

2.9 Water for management of the environment

A major competing water demand not identified by the Commission of Enquiry into Water Matters in 1970 is that for the environmental management of estuaries, lakes, wetlands, riverine habitat and conserved areas.

The objective of environmental management is not purely conservation of the environment but rather the optimal management of all resources in order to obtain the maximum net benefit. The maximum net benefit in an environment is derived from the difference between the total benefits, which include the quality of life of people affected by a project, and the total costs. The Commission of Enquiry considered that Lake St Lucia and the Kruger National Park were the only cases to which this objective applied.

The estimated quantity of water required for environmental management in South Africa will increase slightly from the present demand of 2 947 million m³/a to 2 954 million m³/a (see Table 2.10.12). This will constitute about 13 per cent of the total demand in the year 2000, which is about 10 times as much as was estimated by the Commission in 1970 for nature conservation. This estimate probably represents maximum demand and could decrease as a result of further research. In deserving cases the demand for environmental management should be met from developed water sources and any decisions taken in this respect should not be dependent on surplus water being available.

As the extensive water requirements of this sector may limit the quantity of water available for other uses, the water demand for environmental management must be determined more accurately. The estimated requirement has been based on a simplistic model and it is recommended that engineers and scientists undertake intensive research at an early stage to obtain more accurate values. Adequate research funding will be required for this. Where water use for environmental management is in competition with other uses, each case must be judged on its merits.

Estimated water demand

To date water resource development has been undertaken primarily in the interior of South Africa. Potential for additional development lies chiefly in the narrow coastal region in drainage regions E to W (see Appendix 4), where some 61 per cent of the total mean annual runoff (MAR) is available. Most of the estuaries in South Africa occur in this region.

The Commission of Enquiry into Water Matters recommended that provision be made in planning for the utilization of the country's water resources for the reasonable needs of nature conservation areas. However, in each case a thorough study was to be made to ensure that wastage of water was avoided. Lake St. Lucia and the Kruger National Park were identified as nature conservation areas and it was estimated that the water requirements of these areas would be about 220 million³/a. It was considered that the total quantity required for nature conservation would not exceed one per cent of the then estimated total water requirement of South Africa of 29 000 million m³/a by the turn of the century, i.e. a maxi-

Changing catchment, land and water utilization will have an effect on the ecology of rivers, lakes, wetlands and estuaries and it is recognized that these systems will require management in future.

mum demand of 290 million m³/a.

However, awareness of the water requirement for environmental purposes has increased in recent years. During the planning of several proposed water projects located in coastal regions, the Department of Water Affairs has had to quantify the estuarine fresh water demand. From such studies and from discussions with multi-disciplinary groups it has become apparent that the nature conservation requirement was underestimated and as a result it has been revised.

Environmental management

In the National Policy regarding Environmental Conservation (White Paper WP O-'80) it is stated that it is the Government's broad policy 'that a golden mean between dynamic development and the vital demands of environmental conservation should constantly be sought'. Changing catchment, land and water utilization will have an effect on the ecology of rivers, lakes, wetlands and estuaries and it is recognized that these systems will require management in future.

The environmental water demand of estuaries and lakes

Estuaries are amongst the richest and most productive parts of the marine environment and as such call for careful management. Until now no country-wide assessment of the fresh water re-

Table 2.9.1: Fresh water requirements of the estuaries in the primary drainage regions of the RSA

Primary	Major rivers	Gross	Virgin		Fresh	water requi	rements of estu	ıaries	
drainage region		catchment area*	MAR*	tics of	characteris- selected iaries	Total area of estuaries	Evaporative require- ment	Flooding require- ment***	Total require- ment
				Effective area**	Virgin MAR**				
		(km ²)	(million m ³ /a)	(km ²)	(million m ³ /a)	(ha)	(million m ³ /a)	(million m ³ /a)	(million m ³ /a)
A	Crocodile	109 610	2 217	_	A 8-28			_	
В	Olifants	73 790	3 164	_	_	_	_	_	_
C	Vaal	193 470	4 273	_			_	_	_
D	Orange	361 900	7 595	270 450	7 595		_	534,060	534,060
E	Olifants	46 220	1 015	46 080	1 015	648	9,169	66,379	75,548
F	Groen	29 535	110	5 995	37	82	1,293	_	1,293
G	Great Berg	25 570	2 158	15 020	1 365	6 085	58.077	69,073	127,150
H	Breede	15 275	1 954	14 270	1 954	1 472	11,836	136,780	148,616
J	Gouritz	45 715	539	45 450	539	188	1,795	37,730	39,525
K	Krom	7 245	1 372	5 568	876	4 257	30,018	40,482	70,500
L	Gamtoos	34 450	501	34 450	501	175	1,760	35,040	36,800
M	Swartkops	2 540	129	1 957	100	1 163	12,645	6,348	18,993
N	Sundays	20 990	204	20 790	204	268	3,008	14,280	17,288
P	Bushmans	5 015	98	4 465	95	1 416	12,519	7,338	19,857
Q	Great Fish	30 390	526	29 284	526	199	1,672	36,820	38,492
R	Buffalo	8 005	601	3 710	320	861	5,406	21,475	26,881
S	Great Kei	20 611	1 075	20 566	1 064	298	1,594	74,480	76,074
Sub-total:	Cape								
	estuaries	1 030 331	27 531	518 055	16 191	17 112	150,792	1 080,285	1 231,077
T	Mzimkulu	46 670	8 496	8 935	1 938	184	0,687	84,754	85,441
U	Mgeni	18 384	3 171	18 384	3 171	449	1,896	154,302	156,198
V	Tugela	29 101	4 597	29 101	4 597	_	_	230,000	230,000
W	Mfolozi	39 537	4 268	23 985	2 276	39 345	256,649	149,764	406,413
Sub-total:	Natal								
	estuaries	133 692	20 532	80 405	11 982	39 978	259,232	618,820	878,052
х	Komati	28 570	3 370	-	_	_	-	— —	-
Total		1 192 593	51 433	598 460	28 173	57 090	410,024	1 699,105	2 109,129

^{*} Includes the self-governing national and independent TBVC states and Lesotho; excludes Swaziland. Data obtained from the Hydrological Research Unit of the University of the Witwatersrand, Reports Nos 9/81 to 13/81.

^{**} The RSA including the self-governing national states and Lesotho.

^{***} The flooding requirement is not equivalent to the storage capacity of estuaries.



A mountain catchment in the Natal Drakensberg with the Injasuti and Champagne peaks in the background

quirements of estuaries has been made. Storage in and abstraction from reservoirs change the flow regimes of rivers and attenuate or eliminate the more important floods. These changes can have adverse environmental effects on estuaries. In addition, progressively greater water pollution resulting from increasing domestic, industrial and agricultural use is also expected to affect the ecology of estuarine, river and lake systems.

The Global 2000 Report to the President of the USA (1980) points to increasing destruction or pollution of coastal ecosystems, a resource on which the commercially important fisheries of the world depend heavily. It is estimated that 60 per cent to 80 per cent of commercially valuable marine fish species use estuaries, salt marshes or mangrove swamps as habitat at some point in their life cycles. Estuaries are far more productive than the

Criteria are still being developed to assess the environmental importance of estuaries in comparison with the importance of other competing needs. Not all estuaries are equally important.

open sea. In addition they constitute important recreational areas.

Fresh-water and sea-water inflow are both important factors in the ecological balance of an estuary. The fresh-water inflow ensures that hypersaline conditions do not occur and it brings down organic detritus, which is a food source for the estuarine organisms. Flood flows may breach the sand-bars at the mouths of some types of estuaries and flush out accumulated sediment. The sea-water interchange of an estuary system plays a role in the provision of food and keeps the

river mouth open, allowing the migration of fish and other organisms. The estuarine community is adapted to very variable conditions and individual species can tolerate wide ranges of salinity and temperature. These must be quantified to permit effective estuarine management.

Criteria are still being developed to assess the environmental importance of estuaries in comparison with the importance of other competing needs. Not all estuaries are equally important. By using this approach it may be found that certain estuaries have little ecological value and enjoy low priority when water is scarce, whilst others would be regarded as being so important that they would be allocated water in almost any circumstances. Similar criteria could be developed for other environmental water requirements.

Table 2.9.1 shows that the total water surface

The total fresh-water requirement of estuaries and lakes amounts to five per cent of the virgin MAR of rivers selected for study and could be as high as 15 per cent of the utilizable resources.

area of the 148 estuaries and lakes included in a study by the DWA in 1983 covers 59 933 ha. Lake St Lucia, with a water surface area of 32 500 ha, accounts for a large proportion of the total area. The requirements shown are in competition with other demands and it will not necessarily be possible to meet the management demand of each estuary and wetland. Benefits will be weighed carefully against water use in each case.

The estimated water requirements of the estuaries and lakes in the South African coastal regions are shown in Table 2.9.2. While this may be a significant portion of total water demand at present, the proportion decreases significantly in the long term (see Table 2.1.1).

The total evaporative water demand of estuaries and lakes in the RSA is 410 million m³/a, 63 per cent of which is required in Natal. This assess-

Table 2.9.2: Estimated water requirements of estuaries and lakes

Coastal region	Requirements (million m³/a)							
	Evaporative		Flooding		Total			
	Quantity	%	Quantity	%	Quantity	%		
Cape	150	37	1 080	64	1 230	58		
Natal	260	63	620	36	880	42		
Total (RSA)	410	100	1 700	100	2 110	100		
Transkei	190		470		660			
Ciskei	6		14		20			
Grand total	606		2 184		2 790	***		

ment is based on reliable rainfall, evaporation and surface area information.

The total flooding requirement of 1 700 million m^3/a is almost four times the evaporative demand, with the major portion needed in the Cape. This estimate is less accurate than that of the evaporative requirement as it is based on simplifying assumptions. Future research will have to concentrate on the flooding demand in particular (see Table 2.10.11 and Fig. 2.10.13).

The total fresh-water requirement of estuaries and lakes amounts to five per cent of the virgin MAR of rivers selected for study and could be as high as 15 per cent of the utilizable resources.

Water requirements of wetlands and riverine habitat

A number of wetlands exist along riverine systems and these can form important ecological habitats for flora and fauna which may yield valuable sources of food. One example is the extensive pan system on the Pongola floodplain, for the maintenance of which special releases from the Pongolapoort Dam are made. The water demand of riverine habitats is usually allowed for in river losses, although further research is needed on this subject.

Water requirements of nature reserves

Conservation is defined as the management of the human use of the biosphere so as to obtain the greatest possible sustainable benefit to present generations, while maintaining its potential to meet the needs and aspirations of future generations. Three overall goals of conservation are contained within this definition, which has been adopted officially by the International Union for the Conservation of Nature and Natural Resources (IUCN). These are to ensure that the biosphere can continue to renew itself and provide the means for all life, to ensure human survival and well-being and to keep options open.

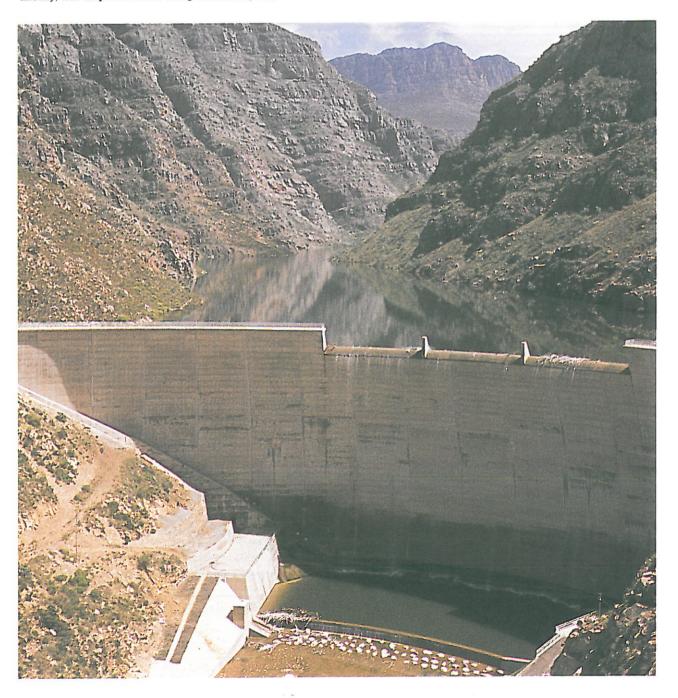
A nature reserve is an area set aside for the purpose of nature conservation. The water requirements for nature reserves can be divided into domestic water for visitors, game-watering and the maintenance of riverine habitat — the latter accounting for approximately 98 per cent of the demand. The present water demand of some 300 public and privately conserved areas with a total area of 3,6 million ha has been estimated for each of the primary drainage regions. The total water demand amounts to 177 million m³/a, of which the Kruger National Park accounts for 110 million m³/a, most of which is for non-consumptive use. It is to be expected that future requirements will increase as more nature reserves are proclaimed (see Table 2.10.10).

During 1977 President Carter of the United States directed the USA Council on Environmental Quality and the USA State Department and other agencies to study the probable changes in the world's population, natural resources and environment until the end of the century. In the Global 2000 Report to the President (1980) it was concluded that, if the present national policies regarding population stabilization, resource conservation and environmental protection were maintained, a progressive degradation and impoverishment of the earth's natural resources would take place. It was found that if these trends were to be changed and the problems diminished, vigorous new initiatives would be required world-wide to meet human needs while protecting and restoring the earth's capacity to support life. Basic natural resources — farmlands, fisheries, forests, minerals, energy, air and water — would have to be conserved and managed better.

The water requirement for estuaries and lakes exists already, but at present it is being met mainly from natural

flows so that no growth in requirements is envisaged for this sector. Future increases in water demand for environmental management will in all probability be confined to extending facilities for visitors at existing and new conservation areas. This will result in a very small growth in water demand for environmental management.

Research is being conducted into environmental water requirements but further comprehensive additional research is required. The Natal Town and Regional Planning Commission and the Department of Environment Affairs are funding research on estuaries and wetlands, in which one of the considerations is the water requirements of these aquatic systems. A steering committee has been formed by the Natal Town and Regional Planning Commission to co-ordinate the conservation of the wetlands of Natal, while the Foundation for Research and Development of the CSIR is co-ordinating the conservation of riverine habitats.



The Roode Elsberg Dam on the Sanddrifskloof River near Worcester, Cape Province

2.10 Tables and graphs of estimated demand for each sector from 1980 to the year 2010

Table	Figure	Description	Section reference
2.10.1	2.10.1	Estimated urban and industrial water demand	2.3
2.10.2	2.10.2	Estimated water demand for power generation	2.4
2.10.3	2.10.3	Estimated water demand for mining	2.5
2.10.4	2.10.4	Estimated water demand for irrigation on Government water schemes	2.0
2.10.5	2.10.5	Estimated water demand for irrigation under control of	2.6
		irrigation boards	2.6
2.10.6	2.10.6	Estimated water demand for private irrigation	2.6
2.10.7	2.10.7	Estimated total water demand for irrigation	2.6
2.10.8	2.10.8	Estimated water demand for stock-watering	2.7
2.10.9	2.10.9	Estimated reduction in runoff by forestry	2.8
2.10.10	_	Estimated water demand for nature conservation	2.9
2.10.11	_	Estimated water requirement for estuaries and lakes	2.9
2.10.12	2.10.10	Estimated water requirement for environmental management	2.9
-	2.10.11	Comparative estimated water demand per secondary region (1980 and 2010)	_
2.10.13	2.10.12	Estimated total water demand of South Africa	2.1
2.10.14	-	Estimated water demand of South Africa for 1980 and 2010 by	
_	2.10.13	drainage region Comparison of estimated evaporation and flooding demands for	2.1
2.10.15		estuaries and lakes	-
to			
2.10.18	-	Estimated water demand and surface runoff per country in South Africa (1980, 1990, 2000 and 2010)	2.1
2.10.19		(2000, 1000, 1000 and 2010)	2,1
to 2.10.22		Curre of all action at all indications and all actions at all acti	
4.10.44		Sum of all estimated irrigation water demands per country in South Africa (1980, 1990, 2000 and 2010)	2.1

Note: Values given in this set of tables have been rounded off to the nearest whole number. Slight discrepancies between items and associated totals and grand totals are due to inaccuracies resulting from truncation and rounding-off of values. Subsequent editions of this publication will give values to a higher accuracy.

Table 2.10.1: Estimated urban and industrial water demand (million m^3/a)

Region	1980	1990	2000	2010
A	427	559	827	1 280
В	148	218	304	442
C	767	1 284	1 851	2 623
D	74	97	128	169
E	8	8	9	10
F	4	4	5	6
G	219	322	464	623
H	21	28	39	51
J	12	14	16	20
K	10	15	21	32
L	3	4	5	7
M	55	86	127	183
N	4	5	7	9
P	4	8	10	15
Q	9	10	12	15
R	55	85	119	167
S	66	94	122	136
T	133	150	173	205
υ	360	484	644	843
v	69	97	144	252
W	68	97	138	198
x	31	64	97	152
Total	2 547	3 729	5 262	7 438

Table 2.10.2: Estimated water demand for power generation (million m^3/a)

Region	1980	1990	2000	2010
A	18	38	52	53
В	158	212	259	296
C	88	176	450	533
D	0	0	0	0
E	0	0	0	0
F	0	0	0	0
G	4	4	4	4
H	2	2	2	2
J	0	0	0	0
K	0	0	0	0
L	0	0	0	0
M	0	0	0	0
N	0	0	0	0
P	0	0	0	0
Q	0	0	0	0
R	0	0	0	0
S	0	0	0	0
T	0	0	0	0
U	0	0	0	0
V	12	12	12	12
W	0	0	0	0
x	0	0	0	0
Total	282	444	779	900

Table 2.10.3: Estimated water demand for mining (million m^3/a)

Region	1980	1990	2000	2010
A	44	57	76	108
В	52	56	60	60
C	272	298	343	376
D	35	35	35	35
E	0	0	0	0
F	5	5	5	5
G	1	1	1	1
H	0	0	0	0
J	0	0	0	0
K	0	0	0	0
L	0	0	0	0
M	0	0	0	0
N	0	0	0	0
P	0	0	0	0
Q	0	0	0	0
R	0	0	0	0
S	0	0	0	0
T	0	0	0	0
U	3	4	6	7
v	7	7	8	8
W	3	4	4	5
х	5	5	5	5
Total	427	472	543	610

Table 2.10.4: Estimated water demand for irrigation on Government water schemes (million m^3/a)

Region	1980	1990	2000	2010
Α	312	351	396	419
В	147	148	148	148
C	653	842	904	964
D	376	521	898	972
E	145	145	145	145
F	0	0	0	0
G	0	0	0	0
H	14	18	18	21
J	86	86	86	86
K	0	10	17	17
L	101	105	107	109
M	0	0	0	0
N	0	0	0	0
P	0	0	0	0
Q	9	14	26	26
R	4	5	6	7
S	38	49	60	69
T	46	58	70	88
U	12	12	13	13
V	19	23	28	34
W	99	120	56	70
X	4	4	4	4
Total	2 065	2 511	2 982	3 192

Table 2.10.5: Estimated water demand for irrigation under control of irrigation boards (million m³/a)

Region	1980	1990	2000	2010
A	33	33	33	33
В	275	281	286	291
C	48	48	48	48
D	224	224	224	224
E	86	88	88	88
F	0	0	0	(
G	83	186	235	234
H	324	418	484	518
J	97	97	97	97
K	0	0	0	C
L	4	6	8	10
M	0	0	0	C
N	108	120	158	221
P	0	0	0	C
Q	254	325	422	474
R	0	0	0	C
S	54	54	54	54
T	1	1	1	1
U	28	40	54	70
V	31	33	35	38
W	62	79	189	225
Х	597	603	.609	614
Total	2 309	2 636	3 025	3 240

Table 2.10.6; Estimated water demand for private irrigation (million m³/a)

(1)	nillion m ^e /a)			
Region	1980	1990	2000	2010
A	678	706	728	758
В	296	339	354	372
C	423	476	528	576
D	664	668	679	689
E	158	168	175	181
F	2	2	2	2
G	169	200	225	254
H	256	289	329	375
J	90	90	89	88
K	50	69	91	123
L	38	41	45	50
M	22	22	22	22
N	60	60	61	63
P	10	11	12	13
Q	76	82	88	96
R	26	31	38	46
S	39	39	39	39
T	111	119	124	129
U	240	326	420	525
V	152	194	239	292
W	500	542	588	643
Х	70	74	91	117
Total	4 130	4 548	4 967	5 453

Table 2.10.7: Estimated total water demand for Government irrigation schemes, irrigation boards and private irrigation (million m³/a)

Region	1980	1990	2000	2010
Α	1 023	1 090	1 157	1 210
В	718	768	788	811
C	1 124	1 366	1 480	1 588
D	1 264	1 413	1 801	1 885
E	389	401	408	414
F	2	. 2	2	2
G	252	386	460	488
H	594	725	831	914
J	273	273	272	271
K	50	79	108	140
L	143	152	160	169
M	22	22	22	22
N	168	180	219	284
P	10	11	12	13
Q	339	421	536	596
R	30	36	44	53
S	131	142	153	162
T	158	178	195	218
U	280	378	487	608
V	202	250	302	364
W	661	741	833	938
Х	671	681	704	735
Total	8 504	9 695	10 974	11 885

Table 2.10.8: Estimated water demand for stock watering (million m^3/a)

Region	1980	1990	2000	2010
Α	31	33	38	49
В	9	11	13	16
C	64	68	72	76
D	41	46	50	56
E	2	3	3	3
F	1	1	1	1
G	5	6	7	8
H	3	3	3	4
J	3	3	3	3
K	16	17	19	21
L	1	1	1	2
M	1	1	2	2
N	2	2	2	2
P	3	3	3	4
Q	5	6	6	7
R	1	2	2	2
S	9	10	11	11
T	25	28	31	34
U	5	8	10	14
V	14	15	16	17
W	16	16	17	19
X	5	5	6	7
Total	262	288	316	358

Table 2.10.9: Estimated reduction in runoff by forestry (million m^3/a)

Region	1980	1990	2000	2010
Α	· 21	24	26	28
В	140	149	159	170
C	1	2	2	2
D	0	0	0	C
E	0	1	1	1
F	0	0	0	0
G	5	6	7	7
H	3	3	4	4
J	5	5	5	5
K	34	34	34	34
L	4	4	4	4
M	0	0	0	C
N	0	0	0	C
P	1	1	1	1
Q	4	4	4	4
R	12	12	12	12
S	15	15	15	15
T	129	129	129	129
U	226	289	347	396
V	27	57	88	109
W	235	247	261	279
Х	422	445	471	500
Total	1 284	1 427	1 570	1 700

Table 2.10.10: Estimated water demand for nature conservation (million m^3/a)

Region	1980	1990	2000	2010
Α	7	8	9	10
В	46	47	48	49
C	40	40	41	41
D	16	18	20	22
E	1	1	1	1
F	0	0	0	0
G	16	16	16	16
H	0	0	0	0
J	0	0	0	0
K	0	0	0	0
L	0	0	0	0
M	0	0	0	0
N	0	0	0	0
P	0	0	0	0
Q	0	0	0	0
R	0	0	0	0
S	0	0	0	0
T	0	0	0	0
U	0	0	0	0
V	0	0	0	0
W	5	5	5	5
X	47	47	47	47
Total	178	182	187	191

Table 2.10.11: Estimated water requirement for estuaries and lakes (million m^3/a)

Region	1980	1990	2000	2010
A	0	0	0	C
В	0	0	0	0
C	0	0	0	0
D	534	534	534	534
E	76	76	76	76
F	1	1	1	1
G	127	127	127	127
Н	149	149	149	149
J	40	40	40	40
K	70	70	70	70
L	37	37	37	37
M	19	19	19	19
N	17	17	17	17
P	20	20	20	20
Q	39	38	38	35
R	51	51	51	51
S	76	76	76	76
T	742	742	742	742
U	134	134	134	134
V	230	230	230	230
W	406	406	407	407
Х	0	0	0	C
Total	2 768	2 767	2 767	2 767

Table 2.10.12: Estimated water requirement for environmental management (total of estuaries, lakes and nature conservation) (million m^3/a)

Region	1980	1990	2000	2010
Α	7	8	9	10
В	46	47	48	49
C	40	40	41	41
D	550	552	554	556
E	77	77	77	77
F	1	1	1	1
G	143	143	143	143
H	149	149	149	149
J	40	40	40	40
K	70	70	70	70
L	37	37	37	37
M	19	19	19	19
N	17	17	17	17
P	20	20	20	20
Q	38	38	38	38
R	51	51	51	51
S	76	76	76	76
T	742	742	742	742
U	134	134	134	134
V	230	230	230	230
W	411	411	411	411
х	47	47	47	47
Total	2 946	2 949	2 954	2 958

Table 2.10.13: Estimated total water demand of South Africa (million m^3/a)

Region	1980	1990	2000	2010
A	1 571	1 805	2 185	2 738
В	1 271	1 461	1 631	1 844
C	2 395	3 273	4 278	5 278
D	1 164	2 143	2 568	2 701
E	476	490	498	505
F	13	13	14	15
G	629	868	1 086	1 274
H	772	910	1 028	1 124
J	333	335	336	339
K	180	215	252	297
L	188	198	207	219
M	97	128	170	226
N	191	204	245	312
P	38	43	46	53
Q	396	479	597	660
R	149	186	228	285
S	297	337	377	400
T	1 187	1 227	1 270	1 328
U	1 008	1 297	1 628	2 002
V	561	668	800	992
W	1 394	1 516	1 664	1 850
Х	1 181	1 247	1 330	1 446
Total	16 291	19 043	22 438	25 888

Table 2.10.14: Estimated water demand of South Africa for 1980 and 2010 by drainage region (million m³/a)

Sector	Direct use	%		1	980		2010	
			Direct and indirect use (excl ecological use)	%	Direct and indirect use (incl ecological use)	%	Direct and indirect use (incl ecological use)	%
Drainage Region A			ON AND					
Domestic	308	20	308	20	308	20	648	24
Industry	119	8	119	8	119	8	632	23
Mining	44	3	44	3	44	3	108	4
Power-stations	18	1	18	1	18	1	53	2
Irrigation	1 023	66	1 023	65	1 023	65	1 210	44
Stock-water	31	2	31	2	31	2	49	2
Nature conservation	7	0	7	0	7	0	10	0
Total	1 550	100						
Forestry runoff reduction		21	1	21	1	28	1	
Total		1 571	100					
Estuaries (provision)				0	0	0	0
			Total		1 571	100	2 738	100
Drainage Region B								
Domestic	77	7	77	6	77	6	285	15
Industry	71	6	71	6	71	6	157	9
Mining	52	5	52	4	52	4	60	3
Power-stations	158	14	158	12	158	12	296	16
Irrigation	718	63	718	56	718	56	811	44
Stock-water	9	1	9	1	9	1	16	1
Nature conservation	46	4	46	4	46	4	49	3
Total	1 131	100						
Forestry runoff redu	ction		140	11	140	11	170	9
	Total		1 271	100				
Estuaries (provision)				0	0	0	0
			Total		1 271	100	1 844	100

Sector	Direct use	%	1980				2010	
			Direct and indirect use (excl ecological use)	%	Direct and indirect use (incl ecological use)	%	Direct and indirect use (incl ecological use)	%
Drainage Region C								
Domestic	432	18	432	18	432	18	1 581	30
Industry	335	14	335	14	335	14	1 042	20
Mining	311	13	311	13	311	13	415	8
Power-stations	88	3	88	3	88	3	533	10
Irrigation	1 124	47	1 124	47	1 124	47	1 588	30
Stock-water	64	3	64	3	64	3	76	1
Nature conservation	40	2	40	2	40	2	41	1
Total	2 394	100						
Forestry runoff redu	ction		1	0	1	0	2	0
	Total		2 395	100				
Estuaries (provision)				0	0	0	0
			Total		2 395	100	5 215	100
Drainage Region D								
Domestic	70	5	70	5	70	4	158	6
Industry	4	1	4	1	4	0	11	0
Mining	35	2	35	2	35	2	35	1
Power-stations	0	0	0	0	. 0	0	0	0
Irrigation	1 264	88	1 264	88	1 264	64	1 885	70
Stock-water	41	3	41	3	41	2	56	2
Nature conservation	16	1	16	1	16	1	22	1
Total	1 430	100						
Forestry runoff redu	ction		0	0	0	0	0	0
	Total		1 430	100				
Estuaries (provision))				534	27	534	20
			Total		1 964	100	2 701	100
Drainage Region E								T
Domestic	5	1	5	1	5	1	7	1
Industry	3	1	3	1	3	1	3	1
Mining	. 0	0	0	0	0	0	0	0
Power-stations	0	0	0	0	0	0	0	0
Irrigation	389	97	389	97	389	82	414	82
Stock-water	2	1	2	1	2	0	3	1
Nature conservation	1	0	1	0	1	0	1	0
Total	400	100						
Forestry runoff redu	ction		0	0	0	0	1	0
	Total		400	100				
Estuaries (provision)				76	16	76	15
			Total		476	100	505	100
Drainage Region F		T					and the second	T
Domestic	3	22	3	22	3	20	5	30
Industry	1	12	1	12	1	11	1	9
Mining	5	41	5	41	5	36	5	31
Power-stations	0	0	0	0	0	0	0	0
Irrigation	2	18	2	18	2	16	2	14
Stock-water	1	7	1	7	1	7	1	8
Nature conservation	0	0	0	0	0	0	0	0
Total	12	100						
Forestry runoff redu	ction	4	0	0	0	0	0	0
	Total		12	100				
Estuaries (provision)				1	10	1	8
				- 11-1				

Sector	Direct use	%		1	980		2010	
			Direct and indirect use (excl ecological use)	%	Direct and indirect use (incl ecological use)	%	Direct and indirect use (incl ecological use)	%
Drainage Region G		THE PARTY OF						
Domestic	186	37	186	37	186	30	505	40
Industry	33	7	33	7	33	5	118	
Mining	1	0	1	0	1	0	1	(
Power-stations	4	1	4	1	4	1	4	
Irrigation	252	51	252	50	252	40	488	3
Stock-water	5	1	5	1	5	1	8	
Nature conservation	16	3	16	3	16	2	16	1
Total	497	100						
Forestry runoff redu	ction		5	1	5	1	7	1
	Total		502	100				
Estuaries (provision))		Lampanya, yan kata kata kata kata kata kata kata ka		127	20	127	10
			Total		629	100	1 274	100
Drainage Region H							L	
Domestic	15	2	15	2	15	2	36	3
Industry	6	1	6	1	6	1	15	1
Mining	0	0	0	0	0	0	0	(
Power-stations	2	0	2	0	2	0	2	0
Irrigation	594	96	594	95	594	77	914	81
Stock-water	3	1	3	1	3	0	4	1
Nature conservation	0	0	0	0	0	0	0	C
Total	620	100						
Forestry runoff redu	ction		3	1	3	1	4	1
	Total		623	100				
Estuaries (provision))		1		149	19	149	13
			Total		772	100	1 124	100
Drainage Region J								
Domestic	12	4	12	4	12	4	19	6
Industry	0	0	0	0	0	0	1	0
Mining	0	0	0	0	0	0	0	0
Power-stations	0	0	0	0	0	0	0	0
Irrigation	273	95	273	93	273	82	271	80
Stock-water	3	1	3	1	3	1	3	1
Nature conservation	0	0	0	0	0	0	0	0
Total	288	100						
Forestry runoff reduc	ction		5	2	5	1	5	1
	Total		293	100				
Estuaries (provision)					40	12	40	12
		40.1	Total		333	100	339	100
Drainage Region K	-	r						
Domestic	8	11	8	8	8	5	28	9
Industry	2	2	2	2	2	1	4	1
Mining	0	0	0	0	0	0	0	0
Power-stations	0	0	0	0	0	0	0	0
Irrigation	50	66	50	45	50	27	140	47
O	16	21	16	14	16	9	21	7
Stock-water	0	0	0	0	0	0	0	0
Nature conservation		+	in the second se					
Nature conservation Total	76	100						
Nature conservation	76	100	34	31	34	19	34	12
Nature conservation Total	76	100		31	34	19	34	12
Nature conservation Total	76	100			34 70	19	34 70	12

Sector	Direct use	%		1	980	-0.0	2010	
			Direct and indirect use (excl ecological use)	%	Direct and indirect use (incl ecological use)	%	Direct and indirect use (incl ecological use)	%
Drainage Region L								
Domestic	3	2	3	2	3	1	7	3
Industry	0	0	0	0	0	0	0	0
Mining	0	0	0	0	0	0	0	C
Power-stations	0	0	0	0	0	0	0	C
Irrigation	143	97	143	95	143	76	169	77
Stock-water	1	1	1	1	1	1	2	1
Nature conservation	0	0	0	0	0	0	0	C
Total	147	100						
Forestry runoff redu	ıction		4	2	4	2	4	2
	Total		151	100				
Estuaries (provision	1)		A second		37	20	37	17
			Total		188	100	219	100
Drainage Region M								
Domestic	39	51	39	51	39	41	130	58
Industry	16	20	16	20	16	16	53	23
Mining	0	0	0	0	0	0	0	0
Power-stations	0	0	0	0	0 .	0	0	o
Irrigation	22	28	22	28	22	22	22	10
Stock-water	1	1	1	1	1	1	2	1
Nature conservation	0	0	0	ō	0	0	0	0
Total	78	100				0		0
Forestry runoff reduction .			0	0	0	0	0	U
	Total		78	100				
Estuaries (provision)				19	20	19	8
			Total		97	100	226	100
Drainage Region N		т	warm see, a disconnect					
Domestic	4	2	4	2	4	2	9	3
Industry	, 0	0	0	0	0	0	0	0
Mining	0	0	0	0	0	0	0	0
Power-stations	0	0	0	0	0	0	0	0
Irrigation	168	97	168	97	168	88	284	91
Stock-water	2	1	2	1	2	1	2	1
Nature conservation	0	0	0	0	0	0	0	0
Total	174	100						
Forestry runoff redu	ction		0	0	0	0	0	0
	Total		174	100				
Estuaries (provision)				17	9	17	5
			Total		191	100	312	100
Drainage Region P	40.1				•			
Domestic	4	25	4	24	4	11	14	28
Industry	0	1	0	1	0	1	1	1
Mining	0	0	0	0	0	0	0	0
Power-stations	0	0	0	0	0	0	0	0
Irrigation	10	58	10	56	10	26	13	25
Stock-water	3	16	3	15	3	7	4	7
Nature conservation	0	0	0	0	0	0	0	0
Total	17	100						
Forestry runoff redu	ction		1	4	1	2	1	1
	Total		18	100				
Estuarias (production			10	100	20	53	20	20
Estuaries (provision	1				- 444			38
			Total	ne-summon e	38	100	53	100

Sector	Direct use	%		1	980		2010	
			Direct and indirect use (excl ecological use)	%	Direct and indirect use (incl ecological use)	%	Direct and indirect use (incl ecological use)	%
Drainage Region C	Ω							
Domestic	9	2	9	2	9	2	15	2
Industry	0	0	0	0	0	0	0	0
Mining	0	0	0	0	0	0	0	0
Power-stations	0	0	0	0	0	0	0	0
Irrigation	339	96	339	95	339	86	596	90
Stock-water	5	2	5	2	5	1	7	1
Nature conservation	0	0	0	0	0	0	0	0
Total	353	100						
Forestry runoff redu	ıction		4	1	4	1	4	1
	Total		357	100				
Estuaries (provision	1)				39	10	35	6
			Total		396	100	657	100
Drainage Region R			10001	-11/-0-21		100	037	100
Domestic ·	45	53	45	47	45	31	142	50
Industry	10	11	10	10	10	6	25	9
Mining	0	0	0	0	0	0	0	0
Power-stations	0	0	. 0	0	0	0	0	0
Irrigation	30	34	30	30	30	20	53	19
Stock-water	1	2	1	1	1	1	2	0
Nature conservation	0	0	0	0	0	0	0	0
Total	86	100						
Forestry runoff redu	ction		12	12	12	8	12	4
A manufacture of a	Total		98	100				
Estuaries (provision)		<u> </u>		51	34	51	18
			Total			100	285	100
Drainage Region S		The state of the s	2002		110	100	200	100
Domestic	26	13	26	12	26	9	70	17
Industry	40	19	40	18	40	13	66	17
Mining	0	0	0	0	0	0	0	0
Power-stations	0	0	0	0	0	0	0	0
Irrigation	131	64	131	59	131	44	162	40
Stock-water	9	4	9	4	9	3	11	3
Nature conservation	0	0	0	0	0	0	0	0
Total	206	100						
Forestry runoff redu	ction		15	7	15	5	15	4
	Total		221	100				
Estuaries (provision)					76	26	76	19
			Total		297	100	400	100
Drainage Region T	and the same of th							
Domestic	50	16	50	11	50	4	121	9
Industry	83	26	83	19	83	7	84	6
Mining	0	0	0	0	0	0	0	0
Power-stations	0	0	0	0	0	0	0	0
Irrigation	158	50	158	35	158	13	218	16
Stock-water	25	8	25	6	25	2	34	3
Nature conservation	0	0	0	0	0	0	0	0
Total	316	100						
Forestry runoff reduc	ction		129	29	129	11	129	10
	Total		445	100				
Estuaries (provision)					742	63	742	56
			Total		1 187	100	1 328	100
				100				

Sector	Direct use	%		1	980		2010	
			Direct and indirect use (excl ecological use)	%	Direct and indirect use (incl ecological use)	%	Direct and indirect use (incl ecological use)	%
Drainage Region U								
Domestic	125	19	125	14	125	13	335	17
Industry	235	36	235	27	235	23	508	25
Mining	3	1	3	0	3	0	7	(
Power-stations	0	0	0	0	0	0	0	(
Irrigation	280	43	280	32	280	28	608	30
Stock-water Nature conservation	5	1 0	5	1 0	5	0	0	1
		+	U	U	0			1
Total	648	100			000	00	200	00
Forestry runoff redu			226	26	226	22	396	20
	Total		874	100				
Estuaries (provision	1)				134	13	134	7
			Total		1 008	100	2 002	100
Drainage Region V		1						1
Domestic	33	11	33	10	33	6	122	12
Industry	36	12	36	11	36	7	130	13
Mining	7	2	7	2	7	1	8	1
Power-stations Irrigation	12 202	67	12 202	4 61	12 202	36	12 364	37
Stock-water	14	4	14	4	14	2	17	2
Nature conservation	0	0	0	0	0	0	0	0
Total	304	100		·				
	Industrial and the state of the	100	0.17		07	-	100	11
Forestry runoff redu			27	8	27	5	109	11
	Total		331	100				
Estuaries (provision)				230	41	230	23
			Total		561	100	992	100
Drainage Region W		T 1	1				277	
Domestic	38	5	38	4	38	3	121	7
Industry	30	4	30	3	30	2	77	4
Mining Power-stations	3	0	3	0	3	0	5 0	0
Irrigation	661	88	661	67	661	48	938	51
Stock-water	16	2	16	2	16	1	19	1
Nature conservation	5	1	5	0	5	0	5	0
Total	753	100						
Forestry runoff redu	ction		235	24	235	17	279	15
	Total		988	100				
Estuaries (provision))				406	29	406	22
			Total		1 394	100	1 850	100
Drainage Region X				- 1				
Domestic	24	3	24	2	24	2	119	8
Industry	7	1	7	1	7	1	33	2
Mining	5	1	5	0	5	0	5	0
Power-stations	0	0	0	0	0	0	0	0
Irrigation	671	88	671	57	671	57	735	51
Stock-water	5	1	5	0	5	0	7	1
Nature conservation	47	6	47	4	47	4	47	3
Total	759	100						
Forestry runoff redu	ction		422	36	422	36	500	35
	Total		1 181	100				
Estuaries (provision)					0	0	0	0

Table 2.10.15: Estimated water demand and surface runoff per country in South Africa for 1980 (million m³/a)

Water use	RSA	Swazi- land	Lesotho	Transkei	Ciskei	Kwa- Zùlu	Bophutha- tswana	Lebowa	Venda	Kwa- Ndebele	Gazan- kulu	Ka- Ngwane	Qwa- qwa	Total
Domestic	1 040	8	21	42	19	35	20	27	6	5	9	1	3	1 236
Public	59	0	0	2	0	0	0	0	1	0	0	0	0	62
Industrial	899	0	2	114	1	3	10	0	1	0	0	1	0	1 031
Urban distribution														
losses	202	0	0	14	1	1	0	0	0	0	0	0	0	218
Total of municipal/														
industrial use	2 200	8	23	172	21	39	30	27	8	5	9	2	3	2 547
Mining	394	1	0	0	0	0	15	16	0	0	1	0	0	427
Power-stations	281	1	0	0	0	0	0	0	0	0	0	0	0	282
Irrigation (GWS)	1 951	0	0	53	22	0	37	2	0	0	0	0	0	2 065
Irrigation boards	2 168	50	4	54	0	0	0	2	0	0	31	0	0	2 309
Irrigation (private)	3 320	252	66	9	18	229	86	46	28	4	46	25	1	4 130
Stock-watering	186	10	12	26	1	8	10	4	2	0	1	1	1	262
Nature conservation	176	0	0	0	0	2	0	0	0	0	0	0	0	178
Estuaries and lakes	2 033	0	0	657	43	35	0	0	0	0	0	0	0	2 768
Forestry	1 044	114	0	74	2	18	0	16	6	0	0	10	0	1 284
Other uses	39	0	0	0	0	0	0	0	0	0	0	0	0	39
Total	13 792	436	105	1 045	107	331	178	113	44	9	88	38	5	16 291
Surface runoff	34 231	1 942	4 132	6 622	409	3 584	403	644	537	78	420	474	50	53 526

 $Table\ 2.10.16:\ Estimated\ water\ demand\ and\ surface\ runoff\ per\ country\ in\ South\ Africa\ for\ 1990\ (million\ m^3/a)$

Water use	RSA	Swazi- land	Lesotho	Transkei	Ciskei	Kwa- Zulu	Bophutha- tswana	Lebowa	Venda	Kwa- Ndebele	Gazan- kulu	Ka- Ngwane	Qwa- qwa	Total
Domestic	1 576	11	29	61	35	53	27	40	8	7	19	2	3	1 871
Public	88	0	0	3	0	0	0	0	1	0	0	0	0	92
Industrial	1 293	0	2	125	3	5	18	0	1	0	0	1	0	1 448
Urban distribution														
losses	299	0	0	16	1	1	0	0	0	0	0	0	1	318
Total of municipal/														
industrial use	3 256	11	31	205	39	59	45	40	10	7	19	3	4	3 729
Mining	433	1	0	0	0	0	21	16	0	0	1	. 0	0	472
Power-stations	443	1	0	0	0	0	0	0	0	0	0	0	0	444
Irrigation (GWS)	2 329	0	0	73	31	22	54	2	0	0	0	0	0	2 511
Irrigation boards	2 495	50	4	54	0	0	0	2	0	0	31	0	0	2 636
Irrigation (private)	3 642	258	66	15	22	296	88	51	31	5	47	26	1	4 548
Stock-watering	202	11	14	28	2	9	13	4	2	0	1	1	1	288
Nature conservation	180	0	0	0	0	2	0	0	0	0	0	0	0	182
Estuaries and lakes	2 032	0	0	657	43	35	0	0	0	0	0	0	0	2 767
Forestry	1 173	120	0	75	2	23	0	17	7	0	0	10	0	1 427
Other uses	39	0	0	0	0	0	0	0	0	0	0	0	0	39
Total	16 224	452	115	1 107	139	446	221	132	50	12	99	40	6	19 043
Surface runoff	34 231	1 942	4 132	6 622	409	3 584	403	644	537	78	420	474	50	53 526

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Table 2.10.17: Estimated water demand and surface runoff per country in South Africa for the year 2000 (million m³/a)

Water use	RSA	Swazi- land	Lesotho	Transkei	Ciskei	Kwa- Zulu	Bophutha- tswana	Lebowa	Venda	Kwa- Ndebele	Gazan- kulu	Ka- Ngwane	Qwa- qwa	Total
Domestic	2 236	14	41	85	50	78	36	60	11	8	28	3	4	2 654
Public	126	0	0	5	0	0	0	0	1	0	0	0	0	132
Industrial	1 838	0	2	136	4	8	53	0	1	0	0	1	0	2 043
Urban distribution		1												
losses	410	0	0	20	2	1	0	1	0	0	0	0	0	434
Total of municipal/														
industrial use	4 610	14	43	246	56	87	89	61	13	8	28	4	4	5 263
Mining	493	1	1	0	0	0	31	16	0	0	1	0	0	543
Power-stations	778	1	0	0	0	0	0	0	0	0	0	0	0	779
Irrigation (GWS)	2 732	0	0	94	46	37	71	2	0	0	0	0	0	2 982
Irrigation boards	2 884	50	.4	54	0	0	0	2	0	0	31	0	0	3 025
Irrigation (private)	3 944	265	66	18	27	371	91	58	34	5	48	39	1	4 967
Stock-watering	218	11	15	31	2	10	18	4	2	1	2	1	1	316
Nature conservation	185	0	0	0	0	2	0	0	0	0	0	0	0	187
Estuaries and lakes	2 032	0	0	657	43	35	0	0	0	0	0	0	0	2 767
Forestry	1 300	126	0	75	2	32	0	18	7	0	0	10	0	1 570
Other uses	39	0	0	0	0	0	0	0	0	0	0	0	0	39
Total	19 215	468	129	1 175	176	574	300	161	56	14	110	54	6	22 438
Surface runoff	34 231	1 942	4 132	6 622	409	3 584	403	644	537	78	420	474	50	53 526

 $Table\ 2.10.18:\ Estimated\ water\ demand\ and\ surface\ runoff\ per\ country\ in\ South\ Africa\ for\ the\ year\ 2010\ (million\ m^3/a)$

Water use	RSA	Swazi- land	Lesotho	Transkei	Ciskei	Kwa- Zulu	Bophutha- tswana	Lebowa	Venda	Kwa- Ndebele	Gazan- kulu	Ka- Ngwane	Qwa- qwa	Total
Domestic	3 104	19	58	118	72	131	49	93	15	10	42	5	5	3 721
Public	168	0	0	6	0	2	0	0	1	0	0	0	0	177
Industrial	2 680	0	2	136	5	16	121	0	1	0	0	0	0	2 961
Urban distribution														135
losses	554	0	0	20	2	2	0	1	0	0	0	0	0	579
Total of municipal/														
industrial use	6 506	19	60	280	79	151	170	94	17	10	42	5	5	7 438
Mining	545	1	0	0	0	0	47	16	0	0	1	0	0	610
Power-stations	899	1	0	0	0	0	0	0	0	0	0	0	0	900
Irrigation (GWS)	2 900	0	0	121	47	52	70	2	0	0	0	0	0	3 192
Irrigation boards	3 099	50	4	54	0	0	0	2	0	0	31	0	0	3 240
Irrigation (private)	4 292	273	65	21	32	456	93	68	36	6	49	61	1	5 453
Stock-watering	236	12	17	35	2	12	29	5	2	1	4	2	1	358
Nature conservation	189	0	0	0	0	2	0	0	0	0	0	0	0	191
Estuaries and lakes	2 032	0	0	657	43	35	0	0	0	0	0	0	0	2 767
Forestry	1 418	133	0	74	2	37	0	19	7	0	0	10	0	1 700
Other uses	39	0	0	0	0	0	0	0	0	0	0	0	0	39
Total	22 155	489	146	1 242	205	745	409	206	62	17	127	78	7	25 888
Surface runoff	34 231	1 942	4 132	6 622	409	3 584	403	644	537	78	420	474	50	53 526

Table 2.10.19: Sum of all estimated irrigation water demands per country in South Africa for 1980 (million³/a)

Region	RSA	Swazi- land	Lesotho	Transkei	Ciskei	KwaZulu	Bophutha- tswana	Lebowa	Venda	KwaNdebele	Gazankulu	KaNgwane	Qwa- qwa	Total
A	966	0	0	0	0	0	18	11	27	0	1	0	0	1 023
В	604	0	0	0	0	0	3	36	2	4	69	0	0	718
C	1 075	0	0	0	0	0	48	0	0	0	0	0	1	1 124
D	1 140	0	69	1	0	0	54	0	0	0	0	0	0	1 264
E	389	0	0	0	0	0	0	0	0	0	0	0	0	389
F	2	0	0	0	0	0	0	0	0	0	0	0	0	2
G	252	0	0	0	0	0	0	0	0	0	0	0	0	252
H	594	0	0	0	0	0	0	0	0	0	0	0	0	594
J	273	0	0	0	0	0	0	0	0	0	0	0	0	273
K	50	0	0	0	0	0	0	0	0	0	0	0	0	50
L	143	0	0	0	0	0	0	0	0	0	0	0	0	143
M	22	0	0	0	0	0	0	0	0	0	0	0	0	22
N	168	0	0	0	0	0	0	0	0	0	0	0	0	168
P	10	0	0	0	0	0	0	0	0	0	0	0	0	10
Q	336	0	0	0	3	0	0	0	0	0	0	0	0	339
R	12	0	0	0	18	0	0	0	0	0	0	0	0	30
S	47	0	0	64	20	0	0	0	0	0	0	0	0	131
T	82	0	0	52	0	24	0	0	0	0	0	0	0	158
U	176	0	0	0	0	104	0	0	0	0	0	0	0	280
V	166	0	0	0	0	36	0	0	0	0	0	0	0	202
W	343	252	0	0	0	64	0	0	0	0	0	2	0	661
Х	590	49	0	0 .	0	0	0	2	0	0	7	23	0	671
Total	7 440	301	69	117	41	228	123	49	29	4	77	25	1	8 504

 $Table\ 2.10.20:\ Sum\ of\ all\ estimated\ irrigation\ water\ demands\ per\ country\ in\ South\ Africa\ for\ 1990\ (million\ m^3/a)$

Region	RSA	Swazi- land	Lesotho	Transkei	Ciskei	KwaZulu	Bophutha- tswana	Lebowa	Venda	KwaNdebele	Gazankulu	KaNgwane	Qwa- qwa	Total
A	1 011	0	0	0	0	0	36	12	30	0	1	0	0	1 090
В	648	0	0	0	0	0	3	41	2	5	69	0	0	768
C	1 316	0	0	0	0	0	49	0	0	0	0	0	1	1 366
D	1 289	0	69	1	0	0	54	0	0	0	0	0	0	1 413
E	401	0	0	0	0	0	0	0	0	0	0	0	0	401
F	2	0	0	0	0	0	0	0	0	0	0	0	0	2
G	386	0	0	0	0	0	0	0	0	0	0	0	0	386
H	725	0	0	0	0	0	0	0	0	0	0	0	0	725
J	273	0	0	0	0	0	0	0	0	0	0	0	0	273
K	79	0	0	0	0	0	0	0	0	0	0	0	0	79
L	152	0	0	0	0	0	0	0	0	0	0	0	0	152
M	22	0	0	0	0	0	0	0	0	0	0	0	0	22
N	180	0	0	0	0	0	0	0	0	0	0	0	0	180
P	11	0	0	0	0	0	0	0	0	0	0	0	0	11
Q	413	0	0	0	8	0	0	0	0	0	0	0	0	421
R	15	0	0	0	21	0	0	0	0	0	0	0	0	36
S	47	0	0	72	23	0	0	0	0	0	0	0	0	142
T	84	0	0	70	0	24	0	0	0	0	0	0	0	178
U	229	0	- 0	0	0	149	0	0	0	0	0	0	0	378
V	205	0	0	0	0	45	0	0	0	0	0	0	0	250
W	380	259	0	0	0	100	0	0	0	0	0	2	0	741
Х	598	49	0	0	0	0	0	2	0	0	8	24	0	681
Total	8 466	308	69	143	52	318	142	55	32	5	78	26	1	9 695

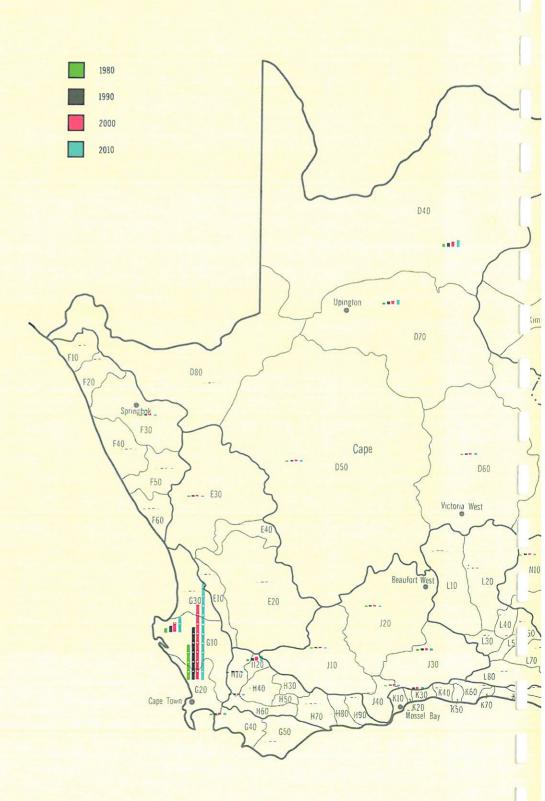
Table 2.10.21: Sum of all estimated irrigation water demands per country in South Africa for the year 2000 (million³/a)

Region	RSA	Swazi- land	Lesotho	Transkei	Ciskei	KwaZulu	Bophutha- tswana	Lebowa	Venda	KwaNdebele	Gazankulu	KaNgwane	Qwa- qwa	Total
Α	1 059	0	0	0	0	0	53	12	32	0	1	0	0	1 157
В	662	0	0	0	0	0	3	47	2	5	69	0	0	788
C	1 428	0	0	0	0	0	51	0	0	0	0	0	1	1 480
D	1 678	0	69	0	0	0	54	0	0	0	0	0	0	1 801
E	408	0	0	0	0	0	0	0	0	0	0	0	0	408
F	2	0	0	0	0	0	0	0	0	0	0	0	0	2
G	460	0	0	0	0	0	0	0	0	0	0	0	0	460
H	831	0	0	0	0	0	0	0	0	0	0	0	0	831
J	272	0	0	0	0	0	0	0	0	0	0	0	0	272
K	108	0	0	0	0	0	0	0	0	0	0	0	0	108
L	160	0	0	0	0	0	0	0	0	0	0	0	0	160
M	22	0	0	0	0	0	0	0	0	0	0	0	0	22
N	219	0	0	0	0	0	0	0	0	0	0	0	0	219
P	12	0	0	0	0	0	0	0	0	0	0	0	0	12
Q	516	0	0	0	20	0	0	0	0	0	0	0	0	536
R	18	0	0	0	26	0	0	0	0	0	0	0	0	44
S	47	0	0	80	26	0	0	0	0	0	0	0	0	153
T	86	0	0	85	0	24	0	0	0	0	0	0	0	195
U	288	0	0	0	0	199	0	0	0	0	0	0	0	487
V	246	0	0	0	0	56	0	0	0	0	0	0	0	302
W	436	266	0	0	0	129	0	0	0	0	0	2	0	833
Х	607	49	0	0	0	0	0	3	0	0	8	37	0	704
Total	9 565	315	69	165	72	408	161	62	34	5	78	39	1	10 974

 $Table \ 2.10.22: Sum \ of \ all \ estimated \ irrigation \ water \ demands \ per \ country \ in \ South \ Africa \ for \ the \ year \ 2010 \ (million \ m^3/a)$

Region	RSA	Swazi- land	Lesotho	Transkei	Ciskei	KwaZulu	Bophutha- tswana	Lebowa	Venda	KwaNdebele	Gazankulu	KaNgwane	Qwa- qwa	Total
A	1 107	0	0	0	0	0	54	13	35	0	1	0	0	1 210
В	675	0	0	0	0	0	4	55	2	6	69	0	0	811
C	1 534	0	0	0	0	0	53	0	0	0	0	0		1 588
D	1 761	0	69	1	0	0	54	0	0	0	0	0	0	1 885
E	414	0	0	0	0	0	0	0	0	0	0	0	0	414
F	2	0	0	0	0	0	0	0	0	0	0	0	0	2
G	488	0	0	0	0	0	0	0	0	0	0	0	0	488
Н	914	0	0	0	0	0	0	0	0	0	0	0	0	914
J	271	0	0	0	0	0	0	0	0	0	0	0	0	271
K	140	0	0	0	0	0	0	0	0	0	0	0	0	140
L	169	0	0	0	0	0	0	0	0	0	0	0	0	169
M	22	0	0	0	0	0	0	0	0	0	0	0	0	22
N	284	0	0	0	0	0	0	0	0	0	0	0	0	284
P	13	0	0	0	0	0	0	0	0	0	0	0	0	13
Q	575	0	0	0	21	0	0	0	0	0	0	0	0	596
R	22	0	0	0	31	0	0	0	0	0	0	0	0	53
S	47	0	0	89	26	0	0	0	0	0	0	0	0	162
T	88	0	0	106	0	24	0	0	0	0	0	0	0	218
U	354	0	0	0	0	254	0	0	0	0	0	0	0	608
V	294	0	0	0	0	70	0	0	0	0	0	0	0	364
W	501	274	0	0	0	161	0	0	0	0	0	2	0	938
Х	615	49	0	0	0	0	0	3	0	0	9	59	0	735
Total	10 290	323	69	196	78	509	165	71	37	6	79	61	1	11 885

Fig. 2.10.1: Estimated urban and industrial water demand



TABLES AND GRAPHS 2.45

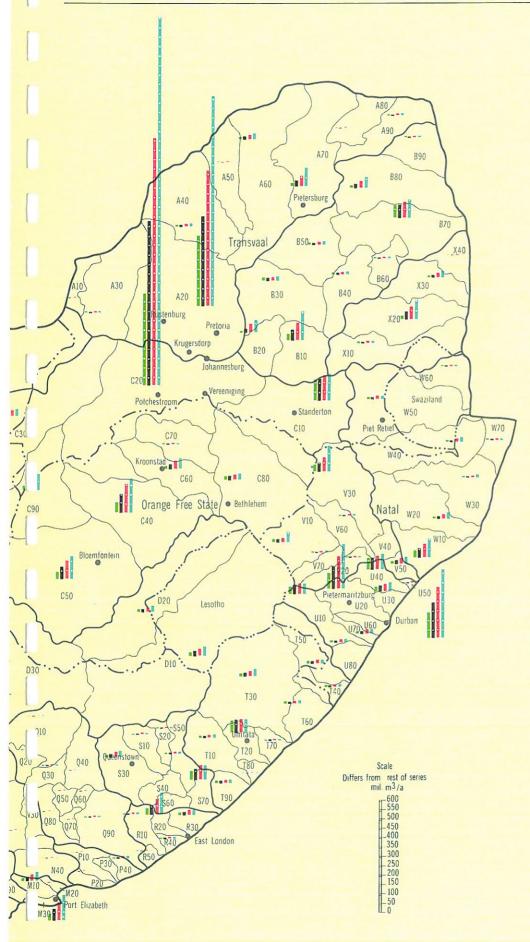
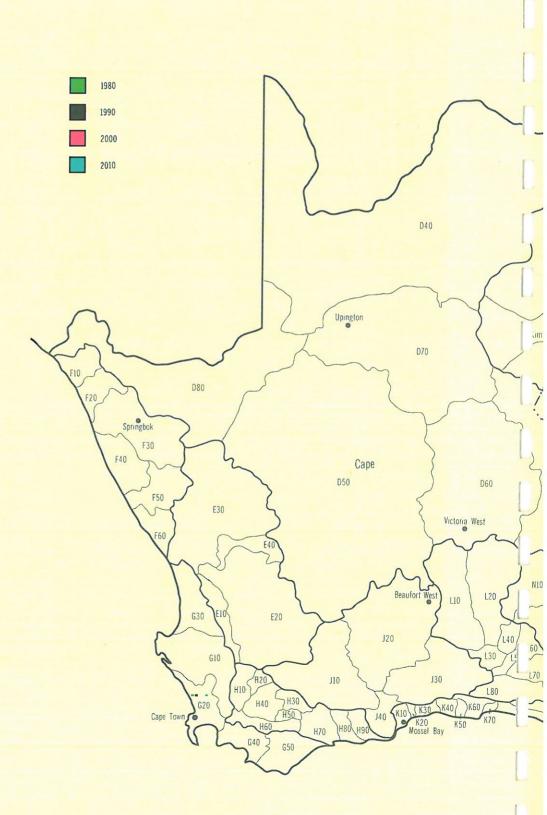


Fig. 2.10.2: Estimated water demand for power generation



2.47

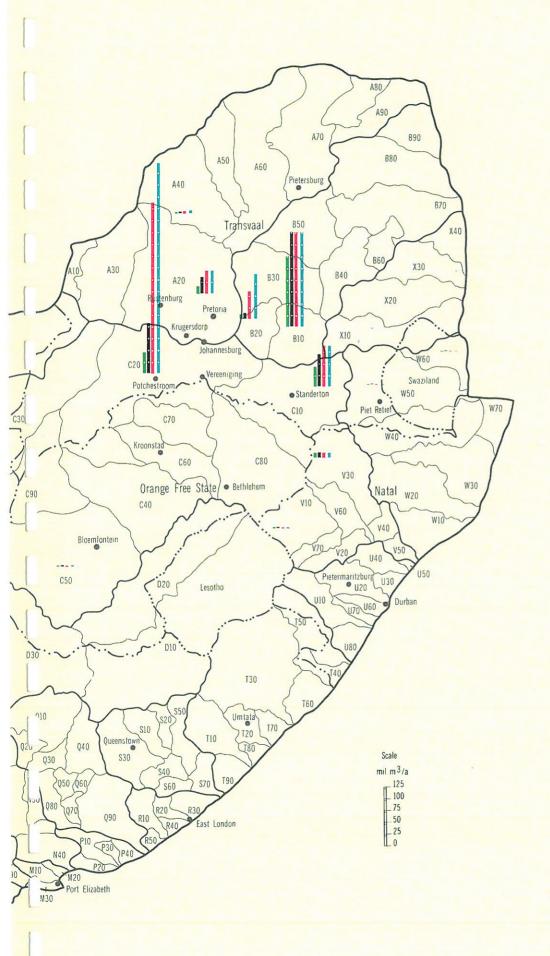
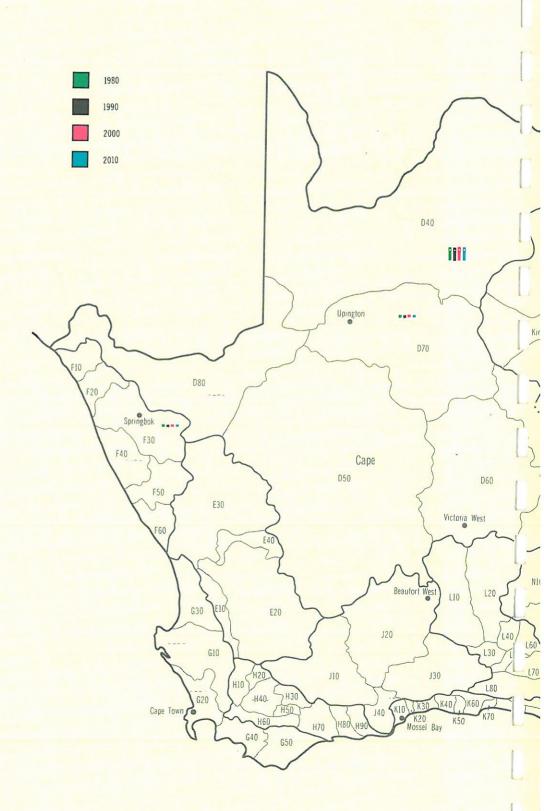


Fig. 2.10.3: Estimated water demand for mining



TABLES AND GRAPHS 2.49

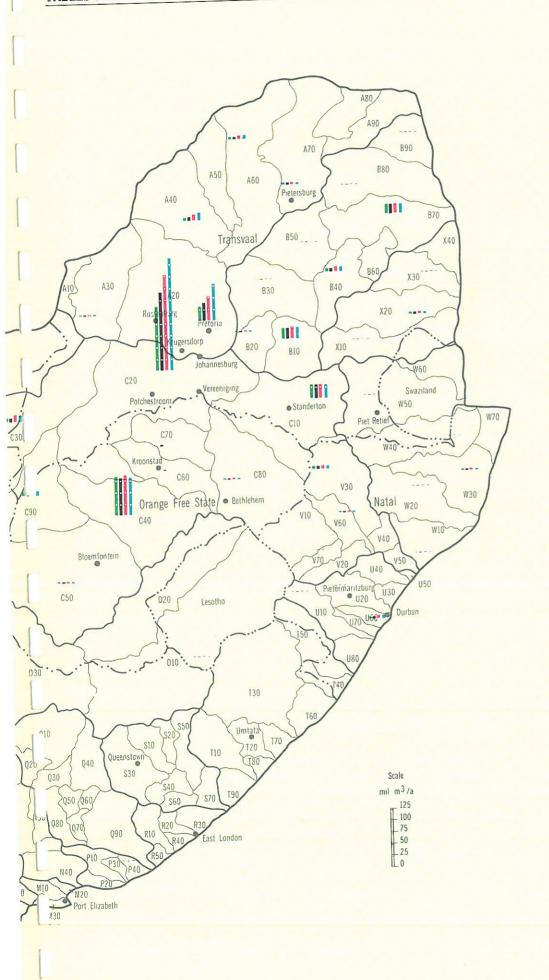
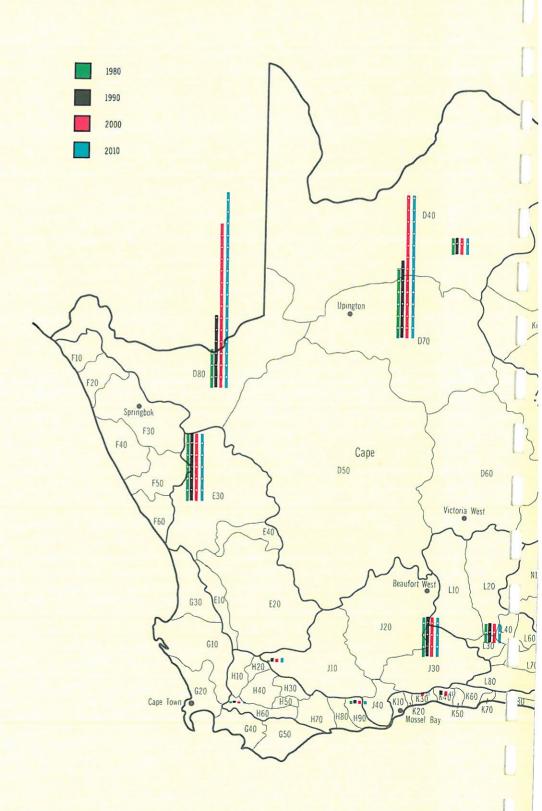


Fig. 2.10.4: Estimated water demand for irrigation on Government water schemes



2.51

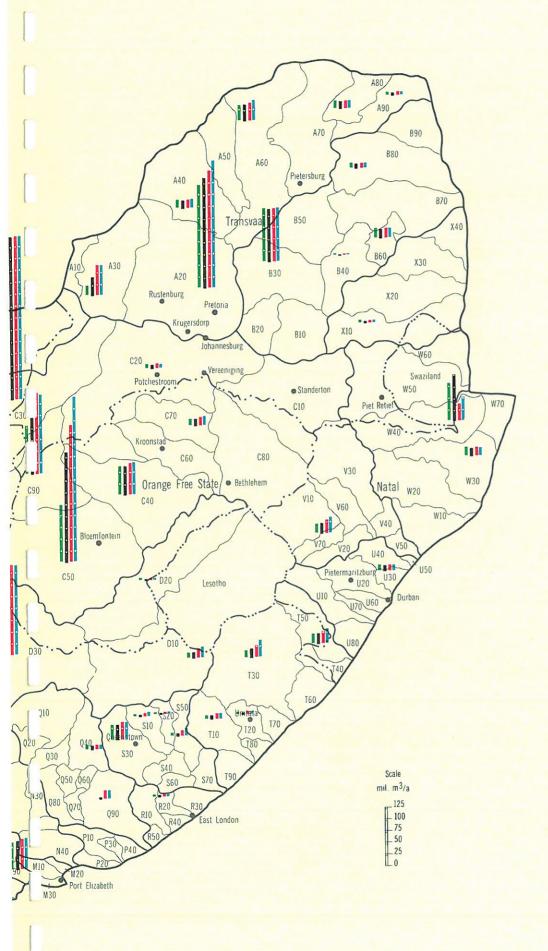
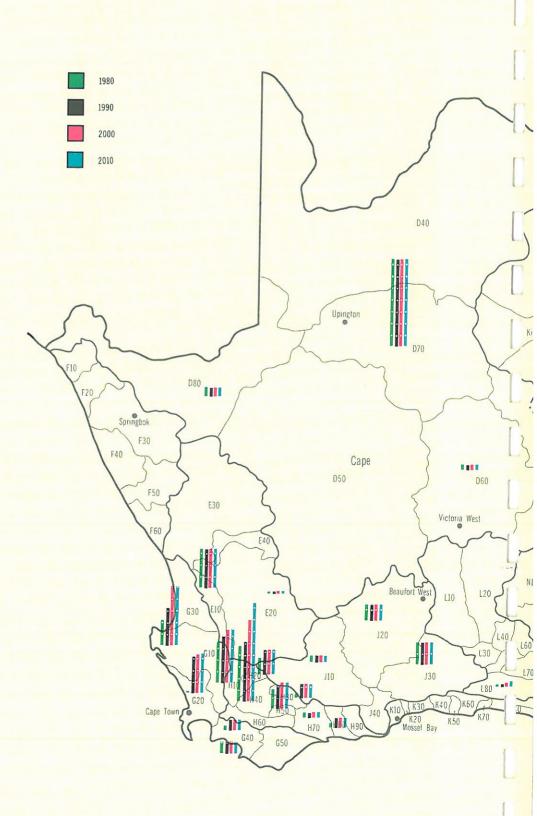


Fig. 2.10.5: Estimated water demand for irrigation under control of irrigation boards



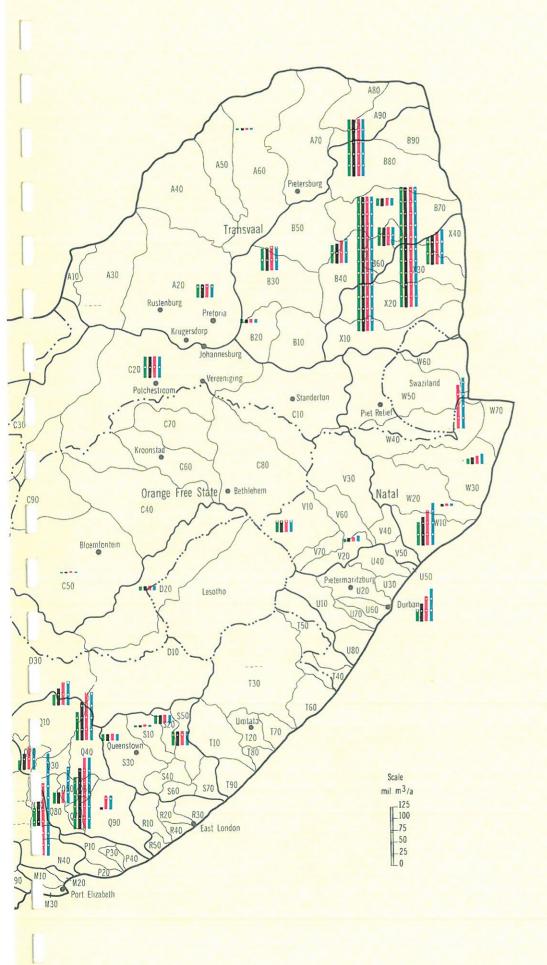
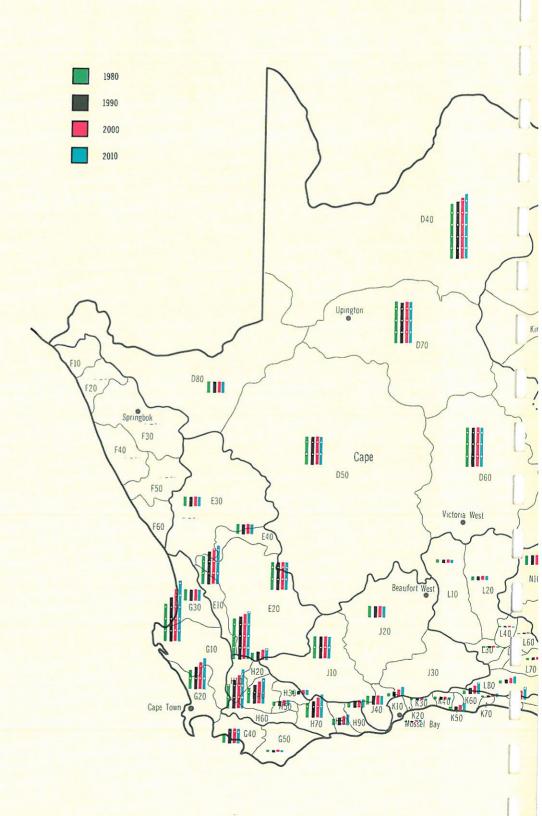
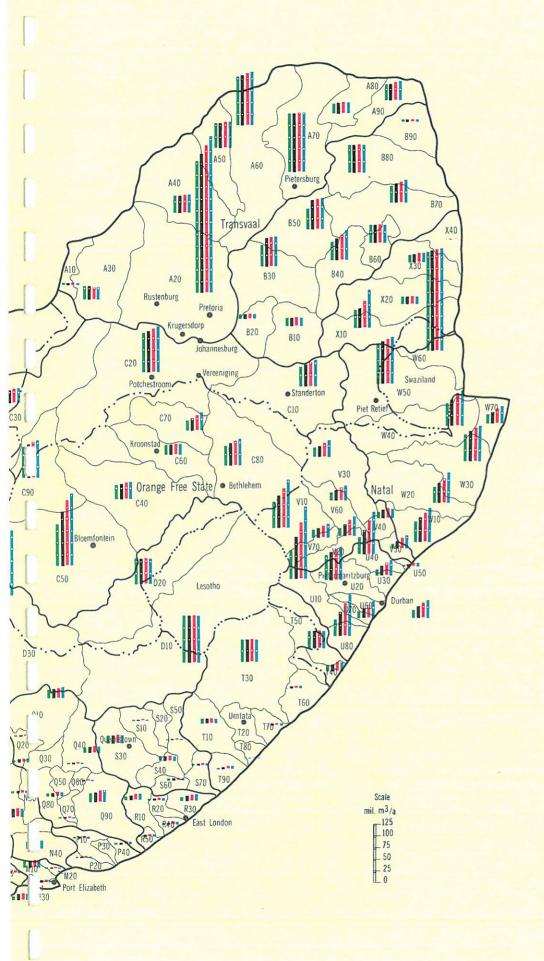


Fig. 2.10.6: Estimated water demand for private irrigation

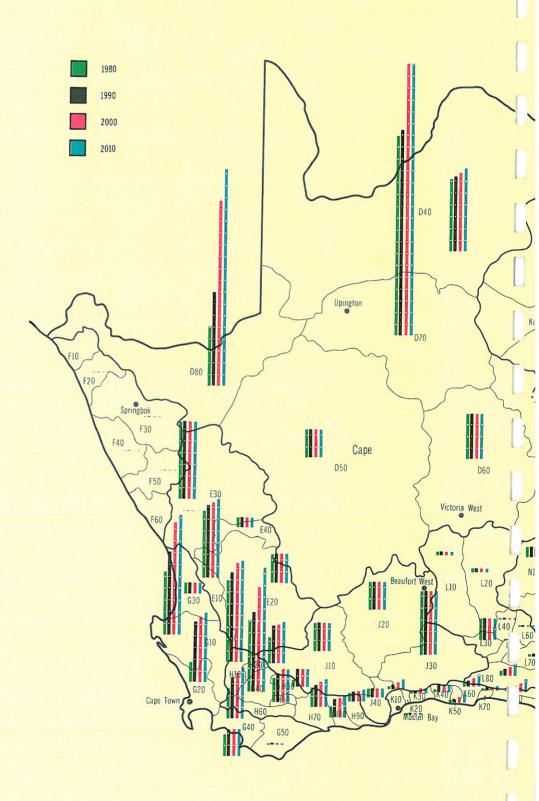


2.55



2.56 WATER DEMAND

Fig. 2.10.7: Estimated total water demand for irrigation



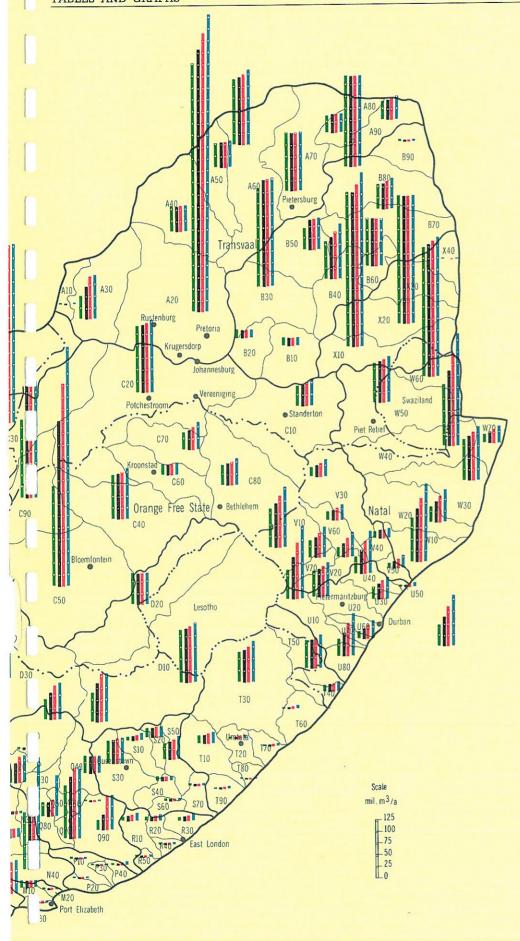
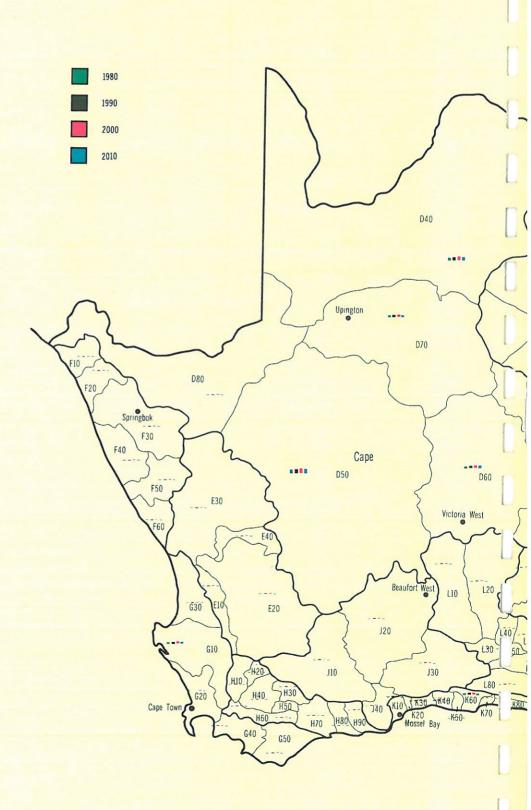


Fig. 2.10.8: Estimated water demand for stock-watering



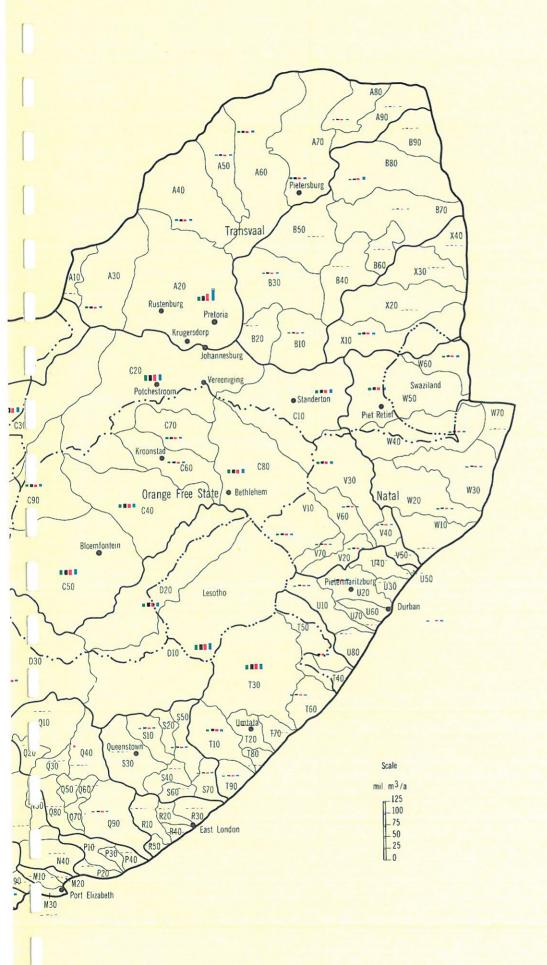
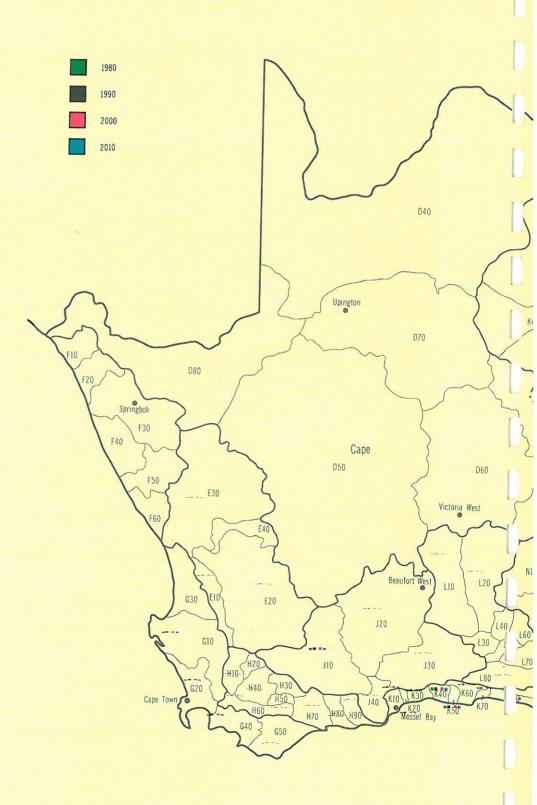


Fig. 2.10.9: Estimated reduction in runoff by forestry



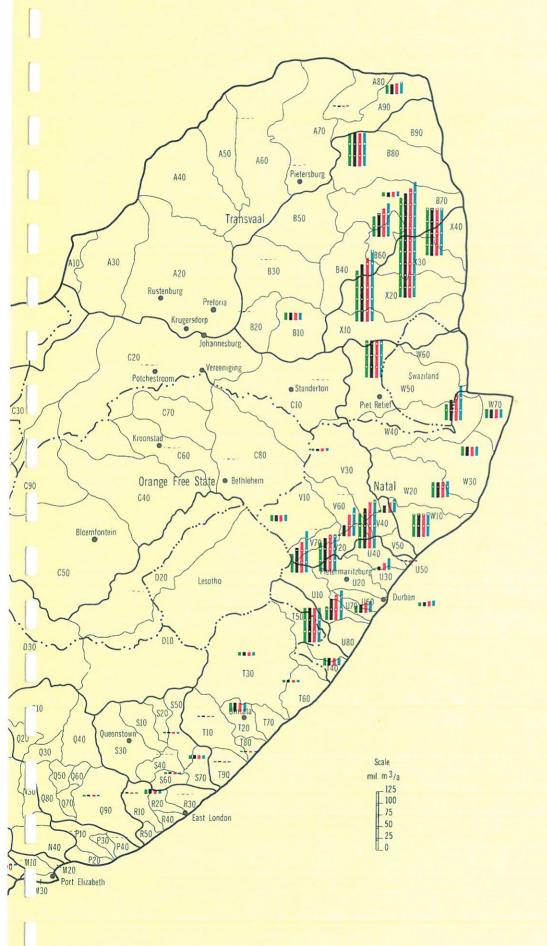
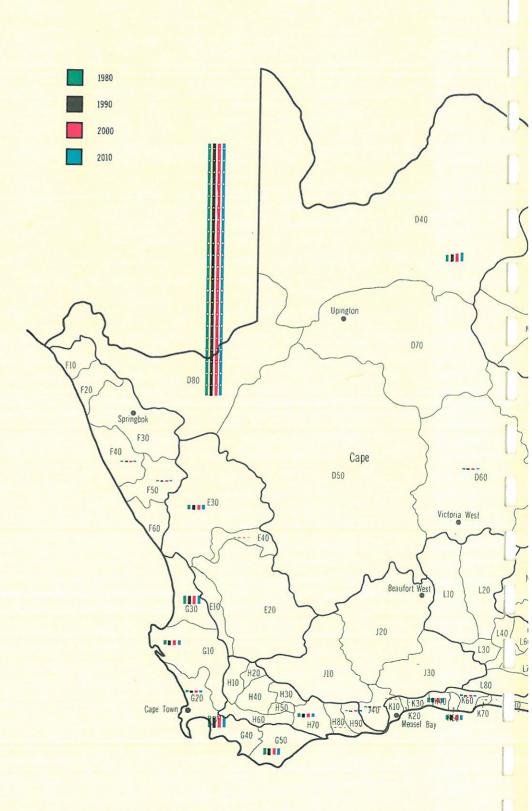


Fig. 2.10.10: Estimated water requirement for environmental management



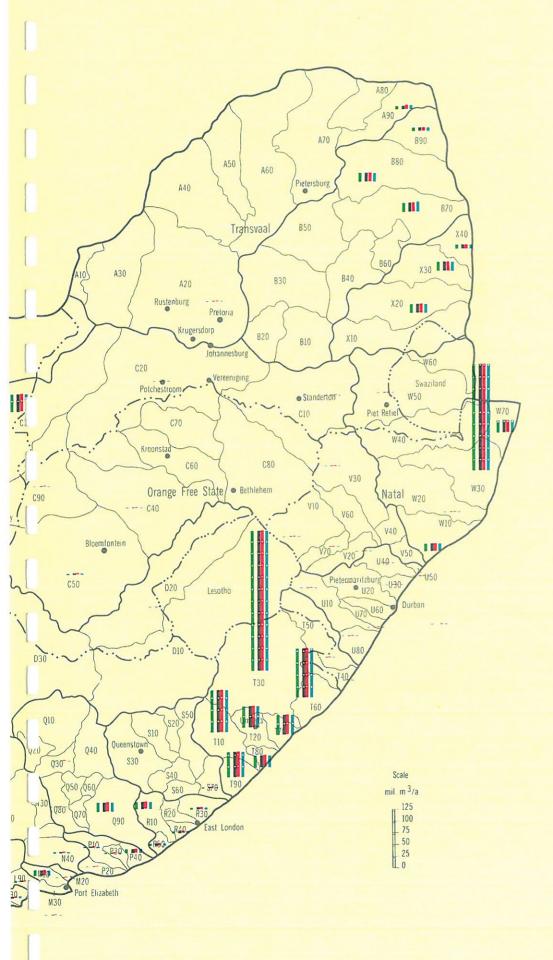
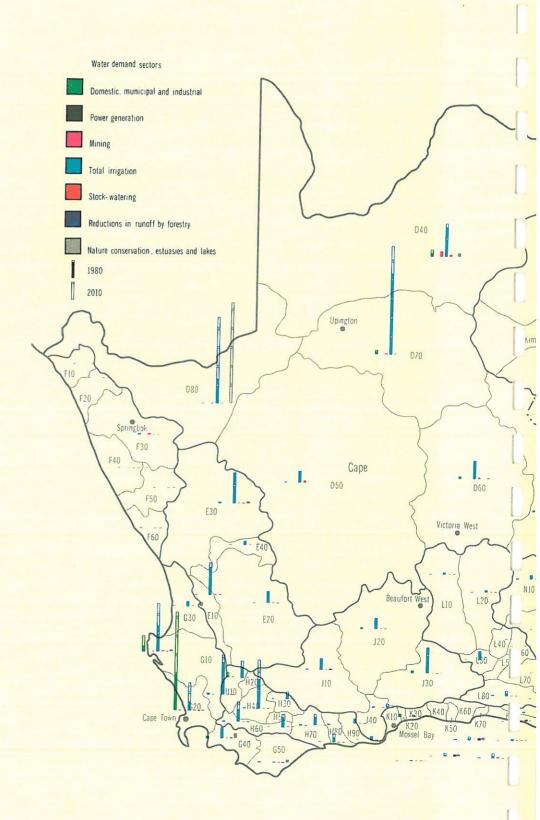


Fig. 2.10.11: Comparative estimated water demand per secondary region (1980 and 2010)



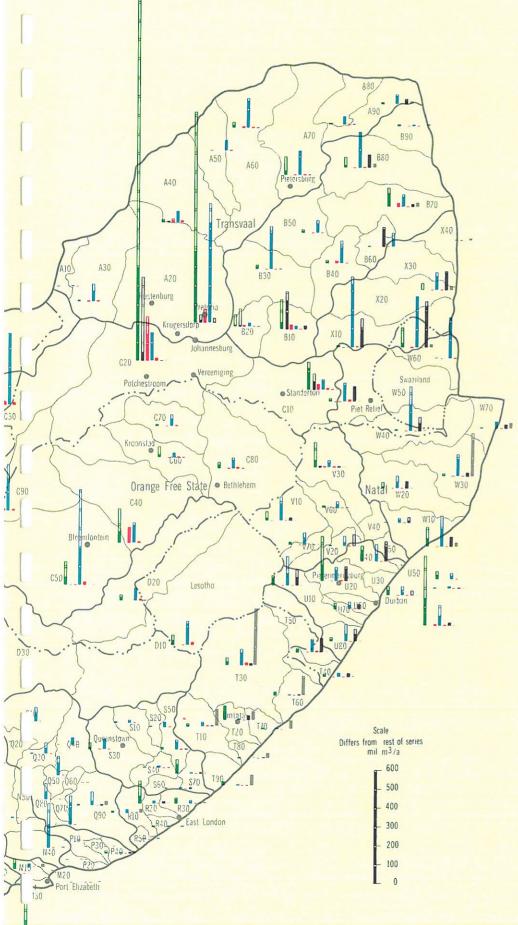
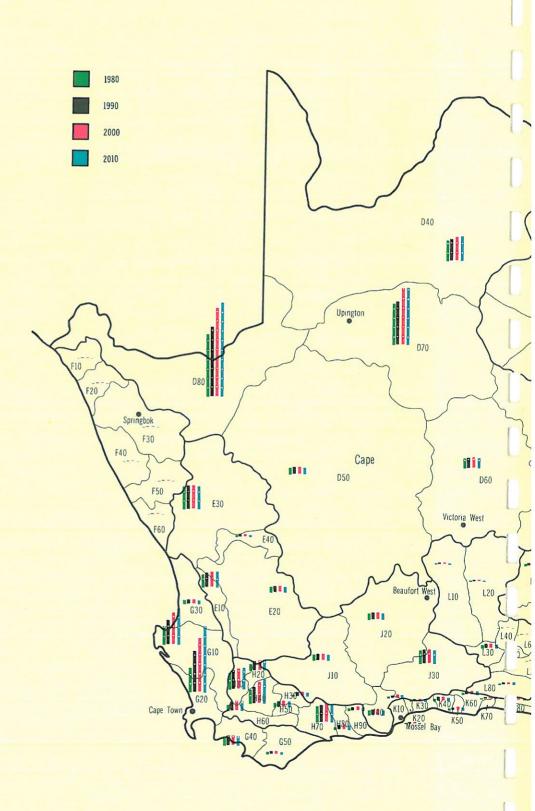


Fig. 2.10.12: Estimated total water demand of South Africa



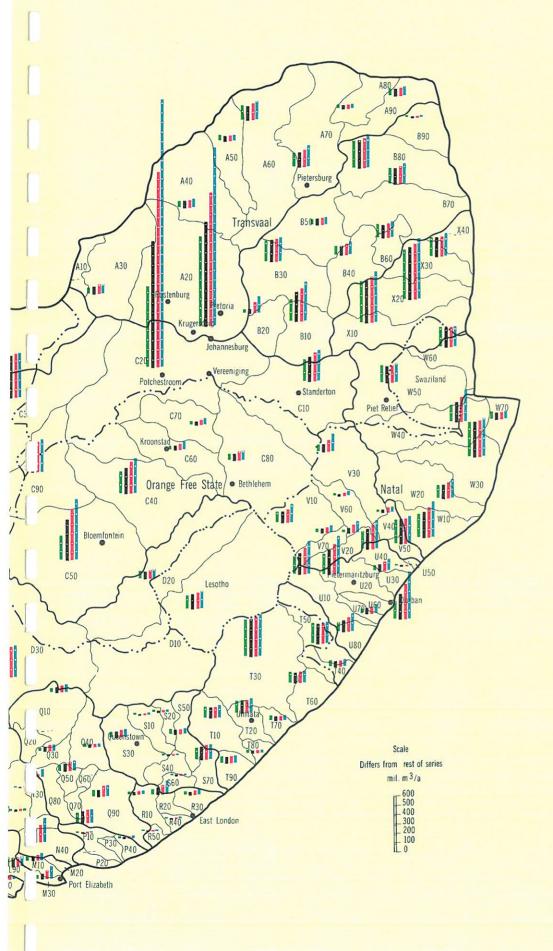
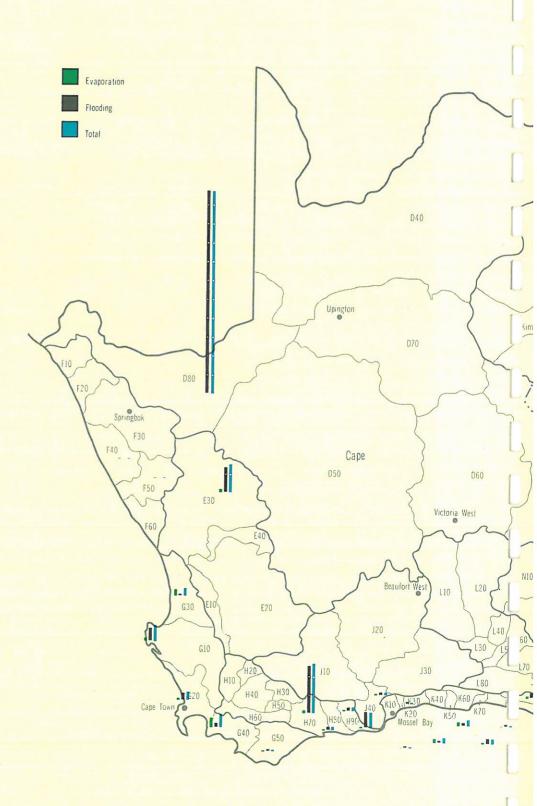
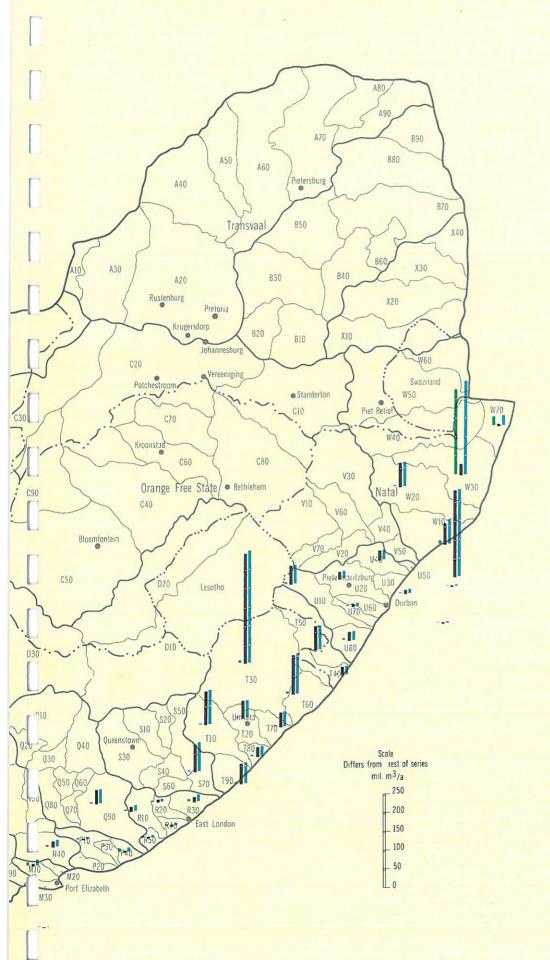
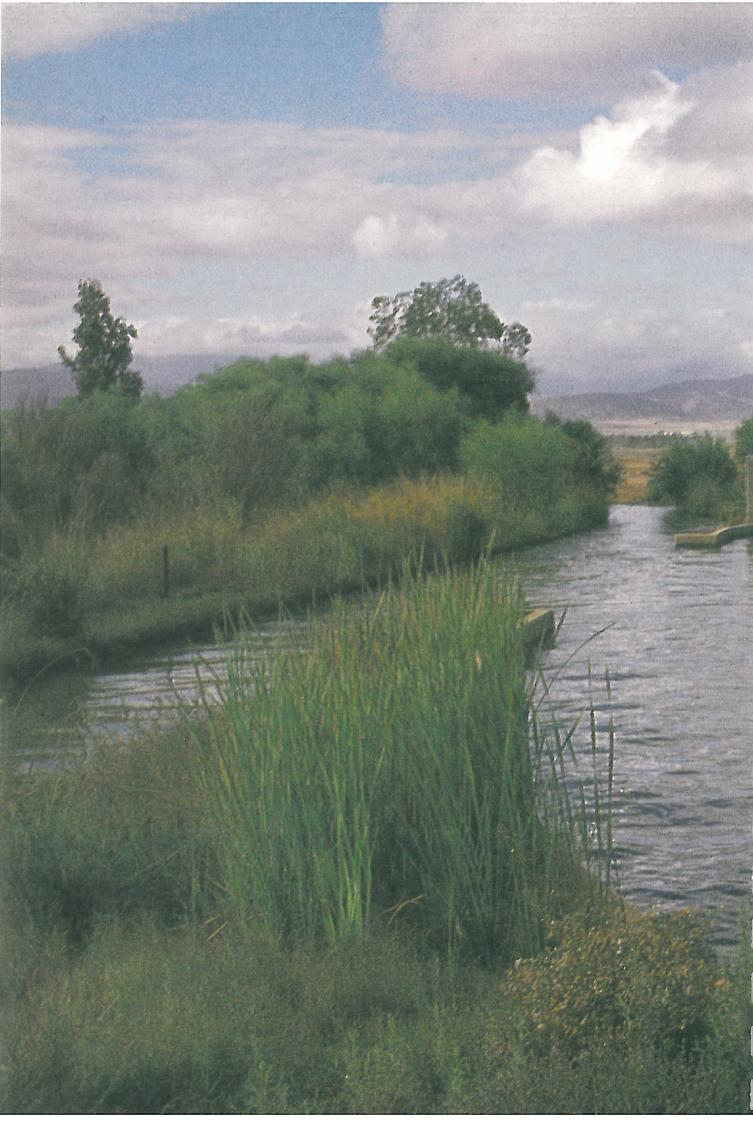


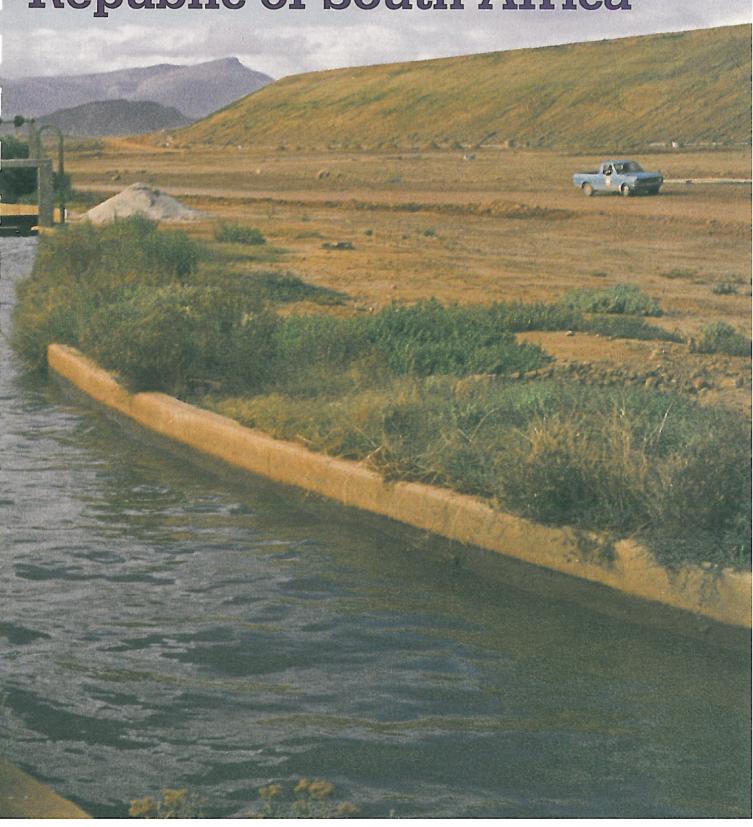
Fig. 2.10.13: Comparison of estimated evaporation and flooding demands for estuaries and lakes











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3.1 Joint use of water by the Republic of South Africa, the self-governing national states, the TBVC states and other neighbouring states

The quantity of surface water available for exploitation in the Republic of South Africa has been affected in recent years by the attainment of independence by states in areas that previously formed part of the RSA. The existence of these states affects the development of projects in that principles of international law relating to water utilization now have to be considered since the provisions of the South African Water Act, 1956 (Act 54 of 1956), have no relevance beyond the RSA's boundaries.

In 1980 an interdepartmental committee reported to Parliament on the division of water between the RSA, the self-governing national states and the Republics of Bophuthatswana and Transkei. Since then, negotiations on the joint use of water have proceeded in accordance with the committee's recommendation that a set of rules drawn up by the International Law Association in Helsinki in 1966 (the Helsinki Rules) be used as the basis for joint use by states. These rules are subject to continual review.

Control of a resource common to independent authorities at differing stages of development requires a high degree of co-operation to overcome difficulties in water apportionment, interterritorial runoff management, erosion control, reservoir sedimentation, flow regulation, diminution of flood damage risk and pollution control. The fact that most South African rivers are international in character may limit the extent to which the available resources can ultimately be developed. The quantity of water that can actually be developed may therefore be less than that now estimated as being available.

Permanent water commissions have been set up between the RSA and each of the independent TBVC (Transkei, Bophuthatswana, Venda and Ciskei) states to monitor development and to advise the governments concerned on the action required to achieve the best joint advantage. Such commissions are also to be established with the self-governing national states. Independence agreements have made provision for reciprocal legislation to deal with problems such as pollution, as outlined at the end of Section 4.3. Details of the Helsinki Rules and the permanent water commissions are given in Section 8.1. The area drained by rivers of common interest, which covers most of South Africa, is shown in Fig. 3.1.1.

The RSA and the TBVC states are represented on a Multilateral Technical Committee on Agriculture and Environment Affairs which provides an authoritative forum where co-operation in water resource development can be promoted. The committee has appointed a Working Group on Water Affairs to liaise with the various permanent water commissions, amongst other functions.

At local level, regional development advisory committees act in a consultative role in the promotion of development across state boundaries and, together with regional liaison committees, can identify needs for water resource development projects.

Co-operation and liaison on water matters between the RSA, Botswana, Mozambique and Swaziland has been maintained through Joint Permanent Technical Committees which have been meeting from time to time for many years. A Joint Permanent Technical Committee

representative of the RSA, Botswana, Mozambique and Zimbabwe, specifically for the Limpopo basin, has also been established. Close co-operation has been maintained with Lesotho concerning water matters and the Lesotho Highlands Project in particular.

Implications of joint control

The South African Water Act, 1956 (Act 54 of 1956), distinguishes between two important classes of public water, namely normal flow, which is sufficiently reliable to enable beneficial irrigation to take place without storage and to which riparian owners are entitled in equitable shares, and surplus water, which the State may apportion to competing demand sectors, including riparian owners, in the best interests of the country. In Government water control areas the State may also exercise control over normal flow. If ongoing international development in the spirit of the Helsinki Rules is to take place without conflicting with the provisions of the Water Act, 1956, a higher degree of sophistication than previously needed in the exercise of jurisdiction by the State will be required.

Government water control areas may need to be proclaimed on an extensive scale in international drainage basins. The Helsinki Rules make provision for continual re-evaluation of the joint use of common resources as circumstances change and for compensation to existing users or the provision of alternative means to enable equivalent benefit to be achieved with less water (such as high technology irrigation systems). An effective financial strategy will therefore be essential for successful development within the framework of the Helsinki Rules.

If ongoing international developments in the spirit of the Helsinki Rules is to take place without conflicting with the provisions of the Water Act, a high degree of sophistication in the exercise of jurisdiction by the State will be required.

Joint ventures

The DWA is refining a dynamic and all-embracing water management and development strategy for the RSA, as described in Section 6.1. In many cases the optimal use of water in South Africa can be achieved only by implementing joint water schemes serving more than one state. Economic and physical constraints such as geographical features determine which schemes are best. Fragmentation of projects by political boundaries could result in serious ineffectiveness in water resource development. The national water management

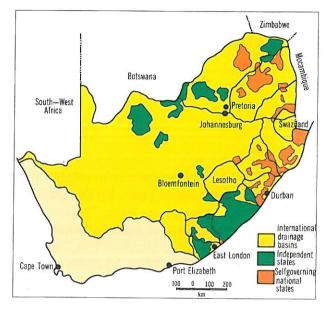


Fig. 3.1.1: International drainage basins

strategy will therefore consider all water that could be used to promote optimal joint utilization, in the conviction that technical integrity and credibility will assist in achieving international accord. This objective can be achieved when planning is done in consultation with all the parties concerned.

To be able to consider apportionment in accordance with the Helsinki Rules requires a high degree of refinement in data collection and evaluation and particularly in hydrological interpretation. The provision of the necessary additional staff and facilities is an absolute requirement for success in this delicate task.

Agreements with TBVC states and negotiations with self-governing national states

Provision for the joint use of water has been made in the independence agreements with Transkei, Bophuthatswana, Venda and Ciskei.

Negotiations based on similar principles are in progress with the self-governing national states of Gazankulu, KaNgwane, KwaNdebele, KwaZulu, Lebowa and Owaqwa. The Government of the RSA has recommended the establishment of permanent water commissions in conjunction with these states to undertake joint basin studies and to make recommendations on the joint use of water. The DWA will be involved in negotiations more directly than in the past. Other aspects

which receive attention in negotiations between states are the management of low-flow conditions and droughts, the use of ground water, the prevention of pollution and the reuse of effluent.

Negotiations with neighbouring states

Ongoing negotiations are being conducted with Botswana, Lesotho, Mozambique, Zimbabwe and Swaziland on the best joint utilization of rivers. When South-West Africa (SWA) becomes independent, similar negotiations will take place with that contry.

In many parts of South Africa fragmented water development is impracticable. Effective international collaboration is required to achieve the optimal allocation of water resources serving different countries. The choice of suitable dam sites to develop the water resources of a river is a complicated process. Many interdependent factors have to be taken into account to arrive at the most economic and appropriate solution. Dams should be built where nature dictates, regardless of political boundaries. The economic advantage of scale decrees that it is generally cheaper to build a single dam, rather than separate ones, each supplying part of the demand.

In general it is desirable to start the development of a river basin at the headwaters. This allows immediate regulation of the longest possible reach of river for the benefit of all users with a smaller and generally more cost-effective structure which is subject to less siltation. Subsequent development will be dictated by technical and economic considerations, and the overall result will be more rational development.

As canals follow contours and allow little choice of route, they cannot be kept within a particular state if the contour crosses borders. Syphons, flumes and tunnels are usually associated with canals, so much the same considerations apply to these works. Routes for pressure pipelines are more flexible, especially in the case of pumping mains, but even they have to stay well below the hydraulic gradient, which places a severe constraint on the planner's freedom of choice. The cost of conduits may be increased substantially if they have to be kept within the borders of one state.

Where urban concentrations are served by the smallest number of large water and sewage purification works practicable, taking sewer layout into account, unit costs are generally reduced.

The boundaries of some self-governing national states have still to be finalized. At present the rivers enumerated below lie within international dráinage basins and the use of their water is subject to international negotiation, although the sharing of some resources, such as the contributions of the intermittent tributaries of the Lower Orange River, may be impracticable. The drainage regions of South Africa are illustrated in Appendix 4.

- 1. The Limpopo River and its tributaries in Botswana, Zimbabwe, Bophuthatswana, Gazankulu, Lebowa, Venda, Mozambique and the RSA (Drainage Regions A20-A90), namely the Ngotwane, Upper Crocodile, Elands, Hex, Pienaars, Sand, Lower Crocodile, Bierspruit, Kgamanyane, Marico, Palala, Magalakwena, Sterk, Nile, Sand, Sterkstroom, Hout, Brak, Nwanedzi, Nzhelele, Mutale and Luvuvuhu Rivers.
- The Olifants, Letaba and Shingwedzi Rivers and their tributaries in KwaNdebele, Lebowa, Gazankulu, Bophuthatswana, Venda, Mozambique and the RSA (Drainage Re-

In many cases the optimal use of water in South Africa can be achieved only by implementing joint water schemes serving more than one state.

gions B10-B90), namely the Little Olifants, Olifants, Bronkhorstspruit, Wilge, Elands, Moses, Steelpoort, Watervals, Ohrigstad, Blyde, Selati, Klaserie, Klein Letaba, Middle Letaba, Great Letaba, Shingwedzi and Letsitele Rivers.

- 3. The Vaal River and its tributaries in Bophuthatswana, Owaqwa and the RSA (Drainage Regions C10-C90), namely the Upper Vaal, Waterval, Klip, Suikerbosrand, Mooi, Schoonspruit, Makwassiespruit, Harts, Vet, Riet, Modder, Vals, Renoster, Elands, Wilge and Lower Vaal Rivers.
- 4. The Orange River and its tributaries in Bophuthatswana, Transkei, Lesotho, SWA and the RSA (Drainage Regions D10-D80), namely the Upper Orange, Kraai, Stormbergspruit, Kornetspruit, Caledon, Vanderkloof, Seekoei, Oorlogspoort, Upper Molopo, Lower Molopo, Renoster, Upper Fish, Lower Hartbees, Upper Hartbees, Upper Sak, Riet, Lower Sak, Lower Fish, Middle Orange, Lower Orange and Fish (SWA) Rivers.
- The Great Fish River and its tributaries in the RSA and Ciskei (Drainage Regions Q10-Q90), namely the Great Brak, Upper Great Fish, Tarka, Middle Fish, Little Fish, Koonap and Lower Great Fish Rivers.
- The Keiskamma River, the Buffels River (Drainage Region R) and coastal rivers in Ciskei and the RSA.
- 7. The Great Kei River and its tributaries in Ciskei, Transkei and the RSA (Drainage Regions S10-S70), namely the White Kei, Indwe, Black Kei, Thomas, Tsomo, Kubusi and Great Kei Rivers.
- 8. Rivers north of the Great Kei River up to and including the Umzimkulu River and their tributaries in Transkei, Kwa-Zulu and the RSA (Drainage Regions T10-T90), namely the Bashee, Umtata, Umzimvubu, Umtamvuna and Umzimkulu Rivers, the Umtente and coastal rivers, the Umgazi and coastal rivers and the Qora and coastal rivers.
- Rivers in the area between and including the Mkomanzi and the Mtwalume Rivers (southern Natal) and their tributaries in KwaZulu, Mozambique and the RSA (Drainage Regions U10-U80), namely the Mgeni, Mdloti, Mvoti, Nonoti, Mlazi and Lovu Rivers.
- 10. The Tugela River and its tributaries in KwaZulu and the RSA (Drainage Regions V10-V70), namely the Upper Tugela, Mooi, Buffels, Middle Tugela, Lower Tugela, Sundays, Bloukrans, Klip, Mlambonja, Mnweni and Boesmans Rivers.
- 11. The Usutu River system and its tributaries in KwaZulu, KaNgwane, Swaziland, Mozambique and the RSA (Drainage Regions W10-W70), namely the Matigulu, Mhlatuze, Mlalazi, White Mfolozi, Black Mfolozi, Bivane, Mkuzi, Ngwavuma, Pongola, Assegaai, Hlelo, Ngwempisi, Usutu, Mpuluzi and Metula Rivers and Kosi Bay.
- 12. The Sabie, Crocodile and Komati Rivers and their tributaries in KaNgwane, Lebowa, Gazankulu, Swaziland, Mozambique and the RSA (Drainage Regions X10-X40), namely the Shiyalongubo, Mlumati, Komati, Crocodile, Elands, Louws Creek, Revolver Creek, Sand, Sabie, Massintonto and Nwanedzi Rivers.

3.2 The effects of changing land use on water resources

The effects of changing land use on runoff urgently need to be determined to ensure the optimal management of water resources. Only after the effects of afforestation on runoff had been quantified through research could a control system be introduced to limit further afforestation in catchments where the water is already heavily committed. Additional research is required to evaluate the effects of other changes in, or aspects of, land use, such as those of urbanization, cultivation, grazing, soil erosion and conservation, veld burning, mountain catchment management and farm dam construction. This information is needed to predict the effects of land use on the quantity and quality of water for an active programme of optimal catchment management (Section 6.17). The objectives are likely to be achieved by, inter alia, the use of satellite imagery, computerized analytic techniques and monitoring equipment, combined with the development of more sophisticated catchment management models.

The hydrological effect of the main land uses Land use patterns

At present statistics on land use in South Africa are confusing. Some sources refer to the RSA only, while others include the self-governing national states but exclude the TBVC states. Many sources refer to no specific area. Table 3.2.1 is based on values published by the then Department of Agriculture in 1982.

South Africa, including the self-governing national states and the TBVC states, but excluding Lesotho and Swaziland, covers an area of 122,11 million ha. Although land use in the whole of South Africa does not differ significantly from the values given in Table 3.2.1, it is recommended that for the purposes of accurate planning statistics be made available for each individual state.

Afforestation (See also Sections 2.8 and 6.13)

Forests and plantations cover 1,1 per cent of the land surface of South Africa. They occur mainly in the mountain catchments, which cover eight per cent of the land area, yet produce about 49 per cent of the mean annual runoff (MAR). Afforested areas are situated in the regions of highest runoff because they are restricted to areas receiving 800

mm of rainfall or more per annum. The distribution of afforested areas is as follows:

Transvaal - Eastern and northern

Transvaal escarpment and the Soutpansberg

51 per cent

Natal - Natal mist belt and the

Zululand coast

37 per cent

Cape

Province - South-western Cape,

Amatola and the

Transkei mist belt 12 per cent

The effect of afforestation on runoff in various experimental catchments in South Africa is summarized in Table 3.2.2.

These experimental results have been confirmed in the flow records from larger catchments, where reductions in runoff varying from 40 per cent to 60 per cent have been observed in heavily afforested catchments. No effect on annual runoff is detectable within the natural runoff variation when forests cover less than 20 per cent of the total catchment area.

The permit system described in Section 2.8 was introduced to control afforestation in all catch-

ments, particularly in the critical water supply catchments, and is based, inter alia, on these experimental results. To improve the efficiency of allocation and of the management of forest areas, research is being continued in order to provide guide-lines for the location of forests within catchments, the management of riparian zones and forest stand dynamics.

Table 3.2.1: Land use in the Republic of South Africa*

Main categories	Subclasses	Area (ha)	%	Area (ha)	%
Natural veld	Mountain catchments**	1 635 100	1,5	78 363 000	73,3
Cultivation	Dryland			12 105 000	11,3
	cultivation	11 205 000	10,5		
	Irrigated land	900 000	0,84	1 130 000	1,1
Forest	Plantations	983 000	0,92	1 130 000	
	Natural forest	147 000	0,14		
Nature conservation				5 131 900	4,8
Urban areas				3 736 600	3,5
Peri-urban (small- holdings)				3 202 800	3,0
Roads, railways, airports				2 135 200	2,0
Mines, Defence Force, etc.				1 067 600	1,0
Total				106 872 100	100,0

Based on values by L G Pienaar, published in Bodembeskermingsnuus, July 1982.

Cultivation

Cultivation of the land has increased steadily to about 11 per cent of the total land area of the RSA. In the main production area on the inland plateau most of the arable land is already being cultivated. The main crops in this region are maize, sorghum, wheat and oilseeds. Flow records, some going back to 1930, show no effect on runoff in areas that have had an up to 50 per cent change from grassland to cultivated land. However, the inland plateau area is still undergoing changes in cropping patterns with crops utilizing moisture more efficiently being introduced. Furthermore, runoff control measures to keep more of the runoff in the soil are still very far from full implementation.

Cultivation of the land has increased steadily to about 11 per cent of the total land area of the RSA.

In the Natal Midlands, which produce far more runoff per unit area than the rest of the country, the transformation of grassland to cultivated land is pursued actively. So far only 10 per cent of the 35 per cent of land which is potentially arable has been developed. Crops which use a large amount of water, such as sugar-cane, could have effects on runoff similar to those of afforestation. Furthermore, the remaining 65 per cent of the land which is not arable has great potential for veld replacement.

Veld management

Natural veld used for grazing and conservation accounts for approximately 75 per cent of the total land area of the RSA. Severe changes occurred in veld types and conditions before the turn of the century as a result of the replacement of the wild herbivore population with highly selective feeders, namely cattle, sheep and goats. This resulted in bush encroachment, land desiccation and soil

Table 3.2.2: The effect of afforestation in experimental catchments

Catchment	Catchment area	Mean annual precipitation	Afforestation	Natural mean annual runoff	Reduction in mean annual runoff	
					During first half of production rotation	At half rotation age
	(km²)	(mm)	(%)	(mm)	(mm)	(mm)
Bosboukloof (Western Cape)	2,0	1 400	58	600	270	325
Biesiesvlei (Western Cape)	0,27	1 430	98	630	313	400
Cathedral Peak (Natal)	1,9	1 400	74	750	257	440
Mokobulaan (Transvaal)	0,26	1 150	100	380	212	340

^{**} State and private lands managed in terms of the Forest Act and the Mountain Catchment Areas Act.

Sixty per cent of the veld in the seven agricultural regions of the RSA is in a poor condition requiring urgent attention and only 10 per cent is in a good condition.

erosion, which subsequently gave rise to the Soil Conservation Act, 1946 (Act 45 of 1946), and later the Conservation of Agricultural Resources Act, 1983 (Act 43 of 1983). The conservation of agricultural resources is assisted by various subsidy schemes administered by the Department of Agriculture and Water Supply.

Nevertheless, the natural veld is still deteriorating. Sixty per cent of the veld in the seven agricultural regions of the RSA is in a poor condition requiring urgent attention and only 10 per cent is in a good condition. To counter this problem a new national strategy, announced by the Minister of Agriculture and Water Supply in 1985, limits livestock farming to proclaimed areas with longterm grazing capacities as determined by climate, soil type and vegetation. Regulations made under the Conservation of Agricultural Resources Act, 1983, provide grazing capacity norms for all parts of the country. In future no subsidies for conservation schemes, or aid during droughts, will be granted to farmers who do not meet the requirements of the regulations. Veld is also deteriorating in large areas of the self-governing national states and in the TBVC states.

At present there is very little experimental information available regarding the hydrological effects of veld management in South Africa. However, plot studies and more recent studies with a rainfall simulator have shown that by improving the vegetal cover of the soil through veld management, soil erosion and, to a lesser extent, runoff are dramatically reduced. Large differences in vegetal cover already exist between well-conserved veld and overgrazed veld in which pioneer species have taken over.

Veld burning is a very common management practice in South Africa. Veld burning experiments in mountain catchments have demonstrated a potential for considerable increases in catchment water yields. A new series of burning experiments has recently been started in the catchment which supplies water to Mossel Bay to determine whether water yields can be enhanced in this way in the long term.

Veld improvement through fertilization, reinforcement or complete substitution has great potential in South Africa. Until now only one per cent of the veld area of South Africa as a whole has been improved. Almost 60 per cent of the inland plateau region and the Natal Midlands could be improved in this way. Since experimental

catchment studies in other countries have shown severe runoff reductions as a result of veld improvement, careful monitoring of this trend in critical catchments is required in South Africa.

Soil erosion and sedimentation

South Africa has a serious erosion problem which leads to impoverishment of the land and high sediment loads in many rivers, with consequent sedimentation of reservoirs and estuaries. Changing land use during this century, brought about by pressure on the available land as a result of poverty, traditional agricultural practices and cultural attitudes, has significantly accelerated the natural geological process of erosion in many parts of the country.

Large parts of South Africa are characterized by steep topography, long slope lengths and shallow, eroded or erodible soils. As shown in Fig. 3.2.1, sediment production from large catchments is as high as 1 000 t/km²/a. It is estimated that more than 120 million t of sediment enters South African river systems annually.

Despite excellent work that has been done since the 1930s through the encouragement of conservation farming, more than half of the arable land in the RSA still has to be protected.

There are, however, signs of decreasing sediment production coinciding with a reduction in runoff over the past 30 years. A marked decrease in sediment in the middle reaches of the Orange River is attributed to a progressive change in the amount of erodible soil material available. Enhanced erosion attributable to the influence of man has been so severe that the recent decrease in sediment yield can be ascribed to the reduced availability of erodible material as a result of the washing away of alluvial valleys and the stripping of topsoil from sensitive soil profiles.

While this has serious implications for agricultural production, the effects of soil erosion on the downstream water environment are just as serious. The average loss in the reservoir capacity of large dams is just under 10 per cent per decade in high erosion hazard regions such as the southern and eastern Cape. Besides the loss of valuable storage capacity, sedimentation causes a deterioration in dam basin characteristics, such as an increased surface area in relation to storage capacity, as well as raised backwater levels. Agricultural damage during large floods results mainly from sediment deposits on low-lying cultivated land. Estuaries along the southern and eastern coasts are also threatened by excessive sediment

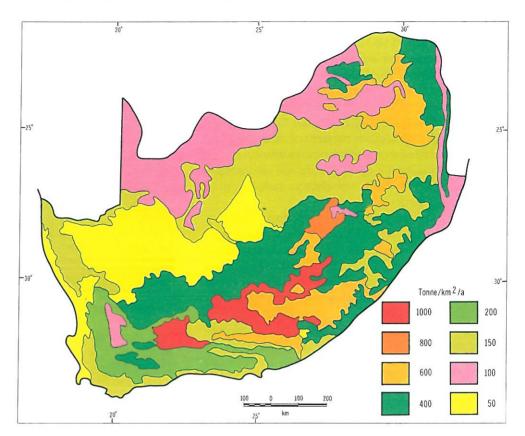


Fig. 3.2.1: Generalized sediment production map

deposits.

The prevention of soil loss in the RSA falls chiefly under the Department of Agriculture and Water Supply. Although the RSA is subdivided into soil conservation districts and about 80 per cent of farms have conservation plans, preventive measures have been implemented on only a small proportion. Despite excellent work that has been done since the 1930s on the erection of conservation structures and through the encouragement of conservation farming, more than half of the arable land in the RSA still has to be protected.

The effectiveness of legislation on conservation has been reduced by difficulties in its implementation and problems with extension work and the exercise of control at farm level. While some of the shortcomings of the old Acts have been remedied in the Conservation of Agricultural Resources Act, 1983, it is essential that a much stronger commitment be made in terms of approach, staff and funds towards extension work and control at farm level. Little or no attention is given to river bank erosion and the soil erosion situation is still deteriorating on communal land. New co-ordinated approaches are urgently required to halt deterioration in areas where traditional agriculture is practised, especially since these areas are often important water catchments.

An agency that is actively promoting soil conservation across international boundaries is the Southern African Regional

Commission for the Conservation and Utilization of the Soil (SARCCUS). From initiatives at the Inter-African Conference on Soil Conservation in 1948 four regional committees were established, SARCCUS being one of them. The SARCCUS Sub-committee for Land Use Planning and Erosion Control has consistently drawn the attention of member countries to the disastrous levels of unchecked soil erosion in the region and has pressed for an assessment of soil erosion throughout the region as a basis for an essential publicity campaign. In 1981 the sub-committee produced a classification system to assess soil erosion. This system makes possible a common approach to the identification and assessment of erosion in the SARC-CUS region and promotes better communication among scientists and administrators, at both the national and the international level.

Farm dams

Where farm dams occur in large numbers, they have a marked effect on catchment runoff. For example, long-term runoff reductions of the order of 40 per cent were observed in tributaries of the Orange and Upper Breede Rivers. The construction of farm dams is still proceeding and their numbers have doubled in Natal over the last 30 years. Their pattern of use is also changing. They are increasingly being built for irrigation in highpotential agricultural regions where the normal flow of rivers has been fully exploited. This represents a far more intensive use than traditional stock-watering did. The effect of farm dams on catchment yield is most noticeable during and after prolonged periods of drought and at the beginning of a rainy season.

Storage in several small dams is normally less efficient than the equivalent storage in a larger

dam because of less favourable evaporation characteristics and the increased cost per unit of storage capacity for smaller dams. Very little is known about seepage losses from farm dams but in some areas these dams contribute towards river regulation as seepage water emerges further downstream. Although the normal flow and surplus water to which other owners of riparian properties are entitled in some instances should be released through these dams, there are indications that this requirement is not always met because of a lack of control.

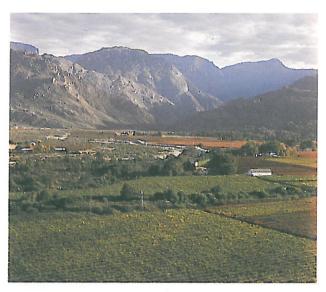
Control over the construction of farm dams is exercised through a permit system in terms of section 9B of the Water Act, 1956, for dams larger than 250 000 m³ and through internal regulations within irrigation districts. Further control is possible through declaration of part or all of a catchment area as a Government water control area to safeguard the inflow to major Government waterworks or to ensure the equitable allocation of water.

Subsidized farm dam construction may threaten large-scale downstream water supplies.

At present there is a potential conflict between the State's long-established policy of encouraging farm dam construction by means of subsidies and measures by the State to control their proliferation where they threaten large-scale downstream water supplies. When considering measures that may be instituted to control farm dams both the benefits and the downstream hydrological effects will be taken into account. A pilot study started in the Mgeni River catchment in 1984 to examine the hydrological effects of farm dams will be extended to include the benefits if this factor is found to be important. Both aspects must be quantified to determine whether controls are necessary in addition to those provided for in section 9B of the Water Act, 1956, for larger dams not situated within a Government water control area.

Land-use data base and use of satellite imagery

Models of various levels of complexity will have to be established to simulate the hydrological effects of different land-use practices for use in catchment management decision-making. To achieve this as a top priority, the main land-use trends must be identified to determine research priorities and management practices. Updated land-use records and other relevant information needed for catchment management are required and must be readily available in the form of maps and statistics for each catchment.



Intensive irrigation of vineyards in the Hex River Valley

No land-use data base is maintained at present, although the Department of Agriculture and Water Supply has initiated a survey on a scale of 1:250 000. The Department of Environment Affairs is compiling a data base on areas under conservation and on sensitive areas. In the meanwhile the use of satellite imagery must be considered as one of the most cost-effective methods to reduce this national backlog and to regularly update the data base in the future (Section 6.1).

Research and large-scale applications have shown that it is possible to map irrigated areas rapidly with a fair degree of accuracy from satellite images. It is therefore feasible to monitor the expansion of irrigated areas on a nation-wide basis. There are strong indications, confirmed by initial research, that satellite imagery can also be used to assess crop stress conditions over large areas such as at the Loskop and the Vaalharts Government irrigation schemes. The use of satellite remote sensing should be able to contribute to better management of large irrigation schemes, within the limitations of the water distribution system.

The feasibility of mapping forests and plantations from satellite images has already been demonstrated and the first 1:250 000 sheet was recently completed. The recent acquisition of processing facilities by the DWA will speed up country-wide coverage considerably. It is also possible to monitor farm dam expansion using digital images but visual images are difficult to use for this purpose.

The science of land-use mapping has been enhanced by the coverage, regularity and differentiation possibilities of satellite images. Hydrologic catchment modelling should make rapid progress with this excellent information base.

3.3 The availability of surface water

Surface runoff is the dominant source of water in South Africa, although on average only nine percent of the total rainfall is discharged by rivers. The total volume of runoff is estimated at 53 500 million m³/a, of which it may be practicable for all the states sharing the water to exploit only about 33 000 million m³/a (see Table 3.8.1 and Fig. 3.8.1).

The construction of storage facilities is generally required in order to make the best use of surface runoff. Existing major dams in South Africa have a total capacity equivalent to 50 per cent of the total mean annual runoff. These dams command virtually the total runoff from the interior plateau while the untapped resources are concentrated mainly along the coast. Fig. 3.3.1 shows the locations of major dams in the country and a full list of dams with important statistics is given in Appendix 2. The maximum practicable exploitation of the conventional water sources of large regions of the interior has therefore already been achieved.

Apart from engineering difficulties associated with the development of the generally short and steep coastal rivers, their exploitation may also be detrimental to sensitive estuaries. Many coastal rivers are also situated within independent territories or territories that may become independent and international negotiation is required for their use. The availability of surface runoff for urban, industrial and agricultural use may be further reduced by an increase in the water required for other purposes such as recreation and environmental conservation.

Distribution and variable nature of runoff

The great escarpment divides South African river systems into two groups — the plateau rivers and those of the surrounding areas. Rivers flowing towards the east, such as the Komati, the Crocodile, the Olifants and the Limpopo have broken through the main scarp and have their headwaters well back on the interior plateau. The eastern plateau slopes, covering 13 per cent of the area of South Africa, account for some 43 per cent of the total surface runoff. This volume is distributed over a large number of small rivers which flow directly to the sea, limiting the possibility of their use.

South of the Vaal-Limpopo divide, which runs east-west along the Witwatersrand, almost the entire plateau, or 48,5 per cent of the area of South Africa, is drained by the Orange River system,

which contributes only 22,5 per cent or 12 057 million m^3 of the total annual runoff. This is partly because of lower precipitation, but especially as a result of a less favourable runoff to precipitation ratio, caused mainly by extensive evaporation losses over the western interior.

From the Mont-aux-Sources area the Orange River traverses 2 250 km from east to west, discharging into the Atlantic Ocean. Its major tributaries are the Caledon River and the Vaal River. The latter is actually longer and drains a much larger area than the main Orange headstream, but it contributes only 37 per cent of the total runoff in the Orange River system. Downstream of its confluence with the Vaal at Douglas, the Orange flows erratically for the remaining 1 200 km of its course. There is hardly any further addition to its runoff and in living memory no water has reached

the river from the large Molopo-Nossob system situated to the north.

In the southern Cape the major rivers are the Gamtoos, Gouritz, Breede, Berg and Olifants, which extend in the order given from a year-round rainfall area to a winter rainfall area.

Perennial rivers occur over only one-quarter of South Africa's surface — mainly in the southern and south-western Cape and on the eastern plateau slopes. Rivers that flow only periodically are found over a further quarter of the surface. Over the entire western interior, rivers are episodic and flow only after infrequent storms. An extreme example is provided by the Hartbees River at Kenhardt, where half of the total discharge between 1932 and 1972 was registered in six months during 1961.

In the absence of lakes and permanent snow-fields to stabilize flow, even the perennial rivers flow irregularly and are very often strongly seasonal. Before construction of the Orange River Project dams the mean natural flow of the Orange River at the Boegoeberg Dam was 14 times larger in February, the peak month, than in August, the month with the lowest flow. Variations in the total annual flow can be equally large. Thus, 26 700 mil-

Perennial rivers occur only over onequarter of South Africa's surface and rivers that flow only periodically are found over a further quarter of the surface. Over the entire western interior rivers flow only after infrequent storms.

lion m³ were registered at Boegoeberg in 1943/44, as against 1 490 million m³ in 1948/49. Strategies for the optimization of water use vary from catchment to catchment owing to the considerable hydrological diversity across the country, as explained in greater detail in Section 6.3.

Fig. 3.3.2 shows the relative runoff contributions of the drainage regions of South Africa. The relative contributions of the main river systems to surface water in South Africa are shown diagrammatically in Fig. 3.3.3 in which the width of each river as drawn is proportional at any point to the cumulative annual flow at that point. Table 3.3.1 gives the mean annual runoff (MAR) of river systems in South Africa. Appendix 3 gives a complete list of the MAR of secondary drainage regions and a map showing the drainage regions is given in Appendix 4.

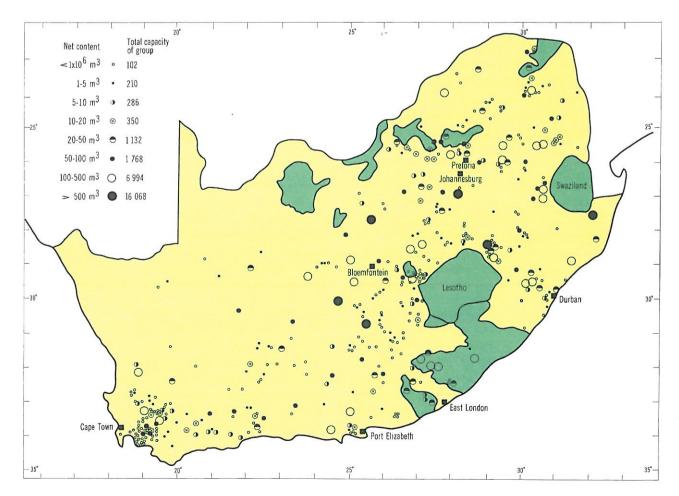


Fig. 3.3.1: Location of major dams in South Africa

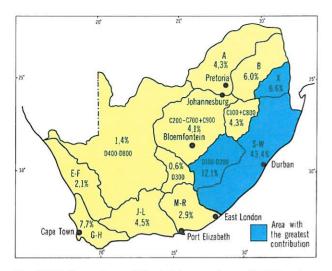


Fig. 3.3.2: Percentage of the total annual runoff of the river systems

Figs 3.3.4 and 3.3.5 are schematic illustrations of the distribution of annual averages of unused runoff for 1980 and estimates for the year 2010. For technical or economic reasons, such as a lack of dam sites or extreme variability in runoff, it may be impractical to exploit all of this water. Return flows are not included.

Reliability of runoff records

Since 1900 an extensive network of hydrological gauging stations has been built up across the country. Although many records are reliable, not all are adequate. This implies that worse conditions than previously-known low flows, often those that occurred during the drought which culminated in 1933, may yet occur, as has been demonstrated recently. Inadequate records are improved and extended by statistically-based and other techniques and by correlation with records in related catchments. In some cases alternative representative time-series are generated by techniques based on similar principles, but these methods are all imperfect.

Problems encountered in analysing records are the changing nature of the runoff resulting from changing rural and urban land use and afforestation, the progressive establishment of dams on rivers and evolving patterns of water use, return flows and seepage. The values given in this report are the best currently available. Much of the information on the availability of surface water is based on the results of a research project conducted by the Hydrological Research Unit, University of the Witwatersrand, funded by the WRC.

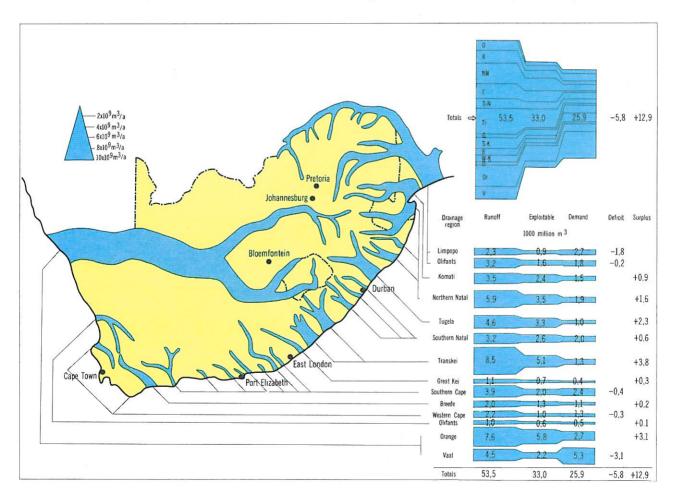
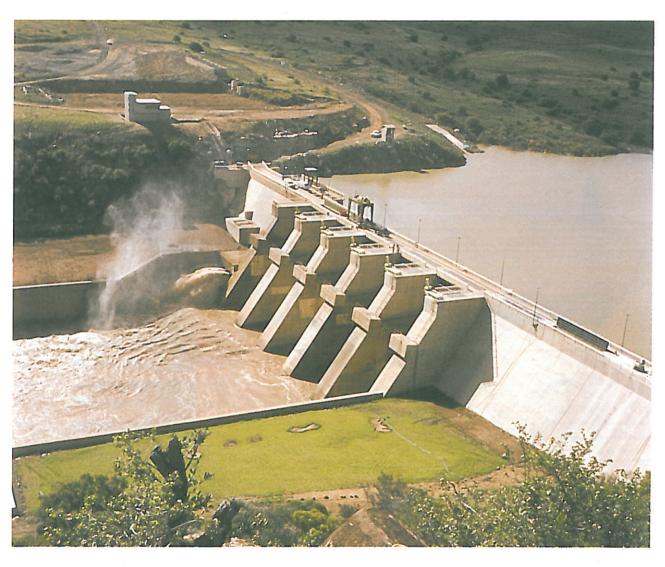


Fig. 3.3.3: Cumulative annual river runoff (quantities in 1 000 million m³/a)

Table 3.3.1: Mean annual runoff of river systems in South Africa

Drai	Surface area	% of total	Annual runoff	% of total	Average annual precipitation	Runoff as % of precipi-	
Region number	Region	(km²)	area	(million m³)	annual runoff	over region (mm)	tation
C10 and C80	Upper Vaal	38 609	3,0	2 288	4,3	751	7,9
C20 - C70 and C90	Lower Vaal	157 738	12,5	2 199	4,1	512	2,7
D10 and D20	Upper Orange	64 931	5,1	6 465	12,1	731	13,6
D30	Middle Orange	34 208	2,7	322	0,6	358	2,6
D40 - D80	Lower Orange	311 172	24,5	783	1,4	246	1,0
C + D	Total Orange	606 658	47,8	12 057	22,5	406	4,9
E and F	West coast	77 509	6,1	1 125	2,1	199	7,3
G and H	South-western Cape	41 073	3,2	4 112	7,7	542	18,5
J-L	Southern Cape	87 045	6,9	2 414	4,5	327	8,5
M-R	South-eastern Cape	67 390	5,3	1 561	2,9	456	5,1
S-W	Eastern plateau						
	slopes	174 565	13,8	23 222	43,4	870	15,3
В	Olifants basin						
	(Transvaal)	73 534	5,8	3 191	6,0	660	6,6
A	Limpopo main basin	109 604	8,6	2 290	4,3	555	3,8
X	Delagoa Bay	31 157	2,5	3 554	6,6	842	13,5
Grand total		1 268 535	100	53 526	100	497	8,5



The Welbedacht Dam on the Caledon River, near Wepener, OFS, provides water to Bloemfontein

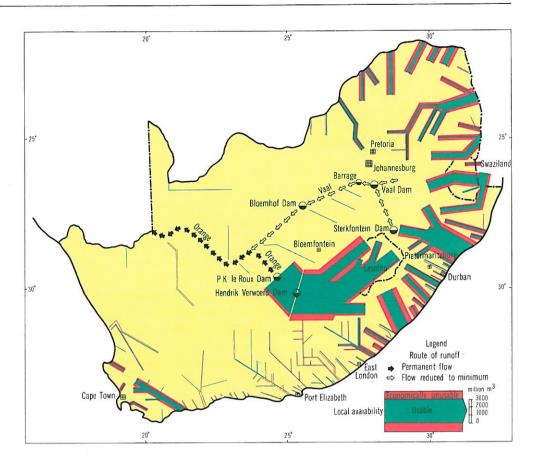


Fig. 3.3.4: Schematic distribution of cumulative unused average runoff in 1980

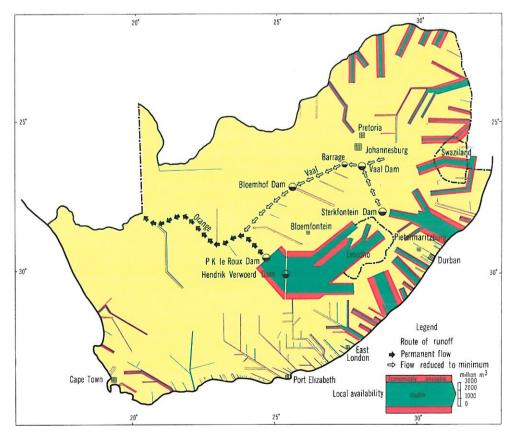


Fig. 3.3.5: Schematic distribution of cumulative unused average runoff in the year 2010

3.4 The distribution, use and potential for the exploitation of ground water

Over more than 80 per cent of the area of South Africa ground water occurs in *secondary* aquifers. These are weathered and fractured rocks which lie directly beneath the surface to depths of less than 50 m. At greater depths unweathered rock formations occur which contain very little ground water because of their dense nature.

The quantity of water stored in the saturated portions of these weathered and fractured rocks is generally very limited and the permeability of these secondary aquifers is usually also low. For these reasons few boreholes are capable of yielding more than a few litres per second for any length of time. The possibility of exploitation offered by secondary aquifers is therefore limited and they are used mainly to provide water on farms for domestic use, for stock-watering and for irrigation on a small scale and to provide water for communities ranging from villages to medium-sized towns. Under favourable geohydrological conditions it may be possible to supply a town with up to five million m³ of ground water per year from a number of secondary aquifers located within economic reach of the town.

By contrast, appreciable quantities of ground water can be abstracted at high rates from boreholes judiciously sited on dolomite. The term 'dolomite' is generally used to designate strata 200 m to 1 900 m thick that are composed of dolomitic rock with subordinate interbedded chert, shale and sandstone.

Dolomitic rock consists almost entirely of the mineral dolomite, a double carbonate of calcium and magnesium that is weakly soluble in carbonated water. Extensive leaching of dolomite in places to depths in excess of 150 m, especially in the southern and western Transvaal, provides ideal sites for high-yield boreholes. Dolomitic aquifers may therefore be exploited for urban supplies and irrigation on a larger scale than ground water in other hard rock formations. The possible incidence of sinkholes resulting from the abstraction of ground water from dolomitic aquifers places a limitation on the degree to which the potential of this source can be exploited. See also Section 5.3.6.

The ground water resources of the country should be visualized as being contained in a multitude of mostly secondary aquifers or aquifer systems with limited quantities of extractable ground water.

Primary aquifers, comprising porous deposits of granular material, also contain substantial quantities of exploitable water but the size and distribution of this type of aquifer is limited in South Africa. Fig. 3.4.1 shows the distribution of dolomite and some of the larger primary aquifers.

The yield of aquifers depends on various factors, one of the more important being the rate of recharge. Estimates of the average volume of precipitation which annually infiltrates the aquifers over the country as a whole varies from 16 000 million m³ to 37 000 million m³. However, only a small portion of the infiltrated water can be recovered by means of boreholes be-

cause of evaporation, transpiration and seepage losses which do not contribute to stream flow. Considerable research has been carried out since the Commission of Enquiry into Water Matters reported in 1970 but it is still difficult to estimate the quantities that could be abstracted on an economic basis from aquifers. In the present circumstances, and as a rough estimate only, it is not likely to exceed 5 400 million m³/a.

The ground water resources of the country should be visualized as being contained in a multitude of mostly secondary aquifers or aquifer systems with limited quantities of extractable ground water. This explains to a large extent why ground water does not play as important a role in the national water supply of this country as it does in other parts of the world where the main source of supply stems from an extensive primary aquifer system. In general, the quality of ground water in the high rainfall regions of South Africa is adequate but problems with poor quality are experienced in some of the more arid areas.

Apart from usually being a dependable supply, ground water can meet the initial demand during early stages of large-scale urban development such as that at Atlantis. Savings can later also be achieved on the cost of pipelines required to obtain water from elsewhere by satisfying peak demand from local ground water sources.

For towns supplied from surface sources, ground water can assist in bridging periodic shortages and in alleviating emergencies, provided investigations and borehole development are undertaken in time.

Potential for the exploitation of ground water

The potential for the exploitation of ground water depends on the manner in which it is exploited. The possibilities are as follows:

- As a renewable resource abstracted continuously at a more or less constant daily rate (for example for urban water supply).
- 2. As a non-renewable resource where recharge is

nil or inadequate, which may be abstracted until the stored volume is exhausted.

- 3. As a combination of (1) and (2).
- 4. As a renewable resource abstracted at high rates for short periods to supplement other sources during peak periods or in cases of emergency.

The utilization of ground water as a non-renew-

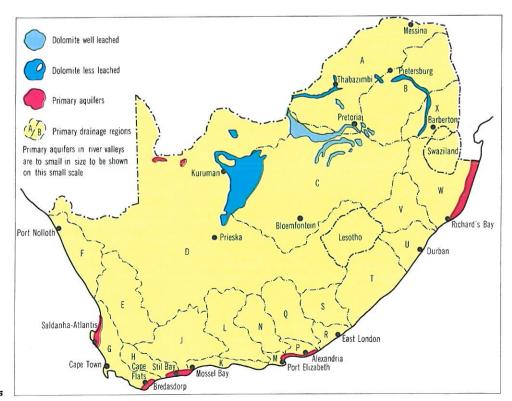


Fig. 3.4.1: Distribution of dolomitic and of primary aquifiers

able resource, such as the dewatering of dolomite in the gold-mining area on the Far West Rand and at the Sishen iron ore mine, may have considerable economic benefits.

Abstraction of ground water from boreholes exploits a renewable resource which, under natural conditions, would emerge as spring flow and seepage to streams or would be lost through evapotranspiration. In some areas, such as mountain catchments, it may be impracticable to intercept seepage to streams by drawing ground water from boreholes and, where this contribution to runoff is required for use downstream, ground water abstraction may even be undesirable.

With the exception of certain dolomitic and primary aquifers, utilization of ground water will be limited to relatively small-scale users in the vicinity of the ground water source.

The amount of infiltration or recharge that can be recovered by pumping from boreholes is difficult to determine. The reason for this is that the establishment of an adequate number of boreholes effectively distributed over a sufficiently large area in order to recover the full aquifer recharge or a predetermined quantity of ground water is limited by practicability and cost. Furthermore, local requirements may not demand full utilization of the available ground water resources and their full potential may never be realized, for example in areas where there are extensive farms such as the Karoo. Here ground water supplies are more than adequate for the local demand but do not warrant abstraction and conveyance as bulk supplies to other places. With the exception of certain dolomitic and primary aquifers, utilization of ground water will be limited to relatively smallscale users in the vicinity of the ground water source.

Primary aquifers consist of unconsolidated or consolidated deposits of sand, gravel and pebbles in which the interstices have not been destroyed by subsequent compaction, recrystallization or cementation. Such water-bearing formations are capable of yielding volumes of water varying from five per cent to about 30 per cent of the gross volume of the formation.

In other parts of the world such deposits are known to cover thousands of square kilometres and have thicknesses ranging from several hundred to more than a thousand metres. However, in South Africa these water-bearing deposits are shallow and cover only a small portion of the country. They occur as alluvial deposits in and along surface watercourses. Examples of these are found in the northern Transvaal, KwaZulu, the western and north-western Cape and the Karoo. Quaternary aeolian (windblown), fluvial (found in a river) and littoral (near the shore) sand deposits occur in the Saldanha-Atlantis area, on the Cape Flats and along the northern Natal coast. Lenses of sandstone and grit of Tertiary age occur in the Kalahari as pri-

mary aquifers. In the Bredasdorp-Stilbaai and Alexandria areas primary aquifers are also present.

Secondary aquifers occur in hard rock formations close to the surface over about 80 per cent of the country. These formations comprise sedimentary, metamorphic and intrusive and extrusive igneous rocks. They contain virtually no primary openings and owe their water-bearing properties to secondary openings caused by the geological processes of deformation (folding, fracturing and faulting), weathering and unloading as a result of the erosion of overlying strata. These openings develop typically in the upper part of the earth's crust, being generally restricted to the first 10 m to 50 m below the surface.

Except in the case of limestone and dolomite, the storage capacity and permeability of secondary aquifers are low and compare poorly with those of primary aquifers. Secondary aquifers vary considerably in their form and in the size of the area which they cover. Areas vary from less than a hectare to several square kilometres and in the case of dolomitic ground water compartments to a hundred or more square kilometres. Such aquifers are bounded and separated from one another by formations with poor permeability.

The most important aquifers in the country are in karstified dolomite, that is dolomite where networks of caverns and smaller channels have formed along pre-existing joints and fractures. These openings as well as those contained in the overlying mantle of weathered material, are capable of storing and transmitting large volumes of water. The dolomitic formations of the southern and western Transvaal and of the northern Cape are divided by intrusive dykes of dolerite and syenite into so-called compartments which range in size from a hectare to more than 100 km². For example, the storage capacities of the Oberholzer and Venterspos compartments have been calculated at 730 million m3 and 450 million m3 respectively. The dolomite has not been subjected to the same degree of karstification everywhere. The most extensively karstified deposits are in the southern and western Transvaal. Elsewhere in the Transvaal and on the Ghaap plateau the degree of karstification is much lower and the porous and permeable mantle of weathered materials is lacking.

The estimated quantity of ground water in South African geological formations is given as an equivalent depth of free water in Table 3.4.1 and the estimated annual yield of ground water sources is given in Table 3.4.2 by main drainage region.

Present and future utilization of ground water

It is estimated that 13 per cent of all water used in 1980 was obtained from underground sources. It is also estimated that in 1980 the use of ground water in the RSA and in the self-governing national states, as well as in Transkei, Bophuthatswana and Venda, was as is shown in Table 3.4.3 (see also Table 3.8.2 and Fig. 3.8.2).

Apart from the contribution of ground water to river flow and the quantities that could be abstracted or mined from non-renewable resources, the maximum quantity of ground water that it would be practically and economically feasible to develop is assessed at approximately 5 400 million m³/a. It is therefore likely that ground water will eventually not constitute much more than 15 per cent of the supply from conventional sources.

However, in all the main drainage regions possibilities exist for substantial increases in the present rate of exploitation.

With the necessary skill the total demand of many small to medium-sized towns could be supplied mainly from ground water. Water supplies

Table 3.4.1: Ground water in South African geological formations, expressed as the equivalent depth of free water

Formation	Equivalent depth of water (m)
Dolomite, Far West Rand (before	
dewatering)	4,9 - 8,3
Grootfontein compartment (Lichtenburg)	1,9
Coastal sand deposits, Atlantis, western	
Cape	2,5-5,0
Typical alluvial deposits along rivers	2,0
Disintegrated, weathered granite	0,5-1,0
Karoo sedimentary rocks	0,1-0,5

As a comparison, the alluvial deposits of the Great Valley of California contain the equivalent of 50 m to 100 m of water.

Table 3.4.2: Estimated quantities of ground water that could be abstracted annually from main drainage regions under foreseeable limitations of economics and practicability

Main drainage region	Quantity	Quality range (Total dissolved		
region	(million m³/a)	solids – mg/ℓ)		
A	500	300 – 1 500		
В	440	200 - 2 000		
C	820	200 - 2 000		
D	1 000	200 - 4 000		
E	90	1 000 - 7 000		
F	10	1 000 - 6 000		
G	175	500 - 3 000		
Н	175	300 - 4 000		
J	100	700 - 4 000		
K	90	500 - 2 500		
L	50	600 - 5 000		
M	15	500 - 3 000		
N	50	700 – 3 000		
P	25	500 - 5 000		
Q	90	800 - 6 000		
R	30	800 - 3 000		
S	80	300 – 2 000		
T	460	200 – 2 000		
U	200	200 - 1 000		
V	210	400 – 1 500		
W	430	200 – 2 500		
X	360	200 – 1 500		
Total	5 400			

Table 3.4.3: Use of ground water in South Africa in 1980

Water use sector	<i>Use</i> (million m³/a)
Urban use (including industrial and mining use from public sources) Rural domestic use Stock-watering Irrigation Mining and quarries (total pumped from mines, quarries and boreholes = 405 million m³/a)	70 120 100 1 400
Total	1 790

from surface sources to other towns could be augmented with ground water. It is expected that the growth in the use of ground water for small-scale irrigation development will continue.

The contribution that the dolomitic ground water sources of the southern Transvaal could possibly make towards urban water supplies is outlined in Section 5.3.6.

On some projects capital expenditure patterns could be improved in the initial stages by exploitation of ground water. However, the legal classification of ground water as private water is an obstacle to its development. To facilitate and encourage the development of ground water sources for urban use in particular, but also for irrigation (when it cannot be applied for urban use), its legal status is being reconsidered (Sections 6.12, 8.3 and 8.4).

The use of ground water for irrigation

The pattern of use of ground water for irrigation is difficult to determine. Utilization figures are based on various agricultural censuses up to 1976 when an area of 178 344 ha was reported to have been irrigated from boreholes and wells. In the self-governing national states and the TBVC states either no irrigation from boreholes and wells takes place or it is insignificant. The largest portion of the total irrigated area is situated in the main drainage regions A, B, C, D, G, H and J.

From 1949 to 1976 the average increase in irrigated areas was four per cent per annum while for the period 1964 to 1976 the average growth was 4,9 per cent per annum. On the basis of these figures the area irrigated from boreholes and wells in 1980 is estimated to have been 215 000 ha. According to the agricultural censuses of 1959/60 and 1964/65, areas of 66 800 ha and 36 500 ha respectively were under private irrigation from springs, in addition to those being irrigated from boreholes and wells. If the area irrigated from springs in 1980 is taken to have been only 25 000 ha, the total area irrigated with ground water would have amounted to 240 000 ha. This estimate does not take into account the periodic use of ground water as a supplementary source on certain Government water schemes or by irrigation districts. It is also not certain to what extent fallow land and multi-crop cultivation in a single year influences the estimate.

There is no hydrogeological reason why the rate of 4,9 per cent per annum by which irrigation from boreholes and wells increased during the period from 1965 to 1976 cannot be maintained in the immediate future. The growth in the use of ground water of acceptable quality for irrigation is likely to be stimulated by the electrification of rural areas.

Rural domestic use and stock-watering

In general, ground water is obtainable to a greater or lesser extent throughout the country and rural domestic use and stock-watering can normally be supplied from this source. In those areas where ground water is scarce or chemically unsuitable for domestic use and stock-watering, it can often be obtained from other parts of a farm or from a source nearby. In this manner certain parts of the Kalahari with insufficient or brackish ground water are supplied from boreholes along the Koranna-Langeberg mountain range. Ground water in Kalahari beds along the Gamagara and Kuruman Rivers can also be developed for water supply to water-deficient farms. In other cases, desalination or the interception of rain in pans or artificially hardened catchment sites and storage in covered reservoirs or aquifers may be the answer to the relatively small demands of extensive farming.

Use of ground water by towns and industry

Although the contribution of ground water to the total available supply for urban and industrial use is relatively small at present, the lack of perennial rivers in the western two-thirds of South Africa will require the utilization of ground water on a more extensive scale.

Available information indicates that about 105 towns across the RSA are committed to using ground water sources exclusively, while an additional 15 towns use both surface and underground sources. It is very difficult to make a reliable estimate of the quantity of ground water that is being used by cities, towns and industry, because, with the exception of local authorities and a few other users, very few records are kept. On the basis of an assumed per capita water consumption of 75 m3/a, the estimated use of ground water by all these towns was 47 million m³ in 1980. In addition the Rand Water Board and the Municipality of Pretoria obtain approximately 26 million m3/a from dolomitic sources. The total estimated urban use is therefore approximately 73 million m3/a.

Notwithstanding the repeated water shortages experienced by many towns, investigations have shown that in general it is possible to obtain sufficient supplies from ground water sources on town commonages and on farms within a radius of 25 km. Depending on hydrological conditions, reliable ground water supplies of up to 5 million m³/a are possible, provided that water is not abstracted only from a single borehole or a few holes in a limited area, but from a range of holes spread over a wider area. The position at De Aar, discussed in Section 5.4.3, serves as an example.

In the drier parts of the country the ground water resources are usually smaller, but adequate

for meeting the demand of smaller towns. Desalination can be applied where sufficient ground water of poor quality exists, as in the vicinity of Garies (Section 3.6). The dolomites of the southern and western Transvaal can supply water on a larger scale, especially if their limited evaporation-free underground storage could be used in conjunction with stored surface water.

The lack of perennial rivers in the western two-thirds of South Africa will require the utilization of ground water on a more extensive scale.

Information on the potential of the dolomitic strata on the Ghaap plateau is inadequate at present. Investigations have shown that supplies of the order of several million cubic metres per annum could be achieved from the upper portion of the dolomite and the overlaying ironstone in certain places in the northern Cape, for example near Sishen-Kathu. Towns such as Griquatown and Vryburg are entirely or partly dependent on dolomitic ground water while Kuruman obtains water from the well-known 'eye' on the town commonage.

In addition to a shortage of funds for the development of boreholes, some rural towns experience the following difficulties in realizing the full potential of ground water sources:

- Ignorance regarding the development and management of ground water.
- Lack of reliable hydrological and geohydrological data.
- A lack of initiative in developing ground water sources.
- 4. Problems in obtaining ground water for town use from privately-owned property.
- An inherent aversion to dependence on an invisible source.

It may be possible to solve such problems with the assistance of an information programme, by amendments to the Water Act, 1956, (Section 8.4) and by greater financial assistance, especially to small communities.

It is estimated that mines and quarries pumped approximately 405 million m³ of water from workings in 1980. There is uncertainty as to how much of the water pumped was intercepted rainwater, seepage resulting from mining activities or underground water in the ordinary sense. It also is not certain to what extent the pumped water was utilized by the mining and quarrying industries before it was disposed of by evaporation or discharged to rivers.

3.5 The reuse of effluent

The reuse of effluent as a source of water will assume increasing importance in many areas of the country, particularly in areas of urban and industrial growth. For this additional source to be used to best advantage requires the purposeful management of effluent and not merely its incidental return to a river. The rate at which water reuse will increase relative to the rate of development of the remaining conventional water resources will be affected by socio-political considerations as well as by the economic implications for users. These factors are being studied at present. The potential for reuse by the urban and industrial sectors is also limited by the proportion of conventional resources that is allocated for direct consumptive use.

Although increasing reuse in an area reduces the rate at which water has to be imported from conventional sources, usually at high cost, it can give rise to water quality problems which limit the potential for further reuse. At present all reuse for potable purposes in the Republic of South Africa is indirect because purified effluent is first discharged to watercourses where dilution and a measure of natural purification may occur before the water is abstracted for subsequent use. Although techniques for reclamation and direct reuse for domestic purposes are now highly developed, such reuse nevertheless requires the approval of the Department of National Health and Population Development. Implementation of direct reuse is left to communities as an economic choice.

The discharge of effluent can alter the flow regimes and base flows of streams. The use of discharged effluent for irrigation by farmers who may consider it to be normal flow or surplus water to which owners of riparian land would normally be entitled will be restricted where necessary by the timeous institution of Government water control areas in terms of Section 59 of the Water Act, 1956 (Act 54 of 1956).

Planning for reuse

Effluent should be considered as a supplementary source of water that can be purified to different standards for various categories of use, such as irrigation, cooling, industrial use and potable supply. As the reuse of purified effluent makes equal volumes of fresh water available for domestic use, water requirements should be carefully evaluated on the basis of quantity and quality. Purification systems should at all times be able to produce water of the required quality on demand and as an economic substitute for fresh water supplies.

The following could be involved in a scheme for

the reuse of effluent:

- ☐ The user. His primary concerns will be those of quality, safety and availability. In most cases the user also discharges effluent to the sewer:
- ☐ The local authority. In most areas the local authority would be responsible for the effluent collection system, the purification plant and the distribution network.
- ☐ The provincial authority. This authority has to approve expenditure for purification schemes required by local authorities (Section 6.6).
- ☐ The health authority. Any purification scheme in

Effluent should be considered as a supplementary source of water that can be purified to different standards for various categories of use.

the RSA reclaiming water for direct industrial or potable reuse has to be approved by the Department of National Health and Population Development (Section 4.3).

- □ The water authority. In the RSA the compulsory return of treated effluent to the source of water is controlled under the Water Act, 1956, administered by the Department of Water Affairs. Purification and beneficial reuse of effluent requires a permit of exemption from compulsory return. Such permits are not withheld unreasonably (Section 4.3).
- ☐ The local water board, if any. This body is responsible for the supply and distribution of water and may become responsible for sewage purification and water reclamation (Section 6.10).

The activities or interests of the various parties concerned should be co-ordinated by a liaison committee which should be established as early as possible. Such a committee already exists for the Pretoria-Witwatersrand-Vereeniging (PWV) area. Committees are envisaged for the Border region, the Pietermaritzburg-Durban area and Cape Town metropolitan area.

The strict effluent discharge regulations promulgated in terms of the Water Act, 1956 (Section 4.3) have resulted in the construction of sophisticated waste water purification plants which discharge highly treated effluent. Such effluent is suitable for certain categories of reuse, but generally requires tertiary purification for direct reuse as potable water. The term 'effluent reclamation' is used here to describe tertiary purification to potable standard.

The increasing use of organo-chemical compounds which may have mutagenic, carcinogenic or teratogenic properties (Section 4.1) and which are present in effluent will necessitate the upgrading of conventional water purification works by the introduction of ozone, activated carbon filtration, osmosis or other processes so that water of acceptable, safe quality for potable use can be produced from raw water sources.

Technically it is possible to purify effluent to any desired quality. Since the cost of purification increases rapidly as higher effluent standards are achieved, it is not economical to provide a uniformly high quality of reclaimed water for all uses when lower qualities may suffice. Quality criteria based on health considerations are generally more stringent than those required for certain non-potable uses. Strict pollution control measures are necessary to maintain effluent quality within standards which permit further purification or reclamation at reasonable cost (Section 4.3).

An increasing demand for fresh water and the advent of effluent reclamation has highlighted the fact that in the past little consideration was given in town and regional planning to the integration of effluent sources and future water supply. Many cities throughout the world are situated in locations where they pollute either their own water supplies or those of others. It has therefore become essential for the following factors to be taken into account in the future planning of new cities and industrial townships:

- \Box The sources of fresh water supply.
- ☐ The points of discharge of sewage effluent.
- ☐ The required quality of such discharges.
- ☐ The possibility of effluent reclamation and reuse.

LEffluent purification schemes should no longer be looked at in isolation, since effluent reuse is now as much a part of water supply systems as other sources of surface or ground water.

Town planning and water management goals should be co-ordinated not only at local authority level but also at regional and national levels. Effluent purification schemes should no longer be looked at in isolation, since effluent reuse is now as much a part of a water supply system as other sources of surface or ground water.

The extent to which effluent reclamation can augment the potable supply in an area depends on how successfully a number of planning principles can be implemented. Co-ordination at the local authority level should provide for the following:

- ☐ Industrial effluent by-laws should be aimed at eliminating the discharge of intractable toxic or hazardous wastes into municipal sewers.
- □ Where feasible the sewers of industrial and residential areas should be segregated so that the respective effluents can be conveyed separately to effluent purification plants, particularly where reclamation is intended. Hazardous industrial effluent could then be excluded from the effluent to be reclaimed.
- □ Where separate sewers are not feasible, industries producing toxic and hazardous effluent should be so located that discharge of their effluent to common sewers is avoided and the



Effluent from a sewage treatment plant must be returned to the stream of origin

treatment and disposal of their effluent by alternative means is facilitated.

- □ Dual supply systems for industrial areas should be considered at the planning stage so that water of non-potable quality can be supplied to processes for which lower quality water can be used. Safeguards are required to ensure that users of potable water are not inadvertently supplied from the non-potable water system.
- □ Industries that produce highly saline effluent should be carefully sited, preferably near the coast. Where this is not possible, such industries should be required to isolate this effluent from less saline effluent and to treat it separately, and not to discharge it to sewers.
- ☐ It would be advantageous to site water-intensive industries within convenient reach of effluent purification facilities so that purified effluent could be utilized as intake water for industrial purposes.
- ☐ Municipal and industrial solid waste disposal sites should be so sited, constructed and protected that pollution of surface or ground water is prevented.
- □ Aquifers should be protected against pollution and considered for possible integration into future water reclamation schemes.

Direct and indirect reuse for potable supplies

The maximum allowable and recommended limits for total dissolved solids (TDS) in drinking water in the RSA are set out in the recently revised SABS Specification 241-1984. The limits are now specified in conductivity units for ease of measurement and repeatability of results. The conversion factor from conductivity to TDS de-

pends on the mineral constituents, but an average factor of 6,5 can be used to convert from electrical conductivity units in mS/m to TDS concentrations in mg/ ℓ . The maximum allowable limit is 300 mS/m or 1 950 mg/ ℓ .

A TDS limit is specified mainly for reasons of taste and the possible economic implications it has for domestic and industrial users. A high TDS concentration in water is an indicator of specific problem constituents and the limits are based on world-wide as well as South African experience and circumstances. While the maximum allowable limit represents a TDS concentration suitable for domestic use in extreme circumstances, the recommended limit of 70 mS/m is the ideal. SABS Specification 241-1984 makes the following statement concerning the application of the two limits:

'The recommended limit should, if possible, be applied to all water supplied for domestic use, and the maximum allowable limit should never be resorted to unless no other practicable water supply is available. In this case, steps should be taken to improve the quality in a reasonably short time by practicable technology.'

There are opposing schools of thought regarding the safest way to integrate reclaimed water with the potable water supply system. The first school reasons that direct integration is preferable and that higher standards of treatment and better control, which can be implemented at the reclamation plant, should theoretically produce safer water from the point of view of health. This school maintains that direct integration would be more desirable than the present practice of indirect reuse in which the effluent of cities and industries is discharged into rivers after secondary treatment and then abstracted and treated by conventional means to produce potable water.

Where water supplied is suitable for general purposes only, those industries that require water of a higher quality should install their own additional treatment facilities.

The second school maintains that the health risks associated with direct integration are still too high. This school believes that before the effluent is discharged to water sources it should be purified to a higher standard than that of the receiving waters and that the downstream purification facilities should be upgraded to give double protection. Dilution, self-purification and the natural death rate of organisms in the natural water environment is not accepted by this school as a

means of lowering the risks and the upgrading of water purification plants to include all the operations, processes and fail-safe procedures that are normally utilized for reclamation of effluent is advocated.

Reclamation and direct integration with potable water supply systems, using advanced purification plants, have definite advantages over indirect reuse. However, as there is a measure of psychological and religious resistance to the direct use of reclaimed water for potable purposes, the DWA intends to allow individual communities to phase in such facilities at their discretion. Where feasible, dual systems should be considered so that the highest quality of water may be reserved for potable purposes. However, such systems are generally only cost-effective in the case of industrial townships or other large water users. Where water supplied to an industrial township is suitable for general purposes only, those industries that require water of a higher quality, for example for steam generation and fine paper production, should install their own additional treatment facilities.

Examples of applications of direct domestic reuse: Windhoek and Cape Town

Early in the 1950s it became clear that Windhoek in South-West Africa would experience serious water supply problems by the end of the following decade and that additional sources would have to be found. In conjunction with the City Engineer, the National Institute for Water Research (NIWR) undertook research to reclaim the city's sewage. A full-scale 4 500 m³/d physico-chemical reclamation plant was designed by a South African firm of consulting engineers and commissioned in 1969. Windhoek became the first city in the world to use reclaimed effluent as potable water on a continuous basis. The reclaimed effluent is mixed with water from the Goreangab Dam. Between 22 per cent and 27 per cent of the city's drinking supply may eventually comprise reclaimed sewage effluent.

In 1970 the CSIR provided funds for the erection of a 4 500 m³/d reclamation plant at the NIWR experimental site at Daspoort, Pretoria. The Division of Physical-chemical Technology of the NIWR operated the plant as a research and demonstration unit from 1971 to 1979 with financial aid from the Water Research Commission (WRC). Research was done on the reclamation of two types of secondary-purified sewage effluent, namely biofilter and activated sludge effluent. The results were applied to improve the efficiency of the unit processes and operations, to reduce reclamation costs and to build multiple safeguards into the reclamation plant.

During 1978 the City Council of Windhoek extended their sewage purification works and adapted the reclamation plant on the basis of research done at Windhoek and at Daspoort.

Research at Windhoek and Daspoort is backed by extensive investigations into chemical and microbiological quality. The quality of the reclaimed effluent must at all times conform to the minimum specifications for drinking water determined by the South African Bureau of Standards (SABS Specification 241-1984). In Windhoek the quality of the reclaimed effluent was monitored continuously by four independent organizations, namely the NIWR, the City Council of Windhoek, the SA Institute for Medical Research (SAIMR) and the SWA Administration. In this system certain fish species were used in continuous bio-essay studies to indicate detrimental changes in the quality of the reclaimed water. In epidemiological studies no connection has been found between patterns of illness in

Windhoek and the use of reclaimed effluent. As the water complied consistently with drinking water criteria the SAIMR recently terminated its participation in the monitoring programme.

The addition of chemicals during physico-chemical effluent purification and reclamation processes increases the concentration of dissolved solids in the final product, thus diminishing the quality of the reclaimed effluent after repeated cycles of reclamation and reuse. At Bellville the NIWR accordingly investigated the application of the reverse osmosis desalination process for the reclamation of secondary-purified sewage effluent. This process also facilitates partial desalination of the reclaimed effluent. It was found that the application is technologically feasible and that water of a better quality than that produced by the physico-chemical effluent reclamation process is delivered at a cost that is only slightly higher. The Municipality of Port Elizabeth is also carrying out a pilot study on the same concept.

It is envisaged that reclaimed effluent will be used after the year 2007 to meet the demands of the Cape Peninsula (Section 5.3.2). Sewage purification is already undertaken on a regional basis to facilitate the integration of reclaimed effluent in the regional supply scheme. Sewage purified at the Athlone works contains a high percentage of industrial effluent and is destined for possible future industrial reuse, while the domestic effluent of the region will be purified at the new Cape Flats sewage works, possibly for unrestricted reuse in the future.

A prototype physico-chemical effluent reclamation plant was erected on the Cape Flats in 1982 to serve as a demonstration plant for the reclamation of activated sludge effluent under local conditions. With financial aid from the WRC, the City Council of Cape Town operates the plant and monitors the quality of the effluent from the various unit processes. The research is aimed at obtaining information concerning the possible application of full-scale effluent reclamation for the Cape Peninsula. The Department of Community Health of the University of Cape Town is at present engaged in an epidemiological study in Cape Town to determine ruling patterns of the incidence of illness. This will serve as a baseline for evaluation of future patterns should water be reclaimed for direct domestic use.

Another option that has been researched extensively by the NIWR is the possibility of artificially recharging the extensive Cape Flats aquifer with reclaimed sewage for later abstraction and purification. The ground water will first be exploited as a direct water source. A pilot scheme commenced in 1985.

Industrial reuse of effluents

A significant saving on fresh water intake and a reduction of the total demand for water can be achieved by recycling water in industy. Water of potable quality is used only for processes where it is essential and effluent is used in processes for which water of lesser quality is suitable. Valuable by-products can often be recovered from concentrated effluent. Research carried out by the NIWR has proved inter alia that water of a quality lower than that obtainable by conventional purification to potable standards could, without deleterious effect, serve as a bulk supply for textile wet processing. The results of this research are relevant to many other less sensitive manufacturing processes, particularly in industrial growth centres experiencing a shortage of water.

Examples of industrial applications

Most water in power-stations is used for cooling. After additional sand filtration and chlorination, secondary-purified sew-

age effluent has been used as cooling water at municipal power-stations in the RSA since 1938. Unfortunately this has not proved practical at Escom power-stations (Section 2.4).

Two-thirds of all non-mining industrial water is required for cooling. In industry purified effluent is used largely for cooling while partly purified effluent is used for the hydraulic conveyance of ash. Examples of this are the following:

- ☐ The Dunswart Iron and Steel Works at Benoni uses 1 700 m³/d of secondary-purified municipal sewage effluent in cooling and wash processes.
- ☐ The De Beers Diamond Mine at Kimberley uses 1 100 m³/d of purified sewage effluent as wash-water.
- ☐ Sasol uses 23 000 m³/d of partly purified effluent to convey ash from its power-station at Sasolburg. Purified effluent is used for cooling at Secunda.
- ☐ The gold mines near Welkom use 13 200 m³/d of purified sewage effluent as process water and for conveying sludge.

Pulp and paper factories use relatively large quantities of water, approximately 30 m 3 /t of product manufactured, depending on the process used and the type of paper manufactured. Two factories in Bellville, namely SA Board Mills and Nampak, use a combined total of 1 300 m 3 /d of purified sewage effluent derived from the Bellville sewage works after sand filtration and chlorination.

At Sappi's Enstra paper factory near Springs and the Mondi paper factory near Durban, where paper of high quality is produced, the physico-chemical technology developed by the NIWR for the reclamation of secondary-purified sewage effluent is being applied to produce water suitable for the manufacture of bleached paper. The Enstra factory is able to restrict its use of Rand Water Board water to 16 000 m³/d by using 27 000 m³/d of secondary-purified sewage effluent supplied by the Municipality of Springs. This also results in a considerable saving in water cost.

The Mondi paper factory is situated on an industrial site sold by the City Council of Durban to the company on condition that the factory uses 9 000 m³/d of secondary-purified municipal sewage effluent. A 12 000 m³/d plant for the tertiary purification of effluent was commissioned on the site in 1972. Thirty per cent of the water used in the factory is purified effluent and some of the factory's own effluent is also recycled to the tertiary purification plant. After recovery of paper fibre, the remaining effluent is discharged to the Durban Corporation's southern sea-outfall sewer.

At Iscor's steel works in Pretoria and Vanderbijlpark water of the best quality is used only in processes for which it is essential. The effluent from these processes is used where water of high quality is not required. Some statistics on water use at Iscor's Pretoria works are listed in Table 3.5.1.

Table 3.5.1: Water consumption at Iscor's Pretoria works to produce 4 200 t of steel per day

Water intake	21 300 m ³ /d
Water recycled	730 000 m ³ /d
Effluent discharged	4 100 m ³ /d
Water recycled per tonne of steel manufactured	$175 \mathrm{m}^3$
Water consumption per tonne of steel manufact	ured 5 m ³

Sasol manufactures liquid fuel from coal and produces a variety of other products at three complexes. Sasol I at Sasolburg has been in operation since 1955 and has a water intake of 63 000 $\rm m^3/d$, of which 31 500 $\rm m^3/d$ is returned to the Vaal River. Intensive recycling of process-water enables this plant to achieve higher production per unit of water consumed than would otherwise be possible.

Irrigation with effluent

Purified sewage effluent has been used for irrigation in South Africa for many years without any obviously harmful effect on crops and the soil. When evaluating the quality of water for agricul-

tural reuse the health aspects and the interaction of the purified effluent with the soil and the crops in question must be considered. The health aspects relate to the direct contact of humans or animals with purified effluent and to the consumption of irrigated fruit and vegetables.

Pathogens, whether viruses or bacteria, are able to survive for several days in most agricultural crops and hence present serious health risks. Health authorities therefore restrict the type of crop that can be irrigated with effluent of different standards of purity. Irrigation with effluent not complying with the general standard is permitted for industrial crops, seed crops, tree nurseries and vegetation not destined for human consumption in the raw state. Table 4.3.1 summarizes effluent standards applied in terms of the Water Act, 1956.

Continual irrigation of heavy clay soils with effluent containing suspended matter has been shown to clog the soil pores while irrigation of light sandy loam soils with similar effluent will improve the organic content of the soil and cause little clogging. Criteria for the suspended matter content of effluent to be used for irrigation should therefore be based on local soil conditions. The salinity and sodium content of effluent also requires careful consideration.

The application rate of effluent should be evaluated carefully in laboratory tests on soil samples from the area to be irrigated to ensure that inferior quality water does not seep into potable water aquifers. Irrigation in dolomitic areas should be restricted, particularly if ground water is abstracted for potable supplies in the vicinity of the irrigated area. Any economic value of nutrients in the effluent is determined by crop response under local conditions. Unless neutralized, acid sulphate effluent from the mining industry is toxic to almost all plants.

Estimates of reuse

The distribution of known and expected return flows available for reuse is illustrated in Fig. 3.8.2 and Table 3.8.2. Tentative estimates of future reuse were compounded from a low potential reuse of irrigation return flows (generally below 10 per cent) and higher reuse of urban and industrial return flows (up to 60 per cent) in at most two cycles of reuse. The findings of special studies in the major metropolitan areas have also been taken into account in the estimates.

The values given, as in the case of Fig. 3.8.2 and Table 3.8.2, should be regarded as provisional and illustrative rather than firm. The reliability of estimates of the potential for reuse should improve markedly in future as a result of more detailed investigations currently in progress.

Tables 3.5.2 to 3.5.7 give data on reuse.

Table 3.5.2: Standards for irrigation with reclaimed waste water in South Africa

	PS	PST	STD	SP- STD	OD
Crops eaten raw					
Lawns (children associated)	•	•	•	Ø	•
Cut flowers		+	Ø	Ø	+
Crops not eaten raw		•			
Fruit trees and vines		+	Ø	Ø	+
Pasturage (not for cows)		+	Ø	Ø	+
Pasturage (milk cows)		•	Ø	Ø	•
Dry fodder crops Seed production Timber plantations Nurseries	+	Ø	Ø	Ø	+
Sports fields:					
Developmental stage	+	Ø	Ø	Ø	+
Non-contact	+	+	+	Ø	+
Contact	•	+	+	Ø	+
Schools		+	+	Ø	+
Parks:					
Developmental stage	+	Ø	Ø	Ø	+
Non-recreational	+	+	+	Ø	+
Public		+	+	Ø	+

Code abbreviations:

- Ø Use permitted without restriction
- + Use permitted with restriction
- Use not permitted

Classification of treated effluents:

- PS Primary and secondary treatment. Humus tank effluent.
- PST Primary, secondary and tertiary treatment.
- STD Effluent measures up to General Standard (i.e. Nil E.coli/100 mℓ)
- SP-STD Advanced treatment measures up to the Special Standard and the quality measures with general drinking water standards.
- OD Oxidation dams with effluent with less than 1 000 E.coli/100 m ℓ

Table 3.5.3: Heavy metal limitations for continuous irrigation (mg/ ℓ)

Metal	Germany	USWPCA* (1968)	EPA** (1972)
Iron (Fe)			5,0
Lead (Pb)		5,0	5,0
Zinc (Zn)	2,0	5,0	2,0
Nickel (Ni)	0,5-1,0	0,5	0,2
Copper (Cu)	5,0	0,2	0,2
Manganese (Mn)	_	2,0	0,2
Chrome (Cr)		5,0	0,1
Cadmium (Cd)		0,005	0,01
Lithium (Li)		5,0	2,0
Aluminium (Al)	-	1,0	5,0
Arsenic (As)	0,3	1,0	0,1
Cobalt (Co)	0,5-1,0	0,2	0,05
Boron (B)	0,3	<u>-</u>	0,7
Fluorine		Martina - miles	1,0
Selenium	1 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1	-	0,02

^{*}United States Water Pollution Control Association

The potential for reuse by the urban and industrial sectors is limited by the proportion of conventional sources used consumptively. The effects of a reduction in direct consumptive use and an increase in the percentage of reuse may be very considerable. A theoretical illustration of the principle is given in Table 3.5.8, which shows the relative gains obtained by reducing the quantity made available to agriculture for direct consumptive use as well as the effect of varying the percentage of indefinite reuse, assuming an availability of 33 000 million m³.

Table 3.5.4: Suggested critical limits for domestic effluent used for irrigation in Israel

Composition	Sensitive crops	Tolerant crops				
Electrical conductivity		THE STREET				
(micromhos/cm)	2 000	3 000				
Chloride (mg/ ℓ)	200	450				
Sulphate (mg/ℓ)	300	500				
Boron (mg/ ℓ)	0,7	2,5				
SAR value	8	15				

Table 3.5.5: Mineral quality requirements for agricultural use

Agricultural use	Total dissolved solids (mg/ ℓ)	Remarks
Crops	< 500	Satisfactory for all crops
	500 – 1 000	Water that can have detrimental effects on sensitive crops; additional water may be required for leaching
	1 000 – 2 000	Water that may have adverse effects on many crops and thus requires careful application practice
	2 000 – 5 000	Water that can be used for tolerant plants on permeable soils with careful management practice
Livestock	2 500* - 5 000†	*Threshold value at which poultry or sensitive animals might show slight effects from prolonged use
		†Animals in lactation or production might show definite adverse reaction.

Table 3.5.7: Crop sensitivity

Sensitive

Citrus, pears, almonds, peaches, apricots, apples, beans, cabbage, potatoes, sweet potatoes, egg plant, celery

Moderately tolerant

Grapes, figs, olives, pomegranate, lucerne, tomatoes, sorghum, winter cereals, rice, sunflowers, lettuce, carrots, parsnips, squash, onions

Toleran

Beet, rape, kale, cotton

^{**}Environmental Protection Agency

Table 3.5.6: Daily volumes of sewage effluent reused for irrigation in South Africa

Locality	Total volume	Volume reused	% of total	Past	Pasture Crops		Parks	Trees	Sports fields	Disposal rate
	available (m³/d)	(m³/d)	reused	Volume (m³/d)	area (ha)	(m³/d)	(m³/d)	(m ³ /d)	(m ³ /d)	(m ³ /d)
Johannesburg	317 800	113 500	35,7	113 500	1820					62
Cape Town	143 000	500	0,3	Part I		44 5 6 4		projection to	500	
Pretoria	86 000	16 500	19,2				200	16 300		
Port Elizabeth	88 000	6 800	7,7						6 800	
Germiston	52 600	8 000	15,2			8 000				
Bloemfontein	25 000	300	1,2	100		200			100	
Benoni	20 400	2 000	9,8			400	1 000		600	
Pietermaritzburg	27 300	6 800	24,9					6 800		
Kimberley	8 000	1 600	20,0			A Vittin I			1 600	
Carletonville	4 500	4 500	100,0					4 500		
Krugersdorp	17 000	13 600	80,0	13 600	100					
Klerksdorp	5 800	5 800	100,0			5 600			200	197 18
Randfontein	4 500	1 400	31,1	1911	,	1 400				
Grahamstown	2 300	2 300	100,0	1000		2 300				
Worcester	5 900	5 900	100,0	5 900	150	44.25	Section of the	Laborate State		39
Westonaria	6 800	6 800	100,0			6 800			The state	
King William's Town	2 300	2 300	100,0	1 400	77				900	18
Total	817 200	198 600		134 400		24 700	1 200	27 600	10 700	
Percentage			24,3	67,7		12,4	0,6	13,9	5,4	
Industries										
Ngodwana Pulp and		-								
Paper		1 300		1 300	54					24
AECI Modderfontein		1 100			1 028					1

Table 3.5.8: Theoretical illustration of the effect of a decrease in irrigation use and reuse of return flow from urban and industrial users on the total availability of water

Pro- portion allocated to irrigation	(1) Available water resources* (million m ³ /a)		(2) Water for irrigation (million m ³ /a)		(3)=(1) - (2) Available for urban and industrial use (million m³/a)		(4) Return flow from urban and industrial users**	(5) Reuse factor after infinite number of use cycles***	(6)=(3)x(5) Total available water for urban and industrial use		Total v res	=(2)+(6) available vater sources	(8)=(7)/(1) Extent to which total resources exceed natural availability
							(%)	(%) (million		million m ³ /a) (million		ion m ³ /a)	
1/2	100	33 000,	75 50	24 750	50	8 2 5 0	40 50 60 70 80 40 50 60 70 80	1,67 2,00 2,50 3,33 5,00 1,67 2,00 2,50 3,33 5,00	42 50 63 83 125 84 100 125 166 250	13780 16500 20625 27475 41250 27555 33000 41250 54950 82500	117 125 138 158 200 134 150 175 216 300	38 530 41 250 45 375 52 225 66 000 44 055 49 500 57 750 71 450 99 000	1,17 1,25 1,38 1,58 2,00 1,34 1,50 1,75 2,16 3,00
1/4	100	33 000	25	8 2 5 0	75	24750	40 50 60 70 80	1,67 2,00 2,50 3,33 5,00	125 150 187 250 375	41 335 49 500 61 875 82 420 123 750	150 175 212 275 400	49 585 57 750 70 125 90 670 132 000	1,50 1,75 2,12 2,75 4,00

Effect for an illustrative unit of 100 million m^3/a of available resources shown in highlight.

- * With the present state of knowledge and technology approximately 33 000 million m³ of the mean annual runoff can be exploited economically (Section 1.1).
- ** Return flow from urban and industrial users which can be reused. The balance is used consumptively.
- *** The total amount of water that can be used per unit of original resource calculated as follows:

Factor =
$$1 + p + p^2 + ... + p^{(n-1)} = (1 - p^n)/(1 - p)$$
, with

p = return flow from urban and industrial users expressed as a fraction and n = number of use cycles.

3.6 Water from unconventional sources

Unconventional sources can be used to augment the total water supply. The tapping of such sources involves techniques such as direct and indirect reuse, desalination, rainfall augmentation, reduction of evaporation from water in storage, exploitation of icebergs, abstraction of moisture from the atmosphere and water harvesting. Apart from reuse none of these options are in use on a significant scale in the Republic of South Africa at present.

Reuse

Reuse, the only source considered to be unconventional and used on a significant scale at present, particularly in industry, is dealt with in Sections 3.5 and 4.3.

Desalination

The oceans can supply unlimited quantities of water, but existing desalination techniques are energy-intensive and are not yet competitive in cost with alternative supplies. Desalination is an attractive method to increase the number of cycles of reuse of water in industry and mines and may also be used to reduce the mineral content of brackish ground water where this is the indicated source for small communities in remote areas.

Desalination techniques, including distillation, electrodialysis, reverse osmosis, ion exchange and freezing, are suited to removing dissolved solids from waste water to render the water more suitable for recycling. Their application in the purification of industrial effluent is growing at a rapid rate, while the efficiency of the processes is continually being improved.

There is limited scope for the economic desalination of seawater and brackish water for domestic and industrial water supply at present. Possible sea-water applications are small-scale plants to meet seasonal peak water demands at holiday resorts in dry areas and the requirements of isolated mining communities. Desalination of brackish water may find application at a number of small communities such as Garies (Section 3.4). Larger towns such as Graaff-Reinet and Beaufort West may in due course have to rely on desalination to augment existing water supplies but most probably only after the turn of the century.

The prospects for the use of reverse osmosis for water recla-

Existing desalination techniques are energy-intensive and are not yet competitive in cost with alternative supplies.

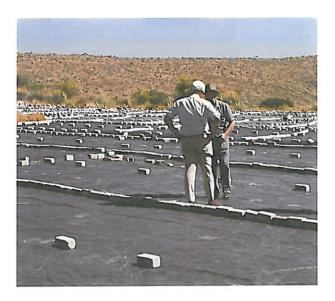
mation from effluent are promising and a few small to medium-sized plants could be established before the end of the century. In the dolomitic areas, e.g. at Kuruman, Sishen, Lichtenburg and Ottoshoop, where total dissolved solids (TDS) concentrations of between 400 mg/ ℓ and 500 mg/ ℓ occur with hardness exceeding 60 per cent of the TDS (mainly as temporary hardness) water can be softened by lime treatment or ion exchange. The hardness could be reduced by between 70 per cent and 80 per cent, producing a water suitable for hot water systems, low pressure boilers and human consumption.

The area in which the most extensive application of desalination technology can be expected is the treatment and desalination of industrial and mining effluent to prevent pollution, to purify effluent for recycling and to recover useful products from concentrated effluent. The power generation, chemical, iron and steel, pulp and paper, textile, mining, food manufacturing and processing and hides and skins industries are using these technologies or could be using them.

Research and development on desalination, particularly membrane processes, is being actively pursued in South Africa with the support of the Water Research Commission (WRC) and the transfer of technology is taking place at an increasing rate. One South African company is already manufacturing tubular reverse osmosis membranes, modules and equipment. Desalination is being applied in industry for a variety of purposes, demineralization for high-pressure boiler feed being one of the major applications.

The problems of large-scale brine disposal have important economic implications. In coastal areas sea disposal is easy and relatively cheap. In inland areas special care must be taken to prevent the pollution of water supplies as a result of runoff, leaching from brine disposal sites or seepage from solar evaporation ponds. Wind-blown sprays around evaporation ponds add to diffuse salt loads in storm runoff.

Commercially available desalination processes include the following:



Rainfall harvesting from a small catchment

- \square Distillation by evaporation and subsequent condensation.
- ☐ Reverse osmosis using membranes under pressure.
- \square Electro-dialysis using membranes and electric currents.
- \square Ion exchange using resins.
- \square Freezing.

Each process has its own feed water quality and operation and control requirements and its own performance and cost characteristics. Distillation is the oldest process and has the largest existing installed capacity. Ion exchange is the most widely used process in South African industry.

Vast areas in the dry north-western, central and south-eastern parts of the RSA are sparsely inhabited, mainly by farming communities and other small settlements and towns which rely on ground water sources for their water supply (Section 3.4). Their ground water supplies are generally brackish with TDS concentrations of more than 1 000 mg/ ℓ . Unfortunately the low levels of socio-economic development in these communities (Section 6.16) and the relatively high cost of desalination limits the potential for the use of ground water. The following communities are experiencing or expecting water supply and quality problems: Bitterfontein, Brandvlei, Garies, Kamieskroon, Kharkams, Nuwerus, Rietpoort, Van Wyksvlei, Kenhardt and Williston.

Numerous farming settlements have to rely on rain-water collected from roofs and on available brackish water. Desalination plants for such communities must be simple, robust, easy to operate and maintain and the cost should not be exorbitant. Electrodialysis and reverse osmosis units fulfil these requirements. The type of process should however be carefully selected, taking into account the constituents in feed water. Impartial technical evaluation of the equipment best suited to the quality of feed water is recommended. Regular technical inspection and service back-up is a prerequisite to prevent irreversible damage to membranes and equipment.

Solar distillation systems are suitable for farms and isolated single households. Design guide-lines have been developed for these systems of limited capacity. Solar energy is utilized to evaporate water, which is then condensed on a transparent inclined cover with collection troughs at the lower side. The large surface area required for a relatively low rate of production of desalinated water renders these units unsuitable for commercial water supply systems.

Desalination of sea-water on a significant scale will probably not become a reality until after the turn of the century. While it could already be used for emergency water supply, the relatively high cost at present, varying from R2,50/m³ to R4,00/m³, currently renders this system unattractive for large-scale applications. Considerable research into appropriate desalination technology is being undertaken by several bodies in South Africa at present.

Rainfall augmentation

The increase of runoff through rainfall stimulation is at present regarded by some scientists as the only large feasible source of additional water in the interior of South Africa. Despite ample proof that rainfall may be stimulated through cloud seeding and the existence of a number of research programmes throughout the world, the knowledge gained has not yet been translated into practical water resource augmentation programmes, except in northern Israel. The results of the research undertaken in many countries have shown clearly that the dominant rain-producing mechanisms in cumulus clouds change markedly from one area to another. As a result atmospheric scientists are in agreement that it is necessary to develop a seeding technology that is suited to the specific local conditions before an attempt is made to change the rainfall in a randomized experiment.

The reliable enhancement of precipitation or the suppression of hail on demand remain distant goals. However, great interest is being shown in the new South African experiment.

There has recently been a slump in weather modification research in the United States of America, which was the leader in this field for a long time, but at least 43 research projects are operating outside the USA. The complexities of atmospheric processes are being increasingly appreciated and there is a growing emphasis in the international scientific community on basic, step-by-step research. Although chances for sudden spectacular breakthroughs are small, no water deficient country should ignore the possibility of ultimate success. A recent upswing in research in the RSA is viewed with great interest by the international weather modification community.

Two major rainfall stimulation projects are currently operating in the RSA, one in the Bethlehem and the other in the Nelspruit region. The Bethlehem project (BEWMEX) which was started in the mid-seventies to determine whether rainfall could be artificially enhanced, is located in the Upper Wilge River catchment and any success it achieves may incidentally benefit the Vaal Dam. The agricultural community is also showing increasing interest in the possible benefits to dryland farming during critical stages of the agricultural season or in dry years. In the past the programme has been hampered by staff problems but these are gradually being overcome with the assistance of the WRC. Leading advisers from Israel and the USA have commented favourably on progress with this project.

A new rainfall stimulation reseach programme was recently launched by the WRC in the Nelspruit region. This succeeded a commercial hail suppression operation funded by the Laeveldse Koöperasie Beperk of Nelspruit, from which much of the scientific equipment for rainfall stimulation research was pur-

chased by the WRC. The project has very strong scientific support from the USA. The aim of the first four-year phase, which will cost about R7 million, is to determine whether there is a seeding potential along the escarpment of the Lowveld and to develop a suitable seeding technology for the area. If such a potential is established it will have to be proved by further phases of research with randomized seeding and confirmatory experiments.

The biggest problem besetting weather modification is the large natural variability and the highly skewed distribution of events, i.e. a few storms may produce most of the precipitation. With the known shifts in average precipitation from decade to decade in South Africa and with the multitude of factors in the synoptic, meso and cloud physical scales that influence cumulus cloud formation, the possibility of exploiting results of past experiments is almost negligible. New techniques such as those being employed at Nelspruit and Bethlehem are necessary.

It is impracticable to modify weather by competing directly with the energies prevailing in the atmosphere, except on a local scale. There is little evidence that precipitation, hail, lightning or wind can be modified artificially to any significant degree. It is now realized that the complexity and the variability of clouds makes it very difficult to understand and to measure the effects of attempts at artificial modification. Some of the optimism of the 1950s has therefore given way to a more cautious approach.

As knowledge of cloud physics and its applications to weather modification has increased, new assessment criteria have evolved for evaluating cloud seeding experiments. The development of equipment such as airborne platforms with microphysical and air-motion measuring systems, radar, satellites, rain-gauge networks and mesoscale network stations has introduced new dimensions. Equally important are advances in computer systems that permit large quantities of data to be processed. New data sets, used in conjunction with increasingly sophisticated numeric cloud models, help in testing various weather modification hypotheses. In most cases experiments must run for several years to achieve statistically significant results.

Viewed from these perspectives, most of the past weather modification experiments are considered inconclusive and the reliable enhancement of precipitation or the suppression of hail on demand remain distant goals. As many reputable scientists have left the field, great interest is being shown in the new South African experiment, which could provide badly needed continuity in world-wide weather modification research and enable American researchers to use their most recent findings and experience in the design and evaluation of the new experiment.

In the USA and in Australia funds for experimental programmes have dwindled, although the USA is making a serious effort to return to the mainstream of activities. Apart from snow-pack enhancement programmes in the USA, only the Israeli experiments, which have led to an operational precipitation enhancement programme in an area where climatic conditions are favourable, are generally accepted as conclusive. Research has declined because of underestimation of the magnitude and complexity of the natural variability of cumulus systems, over-optimism after apparent initial successes, premature evaluation through early media involvement, deception of the public by commercial practitioners and loss of reputable scientists from the field as a result of dwindling funds.

The South African and Israeli experiments may be the last hope for progress during the next few decades. If the results are promising, a national weather modification policy with clear objectives will be formulated to ensure the compatibility of further research with the national water management strategy, which also takes account of non-meteorological issues such as benefit-cost considerations, environmental impact and social issues such as public acceptability.

Based on progress with the present programmes and assuming success in every phase, an operational programme to augment water resources cannot be contemplated before the turn of the century. With the high expenditure involved, close integration of the two South African weather modification projects is deemed advisable.

Suppression of evaporation

Extensive experimentation with evaporation suppressant films applied to large water surfaces in dams has provided little hope of finding economically viable and practical techniques for routine application. Evaporation losses can be minimized by storing water in dams with more favourable reservoir characteristics, e.g., in the Sterkfontein Dam upstream of the Vaal Dam rather than in the Vaal Dam itself. The storage of water in underground dolomite compartments has limited possibilities, but it may reduce evaporation if technical problems such as recharge, prevention of pollution and withdrawal can be overcome (Section 3.4).

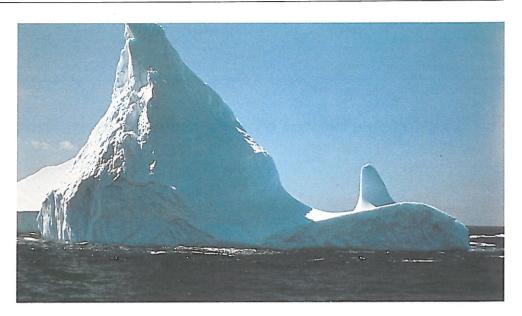
Research on evaporation in the RSA has been confined to chemical evaporation suppressants of the fatty alcohol group, such as cetyl and stearyl alcohols, of which the long-chain molecular structure is such that partial suppression of evaporation is achieved through the development of a mono-molecular layer on the water surface. The advantages of this type of suppressant are the powerful spreading properties of the layer or film, its self-healing properties when ruptured, the ease with which it can be applied and the fact that it has no harmful effect on the quality of the water and need not interfere with the use of the water for sport and recreation. Application can be suspended at will when conditions are such that little benefit would be derived from evaporation control. The main disadvantages of these chemicals are the fragility of the film, the fact that it drifts with the wind and its decay after a few days. mainly through bacterial action.

During large-scale evaporation suppression experiments on the Vaal Dam in the 1960s, various effects were observed which led to the abandonment of further large-scale attempts until justified by new developments or special circumstances. Evaporation suppression of up to 61 per cent was observed in pan experiments in which the surface was covered with various types of long-chain molecules. However, the rate of suppression depended on the size of the area covered and this was in turn influenced by wind effects and thermal currents which could not be controlled on a large scale. The surface layer thus had to be renewed continually, which proved to be uneconomic. Surface layers increase the temperature of the underlying water by preventing latent heat loss, which causes higher evaporation in adjoining open areas. This cannot be avoided on large surfaces under natural conditions.

Observed decreases in evaporation loss were smaller than the accuracy of measurement obtainable in calculating the dam water balance. The DWA is monitoring new developments in the field of evaporation suppression and will resume experiments as soon as there are signs that the mobility of the suppressant layer can be controlled. To be effective, an evaporation suppressant requires both evaporation suppressing and solar radiation reflectant properties.

Icebergs

Some 80 per cent of the world's fresh water is locked up in polar ice. Its utilization is a matter of economics, time and the development of appropriate technology. Too little is yet known about the possibilities, techniques and problems of exploiting icebergs as a source of water, and because international opinion is divided on whether icebergs belong to the international community or not, the DWA is not actively investigating this source at



Icebergs are a potential source of water

present. It is, however, monitoring international developments.

Although several world conferences have been held and feasibility studies have been carried out, the present lack of information on the science and logistics of iceberg exploitation still prevents an accurate prediction of the cost and likelihood of success of a large-scale Antarctic ice-harvesting operation.

Apart from non-technical, usually intractable, factors such as world politics and the law of the sea, navigational hazards, military strategy and the vagaries of currents and the weather, the purely technical and logistic expertise needed still seems to be lacking despite studies having been made. It is known, for instance, that effective surveillance of suitable iceberggathering areas can be carried out by satellite and that suitable Antarctic icebergs exist but that the southern circumpolar ocean is a very inhospitable environment for more than half the year, with pack-ice, gales, drift currents and high seas contributing to the grim and chilly conditions.

The towing of large icebergs by super tugs, preferably nuclear-powered, is still untried, and a small-scale exercise would be required. Factors such as the melting rate, tilting, Coriolis effects and current, wind and wave effects, drag and added mass and upwelling need to be investigated. A journey time of several months, including some weeks for accelerating a large berg to a towing speed of about one knot, would be involved. The docking of icebergs, hundreds of metres thick, in suitable deep-water harbours would appear to be out of the question, unless the icebergs were first subdivided by mechanical means or with the aid of lasers. An alternative might be to transport suitably-sized ice blocks from Antarctica in bulk carriers. The ecological impact on the region where the ice is landed would also have to be determined.

The recovery of water from the ice mass, suitably docked or grounded offshore, is a major problem that requires investigation. Techniques such as melting by solar or waste heat, grinding and slurry pumping by floating or submerged pipelines to shore have been investigated superficially. It may also be possible to transfer the fresh water from an iceberg grounded somewhere out on the Agulhas Bank to shore by tanker. The water would require some treatment, but possibly only chlorination.

Abstraction of moisture from the atmosphere

Direct abstraction of moisture from the atmosphere is possible by using methods such as hygroscopic chemicals and mechanical cooling below the saturation temperature. Experiments carried out on the use of condensation screens at Mariepskop, just east of the Blyderivierpoort Dam, between 1969 and 1975 have shown that about 450 ℓ/m^2 per month could be abstracted from a vertical screen at right angles to the prevailing

*Innovative local methods of water harvesting require emphasis and encouragement.**

wind. These are small-scale methods limited to supplying single households located in a very few suitable areas of the country. Although their practical feasibility has been demonstrated, the application of a particular method will depend on the cost of obtaining water from alternative conventional sources where these are available.

Water harvesting

In addition to the collection in tanks of rain from roofs, several methods for small-scale water harvesting have been suggested from time to time. These consist of the use of impervious surfaces such as concrete and plastic sheeting on, or the application of water repellent chemicals such as silicone compounds or paraffin wax to, the soil surface. Such methods are suited to the requirements of cattle and sheep farming. They are simple to apply but their feasibility is primarily a matter of economics. Storage of harvested rain-water underground in porous or fractured permeable formations from which it could again be abstracted by pumping could make rain harvesting more economically feasible as it would eliminate the cost of constructing covered reservoirs for storage. Innovative local methods of water harvesting require emphasis and encouragement.

3.7 The importation of water from neighbouring states

When the limited total surface and ground water resources of the Republic of South Africa have been exploited to the practical and economic limit of reuse, water supply could be augmented by desalination, rainfall stimulation or the development of other unconventional supply techniques. The importation of water from neighbouring states may also prove attractive should the political climate for sustained co-operation be favourable. Negotiations are currently proceeding with Lesotho for a joint scheme to divert the headwaters of the Upper Orange River to the Pretoria-Witwatersrand-Vereeniging (PWV) complex.

By the middle of the 21st century the water shortage in the Vaal-Olifants-Limpopo catchment area may exceed 8 000 million m³/a, while the combined quantity that can be imported from the Tugela and Orange Rivers will probably be less than 4 000 million m³/a. The deficit of 4 000 million m³/a could be imported from neighbouring states. The technical feasibility of conveying water from the Okavango and Zambezi Rivers, to which the RSA is not entitled as it is not a basin state (Section 8.1), has already been established in broad terms. However, ecological considerations and the fact that many other states in Southern Africa, such as South-West Africa, Angola, Zambia, Zimbabwe, Mozambique and Botswana, also have an interest in these resources, could put an upper limit to the feasible rate of abstraction.

Excess water from the Umzimvubu River in Transkei could also be pumped to the upper reaches of the Orange River, from where it could be delivered to the PWV area via the proposed Lesotho Highlands Project, or water from the Transkei could be directed westwards towards the Border area. While there are no detailed plans at present, such options are being kept in mind for implementation in a favourable economic and political climate.

The Okavango River rises in Angola and forms the border between that country and SWA before entering Botswana and spreading out to form the Okavango Delta. Where it enters the Delta the Okavango River has a mean annual runoff of 11 000 million m³. On average only two per cent of this emerges from the Delta into the Boteti River. The remaining 98 per cent is lost from the swamps through evapotranspiration. The swamps are an extremely valuable and sensitive ecosystem in an almost virgin condition, which conservationists are anxious to preserve despite the water needs in Botswana and South Africa. However, a portion of the inflow could probably be abstracted without significant environmental impact.

The mean annual runoff of the Zambezi River at Cahora Bassa in Mozambique is about 88 000 million m³. Except for power generation at the Victoria Falls, Kariba and Cahora Bassa, little use is made of this water at present. If agreement could be reached with the basin states, substantial quantities could be abstracted for use in Botswana and South Africa. It is unlikely that a supply to Botswana would be economic without the advantages of scale associated with a joint scheme to meet the needs of South Africa too. The power needs of such a project could stimulate large-scale development of the coalfields in Botswana and provide that country with cheaper electricity.

TABLES AND GRAPHS

3.8 Tables and graphs of estimates of water availability from each source from 1980 to 2010

Table Figure		Figure Description					
3.8.1	_	Mean annual surface runoff (natural MAR) and utilizable MAR in 1980					
-	3.8.1	Mean annual surface runoff					
3.8.2	3.8.2	Estimated mean annual ground water abstraction					
3.8.3	3.8.3	Estimated mean annual return flow					
3.8.4	3.8.4	Estimated mean annual total available water					
3.8.5	_	Estimated mean annual total utilizable water					
_	3.8.5	Estimated mean annual total available water per source for 1980					
3.8.6	3.8.6	Estimated mean annual intentional evaporation and disposal of poor					
	000000000000000000000000000000000000000	quality water					

Note: Values given in this set of tables have been rounded off to the nearest whole number. Slight discrepancies between items and associated totals and grand totals are due to inaccuracies resulting from truncation and the rounding-off of values. Subsequent editions of this publication will give values to a higher accuracy.

Table 3.8.1: Mean annual surface runoff (natural MAR) and utilizable MAR in 1980 (million m^3/a)

Region	Surface MAR	Utilizable MAR	Utilizable % of MAR
Α	2 290	936	41
В	3 190	1 605	50
C	4 487	2 149	48
D	7 570	5 757	76
E	1 015	586	58
F	110	4	4
G	2 158	1 033	48
H	1 954	1 262	65
J	539	228	42
K	1 372	812	59
L	504	313	62
M	129	52	40
N	200	71	36
P	102	34	33
Q	529	204	39
R	601	387	64
S	1 064	662	62
T	8 501	5 104	60
U	3 174	2 563	81
V	4 589	3 310	72
W	5 894	3 484	59
X	3 554	2 398	67
Total	53 526	32 954	62

Table 3.8.2: Estimated mean annual ground water abstraction (million m³/a)

Region	1980	1990	2000	2010
Α	361	382	406	432
В	170	205	215	226
C	526	585	657	757
D	163	187	218	253
E	22	22	23	23
F	6	6	6	6
G	84	90	97	104
H	113	113	113	113
J	55	56	58	59
K	10	12	14	16
L	25	28	31	36
M	6	6	6	6
N	32	34	36	39
P	4	5	6	7
a	37	44	51	59
R	8	12	16	20
S	17	26	34	40
T	79	89	103	120
U	7	7	7	7
V	13	13	13	13
W	26	26	26	26
x	19	21	23	24
Total	1 783	1 969	2 159	2 386

Table 3.8.3: Estimated mean annual return flow (million m^3/a)

Region	1980	1990	2000	2010
A	196	263	414	666
В	75	76	79	81
C	458	669	1 079	1 518
D	133	151	194	209
E	101	103	114	117
F	1	1	1	1
G	87	120	166	206
H	5	7	9	10
J	49	49	49	49
K	4	7	10	13
L	9	10	11	12
M	22	35	50	72
N	14	16	20	26
P	3	4	5	8
Q	33	40	50	55
R	13	23	46	68
S	22	26	29	32
T	41	44	49	56
U	32	32	32	32
V	8	11	15	23
W	6	7	7	8
X	8	11	11	12
Total	1 320	1 704	2 440	3 274

Table 3.8.4: Estimated mean annual total available water $(MAR + estimated \ return \ flow + estimated \ ground \ water \ abstraction) \ (million \ m^3/a)$

Region	1980	1990	2000	2010
A	2 847	2 935	3 110	3 388
В	3 435	3 471	3 484	3 497
C	5 471	5 741	6 223	6 762
D	7 866	7 908	7 982	8 032
E	1 138	1 140	1 152	1 155
F	117	117	117	117
G	2 329	2 368	2 421	2 468
H	2 072	2 074	2 076	2 077
J	643	644	646	647
K	1 386	1 391	1 396	1 401
L	538	542	546	552
M	157	170	185	207
N	246	250	256	265
P	109	111	113	117
Q	599	613	630	643
R	622	636	663	689
S	1 103	1 116	1 127	1 136
T	8 621	8 634	8 653	8 677
U	3 213	3 213	3 213	3 213
V	4 610	4 613	4 617	4 625
W	5 926	5 926	5 927	5 928
X	3 581	3 586	3 588	3 590
Total	56 629	57 199	58 125	59 186

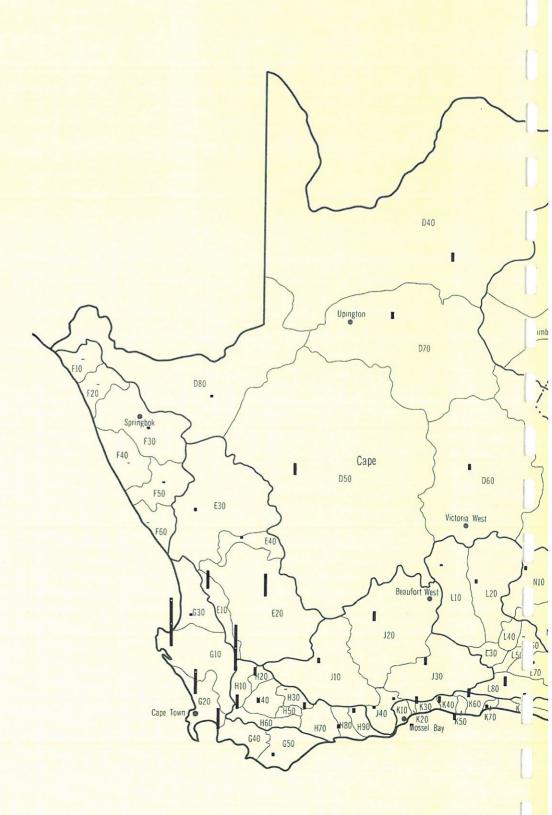
Table 3.8.5: Estimated mean annual total utilizable water (utilizable MAR + estimated return flow + estimated ground water abstraction) (million m³/a)

Region 1980 1990 2000 2010 1 786 2 065 1 493 1 589 В 1 850 1 883 1 894 1 908 C 3 133 3 402 3 934 4 458 D 6 053 6 074 6 146 6 182 E 709 678 675 688 F 11 10 9 G 1 204 1 236 1 335 1 443 Н 1 380 1 350 1 317 1 338 J 332 334 335 338 K 826 820 846 842 L 347 347 355 361 M 80 91 103 128 N 117 120 121 87 P 46 49 41 44 Q 274 287 304 317 R 408 422 448 474 S 701 714 726 734 T 5 279 5 224 5 237 5 256 2 501 U 2 602 2 502 2 601 V 3 331 3 333 3 331 3 337 W 3 509 3 411 3 418 3 516 X 2 425 2 428 2 4 1 9 2 4 1 9 36 057 36 420 37 401 38 362 Total

Table 3.8.6: Estimated mean annual intentional evaporation and disposal of poor quality water (million m^3/a)

Region	1980	1990	2000	2010
A	44	45	45	45
В	57	60	62	62
C	408	409	360	376
D	5	7	8	9
E	0	0	0	0
F	0	0	0	0
G	0	0	0	0
H	0	0	0	0
J	0	0	0	0
K	0	0	1	. 1
L	0	0	0	0
M	2	2	2	2
N	0	0	0	0
P	1	1	1	1
Q	1	1	2	2
R	0	1	1	2
S	0	0	0	0
T	3	3	3	4
U	7	7	7	7
V	25	26	26	27
W	18	26	27	27
Х	5	6	9	11
Total	576	594	554	576

Fig. 3.8.1: Mean annual surface runoff



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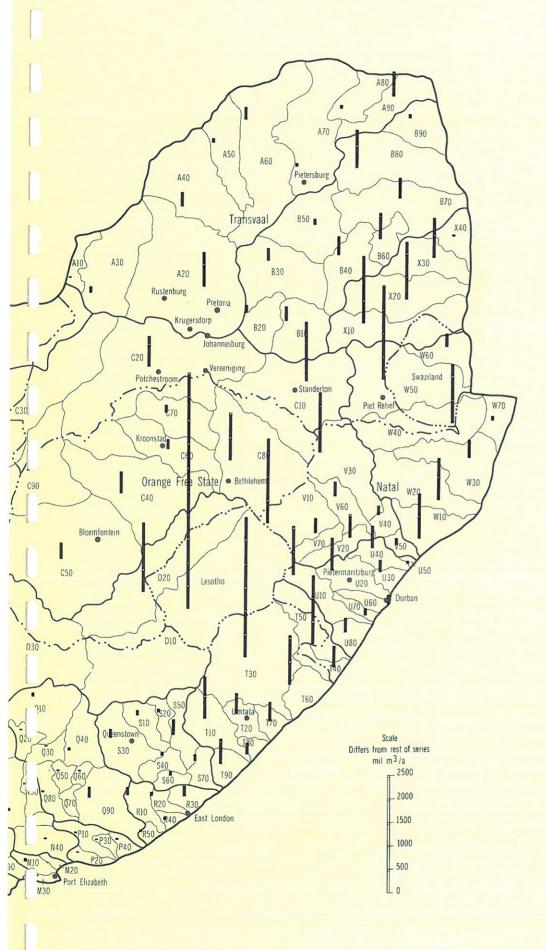
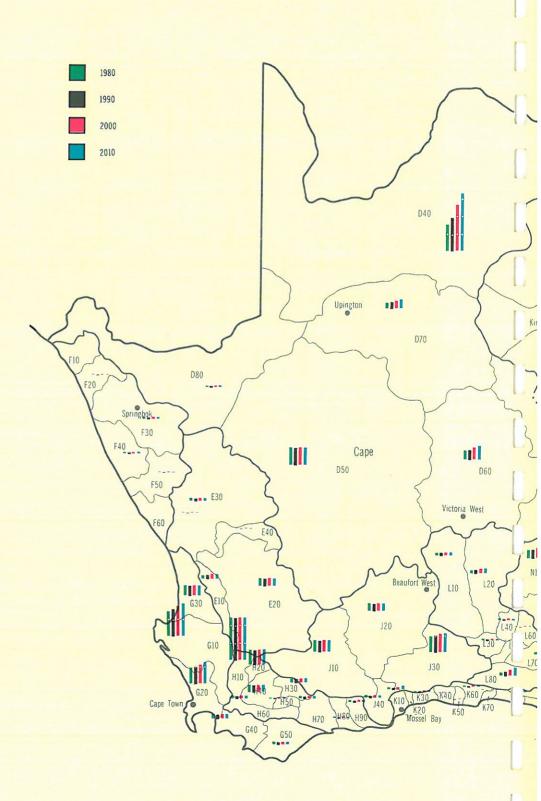


Fig. 3.8.2: Estimated mean annual ground water abstraction



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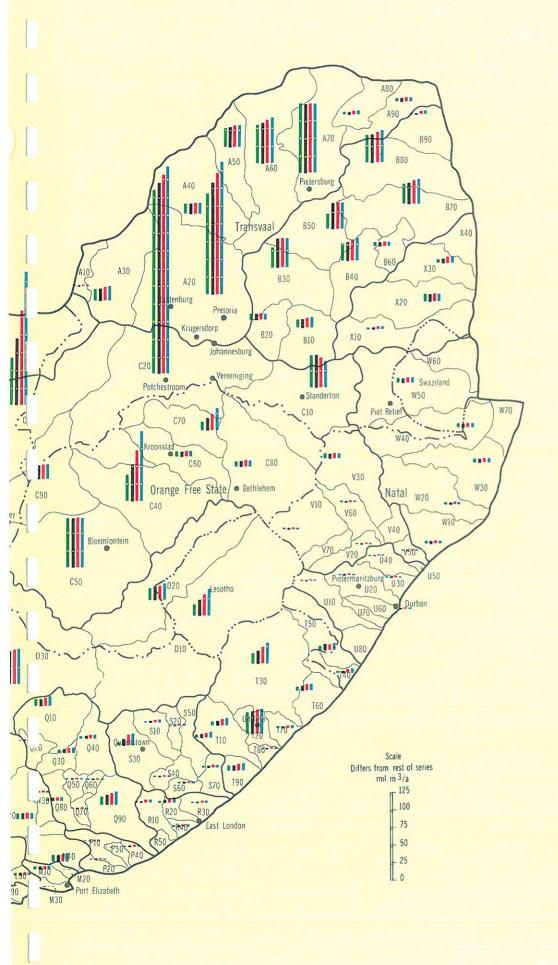
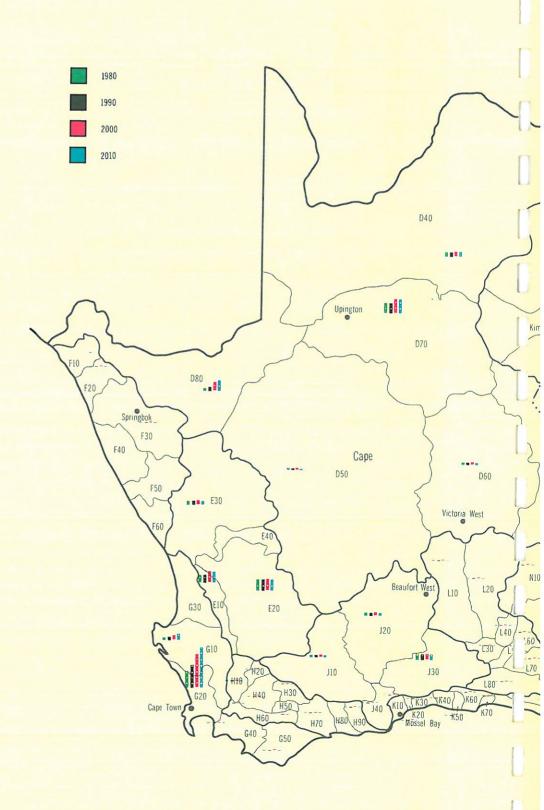


Fig. 3.8.3: Estimated mean annual return flow



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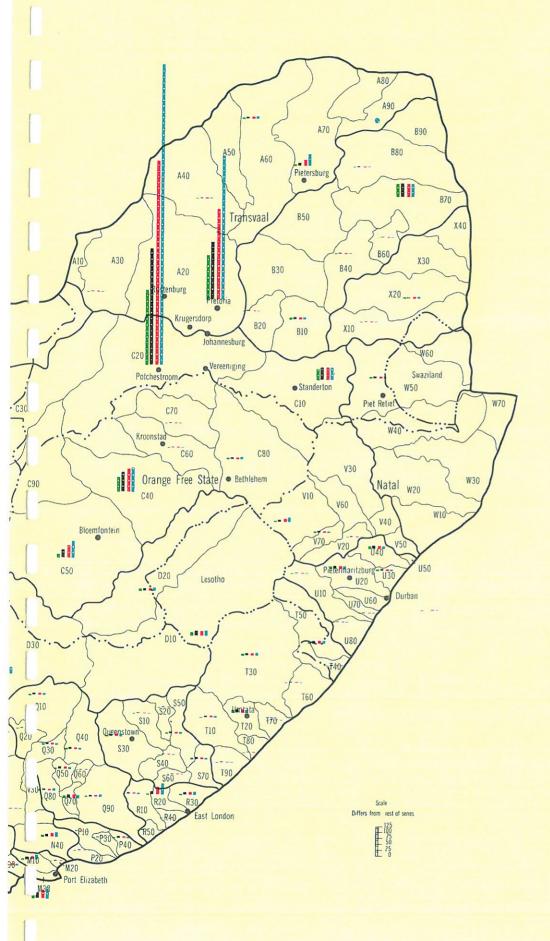
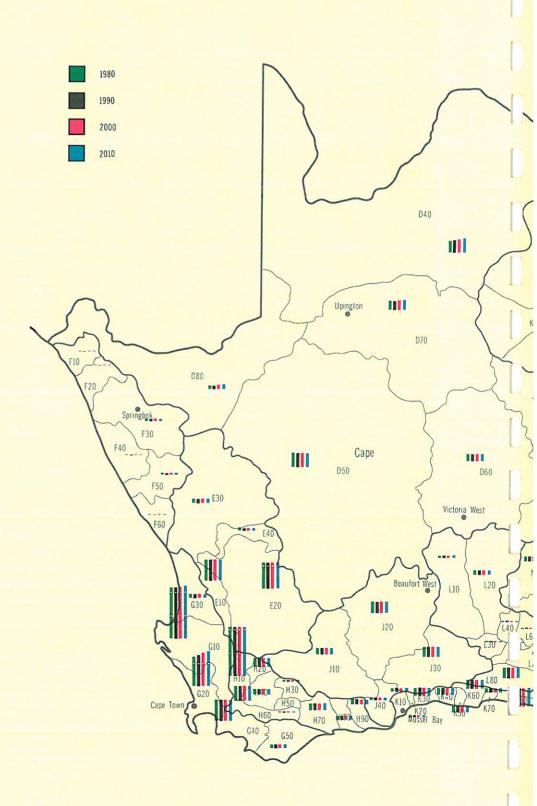


Fig. 3.8.4: Estimated mean annual total available water



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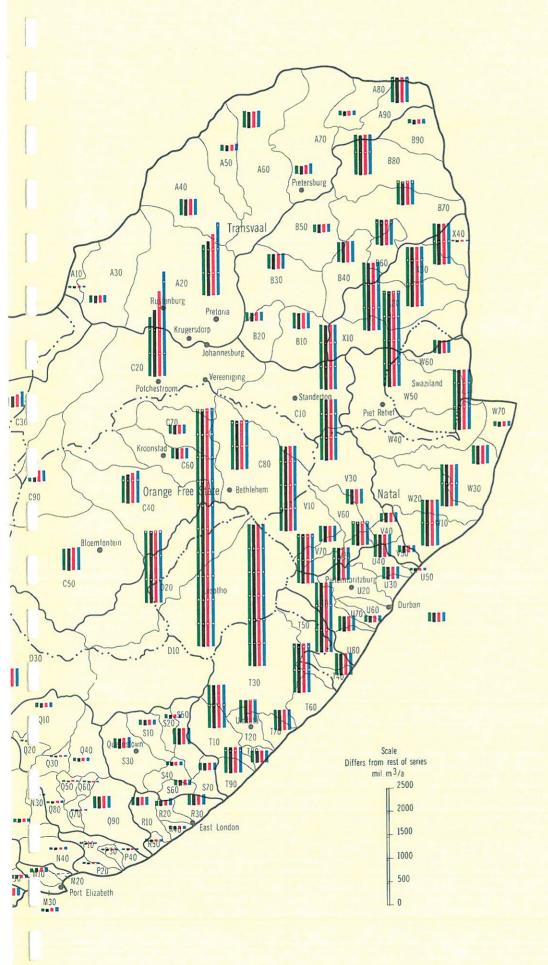
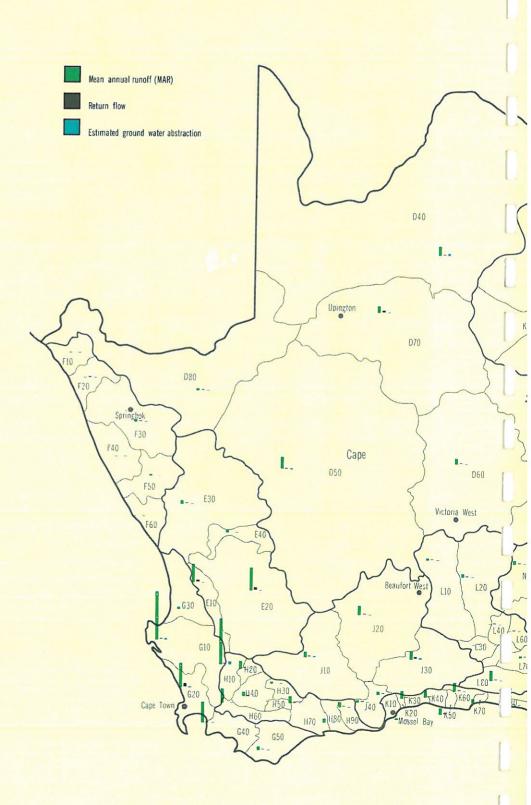
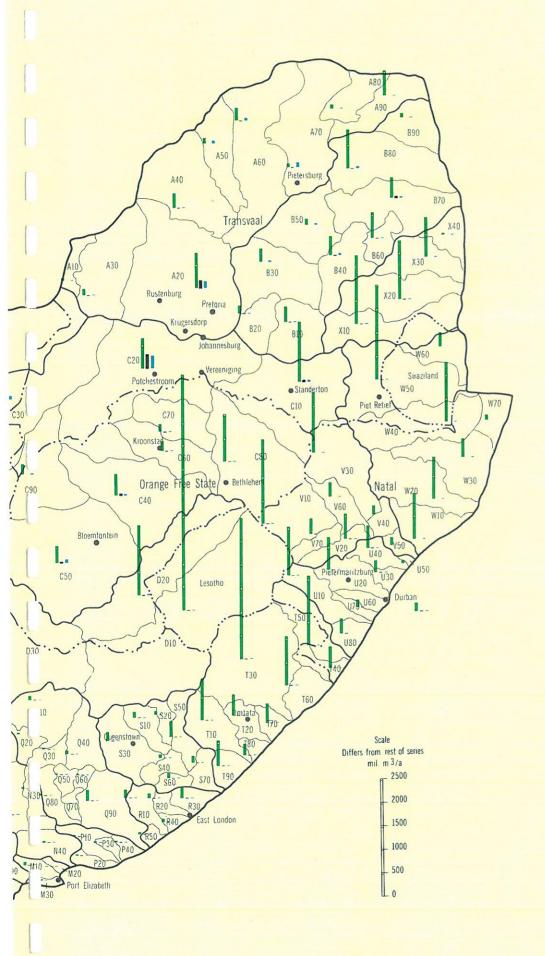


Fig. 3.8.5: Estimated mean annual total available water per source for 1980

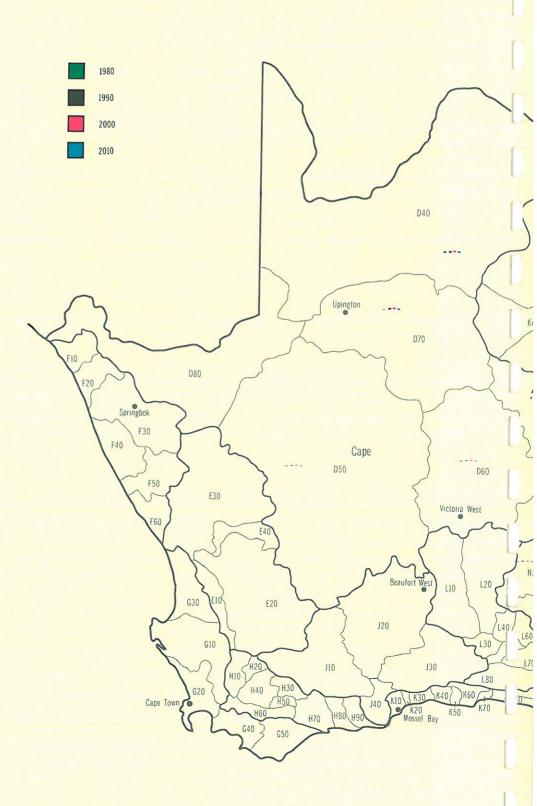


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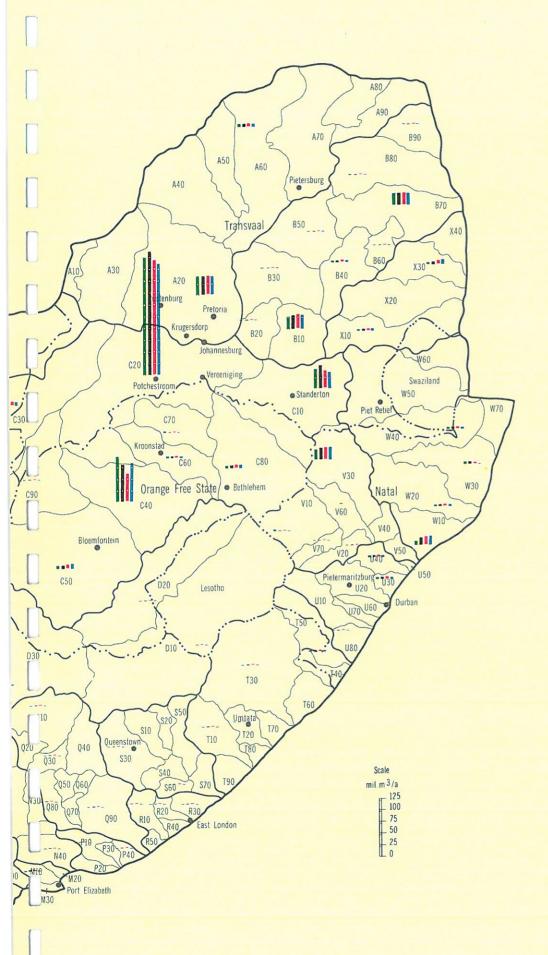


3.46 WATER AVAILABILITY

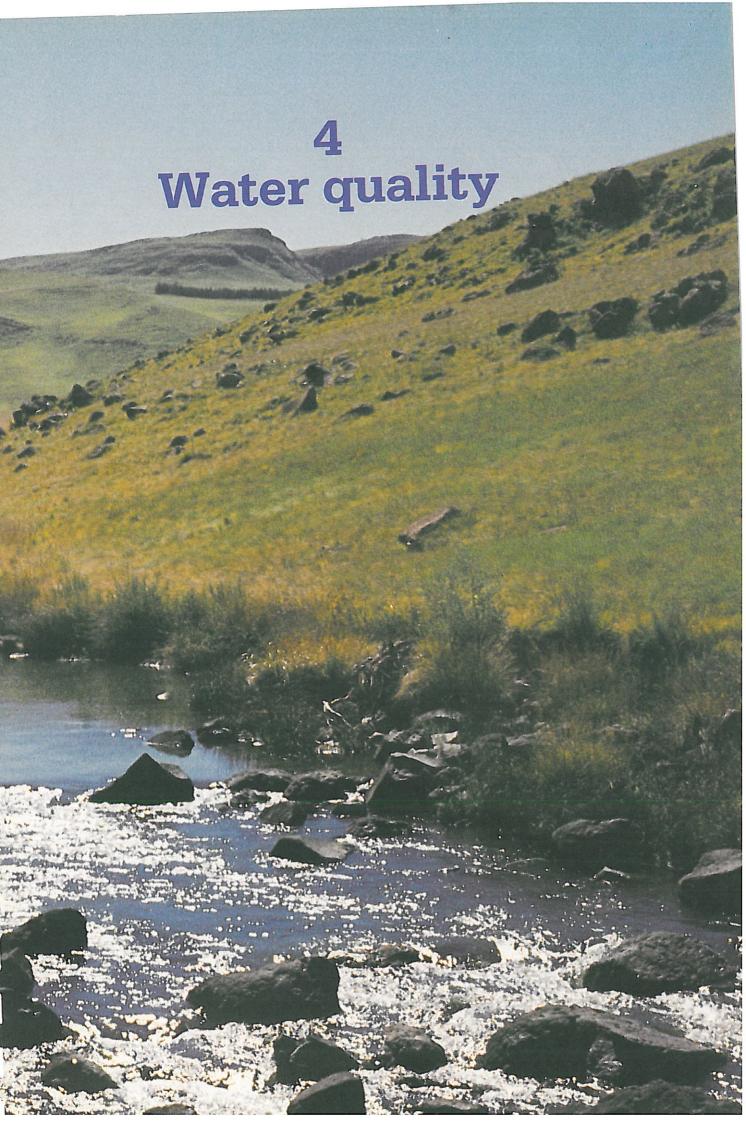
Fig. 3.8.6: Estimated mean annual intentional evaporation and disposal of poor quality water



3.47







Contents

4.1 Water quality in the Republic of South Africa See also Section 8.4	4.3
4.2 Factors influencing regional water quality	4.8
4.3 Control over the pollution and reuse of water	4.16
See also Sections 3.5 and 8.4	

A danger foreseen is half avoided.

Thomas Fuller, 1732

4.1 Water quality in the Republic of South Africa

The quality of many water sources in the Republic of South Africa is declining. This is primarily as a result of salination and to a lesser extent because of eutrophication and pollution by trace metals and micro-pollutants.

Progressive salination of water sources is a world-wide phenomenon often associated with the intensive use and reuse of limited water supplies. Salination of rivers and reservoirs by natural causes has long been recognized as a problem in arid and semi-arid regions of the RSA. There is also concern about the gradual rise in the salinity of water in urban and industrial areas. Increasing salinity renders this water less suitable for urban and industrial supply, to the extent that additional cost could be incurred by the user. Research is under way to find economically viable solutions to this problem.

Eutrophication is the enrichment of water with plant nutrients. It is a natural process that may be accelerated by urbanization and by agricultural and industrial practices. The discharge of effluent rich in soluble nutrients such as phosphates and nitrogen promotes the excessive growth of algae and other aquatic plants. This leads to a progressive deterioration in water quality and reduces its suitability for all uses except irrigation. It hampers recreational use as well as the treatment and conveyance of water.

Although of lesser consequence than salination, eutrophication is a significant problem in the RSA. Accordingly, eutrophication control programmes are needed to improve the water quality of rivers and dams so that the increasing demand of a growing population can be met.

Modern technologies produce many types of organo-chemicals in increasing quantities. Increasing amounts of organic and metal compounds enter surface and underground water through effluent discharges, leachate from solid waste disposal sites and agricultural and urban runoff and possibly by atmospheric deposition. Many compounds have chemical structures that are highly resistant to physical, chemical and biological degradation and as a result they persist in the environment for a long time. Some of these trace metals and micro-pollutants, which are progressively polluting water sources, may be toxic, carcinogenic (cancertants, which are progressively polluting water sources, may be toxic, carcinogenic causing), mutagenic (producing genetic changes) or teratogenic (causing prenatal defects) and possess the potential to jeopardize many uses of water, particularly during periods of low flow.

The metabolites and products of degradation of some of these compounds can be many times more toxic than the compound itself. Special attention therefore needs to be given to their occurrence in water, in sediment and in the biota of aquatic ecosystems. Full assessment of their impact is hindered at present by the lack of adequate data and multi-disciplinary research and monitoring programmes for these pollutants have to be established.

Problems caused by salination

With increasing industrialization, urbanization, irrigation and the use of artificial fertilizers and pesticides in agriculture, polluted return flows detrimentally affect the quality of receiving waters. To illustrate the problem the salinity status (expressed as the concentration of total dissolved solids (TDS)) of a number of dams in the RSA is shown in Table 4.1.1. As a comparison, the TDS concentration of sea-water is approximately $34\ 000\ mg/\ell$.

Table 4.1.2 gives an indication of the irrigation water salinity threshold for various crops. If water with salinity in excess of the specified level is applied, crop degradation may result. This may even occur at lower salinity levels if the irrigated soils are poorly drained. Alternatively, on well-drained soils irrigation water with salinity in excess of the threshold can be applied for limited periods without causing serious crop damage.

More specific water quality criteria can be determined only after detailed consideration of the soil properties, the growth stages of crops, the climate, irrigation techniques and the chemical composition of the irrigation water. The latter is especially important since certain crops exhibit a particular sensitivity to specific ions. For example, the quality of tobacco is reportedly sensitive to the chloride content of tobacco leaves and irrigation water with a chloride concentration of not higher than $25 \text{ mg/}\ell$ is therefore required at present. This requirement appears to be becoming more stringent with time and will be very difficult to satisfy in future.

One solution to the problem of poor quality irrigation water may be the development of salt-tolerant crops. It is possible to isolate and transfer genetic material which confers salt tolerance from uneconomic halophytes (salt-tolerant plants) to economic, salt-sensitive crops.

In contrast to the potential of certain plants to become more salt tolerant, many modern industrial processes tend to require water of increasingly higher quality. Awareness of possible health hazards associated with long-term exposure to saline drinking water is also growing. Table 4.1.3 indicates the water quality requirements for a

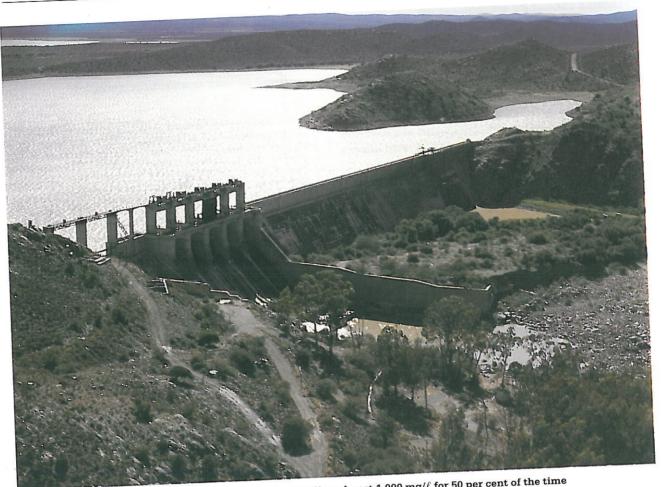
Table 4.1.2: Crop tolerance of saline irrigation water*

Crop	Maximum salinity of irrigation water beyond which crop degradation may be experienced			
	Electrical conductivity (mS/m)	TDS in mg/ℓ (using a conversion factor of 6,0)		
Cotton	510	3 060		
(Gossypium hirsutum)				
Wheat	400	2 400		
(Triticum aestivum)				
Groundnut	210	1 260		
(Arachis hypgaea)				
Orange	110	660		
(Citrus sinensis)				
Lemon	110	660		
(Citrus limonea)				
Apple	100	600		
(Pyrus malus)				
Pear	110	660		
(Pyrus communis)				
Peach	110	660		
(Prunus persica)				
Apricot	110	660		
(Pyrus armeniaca)				
Grape	100	600		
(Vitus spp)				
Potato	110	660		
(Solanum tuberosum)				
Maize	110	660		
(Zea maize)				
Alfalfa (similar to				
lucerne)	130	780		
(Medicago sativa)	and the same			

After Ayers, R.S. 'Water quality for agriculture'. *Irrigation and Drainage Paper 29.* Food and Agriculture Organization of the United Nations, 1976.

Table 4.1.1: Salinity status of a number of dams in the RSA

Name of dam	Capacity	Capacity TDS concentration, in mg/ℓ , equalled or exceeded for various percentages of time		Sampling period	
	(million m ³)	10%	50%	90%	
Vaal	2 190,6	177	137	99	4/1968 - 11/1984
Vaal Barrage	61,5	710	495	210	1/1973 - 9/1985
Bloemhof	1 273,0	511	305	240	11/1972 - 6/1984
Hartebeespoort	193,7	446	417	382	6/1962 - 8/1985
Loskop	180,0	182	139	106	5/1968 - 9/1985
Krugersdrift	76,7	1 007	849	195	3/1975 - 7/1983
Kalkfontein	321,8	710	594	330	4/1968 - 8/1983
Stompdrif	55,3	1 312	591	381	4/1968 - 1/1983
Miertjieskraal	1,6	1 163	797	402	8/1977 - 11/1983
Floriskraal	52,2	599	409	297	4/1968 - 9/1983
Lake Mentz	192,5	1 470	955	738	1/1969 - 10/1983
Laing	21,7	811	526	335	10/1968 - 11/1983
Bethulie	2,0	2 220	709	463	2/1978 - 10/1983



Lake Mentz on the Sundays River – a salinity level exceeding almost 1 000 mg/ ℓ for 50 per cent of the time

number of urban and industrial uses.

The TDS limit for drinking water as recommended by the SABS in Specification 241-1984 is expressed in terms of its electrical conductivity (EC) to facilitate analytical procedures and the comparison of results. The conversion of EC to TDS depends on the chemical composition of the water. The recommended limit of 70 mS/m is equivalent to TDS concentrations of between 350 mg/ ℓ and 550 mg/ ℓ , depending on constituents. The maximum allowable limit is given as 300 mS/m, which is equivalent to a TDS concentration of about 2 000 mg/ ℓ .

TDS concentrations below 1 000 mg/ ℓ , which is the 1984 World Health Organization (WHO) guideline value for drinking water, are generally acceptable unless determinands such as sodium, chlor-

Table 4.1.3: Approximate water quality criteria in TDS for urban and industrial uses

Up to 500 mg/l	Up to 750 mg/ℓ	Up to 1 200 mg/ℓ	Up to 2 000 mg/6
Textiles Paper manufacture Domestic supply	Food processing	Soft drinks Chemical industry Petroleum industry	Maximum allowable limit for domestic supply

ides or magnesium make up a large fraction of the minerals present. It is not necessarily the TDS level but the concentration of specific ions that is detrimental to human health. TDS concentrations in excess of about $500 \text{ mg/}\ell$ may be associated with salty tastes in the water. However, this depends on the mineral composition of the TDS.

Certain components of the TDS give rise to effects other than aesthetic when present in high concentrations. For instance, sulphates may give rise to gastro-intestinal irritation, while sodium may be associated with long-term health risks. Heavy metal elements such as lead or cadmium are also associated with health risks.

Certain concentrations of specific ions also cause problems for industrial users, as illustrated in Table 4.1.4.

Table 4.1.4: Some primary determinands that tend to cause problems in industrial processes

Textiles Paper manufacture Food processing Steam generation Soft drinks Chemical industry Petroleum industry	Magnesium, calcium Calcium chloride, magnesium Ammonium, calcium Calcium, magnesium, silica Alkalinity, hardness Calcium, magnesium Calcium, magnesium
--	--

Problems caused by eutrophication

Excessive increases in algae, aquatic plants or both in water impoundments give rise to problems such as the following:

- Water purification costs are increased because filters become clogged, increased chemical dosages for coagulation are necessary and more sophisticated treatment processes are required to remove tastes, odours and other side effects caused by algal growth in water.
- Higher levels of operating and control expertise are required to produce safe potable water.
- Toxins produced by certain species of algae such as microcystis may result in livestock losses and fish mortalities. These toxins may possibly also have sublethal effects on humans.
- 4. Extensive deoxygenation of the bottom layers of dams and lakes may cause disturbances in biological activity and water chemistry and influence the capacity to support desirable fish species. Sediment of decomposing algae and water plants may lead to changes in the diversity of fish species and to undesirable bottom feeders predominating.
- 5. Algal growths on canal linings result in loss of hydraulic capacity.
- 6. Water surfaces are aesthetically degraded.
- The recreational use of water surfaces for such sports as boating, angling and water skiing is adversely affected.
- The values of lakeside properties decrease because of the negative aesthetics of algae-laden water bodies.
- Carcinogenic trihalomethanes may be formed when water from eutrophied sources is chlorinated during purification.

Increased salt concentrations in water cause the precipitation of sediments and reduce turbidities. Under certain conditions the resulting deeper light penetration enhances algal and other aquatic plant growth.

Economic and other impacts of eutrophication

It is not yet possible to assess the full economic impact of eutrophication accurately, since it is associated with imponderables such as the availability of alternative resources, treatment options and the quality of the environment that society is willing to accept.

Problems at potable water treatment plants

Eutrophication has increased costs at several water treatment plants such as those at the Ebenezer, Doringdraai, Rietvlei, Shongweni, Roodeplaat, Wemmershoek and Donkerpoort Dams, amongst others, as well as at the Vaal Barrage and at Lake Mzingazi. When raw water eutrophies, chemical dosages have to be increased up to threefold and the capacity of treatment plants is severely reduced. This problem is currently receiving serious attention from a number of water boards, including the Rand Water Board and the Mgeni Water Board.

It is not yet possible to assess the full economic impact of eutrophication accurately, since it is associated with many imponderables, including the quality of the environment society is willing to accept.

The solution may lie in the installation of one or more additional processes, such as flotation and micro-screening for the physical removal of algae. Activated carbon treatment may be needed for the removal of odours and tastes. These processes may require considerable capital outlay and may significantly increase operating costs and the level of expertise required for their operation. Some local authorities, such as those at Richards Bay and Schoemansville, have had to install and operate additional processes to cope with algae-laden water.

Health effects

Blooms of toxic algae may cause livestock and fish deaths. The effect on humans is not well documented, but cases of gastro-enteritis caused by a toxin produced by microcystis have been reported. There is also some evidence of health risks resulting from increases in the population density of the molluscan (snail) or dipteran (fly) vectors of malaria, filariasis, fascioliasis and schistosomiasis. Extracellular compounds released by algae into the water are suspected precursors of carcinogenic trihalomethanes.

Interference with recreation

Problems have been experienced with water hyacinth on dams used for recreation such as Hartebeespoort, Roodeplaat and Bon Accord. Although the full financial impact of eutrophication on recreation cannot yet be accurately assessed, it is significant and may neutralize investments by provincial administrations and others in developing the recreational potential of impoundments. Increasing environmental awareness may cause the public to press for remedial action. For example, chemical control of water hyacinth in the Hartebeespoort Dam was required at a cost of R220 000 in 1977/78. For several years previously water hyacinth had been removed manually or had been shredded by special barges at a total cost estimated at between R600 000 and R1 million.

Interference with water supply systems

For 1982/83 a sum of R600 000 was budgeted for the control of algae in the Vaal River alone. Similar measures are becoming increasingly necessary in rivers in which water supply systems are being threatened by aquatic plants, such as the Letaba and Lower Vaal Rivers. Severe problems with algae are being experienced in the Vaal Barrage, the Middle Vaal River and the Hartebeespoort and Roodeplaat Dams. Other regions of concern are the Mgeni system, the Olifants River at Witbank, the Berg River and the Middle Buffalo River.

Interference with irrigation

Restrictions on water supply owing to the excessive development of algae in distribution canals have been experienced on Government water schemes such as Hartebeespoort, Kalkfontein, Vaalharts, Albasini, Loskop and Rooikraal. As an example of the costs involved, the control of algal growths in the canals leading from the Hartebeespoort Dam amounted to approximately R55 000 in 1981. Revenue was also lost because the quantity of water that could be supplied was restricted.

Aesthetic problems

Aesthetic problems are caused mainly by the dying-off of algae, which results in unpleasant odours. Problems of this nature are readily noticed by the public, who may exert strong pressure for remedial action.

Effect on values of surrounding land

The consequences of eutrophication may affect the values of surrounding land since the viability of once promising shoreline developments may become jeopardized. An example of this is the Marina da Gama development at Zandvlei in the Cape.

Eradication of water hyacinth at great cost on the Hartebeespoort Dam on the Crocodile River near Brits, Transvaal



Problems caused by trace metals and micro-pollutants

Water sources in the RSA are progressively being polluted by trace metals and micro-pollutants. The concentration of these chemicals in the environment depends on the quantities introduced and the processes that determine their degradation. After degradation, transport processes tend to distribute chemicals throughout the air, water and soil. Distribution and transformation processes within each phase can modify chemicals to new forms of greater or lesser toxicity.

Heavy metals and compounds containing metals are characteristically persistent and accumulate in both sediment and biota. As many organic chemicals are extensively bio-accumulated and are also bound onto sediment, they are readily transported through surface water systems. Increasing loads of trace metals and micro-pollutants discharged to the water environment can lead to serious problems in maintaining the quality of both surface and ground water. Traces of pesticides such as DDT, Dieldrin, Lindane and others are found in fish tissue and bottom sediments of South African rivers and estuaries.

The potential risks to human health of organic compounds in drinking water is still a controversial subject. However, there is evidence that long-term exposure to low concentrations of certain organic chemicals may be an important factor in the development of some chronic diseases such as degenerative disorders of the nervous system, and that it may increase the risk of developing cancer.

Major sources of pollution by trace metals and micro-pollutants

Some major sources of trace metals and micropollutants that are progressively polluting water sources in the RSA are indicated in Table 4.1.5.

Table 4.1.5: Some major sources of organic and metal pollutants in the aquatic environment which are not easily degraded by conventional biological treatment processes

Group	Major sources				
Aliphatic and aromatic hydrocarbons (e.g. phenols, benzenes and petroleum hydrocarbons)	Urban runoff Industrial solvent wastes Plastic, resin and paint production Petrochemical industry wastes Disinfection of water and waste water Industrial solvent wastes Plastic, resin and paint production Aerosol propellants Domestic effluents Algal growths				
Halogenated aliphatic and aromatic hydrocarbons (chloroform, chlorinated benzenes)					
Pesticides	Agricultural runoff Domestic usage Pesticide production				
Polychlorinated biphenyls (PCB) ·	Paper recycling Transformer oils Disposal of hydraulic fluids and lubricants Paint manufacture Fluorescent tube manufacture				
Pthalate esters	Plastic, resin, rubber and paint production				
Polynuclear aromatic hydrocarbons	Urban runoff Petrochemical industry wastes Bitumen production				
Metals	Heavy and fine chemical industry wastes Electroplating industry wastes Mining activities Soil erosion Atmospheric deposition Sewage sludges				

4.8 WATER QUALITY

4.2 Factors influencing regional water quality

The deterioration in water quality, mainly as a result of salination, is caused by different factors, depending on the area in which it occurs.

In rural areas the problem is primarily caused by natural salination and by irrigation return flows. Changing land-use patterns and the use of fertilizers and insecticides may also be a contributing factor. Salinity is highest during dry periods with little surface runoff. This is especially true of the Karoo, where the leaching of salts from the shales gives rise to highly saline base flows, possibly augmented by saline irrigation return flows. During periods of above-average low-intensity rainfall in the Karoo, infiltration to ground water takes place, part of which subsequently reappears as base flow of increased salinity.

In urban areas the deterioration in water quality is mainly caused by point source effluent discharges and by diffuse wash-off into river systems. Water quality in rivers is generally worst during droughts because pollution loads are not diluted or flushed from the system. However, runoff from the first storms after a prolonged dry period may also wash a shock load of salts, which have accumulated in urban areas, into the river system.

In future it will be necessary to manage water supplies of different qualities to achieve the optimum use of resources.

To illustrate the nature of regional deterioration under heavily urbanized and industrialized conditions, water quality problems in the Rand Water Board supply area and in the East London-King William's Town area are discussed in detail in this section. The conditions in these two areas are typical of actual, emerging and expected conditions elsewhere. It will be possible to counter the problems only through the use of effective controls and adequate expenditure.

Salination of rivers in the RSA

As the RSA is a water deficient country, the Water Act, 1956 (Act 54 of 1956), requires that all effluent be purified and be returned to the stream of origin. An effect of this stipulation, however, is that the quality of water in many areas is deteriorating as a result of the increased return flows of saline effluent from growing urban, industrial and agricultural areas. In time, quality may become a more important factor than quantity as regards the availability of water in some areas, particularly in the interior. Although it is possible to slow down the rate of degradation or even to reverse the trend, it is unlikely that it will ever be possible

to prevent pollution of river systems to the extent that they will revert to their pristine condition.

Increasing salinity limits the number of cycles of industrial reuse. Because of salt build-up, water in recycling circuits has to be bled off more often and replaced by fresh water in order to maintain tolerable salt concentrations, and the intake of fresh water is increased as a result. Fresh water supplies for irrigation also have to be increased to meet the greater requirement for leaching associated with higher salinity and there is an ever-increasing need to release part of the water stored in dams to control downstream salinity. In view of the considerable influence these measures have

on available water supplies, the causes and consequences of salination and the efficiency of alternative remedial or ameliorative measures are being studied intensively. This is a complex task.

Apart from salts added by effluent, the effect of the evaporation of water in storage can account for considerable increases in concentrations of dissolved mineral salts. Increases in the capacities of dams to counter sedimentation and to meet growing demand increase their surface areas and evaporation losses and reduce the flushing effect of floods. This results in a gradual increase in the mean salinity levels of water in dams.

In time, quality may become a more important factor than quantity as regards the availability of water in some areas, particularly in the interior.

Evapotranspiration from irrigated land increases salt concentrations in the soil water. These salts have to be leached, resulting in highly saline irrigation return flows to streams. Furthermore, salts leached from weathering geological formations in catchments accumulate in impoundments together with natural salts whose release from the soil is accelerated by dryland agricultural practices. During the process of soil erosion, soil and salts are transported downstream and the dissolved salts become concentrated in the soil in areas where the water is used. If not leached or flushed out, the salinity of the soil will continue to increase to saturation level. Unfortunately, the RSA will not always have sufficient surplus water for flushing.

Salinity in the Vaal River is being studied intensively. Studies are also being undertaken in regions where high natural salinity levels now approach or exceed acceptable levels, for example in the Fish-Sundays River system, where the salinity problem has largely been alleviated by the introduction of Orange River water, and the Berg and Breede River systems of the western Cape. The increased salinity of stored water and ground water in the Cape Midlands, the Karoo regions and parts of the southern Cape is also being researched.

Salinity in the Rand Water Board supply area

The Rand Water Board (RWB) supply area accounts for more than half the gross domestic product of the RSA and is the country's largest user of water for urban, industrial and mining purposes (Section 5.3.6). The quality of the water supplied to this region is thus of the utmost importance. Since local water sources are inadequate to meet growing demand, water is increasingly being im-

6Apart from salts added by effluent, evaporation results in a gradual increase in the mean salinity levels of dams. 7

ported from further afield at a high cost.

The supply area generates large volumes of domestic, industrial and mining effluent, which is discharged into local streams. Most of this effluent reaches the Vaal Barrage and is abstracted together with the natural runoff and returned to the water supply system after processing. The increased recycling of effluent via the Vaal Barrage combined with the wash-off of large quantities of dissolved solids and nutrients from the catchment have resulted in increased salinity and eutrophication.

Concern about this situation led to the establishment of an advisory committee to examine various management options for controlling the salinity of water supplied from the Vaal River system. The Department of Water Affairs, the RWB, the Johannesburg Municipality, the National Institute for Water Research (NIWR) and the Water Research Commission (WRC) are founder members of the committee. The advisory committee was recently expanded to include representatives of the municipalities of Pretoria and Kimberley, the Magalies Water Board, the OFS Goldfields Water Board and the Western Transvaal Regional Water Company.

The Rand Water Board supply area accounts for more than half the gross domestic product of the RSA and the quality of the water supplied to this region is thus of the utmost importance.

The DWA commissioned a firm of consulting engineers to undertake a study under the guidance of the committee, the main thrust of which has been the collection and analysis of relevant data, the refinement and application of a numerical hydrosalinity model developed by the Hydrological Research Unit of the University of the Witwatersrand under the auspices of the WRC, and the evaluation of alternative options for controlling or improving the quality of water supplied to users within and downstream of the Pretoria-Witwatersrand-Vereeniging (PWV) region.

The best solution to the problem was found to be to blend appropriate quantities of Vaal Dam water having a low total dissolved solids (TDS) concentration with Vaal Barrage water that has a high TDS concentration, and so maintain acceptable TDS levels. Some other options are detailed in Section 4.3. The RWB has been requested to implement the blending option.

Development of water sources for the Rand Water Board supply area

The Vaal Barrage at Vereeniging, built in 1923, was the first major structure to supply water to the Witwatersrand area. The Vaal Dam was completed in 1936, primarily to supply water to the Vaalharts irrigation scheme but also to supplement the Barrage. The dam was raised in 1956 and again in 1985. From the date of construction until the late 1960s the Vaal Dam was also used to provide water as far down the Orange River as Upington whenever the natural flow in that river was insufficient for irrigation requirements. See Fig. 4.2.1 for a locality sketch of the main water supply components in the Vaal River and neighbouring systems.

An average of 64 per cent of the water supplied to the southern PWV region is returned to streams as effluent.

The increasing demand for water in the RWB supply area was met by gradually shedding the irrigation load on the Vaal Dam. The Hendrik Verwoerd and the P K le Roux Dams on the Orange River, completed in 1972 and 1977 respectively, provide an assured supply of water for all users downstream of the Vaal-Orange confluence. The completion of the Bloemhof Dam on the Vaal River in 1970 meant that a large proportion of the irrigation requirements at Vaalharts and along the Lower Vaal River to Douglas, the urban requirements of Kimberley and a number of smaller towns and the needs of the Vaal-Gamagara water supply scheme could be met from the new dam. The quantity of water that could be supplied by the Vaal Dam to the RWB supply area and the area above the Bloemhof Dam was thus increased substantially.

By 1975 the water supply potential of the Vaal River was largely committed. No further increase in the supply of water for irrigation was permitted, thus restraining the growth in total demand for additional water from the system. Additional urban, mining and industrial requirements were met by the importation of water from the Tugela River via the Sterkfontein Dam in the upper reaches of the Vaal River. The function of the Sterkfontein Dam was to provide insurance storage during severe droughts and the success of this scheme has been amply demonstrated during the recent drought.

An unexpected development in the 1970s was the establishment of the new Sasol projects at Secunda. This necessitated the construction of the Grootdraai Dam on the Vaal River near Standerton, upstream of the Vaal Dam, in 1979. The new dam intercepts some 26 per cent of the mean annual runoff to the Vaal Dam, thus reducing the yield of the Vaal Dam but increasing the yield of the Vaal River system as a whole. The loss in the yield of the Vaal Dam could be accommodated because water became available from the Tugela-Vaal project. This project began operating in 1976 and has since been expanded by the participation of Escom in the Drakensberg Pumped Storage Scheme, by the completion of the Woodstock Dam in 1982 and by the recent raising of the Sterkfontein Dam. In 1986 the pumping capacity for transferring water from the Upper Tugela River to the Sterkfontein Dam was increased in order to improve the assurance of supply of the Vaal River system.

Until about 1980 the unit cost of water from alternative sources was virtually the only criterion for the selection of the optimum source for additional supplies, but water quality became an increasingly important consideration. Planners had to be able to evaluate the quality and quantity of water available to users when investigating the development of additional sources of water. They also had to be able to assess the costs and efficacy of measures that could be taken within the PWV area to control further deterioration in the quality of these supplies.

Salination of the Vaal River

The problem of salination of the Vaal River became apparent in 1949 when it was decided to make no further extensions to the Vereeniging intakes of the RWB but rather to build the Zuikerbosch intake works upstream of the confluence of the Klip and Suikerbosrand tributaries with the Vaal River. At the time, the annual average TDS concentration of water drawn into the Vereeniging intakes downstream of the confluence with the tributaries was less than 180 mg/ ℓ .

Fig. 4.2.2 illustrates the increase in salination since 1949, when sudden peak TDS concentrations in water abstracted by the RWB at Vereeniging first began to place pressure on industries. By 1969 it was recognized that the quality of water in the Vaal Barrage would deteriorate further owing to increased effluent discharges, greater contamination of natural runoff because of urban and industrial development, increased water demand resulting in reduced spillage of the Vaal Dam and a reduction in the water released from the Vaal Dam for irrigation

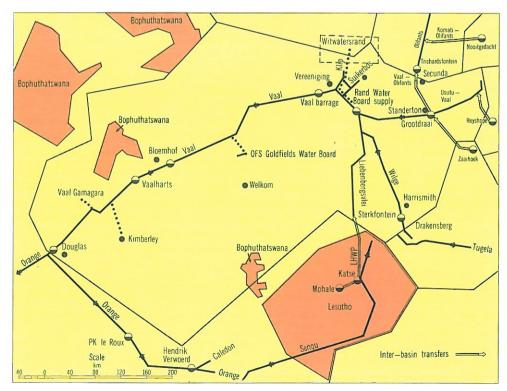


Fig. 4.2.1: Locality sketch of the Vaal River system

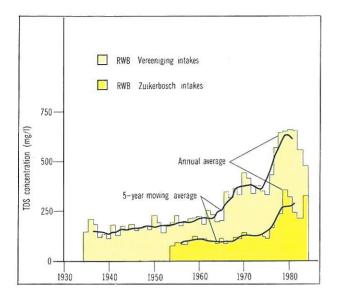


Fig. 4.2.2: Annual TDS concentrations in the Vaal Barrage

upon commissioning of the Bloemhof Dam. Certain industries had to invest heavily in desalination plant in order to cope with the higher salt concentrations.

In 1974 the WRC established a committee to study the problem and to initiate research. The committee comprised representatives from the then Departments of Water Affairs, Planning, Health, Bantu Administration and Development, and Agricultural Technical Services and from the Transvaal Provincial Administration, the RWB and the Chamber of Mines. The committee recommended an extensive research programme to include not only the collection of data concerning the volume of effluent discharged into the streams and the development of mathematical models, but also long-term investigations into such matters as the hydrobiological pattern of the extensive system of vleis in the southern Witwatersrand, the extent and cause of eutrophication in the Vaal Barrage, the extent of sand and slimes migration from the mine dumps into the streams and the cost implications of discharging effluent from regional sewage treatment plants.

The TDS concentration in the Vaal Dam has risen at a rate of 2,5 mg/ ℓ per annum to the 1982 average level of about 150 mg/ ℓ .

The DWA subsequently assumed responsibility for data collection and for the development of the salination models, under guidance of the new advisory committee established to examine management options for controlling salinity in the Vaal River.

The advisory committee concentrated on the following matters:

- The collection of data relating to the volumes and qualities of effluent discharged into the streams flowing to the Barrage.
- The daily monitoring of flow and water quality in terms of TDS concentrations of a number of streams discharging into the Barrage.
- The development of mathematical models that would simulate the volume of water in storage in the dams in the Vaal River system and the salinity of the water at various points in the system.
- The determination of the cost to the community of high TDS concentrations and hardness in the water supply.

The Hydrological Research Unit of the University of the Witwatersrand was commissioned to develop the mathematical models, while the monitoring of streams was undertaken by

The TDS concentration of water abstracted directly from the Vaal Barrage has increased alarmingly over the past decade.

the RWB. Consultants were appointed to undertake the other work.

A desk study on the cost to the community of increasing TDS concentrations in the water supply was completed in 1981. The main provisional findings were that costs of between R76 million and R139 million per annum would have to be borne by users if TDS concentrations were allowed to rise from 300 mg/ ℓ to between 500 mg/ ℓ and 800 mg/ ℓ . In 1985 the WRC expanded and refined the original study. Updated results are expected by the end of 1986.

By the end of 1980 the mathematical models were complete and had been used for determining storage states and water quality in the dams in the Vaal River system under various hydrological conditions and management strategies.

The following deductions can be made from the studies:

- 1. An average of 64 per cent of the water supplied to the southern PWV region is returned to streams as effluent.
- The percentage return flow is highest for urban users, since only 27 per cent of their supply is used consumptively.
- The effect of restrictions on the supply of water to urban users has yet to be evaluated.
- 4. Mine dewatering produces 25 per cent of the total salt load reaching the Vaal Barrage and this is discharged in only five per cent of the effluent volume. Industries and sewage works discharge 35 per cent of the total load in 32 per cent of the effluent volume.
- 5. Diffuse sources contribute 40 per cent of the tonnage of salt generated within the southern PWV region.
- 6. The TDS concentration in the Vaal Dam has risen at a rate of 2,5 mg/ ℓ per annum to the 1982 average level of about 150 mg/ ℓ .
- 7. The TDS concentration of water abstracted directly from the Vaal Barrage has increased alarmingly over the past decade. The effect has been reduced by mixing this water with water released directly from the Vaal Dam. A more precise blending rule will be followed in future.
- 8. During 1980/81 the TDS concentration of water supplied to the Johannesburg area exceeded 400 mg/ ℓ for more than 25 per cent of the time and peak values exceeded 500 mg/ ℓ . In the Vereeniging area the desirable upper limit of 500 mg/ ℓ was exceeded for more than 75 per cent of the time and peaks exceeded 800 mg/ ℓ . The TDS concentration for the RWB supply area as a whole was just within the 500 mg/ ℓ limit.
- 9. Water supplied to the OFS Goldfields area also had a TDS in excess of 500 mg/ ℓ , as did the water supplied to most other users downstream of the Vaal Barrage.

Results of the research project showed that it would be possible to use the mathematical models to examine a number of options that might improve water quality in the RWB supply area and effect savings for the community as a whole.

The DWA then shifted the emphasis of the study from data collection, research and the development of models to an investigation of the feasibility of a number of management options in view of the following developments:

- An exponentially increasing demand for water in the PWV area.
- The increasing scarcity of sources of water to meet this demand.
- The remoteness of these sources and the increasing cost of developing them and of transporting the water to the Witwatersrand.
- The exponentially increasing volumes of effluent and salt loads produced in the PWV area.
- The deteriorating quality of the natural runoff in streams in the PWV area.
- The high dissolved salt loads from sources within the PWV area, particularly from mine pumpage.
- 7. The high diffuse salt loads entering the Vaal Barrage from the catchment.

The quality of water in the Vaal Dam appears to be deteriorating, but will be improved by the importation of high quality water from the catchments of the neighbouring Tugela and Upper Orange Rivers.

The basic objective of the PWV feasibility studies is to provide planners and decision-makers with the necessary data and analytical methods to assess the quality and quantity of water available from additional sources and the costs and efficacy of pollution control measures. To achieve this objective it is necessary to maintain an inventory of available data relevant to the investigations, to test, calibrate and if necessary improve the numerical hydrosalinity model, to determine alternative options for controlling or improving the quality of water in the supply region and to evaluate the expected effect on water quality of proposed water supply augmentation projects for the region.

Several options to improve the water quality were tested (Section 4.3), the blending option being identified as the most attractive. It requires the blending of Vaal Dam water with Barrage water at appropriate ratios and provision must therefore be made for enhancing the supply of water to the Vaal Dam. To keep the TDS concentration of the water supply within acceptable limits, the blending ratio must be adapted continuously to changes in the quality of the untreated water. Blending is an improvement on the mere mixing of Vaal Dam and Barrage water at a fixed ratio without taking quality into account and will be aimed at maintaining an average salinity of 250 mg/ ℓ without exceeding 300 mg/ ℓ . Blending has not only been found to be inexpensive, providing a benefit/cost ratio of about 25:1, but very little additional water is required.

Other aspects highlighted by the investigations

Effluent return flows will increase with increasing water demand. For the southern PWV region as a whole, the average TDS concentration of effluent discharges, excluding mine pumpage, is approximately $500~\text{mg/}\ell$ higher than that of water supplied to the users. The quality of the water supply depends to a large extent on the ratio of recycled water from the Vaal Barrage to fresh water from the Vaal Dam. The TDS concentration in different parts of the area will depend on the relative growth rates north and south of the Witwatersrand divide, while increased demand in the region as a whole will have the adverse effect of reducing the spillage of fresh water from the Vaal Dam, which in the past has helped to dilute the polluted water in the Barrage.

However, the water in the Vaal Dam also appears to be deteriorating since its catchment is subjected to the influences of several power-stations and three Sasol works in addition to gold and coal mining activities. This is in spite of careful effluent and solid waste control at the Sasol works. Air pollution and related acid rain may also have an influence on the deterioration of water quality in the Vaal Dam, although no proof has yet been found that air pollution has a significant impact on the quality of water sources in the RSA.

As urban and industrial development proceeds, it can be expected that the catchment will yield increasing tonnages of soluble salts washed off by rainfall. These salts derive from sources such as industrial and residential areas, solid waste dumps, mine dumps and possibly atmospheric fall-out of the products of combustion. In addition, illegal and undetected discharges of saline industrial effluent into stormwater drainage systems add to the already high contribution of diffuse sources. Interim results of the study being undertaken at present indicate that the TDS load derived from some of the urbanized catchments of the southern PWV region is over 10 times that of comparable undeveloped catchments.

Of particular concern is the insidious nature of the increase in the salinity of natural river flow. For example, model analyses have shown that the introduction of a new industry that doubles the diffuse salt generation within the catchment would increase the average TDS concentration of the natural runoff by only a few per cent in the first year, while in subsequent years the increase would be substantial.

On the other hand, the quality of water in the Vaal Dam will be improved by the importation of high quality water from the catchments of the neighbouring Tugela and Upper Orange Rivers. The effect of the changing quality of water in the Vaal Dam on system management will have to be carefully monitored and adjustments made where necessary.

As demand increases, the increasing cost of supply may encourage a more sparing use of water. It may become profitable for many industries in the RWB area of supply to reuse water to a far greater extent than is the case at present. Although increased reuse of water by industry would reduce growth in demand, return flow volumes would also be decreased. If it is assumed that industrial effluent with the same mass of salts as before will still be discharged to the Barrage tributaries in reduced return flow, TDS concentrations in these streams will rise. In consequence, the quality of water supplied by the RWB would deteriorate, unless part of the saline effluent is desalinated and the resulting brines and salts are effectively isolated from the water environment. The potential recovery of marketable products or by-products such as soda-ash from concentrated effluent could provide incentives to desalinate such effluent

In the PWV area pollutants are produced largely by man, which provides grounds for concern about the synergistic effects of contaminants.

Fig. 4.2.3 shows the percentage of time that various TDS concentrations were exceeded at various points in the RWB supply area during the 1980/81 hydrological year when fairly average runoff occurred. TDS concentrations exceeding 400 mg/ ℓ occurred more than 25 per cent of the time and peak daily values exceeded 500 mg/ ℓ in RWB Supply Area No. 4, the Johannesburg area. The situation in Supply Area No. 1, the Vereeniging area, was considerably worse. Values of 400 mg/ ℓ were exceeded more than 90 per cent of the time and peak daily values exceeded 800 mg/ ℓ .

The salinity in the Vaal River downstream of the Barrage is compounded at the end of a drought when water quality deteriorates with the arrival of the first polluted runoff from diffuse sources. In addition, nutrients give rise to excessive growths of algae and water hyacinth. It is important that measures to reduce nutrient loads, for instance the use of chemicals for phosphate removal, do not exacerbate the already serious salinity problem.

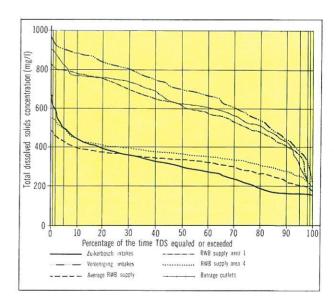


Fig. 4.2.3: Duration curves of observed daily TDS concentrations at various points

The TDS concentrations of water released from the Vaal Barrage for downstream users at Parys, and those of water supplied by the Western Transvaal Regional Water Company and by the OFS Goldfields Water Board, were also high in comparison with recommended standards for potable water. Fig. 4.2.4 shows the composition of various Vaal River waters and Fig. 4.2.5 illustrates the rapid fluctuations of the TDS concentration in the RWB water supply. It shows that conditions giving rise to high concentrations can persist for several days, or even months, in succession.

SABS Specification 241-1984 gives a recommended conductivity limit of 70 mS/m which is equivalent to TDS concentrations of between 350 mg/ ℓ and 550 mg/ ℓ , depending on constituents. The maximum allowable limit is given as 300 mS/m, which is equivalent to a TDS concentration of about 2 000 mg/ ℓ . It appears that in many areas in the RSA and overseas, drinking water supplies have average TDS concentrations well in excess of the recommended limit without readily apparent effects on the health of users. However, in the PWV area pollutants are produced largely by man. This provides grounds for concern about the possible synergistic effects of combinations of contaminants, as well as about the effect of individual and combinations of complex organic substances that are present, even in very low concentrations.

Table 4.2.1 indicates typical concentrations of various chemical constituents contained in samples of Vaal Barrage water for a range of TDS concentrations. The salinity of raw water is not removed by conventional water purification processes.

Since the presence of sulphate and chloride ions promotes and accelerates the corrosion of steel water mains, any reduction in sulphate that can be achieved by keeping mining effluent out of the supply system will obviously be of benefit.

There has recently been an increase in the number of burst

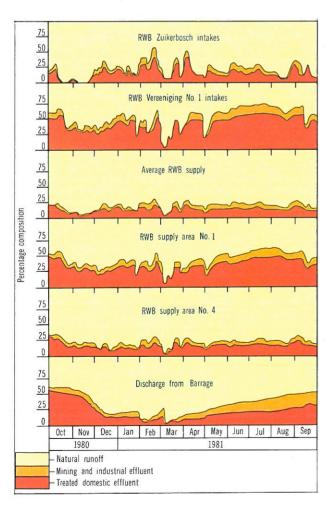


Fig. 4.2.4: Composition of various Vaal River waters

Table 4.2.1: Typical concentrations of various chemical constituents contained in Vaal Barrage water for a range of TDS concentrations

Consti- tuent	Unit	TDS concentration in mg/ℓ							
		100	200	300	400	500	750	1 000	
EC	mS/m	15	28	40	52	65	96	126	
Hardness	mg/ℓ	54	109	160	211	266	399	527	
Ca	mg/ℓ	10	24	37	50	64	97	129	
Mg	mg/ℓ	7	12	17	21	26	38	50	
Na	mg/ℓ	10	20	30	40	51	77	102	
K	mg/ℓ	4	6	7	8	9	13	16	
NO ₃ *	mg/ℓ	-	_	0,9	1,2	1,4	2,0	2,6	
SO ₄	mg/ℓ	3	50	95	140	189	306	419	
C1	mg/ℓ	13	23	32	42	52	67	99	
F*	mg/ℓ	0,2	0,2	0,3	0,3	0,3	0,3	0,4	

^{*}Poor correlation with TDS concentration.

water mains in the Johannesburg and Roodepoort municipal areas. This increase has been attributed to high chloride and sulphate concentrations, which can interfere with protective film deposition and accelerate galvanic corrosion, although higher mains pressures for longer periods because of reduced flow rates may also be a contributory factor. Restrictions in water use under drought conditions have resulted in longer retention times in the reticulation system and enhanced the possibility of anaerobic conditions that could accelerate corrosion. Complaints concerning a secondary corrosion effect in the form of discoloured water have been received.

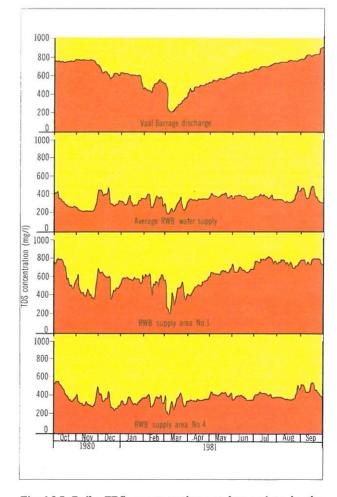


Fig. 4.2.5: Daily TDS concentrations at key points in the RWB system $\,$

Eutrophication in the Vaal Barrage*

Eighty per cent to 90 per cent of nutrients draining to the Vaal Barrage originate from point sources and consist mainly of purified sewage effluent. The increasing eutrophication of the Vaal Barrage in the recent past is illustrated by the change in the chlorophyll concentration level in the water, which is a widely accepted indicator. Chlorophyll concentration levels of 30 micrograms per litre $(\mu g/\ell)$ or more create severe nuisance conditions.

More than 80 per cent of nutrients draining to the Vaal Barrage originate from point sources and consist mainly of purified sewage effluent.

In 1973, 92 per cent of samples from the Vaal Barrage had chlorophyll concentration levels below 5 μ g/ ℓ . By 1982, 87 per cent of samples had chlorophyll concentration levels exceeding 15 μ g/ ℓ , while 34 per cent of samples exceeded 35 μ g/ ℓ .

Water quality in the East London – Berlin – King William's Town area

As the relatively small Buffalo River catchment, about 1 250 km² in extent, supports a large and increasing urban and rural population estimated to be approaching 500 000 people, considerable research has been directed at the optimization and preservation of its water resources. The two major impoundments on the river, the Laing and Bridle Drift Dams, are both situated downstream of the urban and industrial area of King William's Town-Zwelitsha and the present and expected deterio-

ration of the water quality is causing concern (see Fig. 4.2.6 for a locality sketch). Since 1940 numerous assessments of the situation have been made by bodies such as the WRC, the NIWR and the Institute for Fresh Water Studies at Rhodes University.

Historical development of the problems of salination and eutrophication

The Buffalo River catchment can be divided into four reaches:

1. Upper Buffalo catchment

This reach includes the Maden and Rooikrantz Dams, which supply water to King William's Town as well as to the Da Gama Textiles (Ciskei) factory near Zwelitsha. The water quality in these dams is good, having typical TDS concentrations in the range 40 mg/ ℓ to 60 mg/ ℓ , but below the Rooikrantz Dam there is a marked increase in TDS concentrations. The increase is attributed to natural leaching of salts from the Beaufort sandstones and to irrigation development downstream of the dam. Immediately upstream of King William's Town the average TDS concentration has increased from 128 mg/ ℓ in 1964 to 306 mg/ ℓ in 1983.

2. Middle Buffalo catchment

In general the water quality in the river downstream of King William's Town and Zwelitsha has been consistently poor, with average TDS concentrations ranging from 782 mg/ ℓ in 1970 to 994 mg/ ℓ in 1983 and with high nitrogen and phosphate levels. The salinity exceeds the SABS recommended level for potable use (Section 4.1), mainly because of the dissolved salt load in return flows from schemes for the disposal of industrial effluent by irrigation, such as those of Da Gama Textiles (Ciskei) and King Tanning Company.

3. Laing Dam

TDS concentrations in water from the Laing Dam have increased rapidly in recent years, from an average of 384 mg/ ℓ in 1980 to an average of 804 mg/ ℓ in 1983. Drought conditions have led to an almost closed circuit of water use. Water from the dam is pumped upstream to King William's Town and to Bisho and Zwelitsha, while the treated sewage effluent and seepage from irrigation schemes for the disposal of industrial effluent return to the dam. The poor quality of this water has contributed largely to the saline and eutrophic condition of the dam.

4. Lower Buffalo catchment and Bridle Drift Dam

The Bridle Drift Dam receives overflows from the Laing

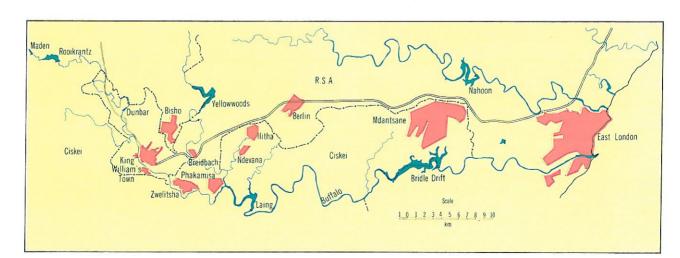
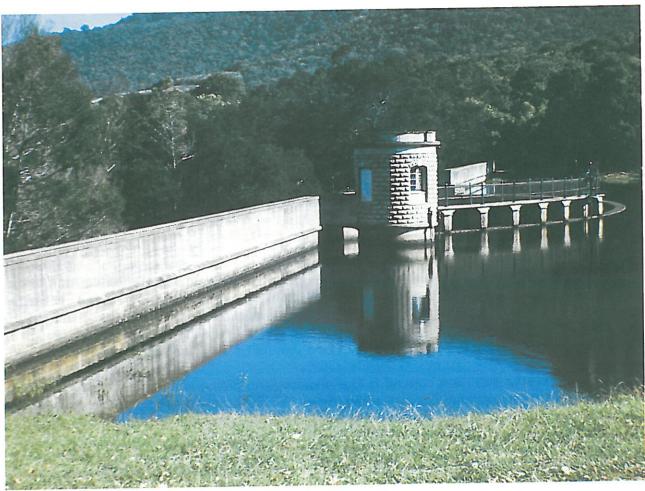


Fig. 4.2.6: Locality sketch of the Buffalo River system

^{*}Source: Dr C Viljoen, Rand Water Board

4.15



The Maden Dam on the Upper Buffalo River supplies King William's Town and the surrounding industrial area

Dam, as well as runoff from tributaries and streams draining the urban areas of Mdantsane. Despite a poorer water quality in these streams, the Buffalo River is the source of about 95 per cent of the nutrients entering the dam. In general, water from the dam is of a fair quality. Despite the availability of large quantities of nutrients, marked eutrophic growth has been restricted. This is possibly because of low sunlight penetration in the highly turbid water and, although other nutrient levels are high, that of phosphorus (which is the limiting nutrient) is relatively low.

Sources of salinity and nutrients

Direct discharge of treated sewage effluent from Zwelitsha and indirect entry of the effluent of King William's Town are responsible for 90 per cent of the phosphorus and most of the nitrogen entering the Laing Dam. Both areas have biofilter works that do not remove nutrients. It is estimated that effluent from Da Gama Textiles (Ciskei) and the King Tanning Company increases the TDS concentration in the river by an average of 455 mg/ ℓ , which is about 88 per cent of the total non-natural load. Disposal of high volumes of saline effluent by means of irrigation does not appear to be properly controlled. Runoff from these irrigated areas and seepages and overflows from evaporation ponds constitute the major threat to the Laing Dam at present.

Water quality control strategies

In response to regulations which came into force in August 1985, which stipulate that phosphate concentrations in effluent may not exceed 1 mg/ ℓ , the municipalities of King William's Town and Zwelitsha have proceeded with the establishment of nutrient removal facilities. The facility at Zwelitsha is almost complete while a start will shortly be made with the King William's Town project.

Amendments to the Water Act, 1956, promulgated in 1984, are designed to ensure that effective action can be taken when effluent which does not comply with the required standards is discharged. It is expected that deterioration in water quality will be controlled more effectively through the application of these measures and the stricter standards which are now in force.

Amendments to the Water Act, 1956, are designed to ensure that effective action can be taken when effluent which does not comply with the required standards is discharged. 7

Contingency plans have been drawn up to cater for the possibility that vigorous industrial growth in the region could generate a quantity and quality of effluent which may render the control of surface water pollution inadequate. These plans include the construction of a pipeline to convey effluent to the coast for disposal at sea. Such a scheme could be implemented in a very short time but the justification for and impact of disposal at sea would have to be studied very carefully.

Although recent amendments to legislation in respect of water pollution control in the RSA do not apply in the Republic of Ciskei, the RSA has agreed to train and establish a water pollution control inspectorate in Ciskei. In terms of a multilateral agreement on water pollution control signed at a summit meeting between the RSA and the TBVC states in November 1985 (Section 4.3) quality standards applicable to effluent discharges to the Buffalo River catchment in the RSA will also be implemented in the Ciskei.

requirements of the Act. Effluent discharged into a canal, sewer or other conduit controlled by a local authority shall be deemed to be effluent produced by or resulting from the use of water for industrial purposes by that local authority. Local authorities can therefore be held liable for pollution caused by the illegal discharge of saline or other effluent into storm-water drains.

Section 22

Measures to prevent the pollution of surface and underground water, including surface runoff and seepage of any substance in use or present on any land, are prescribed by regulation. In terms of this section the DWA can take measures to prevent the pollution of storm-water that drains from industrial and mining premises. Regulations made under this section are also aimed at minimizing diffuse pollution loads from all sources.

Section 23

Any wilfully or negligently performed act that could render public, private or sea-water less fit for the purpose for which it is or could be ordinarily used, or for the propagation of aquatic life, or for recreational or other legitimate purposes, is a

Table 4.3.1: Effluent standards applicable to direct discharges into fresh water sources, as promulgated in terms of section 21 of the Water Act, 1956

General and Special Standards for Effl	uent				
Property	Maximum allowable except where marked (*)		Property	Maximum allowable except where marked (*)	
	General	Special		General	Special
1. Colour, odour or taste	Nil	Nil	12.7 Total chromium (as Cr)	0,5	0,05
2. pH	5,5-9,5*	5,5-7,5*	12.8 Copper (as Cu)	1,0	0,02
3. Dissolved oxygen (percentage			12.9 Phenolic compound (as phenol)	0,1	0,01
saturation)	75	75	12.10 Lead (as Pb)	0,1	0,1
4. Typical (faecal) coli	Nil	Nil	12.11 Soluble ortho-phosphate (as P)	-	1,0
5. Temperature (°C)	35	25	12.12 Cyanides (as Cn)	0,5	0,5
6. Chemical oxygen demand (after	the said of		12.13 Iron (as Fe)	-	0,3
chloride correction) (mg/ ℓ)	75	30	12.14 Sulphides (as S)	1,0	0,05
7. Oxygen absorbed (from N/80			12.15 Fluorides (as F)	1,0	1,0
potassium permanganate			12.16 Zinc (as Zn)	5,0	0,3
in 4 hours at 27°C) (mg/ℓ)	10	5	12.17 Manganese (as Mn)	0,4	0,1
8. Conductivity:			12.18 Cadmium (as Cd)	0,05	0,05
			12.19 Mercury (as Hg)	0,02	0,02
8.1 Above that of intake water	75 mS/m	15%	12.20 Selenium (as Se)	0,05	0,05
8.2 In respect of mining effluent			12.21 Sum of concentrations of		
(mS/m at 25°C)	250	250	cadmium (as Cd), chromium		Tree de
9. Suspended solids (mg/ ℓ)	25	10	(as Cr), copper (as Cu), mercury		
10. Sodium content (above that of intake		Assessment to	(as Hg) and lead (as Pb)	1,0	_
water) (mg/ℓ)	90	50	12.22 The waste water or effluent shall		
11. Soap, oil or grease (mg/ℓ)	2,5	Nil	contain no other constituents in		12122
12. Other constituents (maximum			concentrations that are		
in mg/ℓ):			poisonous or injurious to		
12.1 Residual chlorine (as Cl)	0,1	Nil	- humans, animals, fish other		
12.2 Free and saline ammonia (as N)	10,0	1,0	than trout, or other forms		A LEGIS
12.3 Nitrate (as N)	_	1,5	of aquatic life, or that are		
12.4 Arsenic (as As)	0,5	0,1	deleterious to agricultural use	Applicable*	-
12.5 Boron (as B)	1,0	0,5	- trout or other fish, or other		
12.6 Hexavalent chromium (as Cr)	0.05		forms of aquatic life	-	Applicable

Special Standard for Phosphate

Effluent discharged into the following rivers or their tributaries in the RSA † shall not contain soluble orthophosphate (as P) in a higher concentration than 1,0 mg/ ℓ :

- (a) Vaal River upstream and inclusive of the Bloemhof
- (b) Pienaars and Crocodile Rivers upstream of their confluence (Transvaal)
- (c) Great Olifants River upstream and inclusive of the
- Loskop Dam (Transvaal)
- (d) Mgeni River upstream of the influence of tidal water (Natal)
- (e) Umlaas River upstream of its point of discharge into the sea (Natal)
- (f) Buffalo River upstream and inclusive of the Bridle Drift Dam (Cape Province)
- (g) Berg River upstream of the influence of tidal water (Cape Province)

[†] The locations of these sensitive catchments are shown in Fig. 4.3.1.

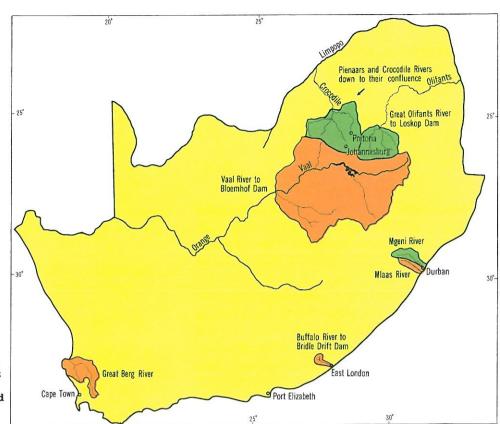


Fig. 4.3.1: Critically sensitive catchments subject to the special phosphate standard for the discharge of effluent

punishable offence in terms of the Water Act, 1956.

Section 24

The Director-General may authorize any person to inspect any area in which water is used for industrial purposes or on which any substance referred to in section 22 is used or is present. If the Director-General is of the opinion, based on the findings of the inspection, that any steps taken to comply with the pollution control provisions of the Water Act, 1956, are insufficient or inadequate for the prevention of water pollution, he may direct the person responsible to take such additional or other steps as he may deem necessary.

The Minister may, by notice in the *Government Gazette*, prohibit or restrict the manufacture, marketing or use of any substance that in his opinion might cause water pollution, or subject such manufacture, marketing or use to such conditions as he may deem fit. For example, the use of phosphates in detergents can be controlled or prohibited when necessary.

Requirements of the Health Act, 1977

The Minister of National Health and Population Development is empowered, after consultation with the Ministers of Water Affairs and of Finance, to promulgate regulations in terms of the Health Act, 1977 (Act 63 of 1977), relating to the following:

Geohydrological investigations must be conducted into the suitability of sites for waste disposal to prevent or limit pollution of ground water.

- □ The supply of water for human use and the establishment of sewage and water purification works.
- ☐ The quality of water intended for human use, the quantity of water to be available for human use and the system of distribution of such water.
- Water sampling and analysis and the addition of any substance to water intended for potable purposes.
- Materials used for the construction of water care works or water supply schemes.

Requirements of the Environment Conservation Act, 1982

Regulations controlling the establishment and operation of solid waste disposal sites have been promulgated in terms of the Environment Conservation Act, 1982 (Act 100 of 1982). One of the main requirements is that geohydrological investigations must be conducted into the suitability of sites for waste disposal in order to prevent or limit pollution of underground water. The regulations are administered by the Water Pollution Control Directorate of the DWA on behalf of the Department of Environment Affairs.

The role of the DWA in combating water pollution

The mechanisms and the effects of rapidly increasing water pollution in the Republic of South Africa are complex. Comprehensive, flexible pollution control measures to protect the public interest without being unduly restrictive are being developed and refined in accordance with information that is continuously updated. Present controls are primarily concerned with the promulgation and application of effluent standards, the disposal of intractable effluent, solid wastes and brines, the prevention of storm-water pollution, the implementation of technical innovation in purification processes, the reuse of water and the regulation by permit of water use for industrial purposes.

The Department of Water Affairs has developed a data base to monitor all factors related to pollution and industrial water use, which, together with improved co-operation between local authorities, industries and mines, should ensure the continued development of adequate measures to deal with the problem.

Pollution control policies, measures and strategies of the DWA

Payment for the abatement of pollution

In keeping with international practice, the DWA has adopted the principle that the polluter pays for the abatement of his own pollution. It is a basic requirement of the legislation on pollution control that effluent purification be an integral part of industrial processes and that the producer of effluent should provide the staff, capital and plant to purify his own effluent to prescribed standards before the purified effluent is returned to its stream of origin.

Salinity control

Present salinity control measures in agricultural areas in the RSA are concerned with the provision

of water for dilution or the use of the river channel for irrigation return flows, while the downstream water requirements are supplied by means of a canal. For instance, water for dilution is provided in the Lower Berg River from the Voëlvlei Dam and in the Breede River and Orange-Fish River schemes. A canal is used in the Lower Sundays River for conveying irrigation water and eventually a similar measure may be required for the Lower Breede River as well. However, the increasing scarcity of fresh water for dilution and the high cost of aquaducts now requires research to be undertaken into alternatives such as the removal and isolation of salts at source.

In keeping with international practice, the Department of Water Affairs has adopted the principle that the polluter pays for the abatement of his own pollution.

In urban and industrial areas, point sources of salinity have been identified and strategies formulated to reduce their impact on the water environment, such as those outlined below for the Vaal River. Once desalination techniques are considered economically viable, industries will be required to use these processes to remove salts from effluent streams. Safe sites for the disposal of the resulting brines and salts will have to be established. The concentration of the salts could also make recovery of marketable constituents viable.

Salinity control strategies for the RWB area (Section 4.2)

A blending option which incorporates an operating rule will be implemented whereby the proportion of Vaal Dam water abstracted and mixed with Vaal Barrage water is varied so that a prescribed maximum TDS concentration in the supply water is not exceeded. Additional water with a low TDS content will have to be supplied to the Vaal system to enable the blending operating rule to be implemented.

Other users situated downstream of the Vaal Barrage may also have to implement blending operating rules in conjunction with the use of ground water, with good quality water either stored off-channel or obtained from sources which are currently being investigated. Effluent standards may have to be raised to reduce the amount of salt entering the system, perhaps in conjunction with compulsory desalination and the provision of salt sinks, which may have a use as recreational areas. In some instances it should be possible to utilize solid waste disposal sites, mine tailings dams and ash dams at power-stations as salt sinks with a limited salt-retaining capacity.

Feasibility studies of the above options indicate that a TDS concentration of 250 mg/ ℓ to 300 mg/ ℓ for water supplied to most industrial and urban users is a realistic and economically viable target.

Control over intractable effluent and the disposal of solid wastes

Measures for the handling of highly saline effluent also apply to the handling of intractable effluent and to effluent that cannot be degraded.

POLLUTION CONTROL 4.21

Disposal into the sea is only permissible if the intractable effluent contains no substances in concentrations that could create marine or other environmental hazards.

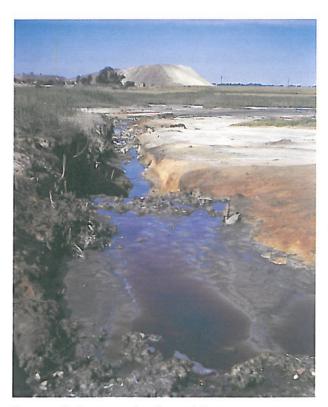
Disposal methods, other than those listed for saline effluent, including encapsulation, co-disposal with certain other wastes, soak-aways under certain circumstances, neutralization, chemical treatment and dumping at sea, may also be used. Although there are waste disposal contractors who deal with this type of problem in the major industrial centres, there may be regions where suitable disposal sites are inadequate or unavailable. Disposal into the sea is only permissible if the intractable effluent contains no substances in concentrations that could create marine or other environmental hazards. Disposal of such effluent is controlled by regulations promulgated in terms of section 26 of the Water Act, 1956.

Control and management of eutrophication

In the RSA 80 per cent to 90 per cent of nutrients in water sources originate from point sources. The biologically available fractions of phosphates emanating from sewage works are also much higher than those from diffuse sources. Consequently, the management of nutrient discharges into the water environment concentrates firstly on point sources. As a first step in a longterm eutrophication control strategy, an effluent phosphate standard was introduced for seven sensitive catchments in 1980 for full implementation by 1 August 1985 (see Fig. 4.3.1). The maximum allowable concentration of 1 mg/l soluble ortho-phosphate (as P) was selected on the basis of two main considerations. Firstly, it was expected to result in a significant reduction in phosphate loads in the water environment. Secondly, it was considered to be technologically achievable at a reasonable cost.

Rapid progress has been made in the development of phosphate removal technology and full-scale biological and chemical methods are becoming available. The choice of technology will depend on the circumstances of effluent dischargers, which may be local authorities, industries, mines or others. In very small plants without skilled operators or supervisors both biological and chemical methods may fail and thereby create pollution problems. There is thus a great need for the development of less sophisticated removal techniques.

The effect that application of the standard has on the water environment will be closely monitored to determine its adequacy and the extent to which a stricter standard or additional legal or other management strategies may be required.



Severe pollution emanating from mining waste

To facilitate effective monitoring, existing models of system reaction to reduced nutrient loading are being refined for South African circumstances. Additional controls are already required at several hypertrophic impoundments and may be required elsewhere as population and urbanization increase. A holistic management approach will be followed in which all practical control strategies, from point-source control to water treatment to remove the deleterious products of eutrophication, will be considered.

A holistic management approach will be followed in which all practical control strategies to remove the deleterious products of euthrophication will be considered.

As about 35 per cent to 50 per cent of the total phosphate load on sewage works can be attributed to phosphates in detergents, a detergent phosphate limitation or ban is seen as a realistic control option in many countries. Such a limitation or ban should be seen as supplementary only, since the total phosphate content of raw sewage would still require removal of phosphates in sewage treatment plants before the effluent standard could be met. A detergent phosphate limitation must be considered with circumspection and must be preceded by a study to determine whether this strategy is more cost effective than

the removal of phosphates in sewage treatment plants.

Other measures to control and manage eutrophication should be seen as complementary and will vary from river to river, depending on the particular circumstances of water use and environment. These could include preventive measures outside water bodies, curative measures inside water bodies, corrective measures at or after the point of abstraction from water bodies, or a combination of these measures, depending on technical feasibility and cost-effectiveness. To find the best eutrophication control measures, important secondary uses of impoundments, such as recreation and aquaculture, must be taken into account in the planning, design and operation of water schemes.

6An eutrophication management strategy has serious economic implications.

An eutrophication management strategy has serious economic implications. The removal of phosphates from waste water will require substantial capital expenditure to build or upgrade waste water treatment plants and will also require the employment of better qualified operators. Consequently, decision-makers in the fields of water resource planning and management require realistic predictions of the consequences of alternative options. A research project to develop an improved reservoir eutrophication model to assist decision-making is under way.

Measures to reduce eutrophication

Nutrient load control at source is the most desirable way to reduce eutrophication. Most development work and application in practice has been based on this approach. Unfortunately, control at source is not always practicable. Consequently, other approaches are being studied and implemented to a limited degree.

The following is an overview of the most common measures being applied*:

1. Preventive measures outside reservoirs:

- (a) Treatment of waste water, e.g. by removal of phosphates and nitrogen.
- (b) Complete diversion of waste water, e.g. by ring canalization.
- (c) Nutrient removal by pre-impoundment.
- (d) Precipitation of phosphates in streams and rivers upstream of dams.
- (e) Catchment protection, e.g. by reafforestation and by restrictions on the use of fertilizers and on the establishment of potential nutrient sources in river catchments.
- (f) Replacement of phosphates in laundry detergents by environmentally less harmful substances.
- *After Vollenweider, R A. 'Eutrophication a global problem'. WHO Water Quality Bulletin 6(3), 1981.

2. Curative measures inside reservoirs:

- (a) Physical manipulation, e.g. by destratification, hypolimnetic aeration, the withdrawal of hypolimnetic water and the alteration of flushing regimes.
- (b) Chemical manipulation, e.g. by nutrient precipitation inside the water body and by the inactivation and removal of sediments.
- (c) Biological manipulation, e.g. by mechanical harvesting of the biomass (macrophytes, algae and fish), the application of toxic substances (herbicides, algaecides and pesticides) and direct manipulation of the food chain.

Corrective measures at or after the point of abstraction from reservoirs:

- (a) Physical removal of algae and macrophytes, e.g. by microfiltration and flotation.
- (b) Prechlorination to kill algae followed by physical removal of dead algae by sedimentation, flotation or screening.
- (c) Oxidation to remove H2S, Fe2 and Mn2+.
- (d) Activated carbon treatment to remove dissolved organic compounds and the precursors of trihalomethanes.
- (e) The use of ozone instead of chlorine as a disinfectant to reduce the possibility of the formation of trihalomethanes during water treatment.

These measures have been applied singly or in combination in many countries, such as in the USA, in Scandinavian and European countries and in Japan. The results achieved have ranged from complete success to complete failure. The successes indicate that reversal of the eutrophication process is certainly possible. However, the less successful cases indicate that sufficient knowledge on eutrophication management is not yet available. Critical analysis is necessary to determine the reasons for the failures.

Recent advances in the understanding of limnological processes and impact prediction models developed in the RSA will be used in decision-making. More emphasis will also be placed on determining technical and economic feasibilities to formulate the best eutrophication management programme for the RSA.

Because the number of Third World urban areas is increasing rapidly, special attention is being given to the development of low-level phosphate removal technology, commensurate with the level of expertise available for the operation of water care works in these areas.

Control over trace metals and micro-pollutants

The following research and monitoring programmes are being established:

- Long-term monitoring programmes to provide a broad coverage of water quality conditions and to establish trends relating to the presence of synthetic pollutants in the water environment.
- Problem-oriented short-term research programmes designed to provide detailed information regarding the sources, accumulation and ultimate fates of metal and organic pollutants.
- A programme dealing with the effective removal of micro-organic compounds in water purification processes.

Application of technical innovation

When an exemption from compliance with relevant effluent standards is considered, factors such as the availability of technology to achieve POLLUTION CONTROL 4.23

The DWA may require industry to implement new water and effluent management technologies within a reasonable period of time, provided such technologies have been proved to be appropriate under local conditions.

standards, the quantity, permanency and quality of the receiving water and the purposes for which it is normally used are taken into account. Where the effect that an exemption may have is uncertain, the effect is monitored and, if necessary, the exemption is modified.

Stringent application of effluent standards has already led to the construction of many sophisticated treatment plants. Completed research projects, directed towards the purification of selected industrial effluent, have given rise to technologies that could lead to new standards and policies for reuse. The DWA assists by giving advice on available technologies.

In terms of sections 12 and 21 of the Water Act, 1956, the DWA may, where appropriate, require industry to implement new water and effluent management technologies within a reasonable period of time, provided such technologies have been proved to be appropriate under local conditions. The local circumstances and merits of each case are taken into account, however. For instance, industries at the coast would probably not be required to implement new desalination technologies if facilities for the safe disposal of highly saline effluent into the sea were available.

Disposal by reuse instead of return to the stream of origin

In terms of the Water Act, 1956, effluent resulting from the use of water for industrial purposes is public water and is therefore subject to control by the State. Disposal by any means other than the return of treated effluent to the stream of origin is subject to approval by the Minister of Water Affairs. The following means of disposal are considered:

1. General reuse by local authorities: Within the areas of jurisdiction of local authorities, permits are granted to encourage the use of treated effluent for watering parks, recreational areas, roads, sports fields and nurseries, provided that fresh water that would have been used is saved. In such use the guide-lines formulated by the Department of National Health and Population Development for the permissible utilization and disposal of treated sewage effluent must be met. Quantities allowed are strictly limited to the normal water requirements of the vegetation of the areas to be irrigated.

- 2. Reuse by irrigation: Where there are practical or economic difficulties in returning treated effluent to the stream of origin, an exemption may be granted to allow disposal of treated effluent by irrigation. The area to be irrigated should preferably have an existing water right that can be exchanged for treated effluent. The DWA prefers irrigation on town commonages to be undertaken by bona fide farmers. As local authorities without riparian rights to irrigation water have no right to use water except for domestic or industrial purposes, many have been refused permits to irrigate with treated effluent. In the case of smaller local authorities that have total average dry weather sewage flows of less than 750 m³/d, the use of oxidation ponds for the treatment of sewage is permissible. As the effluent from such oxidation ponds does not normally comply with effluent standards, the disposal of such effluent by irrigation is compulsory.
- 3. Reuse in industry: Instead of being returned to the stream of origin, treated effluent can be diverted to selected industrial undertakings with the permission of the Minister of Water Affairs. A cascading approach in which subsequent users are able to utilize water that is of a progressively lower quality is desirable (Section 6.6). Large volumes of low quality water available in specific areas could possibly be used for industrial cooling and lower-order uses such as wash water. A dual water supply system that meets the ideal situation of providing different grades of water to industrial areas has been implemented in Port Elizabeth, where the final industrial effluent is discharged into the sea.

Brine disposal

Rapid progress is being made in reducing the cost of desalination and advanced waste water treatment and these processes are being applied by industries to improve the quality of process water. Eventually the large-scale use of these processes will create serious brine and final effluent disposal problems. Whereas disposal sites for virtually all solid, toxic and other wastes can be found or engineered, sites for the effective disposal of brines have not been investigated sufficiently.

Wherever possible, local authorities will have to provide and operate central facilities, such as evaporation ponds, of sufficient capacity to absorb locally produced brines. State involvement in the establishment and operation of regional facilities may be warranted. The full costs of the establishment and operation of brine disposal facilities should be recovered from the brine producers, in keeping with the principle that the polluter pays.

The reclamation of effluent for direct reuse

The indirect reuse of effluent that returns to rivers as a matter of course has been accepted by the public for centuries. In contrast, processes to purify sewage effluent directly to a potable standard have only recently been developed and do not yet enjoy widespread consumer acceptance and confidence. For this reason the Department of Water Affairs does not intend to require direct reuse for domestic purposes for as long as it is practicable and economical to develop conventional sources. Whether, when and to what extent water reclaimed from effluent is to be incorporated into local water supply systems will accordingly be determined in each case by the preferences of local authorities in the light of available alternatives (Section 3.5).

The direct reuse of water of different qualities for industrial purposes is already being applied in practice. The Departments of Water Affairs and of National Health and Population Development must grant approval for the direct reclamation and reuse of sewage effluent.

Guide-lines for the use of reclaimed water for domestic purposes

Sewage effluent has been reused indirectly for many decades in the interior of South Africa, while in coastal areas it is mainly discharged to the sea. In view of the potential of sewage effluent as a future water source, permission to discharge it into the sea is never granted in perpetuity.

The following restrictive guide-lines have been formulated by the Department of National Health and Population Development for the use of reclaimed water for domestic purposes. The increasing use of water reclamation for domestic purposes will make available more information on the health aspects of reclaimed water, which will make it possible to amend the guide-lines.

1. An assurance should be given that alternative economically utilizable conventional water

- sources of suitable quality do not exist. Relatively unpolluted surface and ground water should preferably be used for domestic purposes, while purified sewage effluent should be allocated to the agricultural, industrial and mining sectors.
- 2. Only domestic effluent, with a minimum industrial effluent component of which the quantity and composition is known, should be reclaimed for direct domestic reuse. The reclamation plant should be able to remove pesticides and other potentially harmful and toxic substances that may occur in the sewage effluent.
- 3. The water reclamation process should be based on results of extensive research by the NIWR as contained in its Manual for Water Renovation and Reclamation which was published in co-operation with the WRC. Particulars on the following aspects of an envisaged reclamation process should be submitted for approval:
 - (a) The unit processes to be used, including principles adopted for safeguards, such as the provision of more than one process to remove or inactivate matter that may be harmful to health and pathogenic microorganisms.
 - (b) The staff that will be appointed to operate, manage, control, monitor and maintain the reclamation plant.
 - (c) A timetable in which the duties and responsibilities of every member of the staff is specified.
 - (d) A process control timetable specifying the extent and consistency of observations, instrument readings, sampling and other control procedures. The steps to be taken to obtain the different sampling results must be specified, as must the procedures to be followed under emergency conditions.
 - (e) The nature and extent of the plant maintenance programme.
 - (f) The nature and extent of the quality control programme for the effluent from the different unit processes. Provision must be made for adequate sampling to ensure an effluent of the desired quality after each unit process. This also applies to the final reclaimed water which is the cumulative product of the reclamation unit processes. Provision must also be made for full analysis of the raw effluent, as well as of the treated sewage effluent, in order to make the necessary preparations should unexpected matter have to be removed by the reclamation works. To promote public acceptance and general confidence in the pro-

Daspoort reclamation works – development of technology for the treatment of effluent for direct reuse



cess, it is recommended that the quality analyses be executed by an independent laboratory and that this laboratory participate in the inter-laboratory studies of the NIWR to establish the reliability of its results.

- 4. Provision should be made for a comprehensive permanent data system so that a proper record is kept of the different aspects monitored and consequently of the functioning of the plant and the quality of the reclaimed water. These records will provide valuable information to engineers and scientists concerned with the planning of new water reclamation plants.
- 5. A summary report on the operation of the plant, giving particulars of the breakdown of equipment and of the quality of the reclaimed water, should be made available to the Department of National Health and Population Development at regular intervals.
- 6. Provision should be made to store the reclaimed water before it is supplied to the distribution system until it can be established that it conforms with the quality requirements, thus providing a safeguard against plant malfunction.
- 7. The reclaimed water should be mixed with conventionally treated water and the water supplied to users should consist of not more than 20 per cent reclaimed water.
- Wherever possible, epidemiological surveys should be carried out in the area concerned, both before and after the introduction of reclaimed water for domestic use.
- 9. The use of reclaimed water should be preceded

by an intensive campaign to inform the public on its necessity and safety.

Reciprocal pollution control agreements with the TBVC states

Agreements concluded with the TBVC states include a provision for reciprocal legislation on pollution control. Permanent water commissions have been established to deal with common water matters. The establishment of such commissions is to be extended to the self-governing national states (Sections 3.1 and 8.1).

A multilateral agreement on the control of pollution of water resources in South Africa was signed on 21 November 1985 by Ministers representing the governments of the RSA, Transkei, Bophuthatswana, Venda and Ciskei.

In terms of this agreement, member states will be responsible for promoting the effective control of sources of water pollution, including the enforcement of uniform effluent standards, regulations for solid waste disposal and the control of pollution from mines and mine dumps. Exemptions with regard to effluent standards may be granted to or withdrawn from producers of effluent.

Exemptions may be granted only after consideration of factors such as the possible effects of such exemptions on the water environment or on other users of water from communal sources, as well as the availability of practical methods for treating effluent or the possible effects on water quality in adjoining countries served by a communal water source. Member states may be expected to provide other member states with details of any exemption granted or of the registration of any solid waste disposal site.

Member states will meet annually to consider possible amendments to the agreement and to review programmes regarding the establishment of practical methods for the control of industrial effluent. They will also receive and consider reports from scientific and research bodies providing advice on any scientific or technical matters related to the agreement. Finally, member states will also arrange for technical assistance in and advice on the application of standards and the control of water pollution.

