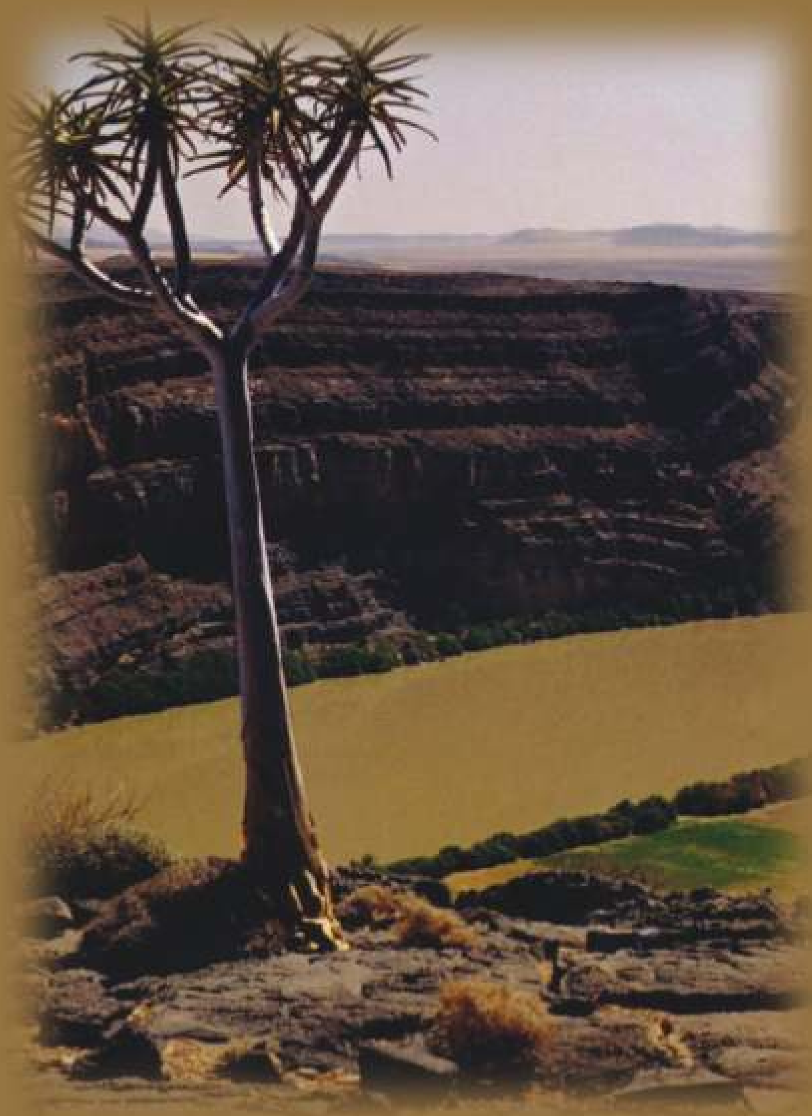
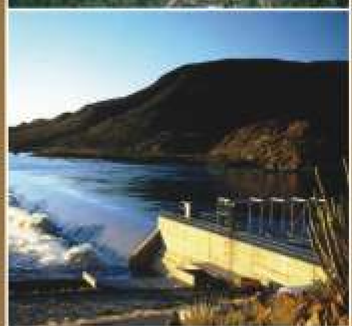


# Proceedings of a Joint RSA-Australian Workshop on Water Resource Management 31 March - 5 April 2003



TT 236/04

Water Research Commission

# Proceedings of a Joint

# RSA-Australian Workshop

# on Water Resource Management

31 March - 5 April 2003
Lancemore Hill, Kilmore, Australia

Organisers and Editors:

Professor Tom McMahon FTSE
Australian Academy of Technological Sciences and Engineering

and

Dr Thinus Basson FSAAE
SA Academy of Engineering

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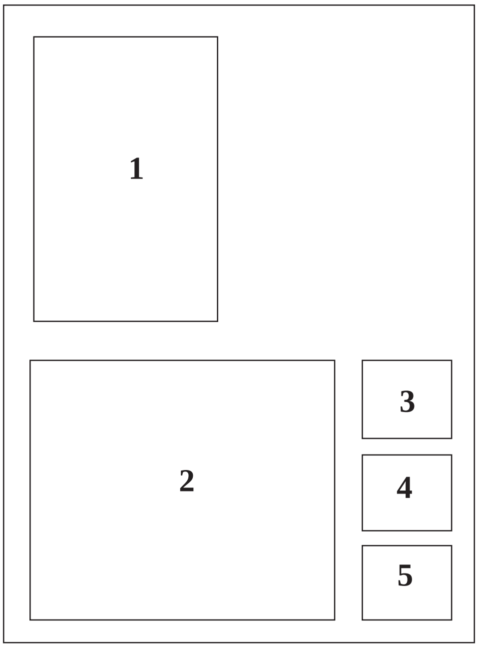


**Cover**:
1 Lower Orange River, South Africa*
2 Lock and Weir, Bookpurnong, South Australia**
3 Lock and Weir No 10, River Murray, Wentworth, New South Wales**
4 Lower Orange River, South Africa*
5 Lower Orange River, South Africa*

* Photo credit: Ronnie McKenzie
** Photo credit: Michael Bell. Image courtesy of the Murray-Darling Basin Commission

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# WELCOME MESSAGE

The Australian Academy of Technological Sciences and Engineering (ATSE) and the Australian Department of Education Science and Training extends a warm welcome to the South African Delegation led by Dr Thinus Basson FSAAE, sponsored by the South African Academy of Engineering.

We wish to express our sincere appreciation to Dr Basson in the development of the program, his selection of such an eminent group of South African participants and for supporting and promoting Science and Technology cooperation between Australia and South Africa.

Water Resources Management is a rich area for potential cooperation and I am pleased to welcome such an eminent group of scientists and technologists from South Africa and Australia. I am delighted that a group of young researchers has agreed to participate and know that they will bring a refreshing and valuable perspective to the many issues discussed and further strengthen ongoing research collaboration between Australia and South Africa.

We are delighted to host the first Australian-South Workshop on Water Resources Management, to be held in Melbourne from 1-5 April 2003. As Australia and South Africa have similar climate and hydrology (both countries have streams with extremely high variability by world standards) and many common water-related problems, a strategic Workshop on “Water Resources Management’ between the two Academies and key stakeholders would build on, explore key issues, and identify approaches taken by one nation that could be of assistance to the other.

We look forward to fruitful discussions and the identification of opportunities for mutual scientific, technological and commercial cooperation between Australia and South Africa, as each country strives to link scientific and technological knowledge with best management practices, to make limited water resources more sustainable.

Professor Tom McMahon FTSE
Australian Convenor

1 April 2003

## ACKNOWLEDGEMENTS

A wide range of people and organisations have been involved in arranging and hosting this workshop between Australian and South African water resource practitioners. The workshop participants and editors of this publication wish to acknowledge the contributions by the following:

- Australian Academy of Technological Sciences and Engineering that took the lead in identifying the need for arranging the Workshop.

- The Australian Department of Education Science and Training, Innovation Access Programme - International S&T, which sponsored the costs associated with hosting the Workshop in Australia.

- The South African Department of Water Affairs and Forestry and Water Research Commission for sponsoring the participation of a large number of the South African participants.

- Other South African participants who paid for their own international traveling costs.

- The South African Water Research Commission for printing this publication.

- Mrs Elizabeth Meier and Ms Colleen Littler of the Australian Academy of Technological Sciences and Engineering for their splendid logistical arrangements and support.

- The ATSE Fellows who participated in the activity and the Australian colleagues who hosted the technical visits in Adelaide and Tatura.

# TABLE OF CONTENTS

## 4. SUPPLYING A GROWING DEMAND

# AUSTRALIA-SOUTH AFRICA WORKSHOP ON WATER RESOURCE MANAGEMENT

1-3 April 2003
Opening Address by
Dr John Zillman AO, President, Australian Academy of Technological Sciences and Engineering

I am delighted, on behalf of the Australian Academy of Technological Sciences and Engineering (ATSE) and as someone with a deep and abiding interest in water resources assessment and management, to have been given the opportunity to welcome our South African colleagues to Australia and to officially open this workshop.

In doing so, I must firstly acknowledge the funding for the workshop provided by the Australian Commonwealth Department of Education, Science and Training (DEST).

Over the past eight years, ATSE has undertaken a very active program of international missions and workshop through the International Science and Technology Networks Component of the Australian Government's Innovation Access Program.

ATSE's International Relations Committee and the Academy Council, and indeed the entire Fellowship, are extremely happy that we are able to continue to build linkages with the South African Academy of Engineering (SAAE) through this workshop.

We greatly value the growing cooperation between the Australian and South African engineering and scientific communities that it represents and will, I am sure, be further strengthened over the next few days.

It would be hard to identify a more appropriate issue as the flag-bearer of that cooperation and the subject of this workshop than water resource management. Our two countries have many water-related things in common but none more significant than the large climatically-induced variability of rainfall and run off. In many ways, we are in the same boat.

And it would have been difficult to choose more appropriate timing for Australian-South African workshopping of the issues associated with water resource management:

- It is the International Year of Freshwater;
- The international focus on water issues through the UN system (UNESCO, the World Meteorological Organization (WMO), Food and Agriculture Organisation (FAO)) is intense;
- In this country, we are experiencing an almost unprecedented public policy focus on water issues as we go through, and are hopefully emerging from, one of the most severe and widespread droughts of the past century;
- The Intergovernmental Panel on Climate Change (IPCC) is about to adopt water as a major cross-cutting theme for its Fourth Assessment Report due in 2007;
- There is a host of ongoing reviews, including a major Parliamentary Inquiry, of Australia's water resources, including issues as controversial as the scope for use of weather modification for enhancement of water supply;

- The relevant Commonwealth-State Ministerial Councils, including the overarching Council of Australian Governments (COAG), are currently focussed directly on water issues;

- An enormous amount of academic work is going on in the universities and Cooperative Research Centres on physical and economic issues associated with property rights and water trading.

- And the ATSE itself has chosen 'WATER – The Australian Dilemma' as the theme for its Annual Invitation Symposium in Melbourne in November this year (I am delighted that the Chairman of the Program Committee for the Symposium, Professor Adrian Egan is partially in this workshop).

ATSE has, in recent years, done a lot on water issues, including a joint study with the Institution of Engineers Australia on 'Water and the Australian Economy' and a current study on Water Reuse.

Australia is fortunate in having such a strong and broadly based community of experts in hydrological science and in all the key dimensions of water resource management.

The organisers of this workshop, ATSE and SAAE, and especially Prof Tom McMahon and Dr Thinus Basson, are delighted that so many of them are represented here and that we have been able to assemble such a powerful contingent from the South African water management community.

On behalf of the Department of Education, Science and Training and the host Academy, ATSE, I am delighted to welcome our South African colleagues to Australia and to thank you all for your participation in this workshop.

You have an excellent program for the next few days. I look forward to the outcome. I hope it will provide a springboard for further joint activity between our two national water communities and our two Academies.

I am pleased to declare the workshop formally open.

# JOINT AUSTRALIA-SOUTH AFRICA WORKSHOP ON WATER RESOURCES MANAGEMENT

Opening Address by South Africa

MS Basson, Leader of SA Delegation, 2 April 2003

The South African Academy of Engineering greatly appreciates the initiative taken by the Australian Academy of Technological Sciences and Engineering in arranging this august occasion between distinguished professionals from our countries, on one of the most topical issues of the 21$^{st}$ century – the management of the most precious and fundamental of natural resources, our water. It is indeed a great privilege and honour for the South African delegation to participate in this workshop and we look forward to learning from our Australian counterparts, and also to share our knowledge and experiences, all to the mutual benefit of our countries and possibly others.

**South African Academy of Engineering**

The South African Academy of Engineering was established as an independent body in 1997. Although still small and inexperienced on academy matters, it is now reaching the stage where its eminent engineering membership of 96 fellows can begin to provide the service needed to fulfil its Mission.

We are indebted to the Australian Academy of Technological Sciences and Engineering for reaching out to us shortly after our establishment, in inviting our President to attend the 1998 ATSE Convention in Australia as a guest, and to learn from the ATSE structure and operational experience. During Dr Bingle Kruger's very successful and informative visit to Australia, the two academies agreed to hold a first joint conference in South Africa on a topic of mutual importance.

This culminated in the highly successful joint South African-Australian conference on **Public Private Partnerships for 2000 and Beyond**, held in Pretoria in November 1999 and attended by some 200 invited delegates. It was also the first event of its kind by the South African Academy of Engineering. The two academies then agreed to continue the excellent relations with a joint Workshop in Australia within a few years – with that goal being realised today.

We have only been in Australia for a brief period so far, and are already immensely impressed with what we have seen and experienced. You certainly have a great country to feel passionate about.

**South Africa**

South Africa also has some unique characteristics which I would like to share with you. It is a land of beauty and spectacular contrasts, and of different peoples contributing to a rich cultural heritage. A land in need and a land of opportunity. Much of its natural splendour being a result of the variations in, and often the harshness of its climate.

We are blessed with some of the richest floral and animal kingdoms on earth, with abundant diversity of species. The Cape Floral Kingdom, also referred to as the Cape Fynbos and which is regarded as one of the floral wonders of the world, has 8 600 plant species, 5 800 of which are endemic. The 1 500 plant species which occur on Table Mountain alone, is equal to that of the British Isles. Similarly, the Karoo Succulent Floral Kingdom represents the greatest variety of arid climate and desert plants found in any one country, most of which also being unique to South Africa.

Probably better known to most people, is the bounty of our animal kingdom, some of which is shared with other parts of the African continent. The impressive beasts such as elephant, rhinos, lions, giraffe and others are only the larger and more obvious specimens of a truly remarkable faunal ecosystem. Few experiences would surpass the tranquility of watching a sunset over the African Bush and having a herd of Elephant majestically walking by.

It is one of our prime duties as engineers and scientists, to perform our work in such a way so as to best protect and preserve this unique and irreplaceable natural heritage of our country and our planet for future generations.

South Africa is the country where the world's oldest rocks and fossils are found. The Cradle of Man World Heritage Site just north of Johannesburg, according to anthropologists, is where the oldest remains of the ancestors of the peoples of the world have been found. It is also the country of the world's youngest democracy.

**Australia**

Similar to South Africa, Australia is home to unique plant and animal species and we greatly look forward to experiencing at least some of these during our extended stays in the country.

Evidence abounds of many fields where Australia has taken up position with the leading nations in the world. In the field of technology it is Australians that developed the "Black Box" flight recorder, they also developed the world's most efficient solar cells and discovered the gene that determines when plants stop their vegetation growth and start flowering. To my knowledge, Australia is one of the only countries in the world (if not the only one) with a formal Government Strategy aimed at fostering innovation, supported by a five-year programme of nearly A$3 billion.

A recent showcase of Australian achievement was the Sydney Olympics, generally regarded as the best staged Olympic games ever. Despite its relatively small population, Australia has also consistently has reached the highest level in most sports. This excellence is not only attributable to a passion for sports, however, but also serves as a demonstration of the successful integration of high level achievements in a number of specialist fields such as biomechanics, physiology, sport psychology, nutrition, talent search programs, coaching and other scientific research.

It is because of these achievements by Australia and what we sense as a national commitment to innovation and progress, that we believe we have much to learn from Australia during this workshop.

**Parallels between Australia and South Africa**

Amongst the best known of South Africa's technological achievements are the first successful human heart transplant in 1967 and our successes in the production of fuel from coal, whilst innovations such as the tellurometer for electronic distance measurement may be equated to the "black box". We also have our occassional moments of glory on the sports fields, but often have to bow the knee to Australia.

In the field of water resource management, the South African National Water Act is widely regarded as one of the leading pieces of legislation in the world. We believe that we have also contributed to the international pool of knowledge with respect to systems and probabilistic approaches in water resources management, and the assessment and management of ecological water requirements. Whilst we would like to share these experiences with you, we are profoundly aware of the fact that much remains to be done.

Australia and South Africa are generally regarded as two countries with comparable climates and similar issues of importance with respect to the management of their water resources. What may be misleading, is the fact that Australia's land area is more than 6 times that of South Africa. With similar climates, although Australia being slightly wetter on average, this results in the total renewable freshwater supply in Australia of approximately 8 times as much as in South Africa.

The main difference being the South African population of more than double that of Australia, resulting in a per capita freshwater availability in Australia of nearly 18 times that in South Africa. In many instances, therefore, there is a greater urgency in having to address water issues in South Africa than what one would expect in Australia.

**Challenges to Engineering**

We live in a world today where we are faced with unparalleled challenges and opportunity. A world where natural resources are often at the verge of being taxed to the limit and where more than 20% of the people live below the threshold of extreme poverty, taken at a per capita income of US $1 per day. The African continent, which we are part of, being the poorest of all. It is a part of the world where millions of people do not have access to safe drinking water and adequate sanitation, many of whom are in our own country, and where the development and improved management of water resources can make a meaningful difference to the livelihood of people. Other resources are often under-developed, inefficiently utilised, or poorly managed and protected, resulting in widespread degradation that may be difficult to reverse. As engineers we can contribute significantly to improving the situation, and it is our duty to do so.

We also live in a world of globalisation, and where the health and wealth of nations are increasingly defined by global forces. Where technology is generally accepted to be one of the key distinguishers among nations in the 21st century. It is of great concern therefore, that South Africa experienced a nett loss of skilled human resources during recent years, a significant proportion of whom now reside in Australia. Although partly countered by unlocking the skills of people who may have been deprived of reaching their full potential under the previous political dispensation in South Africa, we are still seriously in need of extending our technological and entrepreneurial capability.

Technology, however, should not be viewed as the sole key to success. To efficiently unlock its full potential and judiciously apply the benefits to society, technology should be built on the sound foundation of our moral, cultural and spiritual values, within the enabling framework of a just political and legal system – all essential components of a balanced society. Fortunately, I believe this is the situation which prevails in both our countries.

As engineers and scientists we should guard against acting within a restrictive framework as technocrats, as we sometimes tend to do, and take up the leading and guiding roles which society expects of us. Technology also has shelve life in an ever changing environment and can only remain relevant through continuous development and innovation. In this respect we are on a journey towards better understanding, managing and living in harmony with our environment, and not at a destination. We need all components of the fabric in proper balance with one another, to really be successful in realising our goals.

**Workshop on Water Resources Management**

The South African delegation is therefore delighted to take part in this second joint workshop hosted by the ATSE in Australia. We are told by geologists that our countries once were part of the same ancient super continent. Some corresponding plant families which are common to both Australia and South Africa bear testimony of that time. Our academies of engineering are now bridging this gap caused by continental drift, by playing our role in bringing two countries which have so much in common, closer together again.

On behalf of the South African Academy of Engineering and our delegation as well as of our professional colleagues at home who also stand to benefit from it, I wish to thank the Australian Academy of Technological Sciences and Engineering for the initiative which you have taken. We look forward to what I am confident will be a very successful workshop and to forge relationships for continued future cooperation.

We need to pursue a spirit of stimulating positive change, of living within the realms of environmental sustainability, of fostering life-long learning, of nurturing our intellectual capital and of developing a knowledge sharing mentality globally.

May these initiatives develop in an ongoing programme of activities to the mutual benefit of our academies and of our countries.

# FROM PRINCIPLES TO IMPLEMENTION OF INTEGRATED WATER RESOURCE MANAGEMENT

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***ABSTRACT***

*South Africa is largely a semi-arid country with a highly varied climate. Surface water resources are already well developed although the same attention was not always bestowed on groundwater and the aquatic needs of the environment. The distribution of South Africa's water to its cumulative population is even more unequal when measured in terms of class, race and gender.*

*The political transition in South Africa created a unique opportunity with the required political will to effect new legislation to address integration of water resource management in terms of quantity and quality, surface and ground water, with a strong emphasis on equity, efficiency and sustainability. The water law reform process developed key principles through a wide public participation process before it were entrenched in the National Water Act in 1998. Meeting basic needs and ensuring sustainability of the environment are key principles, as well as developing human resources and building the economy through involvement of all water users and stakeholders.*

*The National Water Act has substantially altered the framework for access to water, ensuring the improved and equitable distribution of this precious resource. Ecologically requirements and basic human needs are given first rights to water. The concept of private water is abolished and groundwater is managed as part of the integrated water cycle. Access to water is divorced from land ownership, and changed the perceived permanent rights to water to time-limited authorisations and licences.*

*The National Water Resource Strategy is the implementation strategy for the National Water Act and provides the legally binding framework within which the water resources of South Africa will be protected, developed and managed. It outlines the goals and objectives of water resources management for the country and sets out the strategies, plans and procedures to achieve these goals. It identifies opportunities for social and economic development where water is available. Greater integration will be required in all the major functional areas of water resources protection, allocation and conservation. Infrastructure development, water demand management and water quality management should be harnessed together in order that water is used in the most beneficial and efficient way. Some of these measures are already being implemented including the determination of ecological flow requirements before authorising any other new water use. Verification of existing lawful uses needs to be done in the near future and eventual compulsory licences will ensure equitable, efficient and sustainable water use.*

*The need for integrated management of water resources on a catchment basis to support sustainable development has been adopted as a key principle. The country is divided into 19 water management areas, and a catchment management agency responsible for water management area will eventually be established in each water management area. Water resource management is an important tool to build a socially and environmentally just society. One of the major challenges in the water services sector is the large number of*

*different institutions involved. All three spheres of government have a role, as well as water boards, community based organisations, municipalities acting as water services authorities and water services providers, and the private sector. To develop a regulatory framework and regulations to cover all these institutions and yet, be simple and transparent is a particular challenge. Everyone in the country is required - and should be enabled - to play an active part in water management.*

*The South African National Water Act and the National Water Resource Strategy provides the required legislation and statutory framework to achieve the principles of equity, efficiency and sustainability of water resources through active participation of all sectors of society.*

## 1. INTRODUCTION

The South African National Water Act provides the foundation for water to be managed in South Africa in an integrated manner based on the principles of equity, efficiency and sustainability and supporting the democratic values of participation. The integrated nature and interdependence of water in all its forms within the total water cycle form the basis of management on a catchment or watershed level. A drastic change in the philosophy and practice of water resource management was vital to address the new constitutional obligations and a new approach to the management, protection, use, development, conservation, and control of water was put in place. The basic principles and innovative approaches and instruments that have been developed in the water legislation to reflect these values are described.

## 2. WATER RESOURCES OF SOUTH AFRICA AND THE DEVELOPMENT OF LEGISLATION

South Africa is largely a semi-arid country with a varied climate. A gradual change in climatic conditions occurs from the wet and sub-humid eastern regions to the arid western coastal belt along the Atlantic Ocean. The average annual rainfall in KwaZulu/Natal reaches 1 200mm at the east coast whereas the Namaqualand coastal plains on the west coast receive rainfall well below 100 mm. In the south, the presence of the east-west stretching Cape mountain ranges, up to 2 000m high, has an orographic effect on rainfall with the mountains receiving up to 2 000mm and the valleys only between 200 and 300mm.

Being an arid country, pressure on resources became critical in the 1980 and 1990s. The previous Water Act of 1956 had to be extensively amended from time to time to try to address issues such as quality management and controlled areas. Due to the impact of activities such as commercial forestry upon the reduction of streamflow, new commercial afforestation was already managed under delegation in terms of the Forestry Act. The same quantity of water has to be shared between a larger number of users and the growing needs of a developing society. Environmental needs were recognised to a larger extent.

Water use in South Africa is dominated by irrigation, which uses approximately 60% of all water used in the country. Domestic and urban use accounts for about 11% of water use, while mining and some large industries account for approximately 8%. Commercial forestry plantations use around 8% by reducing runoff into rivers and streams.

The distribution of South Africa's water to its cumulative population is even more unequal when measured in terms of class, race and gender. Meeting basic needs as well as developing human resources and building the economy are key considerations. The eradication of poverty is recognised as one of the most fundamental challenges facing South Africa. The fundamental principle of our water resources policy is the right to access to clean water – ‘water security for all’. The added emphasis on demands of equity and social transformation made it an opportune time to reform South African water law fundamentally.

The management of water resources thus poses a huge challenge to manage shortages and ensure equity, efficiency and sustainability in the use of South Africa’s water resources.

South Africa, as part of its new democracy, passed a new Constitution in 1996 after the whole nation was engaged in the drafting process. The review of the water law was guided shortly after this through a wide public participation process, culminating in a set of basic principles. These principles were embodied in the White Paper on National Water Policy, 1997, as a statement of Policy and followed up by enacting it in legislation with the Water Services Act, 1977, and the National Water Act, 1998. Three fundamental objectives for managing South Africa's water resources arise from the Principles:

To achieve equitable access to water, including access to water services, to the use of water resources, and to the benefits from the use of water resources.

- To achieve sustainable use of water, by making progressive adjustments to water use to achieve a balance between water availability and legitimate water requirements, and by implementing measures to protect water resources.

- To achieve efficient and effective water use for optimum social and economic benefit.

Water comprises an ecological system with a close interaction between different dimensions of surface and groundwater, quantity and quality. There is a close interaction between water, land and the environment and changes in any one of them will influence the other. There is also a strong interrelationship between water and social and economic development. Integrated water resource management may be described as an evolving, iterative process for the co-ordinated planning and management - using a balance of technological and social approaches - of water, land and environmental resources for their equitable and sustainable use. The National Water Resource Strategy established in accordance with the National Water Act sets out the strategies, plans and procedures to achieve the aims of integrated water resource management.

## 3. PRINCIPLES OF NATIONAL WATER LAW

The water law reform process developed key principles through a wide public participation process before it were entrenched in the National Water Act in 1998. Principles that guided the revision of the water law, the concepts endorsed and instruments provided in the Water Services Act and National Water Act are highlighted.

### 3.1 Constitution

> Principle 1
> *The water law shall be subject to and consistent with the Constitution in all matters including the determination of the public interest and the rights and obligations of all parties, public and private, with regards to water. While taking cognisance of existing uses, the water law will actively promote the values enshrined in the Bill of Rights.*

The Constitution allocates responsibility for specific functions between the different spheres of government at national, provincial and local level. The National Department of Water Affairs and Forestry is to act as the custodian of water as a public resource and ensure that it be managed for the optimal benefit of society as a whole. Local government is responsibility for the provision of water services whilst national government has a regulatory and supportive function.

As part of the Bill of Rights the Constitution guarantees everyone the right to have the environment protected while promoting justifiable economic and social development, the right to access to sufficient food and water and the right to dignity.

### 3.2 Water services

Principle 25
*The right of all citizens to have access to basic water services (the provision of potable water supply and the removal and disposal of human excreta and waste water) necessary to afford them a healthy environment on an equitable and economically and environmentally sustainable basis shall be supported.*

Principle 26
*Water services shall be regulated in a manner which is consistent with and supportive of the aims and approaches of the broader local government framework.*

Principle 27
*While the provision of water services is an activity distinct from the development and management of water resources, water services shall be provided in a manner consistent with the goals of water resource management*

Principle 28

*Where water services are provided in a monopoly situation, the interests of the individual consumer and the wider public must be protected and the broad goals of public policy promoted.*

One of the major objectives of the new government was to address the historical backlog in the supply of water and sanitation to all South Africans. It has been estimated in 1994 that 12 million people did not have adequate access to clean water within a reasonable distance, and thus not afforded quality of life and health benefits coming from the provision of water and sanitation.

Although the local authorities have the primary function of water provision, capacity as water services providers had to be strengthened through training and empowerment. The Department of Water Affairs and Forestry played an implementing role where capacity was lacking in local authorities. A large number of schemes were built and funded in support of local authorities and in consultation with communities. The role of monitoring and regulating the water services authorities is gradually being developed.

The provision of water services must be properly planned, managed and controlled, taking into account the basic right to access to water, adequate levels of service, water availability and efficient water use. The development of water supply is playing an important role to attack poverty, as access to safe water and adequate sanitation are basic requirements for eradicating poverty.

In order to achieve this, the Water Service Development Plans (WSDP) is required for local authorities as a planning, but also a regulating instrument. The interaction with water resource management forms part of these plans to ensure that water balance in resource, water availability and water conservation are taken into account. The WSDP played an important part of the Integrated Development Plan of local authorities in terms of the

Municipal Systems Act. The WSDP indeed were amongst the first sections of the Integrated Development Plans to be developed and laid the foundation to integration of development function on local authority level.

The Water Services Act, 1997 (Act 108 of 1997) is the governing legislation for water services and sanitation and provides for:

- The rights of access to basic water supply and basic sanitation
- The setting of national standards and of norms and standards for tariffs
- Water services development plans
- A regulatory framework for water services institutions and water service intermediaries
- The establishment and disestablishment of water boards and water service committees and their powers and duties
- The monitoring of water services and intervention by the minister or by the relevant province
- Financial assistance to water services institutions
- Certain general powers of the minister
- The gathering of information in a national information system and the distribution of that information

### 3.3 The Water Cycle and integration of groundwater

Principle 2
*All water, wherever it occurs in the water cycle, is a resource common to all, the use of which shall be subject to national control. All water shall have a consistent status in law, irrespective of where it occurs.*

Principle 5
*In a relatively arid country such as South Africa, it is necessary to recognise the unity of the water cycle and the interdependence of its elements, where evaporation, clouds and rainfall are linked to underground water, rivers, lakes, wetlands and the sea, and where the basic hydrological unit is the catchment.*

Principle 6
*The variable, uneven and unpredictable distribution of water in the water cycle should be acknowledged.*

Surface water, groundwater, wetlands, quantity and quality are all linked in a continuous hydrological cycle of rainfall, runoff from the land surface and infiltration into the ground, and evaporation from surface water and plants back into the atmosphere. Each component may influence the other components, and each must therefore be managed with regard to its inter-relationships with the others.

The new water policy in South Africa, with a strong emphasis on sustainability, focuses on a much more integrated management of surface water and groundwater resources than in the past. This need is reinforced by the growing importance of groundwater as a community water supply. Surface water resources are already well developed although the same attention was not always given to groundwater. This is due to the fact that groundwater was regarded as private water in the previous Water Act and not subject to the same control as surface water. A greater integration will be required in all the major functional areas of water resources protection, allocation and conservation.

The role of groundwater and ways to integrate it into overall water management is a particular challenge. This reflects the essential role which groundwater will have to play, particularly to meet the massive community water supply backlog in South Africa. It should also reflect the widespread and persistent underestimation of the value of groundwater systems and the need for their conjunctive use with other water resources.

### 3.4 Sustainability and the Reserve

Principle 7
*The objective of managing the quantity, quality and reliability of the nation's water resources is to achieve optimum, long term, environmentally sustainable social and economic benefit for society from their use.*

Principle 8
*The water required to ensure that all people have access to sufficient water shall be reserved.*

Principle 9
*The quantity, quality and reliability of water required to maintain the ecological functions on which humans depend shall be reserved so that the human use of water does not individually or cumulatively compromise the long term sustainability of aquatic and associated ecosystems.*

Principle 10
*The water required to meet the basic human needs referred to in Principle 8 and the needs of the environment shall be identified as "the Reserve" and shall enjoy priority of use by right. The use of water for all other purposes shall be subject to authorisation.*

The Act recognises water as a renewable natural resource. Sustainable development is therefore a key basis for all management actions.

The water required for basic human needs and the aquatic needs of the environment enjoy priority of use while use of water for all other purposes would be subject to authorisation. The degree of utilisation that can be sustained by a water resource must be recognised and respected. This depends on maintaining a basic level of ecological integrity and function. The Act recognises this basic level as *the Reserve*. The Reserve is intended to protect the resilience of water resources, to satisfy basic human needs by securing a basic water supply and to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the water resource. The ecological reserve or resource base, i.e. the quantity, quality and reliability of water required to maintain the ecological functions on which humans depend, should be reserved so that the human use of water does not individually or cumulatively compromise the long-term sustainability of aquatic and associated ecosystems. The Reserve is not intended to protect the aquatic ecosystem at the expense of all development but at levels that are sustainable in the long term.

Classification of water resources is one of the major management instruments in the National Water Act. A classification system can describe the conservation, protection and/or use status of water resources and link management requirements to different classes. It is a powerful instrument to set out the various attributes of a particular class, for example the purpose for which the water or adjacent land may be used, or the measures required to protect and improve water quality. It is a way of setting objectives, prioritising management actions and informing all stakeholders in this regard.

In addition, aquatic ecosystems that are particularly fragile or important can receive additional protection. For this, the Act provides for ecological categories in assessing the Reserve, a management classification system, and resource quality objectives.

### 3.5 International and Inter - Water Management Area allocations

Principle 11
*International water resources, specifically shared river systems, shall be managed in a manner that optimises the benefits for all parties in a spirit of mutual cooperation. Allocations agreed for downstream countries shall be respected.*

Principle 12
*The national government is the custodian of the nation's water resources, as an indivisible national asset. Guided by its duty to promote the public trust, the national government has ultimate responsibility for, and authority over, water resource management, the equitable allocation and usage of water and the transfer of water between catchments and international water matters.*

Specific obligations towards neighbouring countries are recognised. International water resources, specifically shared river systems, would be managed in a manner that optimises the benefits for all parties in a spirit of mutual cooperation. Allocations agreed to in bilateral international commissions for downstream countries will be respected. Water resources frequently cross political boundaries, and therefore overall governance should reside at national level.

Water use allocations for international requirements as well as use of strategic importance, such as development of electricity for the national electricity network, as well as water transferred from one water management area to another will not be delegated and will be authorised by the Minister of Water affairs and Forestry.

### 3.6 Water Use and conservation

Principle 13
*As custodian of the nation's water resources, the national government shall ensure that the development, apportionment, management and use of those resources is carried out using the criteria of public interest, sustainability, equity and efficiency of use in a manner which reflects its public trust obligations and the value of water to society while ensuring that basic domestic needs, the requirements of the environment and international obligations are met.*

Principle 14
*Water resources shall be developed, apportioned and managed in such a manner as to enable all user sectors to gain equitable access to the desired quantity, quality and reliability of water. Conservation and other measures to manage demand shall be actively promoted as a preferred option to achieve these objectives.*

The purpose of the Water Conservation and Water Demand Management Strategy is to improve the efficient and effective use of water and minimize loss or waste of water in order to achieve sustainable, efficient and affordable water supply to all consumers. The emphasis has shifted away from the traditional primary focus on the development of additional water sources to new approaches which focus on the way water is used and how it can be conserved in each user sector. Water pricing and demand management will become some of the most important policy instruments in support of water conservation.

One of the critical considerations in this optimal management is the control of invading alien plants, such as wattles, pines and gums. The *Working for Water* programme co-ordinates the clearing of these invading alien plants for six principal reasons:

- It gives a greater assurance of water supply. Estimates are that invading alien plants are currently using – wasting – about 7% of our mean annual runoff of water. In times of drought, they use proportionally more, which aggravates the situation.

- They have a crippling impact on the productivity of land – i.e., our ability to profit from both cultivated and uncultivated land.

- Invading alien plants are considered to be the single biggest threat to biological diversity and to the ecological functioning of natural systems.

- Invasive alien plants greatly aggravate the intensity of fires and floods. Several large fires have been experienced with millions of Rands of damage encountered.

- The programme delivers four principal products: water, productive land, wood and trained people. In terms of the wood, it provides the base for substantial development of secondary industries, such as crafts, furniture, firewood, charcoal and many such applications.

- An important reason is the labour-intensive approaches that have been adopted, and the community building initiatives that have accompanied these opportunities.

### 3.7 Water quality

Principle 15
*Water quality and quantity are interdependent and shall be managed in an integrated manner, which is consistent with broader environmental management approaches.*

Principle 16
*Water quality management options shall include the use of economic incentives and penalties to reduce pollution; and the possibility of irretrievable environmental degradation as a result of pollution shall be prevented.*

Principle 17
*Water resource development and supply activities shall be managed in a manner which is consistent with the broader national approaches to environmental management.*
Principle 18
*Since many land uses have a significant impact upon the water cycle, the regulation of land use shall, where appropriate, be used as an instrument to*

*manage water resources within the broader integrated framework of land use management.*

Water quality is an important factor to be taken in account with quantity considerations in the management of water resources. Some important approaches include:

The Receiving Water Quality Objectives approach assumes that the water environment has a finite capacity to assimilate non-hazardous wastes discharged into it without violating water quality objectives. Consideration of applications to discharge wastes will be preceded by assessments of the impacts of the proposed discharges.

The approach to promoting the water quality dimension of resource protection is as follows:

- The prevention, reduction, recovery and treatment of waste will be encouraged by applying best management practice measures as part of source-directed controls.
- If the application of best management practice measures still results in a need for discharge of water containing waste or the disposal of waste, a minimum requirement or standard will apply.
- If the applicable minimum requirements or standards are not sufficient to ensure suitable water quality as required by resource quality objectives, requirements or standards stricter than the minimum requirements or standards will be applied.
- Deviation from minimum requirements or standards, or from special or site-specific source-directed controls, will receive consideration if enforcement of these measures could have significant negative social or economic impact, which outweighs the ecological benefits.
- Reclassification of the water resource, due to irreversible water resource impairment, will be considered only under very special environmental value requirements.

Remediation strategies will address impaired, degraded and contaminated land areas and water resources. Clean-up levels and targets, remediation approaches and measures as well as prioritisation of remediation focus and effort will be primarily dictated by appropriate risk-based approaches.

### 3.8 Water use authorisations

Principle 3
*There shall be no ownership of water but only a right (for environmental and basic human needs) or an authorisation for its use. Any authorisation to use water in terms of the water law shall not be in perpetuity.*

Principle 4
*The location of the water resource in relation to land shall not in itself confer preferential rights to usage. The riparian principle shall not apply.*

Principle 19
*Any authorisation to use water shall be given in a timely fashion and in a manner which is clear, secure and predictable in respect of the assurance of*

*availability, extent and duration of use. The purpose for which the water may be used shall not arbitrarily be restricted.*

Principle 20
*The conditions upon which authorisation is granted to use water shall take into consideration the investment made by the user in developing infrastructure to be able to use the water.*

Principle 21
*The development and management of water resources shall be carried out in a manner which limits to an acceptable minimum the danger to life and property due to natural or manmade disasters.*

Use of water for all purposes will be subject to formal authorisation that will impose limits and restrictions. The following water uses are controlled:

- Taking water from a resource
- Storing water
- All aspects of the discharge of wastes into water resources, including:
  - Discharging waste or water containing waste into a water resource;
  - Disposing of waste in a manner which may detrimentally impact on a water resource;
  - Disposing in any manner of water containing waste from, or which has been heated in any industrial or power generation process;
- Removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people;
- Making changes to the physical structure of rivers and streams:
  - Impeding or diverting the flow of water in a watercourse;
  - Altering the bed, banks, course or characteristics of a watercourse;
- Certain activities which may affect the quantity or quality of water in the resource:
  - Engaging in a stream flow reduction activity – at present commercial forestry;
  - Engaging in a controlled activity – at present irrigation with water from waste treatment plants;
- Using water for recreational purposes.

Access to water is divorced from land ownership and has removed the previous expectation of permanent rights to water. Criteria for allocation of water must take the following criteria into account:

All water use will be allocated through time-limited licences. Individual licences can be issued for productive or beneficial purposes. All licences will be valid for a limited time period with a maximum time of 40 years and must be reviewed at least every 5 years.

Water is recognised as an economic enabling mechanism. Access to water has tremendous commercial potential – ranging from big business, industry and mining right down to the small scale community based market gardening and brick making operations emerging in rural areas.

Compulsory licences will be implemented in respect of a water resource:

- If it is necessary to review existing water use to achieve equity in allocations;
- To achieve a fair allocation of water from a stressed water resource;
- To promote beneficial use of water in the public interest;
- To facilitate efficient management of the water resource and to protect water resource quality.

The importance of information for effective resource management and protection is recognised and places the responsibility on the Minister to establish national information systems. New management instruments such as classification, setting of the reserve and catchment management plans will be information-intensive. The need for integrated management of the hydrological cycle will create a need for much greater integration of the relevant information systems, e.g., hydrology, geohydrology, water quality and land type, use and cover.

### 3.9 Institutional arrangements

Principle 22
*The institutional framework for water management shall as far as possible be simple, pragmatic and understandable. It shall be self-driven and minimise the necessity for state intervention. Administrative decisions shall be subject to appeal.*

Principle 23
*Responsibility for the development, apportionment and management of available water resources shall, where possible and appropriate, be delegated to a catchment or regional level in such a manner as to enable interested parties to participate.*
Principle 24
*Beneficiaries of the water management system shall contribute to the cost of its establishment and maintenance on an equitable basis.*

Integrated water resources management is not the exclusive responsibility of water managers, engineers and scientists. It is successful when everyone in the country is required - and enabled - to play an active part in water management. The decentralisation of responsibility and authority for water resource management to appropriate, representative institutions on a regional or local level is a fundamental transformation process.

Water is a unitary natural resource, best governed within its catchment boundaries. South Africa is divided into 19 water management areas, and a catchment management agency responsible for water management area will be established in each water management area. Some of the functions and responsibilities of catchment management agencies include:

- Development of a catchment management strategy;

- Management of water resources;
- The co-ordination of the water related activities of water users; and
- The co-ordination of activities of other water management institutions.

One of the major challenges is the large number of different institutions involved in the management of water. All three spheres of government (national, provincial and local) have a role, as well as water boards, community based organisations, municipalities acting as water services authorities and water services providers, water user associations and the private sector. To develop a regulatory framework and regulations to cover all these institutions and be simple and transparent is a particular challenge.

Water resource management charges are being levied to cover the cost of water management in a particular water management area. These charges will also be used to fund the management functions of catchment management agencies when established to ensure their viability.

There are four general approaches that catchment managers may use to intervene to achieve the aims of catchment management and all should be adopted to support integrated water resource management at a catchment scale. These approaches may be summarised as:

- *Direct intervention*: through water resource development and rural community water service interventions.
- *Control and enforcement*: through regulations and licensing (quantity, quality & habitat).
- *Co-operative government*: for land use planning & management (agriculture, rural & urban).
- *Influence*: of other authorities and stakeholders for economic, social and spatial planning.

## 4. CONCLUSION

Water legislation in South Africa has been fundamentally changed. The challenge to apply new legislation in water management in an integrated manner is supported by sound principles embodied in the National Water Act and Water Services Act. The National Water Resource Strategy Water outlines the goals and objectives of water resource management for South Africa. The challenge is to use the opportunities for social and economic development.

Water resource management should be done as a multi-disciplinary exercise involving all sectors of society, to ensure:

- The planning and development of our national water resources;
- The regulation of water allocation;
- The regulation of water use for purposes of water demand management, abstractions and water quality management;

- The prevention of pollution of our water resources;
- The collection and dissemination of information on water availability – of surface and ground water including the quality of available resources;
- The control over dam safety, flood and drought management; and
- International co-operation particularly with neighbouring countries with whom many of the rivers of South Africa shared

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NATIONAL WATER POLICY

# LESSONS FROM THE MURRAY DARLING BASIN THAT MIGHT INFLUENCE THE NATIONAL WATER POLICY

Mr Don Blackmore

ABSTRACT AND PRESENTATION

***ABSTRACT – DON BLACKMORE***

*Australia has less than 1% of the world's water and a climate which delivers highly variable rainfall and hence stream flows.*

*The Murray-Darling Basin is 15% of Australia's land mass, almost identical in size to South Africa, yet it only has 6.4% of Australia's water.*

*In recent years water users in the Murray-Darling Basin have had to face up to the fact that water is a scarce resource. Policies, at a Basin scale, have been developed to manage scarcity and to ensure the equitable sharing of water between the States. The main management instrument is the Cap on Water Use restricting any growth in consumption above that required to meet the 1993/94 level of development. This has been complimented by the introduction of water trading regimes.*

*In the broader Australian context all governments have committed to a coordinated water reform agenda for the last decade, primarily focused on improving the economic performance of water. A decade on, there are still a number of key issues to be resolved:*

- *How to define water access rights that balance the needs of the farmer for investment certainty and deal with the changing natural environment?*
- *How do we balance consumptive use with what water should be left in rivers to ensure they are sustainable?*
- *How do we refine our existing water trading regimes to facilitate the movement of water to the highest value use both within and between States?*
- *How do we establish pollution management systems at a catchment scale?*
- *How do we identify and protect our heritage and conservation rivers? And*
- *What are the policies that will positively guide development in water in the 21st century?*

*The paper uses the Murray-Darling Basin experience as a case study to show case policy options for Australia.*

## Australian Academy of Technological Sciences and Engineering

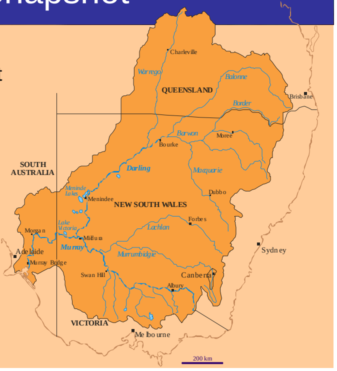
Australia/South Africa Joint Workshop on Water Resource Management

"Lessons from the Murray-Darling Basin that might Influence a National Water Policy"

D J Blackmore
Chief Executive
2 April 2003

## Murray-Darling Basin A Snapshot

- The Basin covers 1 million sq. km (equivalent to the size of South Africa)
- Major river system by world standards
  - River Murray 2530 km
  - River Darling 2740 km
  - Longest river distance 3750 km
  - Comprises 24 major rivers




**SIX GOVERNMENTS**
C'wealth NSW Vic SA Qld ACT

**MURRAY-DARLING BASIN MINISTERIAL COUNCIL**
Up to 3 Ministers from each Government representing land, water and environment

**Community Advisory Committee**
21 Regional & special interest representatives

**MURRAY-DARLING BASIN COMMISSION**
1 Independent President
2 Commissioners from each Government

**Commission Office**
Technical and administrative secretariat

## Council of Australian Governments

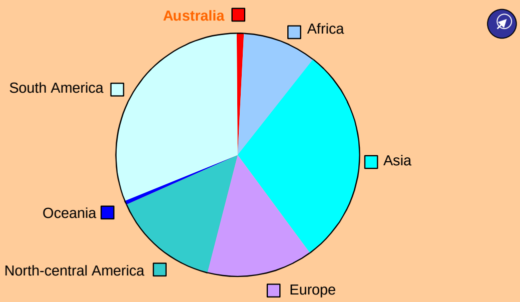
Water Reform Framework 1994

- Commercial Water Business
- Improved Pricing
- Full Cost Recovery (Urban)
- Balance Consumption vis-a-vis Environment
- Institutional Reform – Regulation vis-à-vis Operation

## Key messages

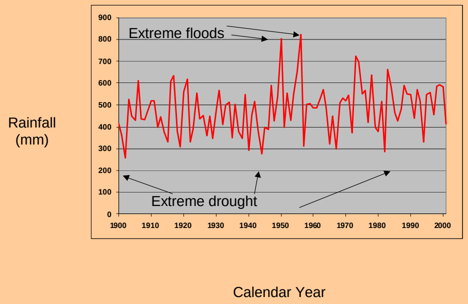
- Australia is dry by world standards
- Highly variable rainfall and streamflow
- Opportunities to improve performance (Production and Environment) with better policy and technology
- Clear objectives are needed to guide investment
- Secure and well defined access rights for <u>all</u> water use

## Global water resources




FAO AquaStat Data

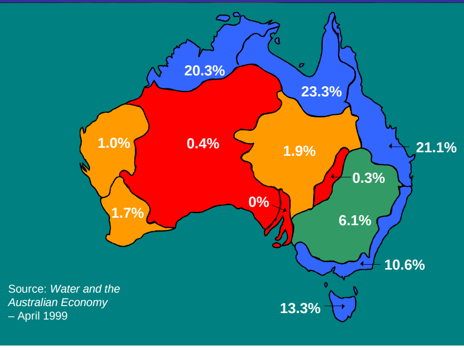
## Annual mean Murray-Darling Basin rainfall



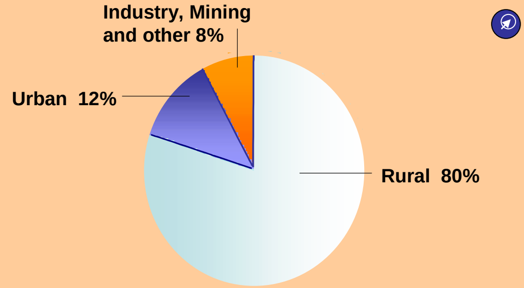

## Ratio of maximum annual flow to minimum annual flow for selected rivers

| COUNTRY | RIVER | RATIO BETWEEN THE MAXIMUM and the MINIMUM ANNUAL FLOWS |
|---|---|---|
| BRAZIL | AMAZON | 1.3 |
| SWITZERLAND | RHINE | 1.9 |
| CHINA | YANGTZE | 2.0 |
| SUDAN | WHITE NILE | 2.4 |
| USA | POTOMAC | 3.9 |
| SOUTH AFRICA | ORANGE | 16.9 |
| AUSTRALIA | MURRAY | 15.5 |
| AUSTRALIA | HUNTER | 54.3 |
| AUSTRALIA | DARLING | 4705.2 |

## Distribution of Australia's surface runoff



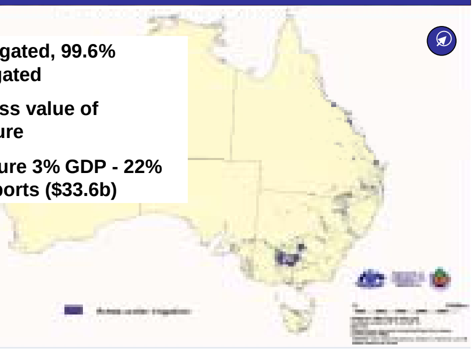

## Water use by industry




adapted from *Water and the Australian Economy*- April 1999

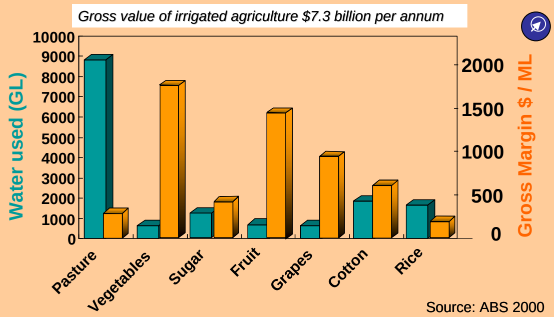
## Irrigated agriculture

- **0.4% irrigated, 99.6% non irrigated**
- **25% gross value of agriculture**
- **Agriculture 3% GDP - 22% total exports ($33.6b)**



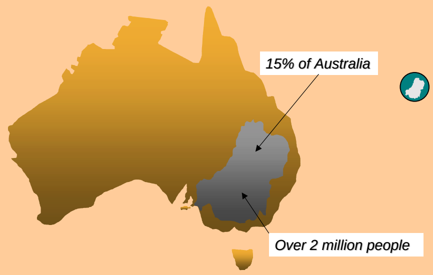
## Turning water into wealth

(by Commodity)

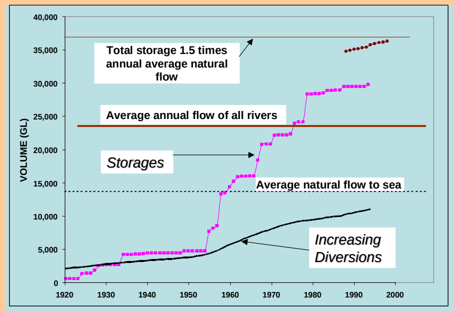



Source: ABS 2000

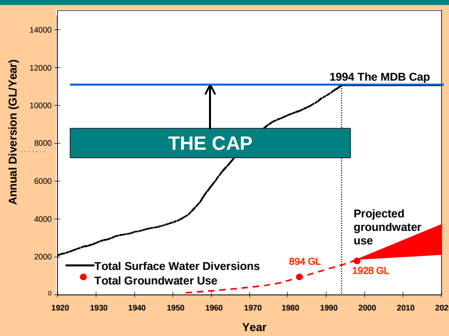
## Murray-Darling Basin case study




## Storage capacity and diversions in the Murray-Darling Basin




## Growth in use of surface and groundwater




## River Murray environmental flows

## Ministerial Council March 2001

- **Vision**

  …..a healthy River Murray System, sustaining communities and preserving unique values

  …a healthy working river ?

- **April 2002**

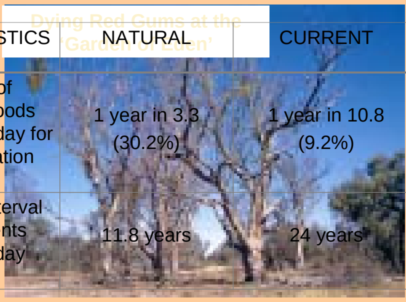
  … Reference points 350 - 750 – 1500 GL

  … Community engagement

## Is the river healthy?

## Change in Flooding

*Case study: Chowilla Floodplain*




| KEY STATISTICS | NATURAL | CURRENT |
|---|---|---|
| Percentage of years with floods >85,000ML/day for 30 days duration | 1 year in 3.3 (30.2%) | 1 year in 10.8 (9.2%) |
| Maximum interval between events >85,000ML/day | 11.8 years | 24 years |

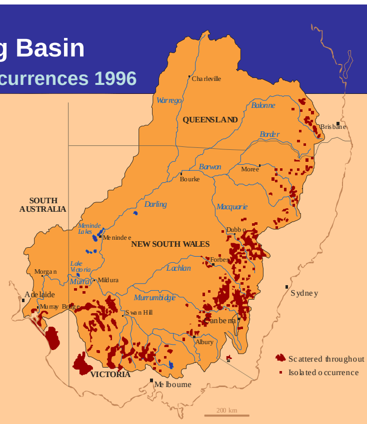
## Scale of the Decision

| Water Recovered | Probability Of a Healthy Working River | Cost $M |
|---|---|---|
| 350 GL | Low | 200 |
| ↓ | ↓ | ↓ |
| 1500 GL | Moderate | 1500 |

Timing – 10 years

## Murray-Darling Basin

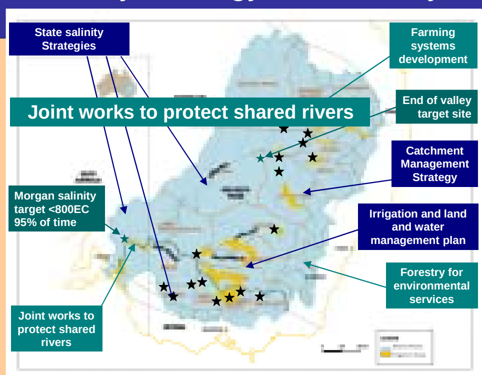
**Dryland salinity occurrences 1996**




## River Salinities - New South Wales

| River Valley | Average River Salinity (EC) | | | |
|---|---|---|---|---|
| | Current | 2020 | 2050 | 2100 |
| Murrumbidgee | 250 | 320 | 350 | 400 |
| Lachlan | | | | |
| Forbes | 530 | 780 | 1150 | 1460 |
| Darling | | | | |
| Menindee | 360 | 430 | 490 | 530 |
| Bogan | 730 | 1500 | 1950 | 2320 |
| Macquarie | 620 | 1280 | 1730 | 2110 |
| Castlereagh | 640 | 760 | 1100 | 1230 |
| Namoi | 680 | 1050 | 1280 | 1550 |
| Gwydir | 560 | 600 | 700 | 740 |
| Macintyre | 450 | 450 | 450 | 450 |

## Salinity Strategy in Summary



## Water Access Rights

- All water vested in the Crown

Criteria
- Provides sufficient investor certainty
- Provides capacity to adjust for changes in environmental conditions
- Supports water trading

## Water Access Rights

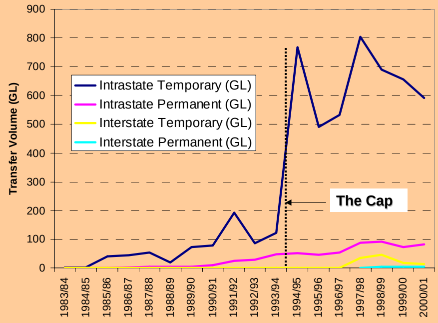
- Secured for 15 years
- Defined review arrangements
- Maximum reduction without compensation specified
- Open registry system

## Water trading

**From this ....**

**To this ....**

## Murray-Darling Basin water entitlement transfers - 1983/84 to 2000/01




## Water Trade

- Open trade to largest geographical areas possible (including between States)
- Eliminate administrative barriers
- Determine exchange rates
- Agree environmental rules

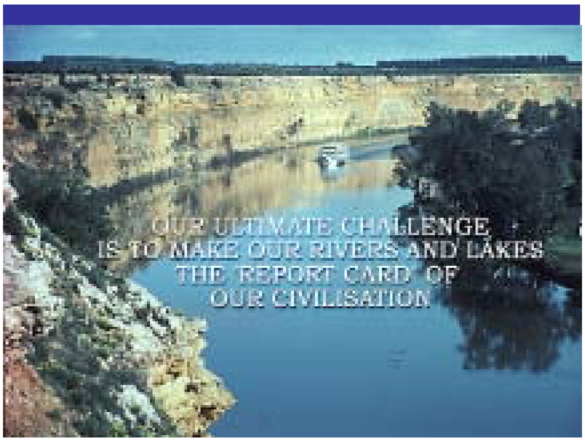
## Active Environmental Management

## Responsibility of Water Users

- Train and accredit water users (30% rate discount)
- Irrigation efficiency parameters implemented
- Rural Water Authorities benchmarked

## Classify our Rivers

| River Class | Maximum Extraction % |
|---|---|
| Heritage | < 5% |
| Conservation | <15% |
| Sustainable Working River | <33% |
| Managed Working River | <67% |
| Stressed River | >67% |



# SOUTH AFRICAN WATER RESOURCES AVAILABILITY, DEMANDS AND STRATEGIC ISSUES

by
M J SHAND AND M S BASSON

## 1. INTRODUCTION

South Africa is a semi-arid country with an average rainfall of about 450 mm per annum, well below the world average of some 860 mm per annum. The Mean Annual Runoff (MAR) of the whole country is approximately 49 200 million m³ per annum, and is highly variable, particularly in the dryer areas, necessitating the provision of large reservoir storages for relatively low yields.

In 2000, the total water requirements of South Africa were 13 280 million m³ per annum, with irrigation and urban usage accounting for 59% and 25% respectively, and the 16% balance being for rural water supply, mining and industrial use, power generation and afforestation. Surface water supplies provided 79% of these water requirements after provision for the Reserve of 9 542 million $m^3$ per annum (for basic human needs and the ecology) and for international obligations to Botswana, Lesotho, Mozambique, Namibia, Swaziland and Zimbabwe of 127 million $m^3$ per annum. Groundwater accounted for only 7% of the water supplied, mainly from primary aquifers and from low yielding hard rock aquifers supplying water for irrigation, rural usage and small towns. Effluent return flows from irrigation and from the urban, industrial and mining sectors contributed about 14% of the supplies, mainly in the interior, as coastal towns currently discharge most of their effluent to sea.

In 2000, the available total supply of 13 911 million m³ per annum slightly exceeded the total demand, however significant deficits occurred in some catchments. By 2025, water demands are expected to increase to between 14 500 and 17 300 million m³ per annum, mainly on account of the projected growth in the population from 44 million to between 50 and 53 million, and mostly in the urban areas in spite of HIV/AIDS. Water conservation and demand management will temporarily slow the growth in water demand and thereafter effluent re-use, particularly by the coastal cities, together with additional dams, interbasin transfer schemes and further groundwater development, will augment the supplies. However deficits in a few areas will persist unless some allocations are reduced or irrigation allocations are transferred to urban users. Thereafter some additional interbasin transfer schemes, and desalination in the coastal areas may be possible.

The National Water Resource Strategy (NWRS) for South Africa (DWAF 2002) has been developed and published in accordance with the requirements of the National Water Act (NWA) (DWAF 1998). Much of the information listed above and contained in the following sections of this paper has been abstracted from the First Edition of the NWRS that has been published for comment (DWAF 2002).

## 2. THE CLIMATE AND LAND USE

### 2.1 Climate

The water resources of South Africa are determined by the climatic variation across the country as shown in Figure 1. The rainfall exceeds 1 000 mm per annum along the north east coast and escarpment including the Lesotho Highlands, and also in the southern and south western coastal mountains. On the other hand, evaporation ranges from about 1 200 mm per annum at the coast to more than 2 500 mm per annum in the arid western interior.

Most of the country receives summer rainfall, arising from tropical cyclones and thunderstorms, mainly in the interior. The south western coastal region (near Cape Town) experiences a Mediterranean climate with wet winters and dry summers. Part of the southern coastal region, between the winter and summer rainfall areas, receives year round rainfall.

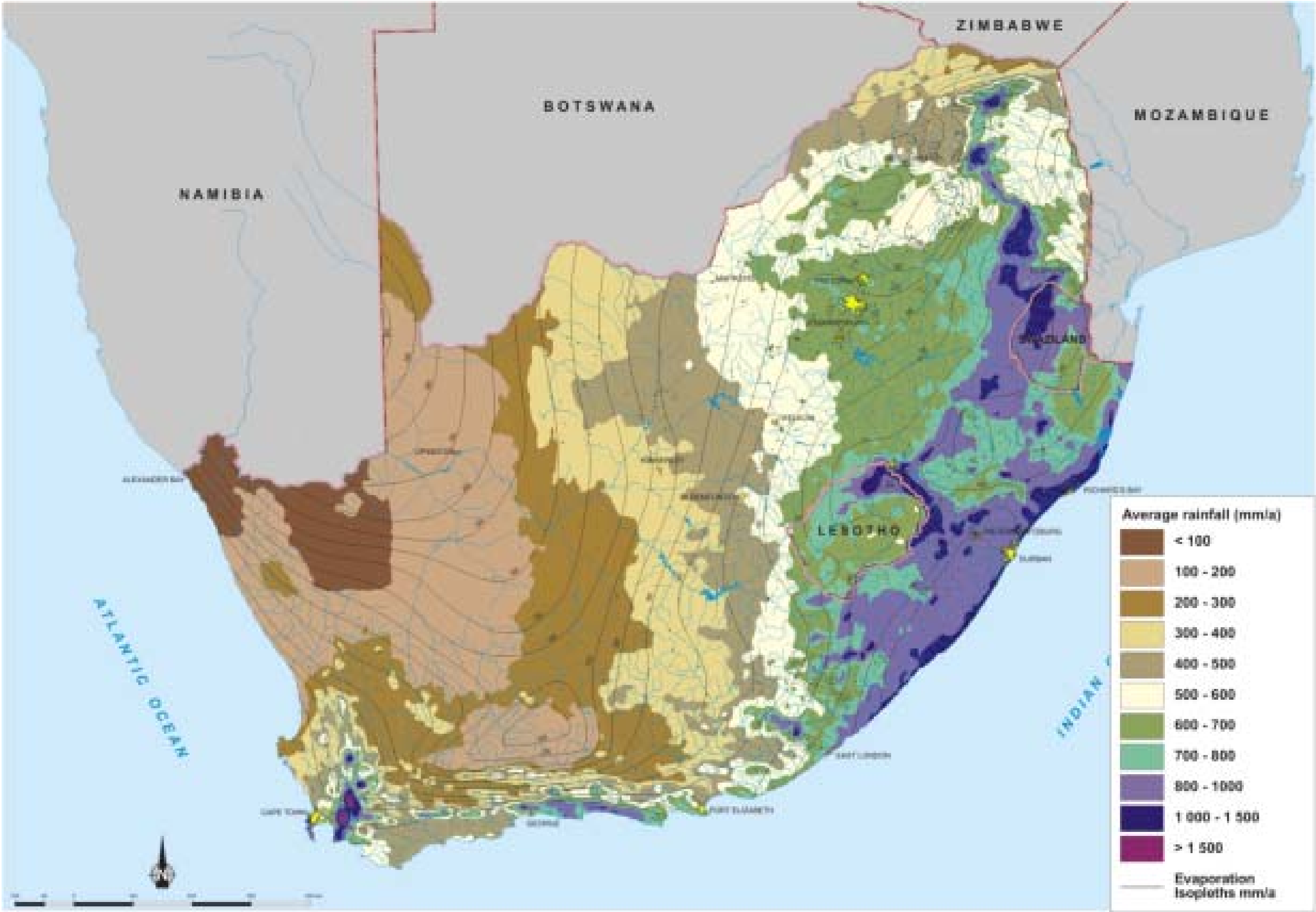
## 2.2 Land-use

Rainfed (dry land) farming takes place in the high to moderate rainfall regions where the topography is suitable. Afforestation is mainly practiced along the high rainfall escarpment in the east and north east and along the southern coast in the year round rainfall area.

Most of the irrigated areas are situated on suitable land close to the main rivers. The larger irrigation schemes are supplied from storage dams, and in a few areas by interbasin transfers from dams. Farm dams supply irrigation water for many farmers, and some run-of-river irrigation also takes place, particularly at the older schemes.

Most of the urban and industrial complexes have developed remotely from substantial water resources necessitating the transfer of water over long distances. Johannesburg/Pretoria, the commercial, industrial and mining hub of South Africa, imports water from the 100 km distant Vaal River that is supplemented by two remote interbasin transfers, one of which is from Lesotho and the other from the Thukela River. Durban and Cape Town as well as most of the other large urban and industrial areas import water from remote catchments.

**FIGURE 1: RAINFALL AND EVAPORATION**



## 3. RIVER SYSTEMS

Nineteen Water Management Areas (WMAs) have been promulgated by the Minister of Water Affairs and Forestry to facilitate the management of local water resources by Catchment Management Agencies (CMAs). The Minister will retain control of the Reserve, international obligations, strategic usage such as the generation of electricity, and transfers between WMAs (Figure 2). Some of the features of the main river systems are briefly described below (Figures 2 and 3) and the current supplies of and demands for water are shown in Table 1.

The MARs shown in Table 1 are the natural flows that would have occurred in the river systems prior to any development taking place. As the ecological Reserve will be released to the river as a priority before other users are supplied, both the Reserve and the yield after provision of the Reserve are quoted at an assurance of supply of 98% (corresponding to a 1 in 50 year risk of failure). All water demands are also quoted in terms of an assurance of supply of 98%, although the actual assurances of supply may be lower, particularly for irrigation. Therefore the demands can be compared directly with the supplies, both at an assurance of 98% (Table 1).

### 3.1 Orange/Vaal River System

The Orange River and its main tributary, the Vaal River form the largest river system in South Africa with a mean annual runoff (MAR) of 11 162 million $m^3$ per annum and a preliminary ecological reserve of 1 874 million $m^3$ per annum. The Upper Orange and Vaal contribute 6 981 million $m^3$ per annum (63% of MAR) and 3 679 million $m^3$ per annum (33% of MAR) at their confluence respectively, with the Lower Orange contributing only 502 million $m^3$ per annum (4% of MAR). The Orange is an international river shared with Lesotho, Botswana and Namibia. The main features of the river system are described below:

a) The Orange River rises in the high rainfall mountains of Lesotho where three of its tributaries are dammed by Phase 1 of the Lesotho Highlands Water Project (in the Upper Orange WMA) which supplies some 600 million $m^3$ per annum via an 80 km long tunnel to the headwaters of the Vaal River (in the Upper Vaal WMA).

b) After crossing the Lesotho/South Africa border, the Orange flows into Gariep Dam and thence into Van der Kloof Dam (in the Upper Orange WMA), which together regulate but substantially modify the natural flow regime of the river in order to serve downstream irrigators (in the Upper and Lower Orange and the Vaal WMAs) and also to generate hydropower.

| RIVER SYSTEM | | ORANGE/VAAL | | LIMPOPO | | INKOMATI | | EAST & WEST COAST | | TOTALS | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| WATER MANAGEMENT AREAS | | 8 Upper Vaal<br>9 Middle Vaal<br>10 Lower Vaal<br>13 Upper Orange<br>14 Lower Orange | | 3 Crocodile West/Marico<br>2 Luvuvhu/Letaba<br>4 Olifants<br>1 Limpopo | | 5 Inkomati | | 6 Usutu/Mhlatuse<br>7 Thukela<br>11 Mvoti/Mzimkulu<br>12 Mzimvubu/Keiskamma<br>15 Fish/Tsitsikamma<br>16 Gouritz<br>18 Breede<br>19 Berg<br>17 Olifants/Doring | | | |
| **MEAN ANNUAL RUNOFF** | | **11162** | | **5067** | | **3539** | | **29460** | | **49228** | |
| Reserve | | 1874 | | 1005 | | 1008 | | 5658 | | 9545 | |
| International | | 54 | | 10 | | 63 | | | | 127 | |
| **YEAR 2000** | | | | | | | | | | **0** | |
| SUPPLIES: | Surface Water | 4433 | (80%) | 1014 | (53%) | 857 | (91% | 4624 | (83%) | 10928 | (79%) |
| | Ground Water | 301 | (6%) | 352 | (19%) | 9 | (1% | 380 | (7%) | 1042 | (7%) |
| RETURN FLOWS: | Irrigation | 189 | (3%) | 115 | (6%) | 58 | (6% | 310 | (6%) | 672 | (5%) |
| | Urban | 435 | (8%) | 360 | (19%) | 8 | (1% | 212 | (4%) | 1015 | (7%) |
| | Mining/Industry | 166 | (3%) | 55 | (3%) | 11 | (1% | 22 | (0%) | 254 | (2%) |
| **TOTAL SUPPLIES 2000** | | **5524** | **(100%)** | **1896** | **(100%)** | **943** | **(100%** | **5548** | **(100%)** | **13911** | **(100%)** |
| DEMANDS | Irrigation | 2355 | (58%) | 1488 | (50%) | 737 | (71% | 3256 | (62%) | 7836 | (59%) |
| | Urban | 1142 | (28%) | 831 | (28%) | 65 | (6% | 1294 | (25%) | 3332 | (25%) |
| | Rural | 195 | (5%) | 141 | (5%) | 24 | (2% | 212 | (4%) | 572 | (4%) |
| | Mining Industry | 276 | (7%) | 236 | (8%) | 24 | (2% | 220 | (4%) | 756 | (6%) |
| | Power | 80 | (2%) | 215 | (7%) | 0 | (0% | 1 | (0%) | 296 | (2%) |
| Generation | | | | | | | | | | | |
| | Afforestation | 0 | (0%) | 47 | (2%) | 198 | (19% | 243 | (5%) | 488 | (4%) |
| **TOTAL DEMANDS 2000** | | **4048** | **(100%)** | **2958** | **(100%)** | **1048** | **(100%** | **5226** | **(100%)** | **13280** | **(100%)** |
| MAJOR TRANSFERS | | | | | | | | | | | |
| <u>Between River System WMAs:</u> | | | | | | | | | | | |
| Thukela to Upper Vaal | | 430 (1) | | | | | | -430 (2) | | 0 | |
| Upper Vaal to Crocodile West/Marico | | -650 (2) | | 650 (1) | | | | 0 | | 0 | |
| Upper Orange to Fish/Tsitsikamma | | -570 (2) | | | | | | 570 (1) | | 0 | |
| <u>Major Transfers Within River System WMAs:</u> | | | | | | | | | | | |
| Upper Orange to Upper Vaal | | [600] (3) | | | | | | | | | |
| Breede to Berg | | | | | | | | [200] (3) | | | |

**Note** (1) Transfers in are positive
(2) Transfers out are negative
(3) Major internal transfers are bracketed

**FIGURE 2: WATER MANAGEMENT AREAS AND MAIN WATER TRANSFERS**

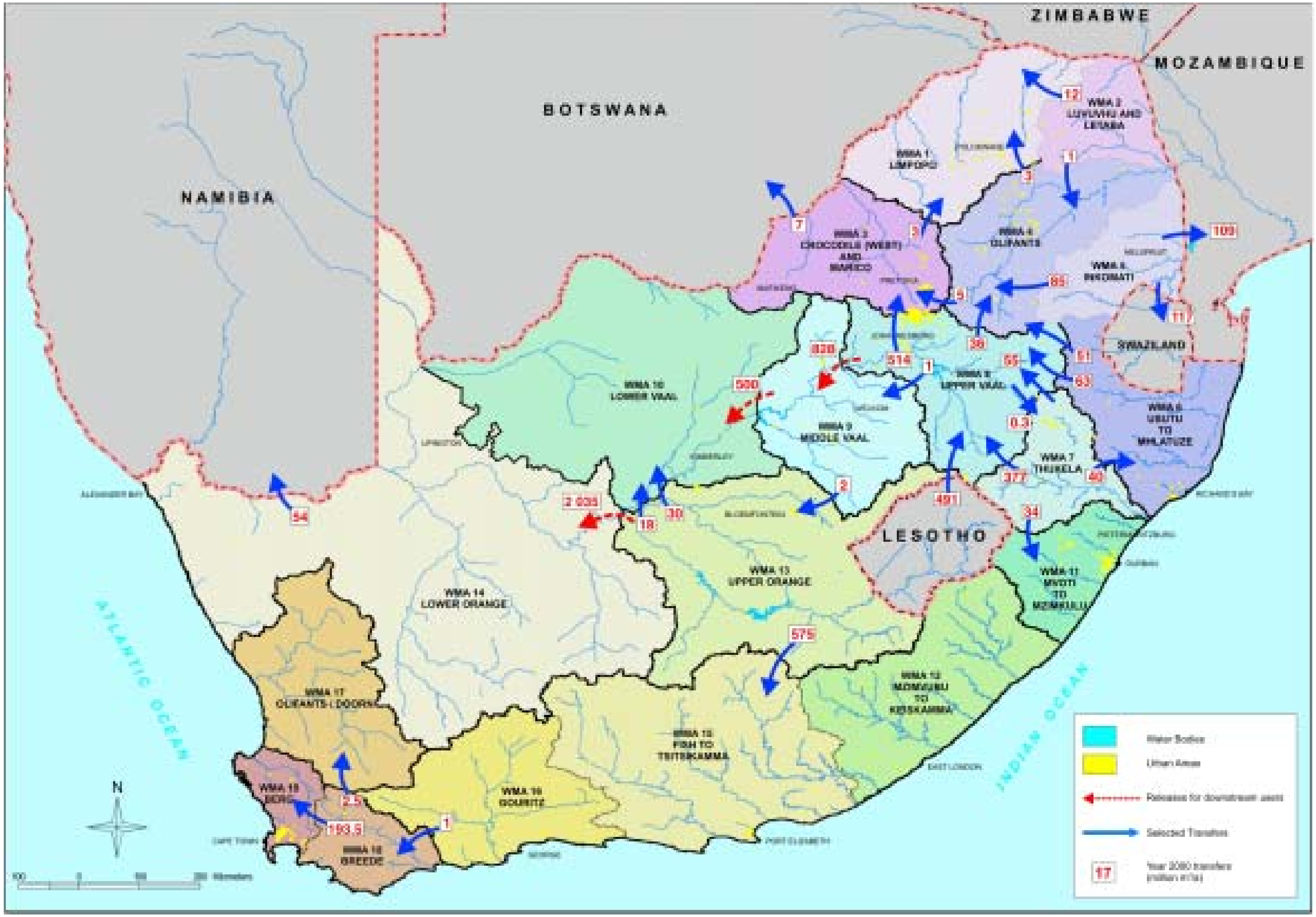


**FIGURE 3: RIVER SYSTEMS AND INTERNATIONAL RIVERS**

b) Some 570 million m³ per annum are diverted from Gariep Dam into the Fish (via the 80 km long Orange Fish tunnel) and thence into the Sundays Rivers (via canals and tunnels) for irrigation and to supplement supplies to Port Elizabeth (in the Fish to Tsitsikamma WMA).

c) Vaal Dam on the Vaal River (in the Upper Vaal WMA) supplies 650 million m³ per annum to Johannesburg/Pretoria.

e) Interbasin transfers of 600 million m³ per annum from the Lesotho Highlands Water Project (Upper Orange WMA), as described in (a) above, and 430 million m³ per annum from the Thukela River (Thukela WMA) supplement the inflows into Vaal Dam.

f) Relatively high nutrient rich return flows of nearly 500 million m³ per annum, mainly from Johannesburg, are returned to the Vaal River, which is further regulated by Bloemhof Dam some distance downstream of Vaal Dam, to serve irrigators and other users (in the Middle Vaal WMA).

g) Downstream of the Orange/Vaal confluence (in the Lower Orange WMA), the Orange River serves irrigators and mines in South Africa and supplies 54 million m³ per annum to Namibia before flowing into the estuary which is a RAMSAR site.

h) There is virtually no runoff from the Botswana catchments of the Lower Orange River, and only occasional flood runoff from the Fish River in Namibia.

ii) For the high growth 2025 scenario, the large potential deficit in the Upper Vaal WMA could be met by further interbasin transfers from the Thukela WMA and the Upper Orange WMA.

### 3.2 Limpopo River

The Limpopo River forms the border between South Africa and its neighbours, Botswana and Zimbabwe, before flowing into Mozambique where disastrous floods occurred in 2000. The natural MAR is 5 067 million m³ per annum mainly occurring during large floods followed by long periods of little or no flow. The preliminary reserve is 1 005 million m³ per annum. The main features of the Limpopo River catchment are summarised below:

a) Parts of Johannesburg/Pretoria are situated in the upper reaches of the Crocodile River (in the Crocodile West/Marico WMA) and are supplied with 650 million m³ per annum of water transferred from Vaal Dam (in the Upper Vaal WMA) as described in 3.1(d) above.

b) Some 340 million m³ per annum of this imported water is returned to the upper tributaries of the Crocodile River as treated but nutrient rich effluent, which has resulted in eutrophication of dams, whereas the natural runoffs of the Crocodile and Marico Rivers (in the Crocodile West/Marico WMA) together equal only 202 million m³ per annum. Dolomitic aquifers supply 111 million m³ per annum.

b) 10 million m³ per annum of water from the Crocodile and Marico Rivers (in the Crocodile West/Marico WMA) are provided for Botswana.

d) The demand for water in all the South African tributaries of the Limpopo River is dominated by the irrigation requirements, followed by urban usage mainly in the Crocodile River as mentioned in (a) above. 215 million m³ per annum is supplied for power generation and 47 million per annum is used by afforestation.

d) All the South African tributaries of the Limpopo are partially regulated by dams, but there are no dams on the Limpopo itself.

f) The potential moderate deficit in the Limpopo WMA itself, for the high growth 2025 scenario, should be met by the increasing return flow from the Crocodile West/Marico WMA.

### 3.3 Inkomati River

a) The Inkomati River (in the Inkomati WMA) rises in South Africa and flows through Swaziland before re-entering South Africa and then flowing into Mozambique. This river has a MAR of 3 539 million $m^3$ per annum, and a Reserve of 1 008 million $m^3$ per annum. Irrigation is the dominant water usage followed by afforestation usage of 198 million $m^3$ per annum.

b) Maguga Dam has recently been constructed jointly by South Africa and Swaziland, and this together with the other dams on the South African tributaries are operated conjunctively to meet the demands of their users and also to supply a minimum flow of 63 million $m^3$ per annum to Mozambique. Irrigation is the dominant usage followed by afforestation.

c) A potential deficit could occur in 2025, which might have to be met by reallocation.

### 3.4 East and West Coast Rivers

a) All the East and West Coast Rivers are situated wholly within South Africa except the Usutu River in the north east (in the Usutu/Mhlatusu WMA) which rises in South Africa, flows through Swaziland and thence into Mozambique together with the Pongola River, which also rises in South Africa.

b) The combined runoff of the East and West Coast Rivers is 29 460 million $m^3$ per annum and the preliminary ecological Reserve for the rivers is 5 658 million $m^3$ per annum, which may not be sufficient to provide for the ecological water requirements of the many important estuaries.

b) The headwaters of the Thukela River (in the Thukela WMA) are dammed to transfer 430 million $m^3$ per annum to the Vaal River (Upper Vaal WMA) via the Drakensberg Pumped Storage Scheme as described in 3.1(e) above.

d) Further interbasin transfers from the Thukela River are contemplated as well as possible transfers from the relatively undeveloped Mzimvubu River (to the west of Lesotho).

e) Some of the coastal rivers have been extensively developed to serve irrigators, and most of the cities of Richards Bay, Durban, East London, Port Elizabeth and Cape Town obtain their supplies from remote dams via long canals or pipelines. Many of these cities discharge their effluent into the sea.

f) The water transfer from the Orange River (in the Upper Orange WMA) serves irrigators in the Fish and Sundays Rivers as well as the City of Port Elizabeth (in the Fish to Tsitsikamma WMA) as described in 3.1(c) above.

f) Cape Town and the adjacent irrigated areas rely on two interbasin transfer schemes from the adjacent WMA (the Breede WMA). The Palmiet Pumped

Storage Scheme transfers about 30 million m³ per annum and a separate tunnel system 170 million m³ per annum.

h) Saline runoff from sediments of marine origin together with elevated salinity concentrations in irrigation return flows necessitate the release of water for dilution purposes in the Fish and Sundays Rivers (in the Fish/Tsitsikamma WMA) and in the Breede River (in the Breede WMA).

i) Waste water effluent return flows and diffuse pollution from agricultural areas have resulted in eutrophication of some reservoirs.

j) Health problems have occurred in some of the rural villages on the East Coast where there is a lack of both formal water supplies and sanitation. The supply of good quality water and sanitation for all citizens is a national priority.

k) The 2025 high growth scenario demands of most of the coastal areas could be met by further local transfers except in the Cape Town area (Berg WMA) where desalination or the exchange of irrigation allocations are likely to be the only long-term options.

## 4. KEY ISSUES

Some of the key issues concerning the management of water in South Africa are summarised below:

- Growing Water Usage and Limited Development Potential
- Water Quality Deterioration
- Inequitable Allocations
- International Rivers
- Insufficient Provision for the Environment
- Low Water Use Efficiency

These issues are described in more detail in the following sections:

### 4.1 Growing Water Usage and Limited Development Potential

The NWRS has identified a number of strategies to meet existing supply shortfalls, and also the potential growth in water demand from 13 910 million m³ per annum in 2000 to between 14 500 million m³ per annum and 17 300 million m³ per annum in 2025. These interventions include:

- The implementation of water conservation and demand management in all user sectors and particularly urban and irrigation usage.

- The removal of existing alien vegetation infestations, pines from Europe and wattles, acacias and eucalypti from Australia, that have no natural pests in South Africa and consume large quantities of water compared with the natural vegetation. The Working for Water Program has been addressing this for a number of years.

- Increased re-use of treated effluent return flows, particularly in coastal cities where these are discharged to sea.

- There is a need for larger additional transfers to supply Johannesburg/Pretoria, and also to plan the re-use of the associated increased return flows.

- Where surpluses are available and are likely to be taken up by the future growth in urban demands, these surpluses should be reserved for urban use and not allocated to agriculture. For example, the surplus in the Upper Vaal should be reserved for supplying Johannesburg/Pretoria.

- The trading of water allocations should be encouraged, particularly where allocations from irrigation could satisfy the growth in urban demands without negative socio-economic consequences in the irrigated areas.

- 16 Large scale water resource development schemes are identified in the NWRS strategy, 5 primarily for irrigation and 11 primarily for domestic, urban, industrial or mining purposes.

- There is potential for more extensive groundwater aquifer development than has hitherto taken place.

- Integrated management of surface water schemes and conjunctive usage with groundwater should be practised to maximise the yields of schemes.

- Ultimately it is likely to be necessary to reallocate water from irrigation to the urban and industrial sectors and to desalinate seawater in order to supply some of the coastal cities.

### 4.2 Water Quality Deterioration

The increased return flows from irrigation and the domestic, industrial and mining sectors are resulting in a deterioration in water quality on account of increases in salinity and in nutrient loads, the latter in part due to increased fertilizer washoff from both dryland and irrigated agriculture and to runoff from urban areas. Regulation of water resources also impacts on salinity due to evaporation. Interventions include:

- Source directed measures to control the quality of all point source return flows through licensing so that effluent quality is consistent with the assimilative capacity of the river or water body and is fit for the environment and for downstream users.

- Management of existing irrigation schemes including dilution to lower salinities and maintenance of fitness for use.

- Ensuring that planning of future irrigation developments, and of potential diffuse and point sources of pollution takes full cognisance of any impacts on water quality in rivers and improvements.

- Utilization of desalination where the salinity or mineral content of water may still render it unfit for human consumption after normal treatment.

- Management of eutrophied water bodies and the control or removal of aquatic plants such as water hyacinth and typha that thrive on nutrients.

### 4.3 Inequitable Allocation

Many historically disadvantaged individuals (HDIs), those South Africans who had no political vote prior to 1994, do not have sufficient access to good quality water, or to irrigated agriculture. Therefore the following have been assigned high priorities:

- The provision of not less than 25 litres per person per day of good quality water for all South Africans within 200 meters of their homes.

- The identification and provision of land, water, capital and expert guidance to enable HDI's, who are Resource Poor farmers, to acquire land and practice irrigation farming.

### 4.4 International Rivers

The NWA makes specific provision for water allocations to meet the needs of neighbouring countries with which water courses are shared. Several commissions have been established with neighbouring countries and various agreements on water sharing are in place.

### 4.5 Insufficient Provision for the Environment

The NWA requires that before water is provided for any other use a Reserve be set aside for basic human needs and to sustain the environment. The Reserve is a new concept, only introduced in the NWA of 1998, and for this reason many existing dams, particularly these constructed prior to about 1980, make insufficient releases for the environment or make releases that may be contrary to the natural seasonal flow in rivers. Therefore implementation of the Reserve may have significant impacts on the supplies from existing dams, particularly on those where deficits already exist. Resource Directed Measures are being developed to provide a framework for classifying and determining the ecological Reserve.

### 4.6 Low Water Use Efficiency

Water conservation and demand management will address water use efficiency by minimising losses and wasteful usage. However, water use efficiency can also be measured in terms of economic return or jobs created per cubic meter of water. In this regard, irrigated agriculture contributes approximately 1,5% of the GDP but only provides about 4% of formal employment, whereas it utilizes 59% of the water. Therefore careful consideration will be given to ensuring that future water allocations for irrigation will be in the greatest national interest and will not prejudice other more economically favourable sectors. Trading and purchases of irrigation allocations for urban use will be encouraged where this would not have adverse socio-economic consequences.

## 5. CONCLUSION

South Africa's NWRS provides a clear understanding of existing supplies and of current and future water demands in each of the 19 WMAs. The NWRS provides strategies for addressing deficits and surpluses, water quality, inequitable allocations and international allocations. Other challenges include the implementation of the environmental Reserve, particularly for existing schemes and where demands already exceed supplies, the future allocation of water between user sectors in accordance with the best national interest, and the management of water quality.

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# DEMAND AND SUPPLY OF WATER IN AUSTRALIA: OUTLOOK AND POLICY SCENARIOS TO 2020

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***ABSTRACT - JON THOMAS***

*This paper considers the role of water as an input to the Australian economy and options for its future role. Demands for water are examined using a detailed regionalised model of the Australian economy. Present and future water demands are related to potential growth in production in 55 industry groups across 18 regions.*

*It is not possible to sustain the past rates of growth in water use in many regions, because of restricted water availability. If water were to remain in its current uses environmental problems would worsen, new development could only occur in regions with currently undeveloped resources, and the rate of growth and output and incomes in "high value" water uses would be constrained.*

*Conversely, if water resources policy were adapted to this tightening supply situation through extension of trading arrangements, changed pricing, and improved water use efficiency in distribution systems and amongst end-users then: (i) water could be progressively transferred to industries with growth prospects, higher productivity and high marginal values for water supply; (ii) irrigated beef and dairy producers would adopt less water-intensive production systems while sustaining their output and profitability; (iii) there would likely to be some regional re-distribution of rice, cotton and sugar production to northern and particularly north western Australia; and (iv) urban areas would continue to experience some growth in demand and supply of water whilst reducing their per capita consumption*.

*Under this scenario it would be possible to sustainably expand national water production from around 18,000 GL at present to around 27,000 GL by the year 2020-21. However, in the main water-using region, the Murray-Darling Basin, the use of water for economic production will be static or declining, as policy for that major basin will concentrate on restituting aquatic and riparian environments, and pegging back water entitlements that currently exceed the available resource. In all regions there will be an increasing need to ensure that the water resource is managed in its totality, including regulated and unregulated surface waters, farm dams, groundwater, water quality, and environmental flow provision.*

*Mining and energy exports are crucial to Australia's future. Water requirements in these industries are small relative to use in irrigation. However, many of the export mining and energy industries are located in arid regions where water supplies are sparse, often of low quality and expensive. Groundwater management is of particular importance for this sector*.

## 1. INTRODUCTION

### Overview

This paper presents scenarios describing the present and future role of water resources in Australia's economy. Against this background it assesses the potential economic impacts of (i) the National Water Reform Agenda, and (ii) the "Cap" on water use imposed in the nation's largest river basin system, the Murray-Darling.

The Academy of Technological Sciences and Engineering and the Institution of Engineers Australia undertook the study because of the obvious scope for diverging views and policy directions in this nationally important field. The full study report is available on the Academy's website: http://www.atse.org.au.

### Data

It should be noted that the data on water use in this paper represented the best available estimates at the time of the study. Since then, the Australian Bureau of Statistics Water Account project (Australian Bureau of Statistics, 2000) has produced more accurate data for water use in 1995-96. However, the differences between the data sets are not so large as to affect the conclusions of this study, and in some areas, such as water use in agricultural industries, this study provides estimates that are not available in the ABS data. Since 1995-96 the level of water use has been much affected by drought conditions and reduced availability.

Data on economic output and value added by industry for 18 regions in Australia are taken from official published sources, and estimates by the Centre of Policy Studies at Monash University.

### Acknowledgement

The author gratefully acknowledges the indispensable inputs of Professor Peter Dixon and Dr Philip Adams of the Centre of Policy Studies at Monash University, and Dr Nigel Hall and Dr Bill Watson of Hall Resource Economic Modelling.

### Outline of the paper

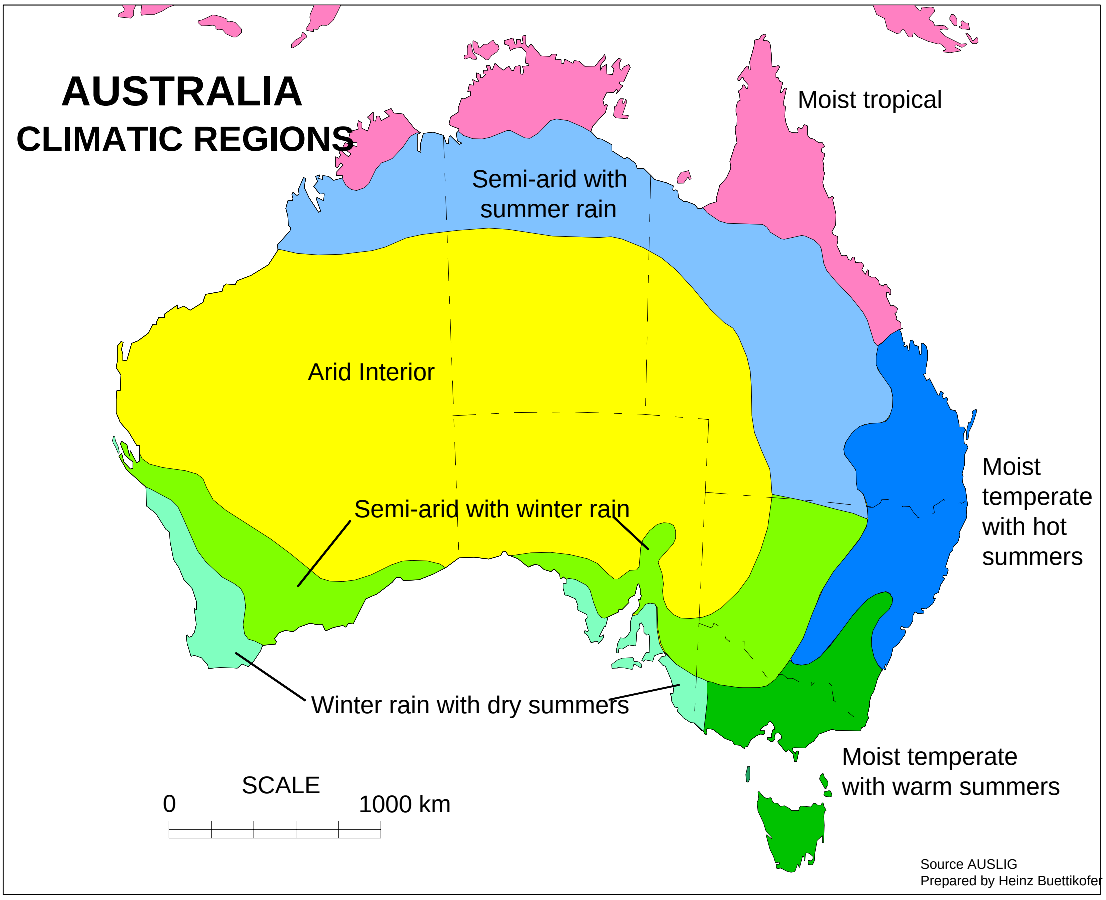
The paper begins with two short sections on Australia's climate and pattern of land use, respectively. This is followed by an account of current water use as related to economic activity. The theme and methodology of the paper are next described. Three Scenarios named (i) Trend, (ii) Non-Reform case and (iii) Reform Case are outlined. The following three sections discuss the results of each scenario in terms of national, regional and industry-specific economic outcomes. The concluding section brings together the principal findings about the impacts of policy alternatives on Australia's future economic performance.

## 2. AUSTRALIA'S CLIMATE

Seven climatic zones are represented within the Australian continent (See Figure 1), ranging from Moist Tropical to Moist Temperate. However, arid or semi-arid climates cover most of its area. The natural scarcity of water is exacerbated by great climatic variability. McMahon and Findlayson (1991) demonstrated that even within a single climatic zone, Australia, like Southern Africa, experiences up to four times as much variability in rainfall as northern hemisphere land masses. A period of extensive droughts was experienced in Australia during the1990's, the most recent and most severe of which continues today. Thomas and

Bates (2001) discuss management responses to the increasing uncertainty and variability of Australia's climate.

**Figure 1: Climatic zones of Australia**




## 3. LAND USE

With some notable exceptions, the pattern of land use in Australia is aligned with the distribution of rainfall.

Areas that experience moist temperate conditions and warm to hot summers (notably the eastern and southern sea board of Queensland, New South Wales and eastern Victoria) or dry summers with winter rainfall (notably the south west of Western Australia, the south of South Australia and western Victoria) contain the national capital, five mainland State capital cities, numerous country and industrial towns, and have been developed for predominantly rain-fed agriculture.

Large parts of the Murray-Darling Basin, which mostly comprises the dry interiors of south west Queensland, New South Wales, northern Victoria and eastern parts of South Australia, have been developed for irrigated agriculture through the interception, storage, regulation and diversion of large volumes of flow from the westward-draining (and in the case of Victoria, northward-draining) rivers of the Great Dividing Range. Canberra also lies within the upper reaches of this Basin. The basin accounts for around 60% of total national water use.

Further north, the arid interiors of Queensland, New South Wales and South Australia have been developed for pastoral use through exploitation of groundwater from the Great Artesian Basin.

The large quantities of water that are present in the tropical north are relatively undeveloped. Historically, this has been the result of the high costs of water development, which is related to hydrological characteristics, and the technical difficulties experienced in establishing cropping industries in the tropics. Rural development in the north of Australia has generally been confined to beef cattle grazing in pastoral areas, the sugar industry and tropical fruits industries in northern Queensland, and more recently mixed cropping in the Kimberley region of Western Australia.

The geographic distribution of Australia's mining and energy industries is largely independent of the rainfall pattern. Production of coal, bauxite and mineral sands occurs predominantly in the higher rainfall areas. However, large reserves of iron ore, natural gas, gold, nickel and copper are mined in arid regions. Water for mine settlements, mining, ore processing and on-shore gas processing is often very scarce or of very poor quality in these locations.

## 4. ECONOMIC STRUCTURE AND WATER USE

Water use in Australia is strongly influenced by the structure of the economy, particularly the production of agricultural commodities using irrigation. Total water use in Australia in 1995-96 was estimated to be of the order of 20,000 GL. This includes urban and rural uses, both for production and consumption. The definition of "water used" used here is *gross water supplied,* which includes a significant amount of water that is lost in delivery systems (estimated to be about 10% to 15% in urban areas, but much higher, perhaps 30%, in irrigation areas supplied with unlined channels).

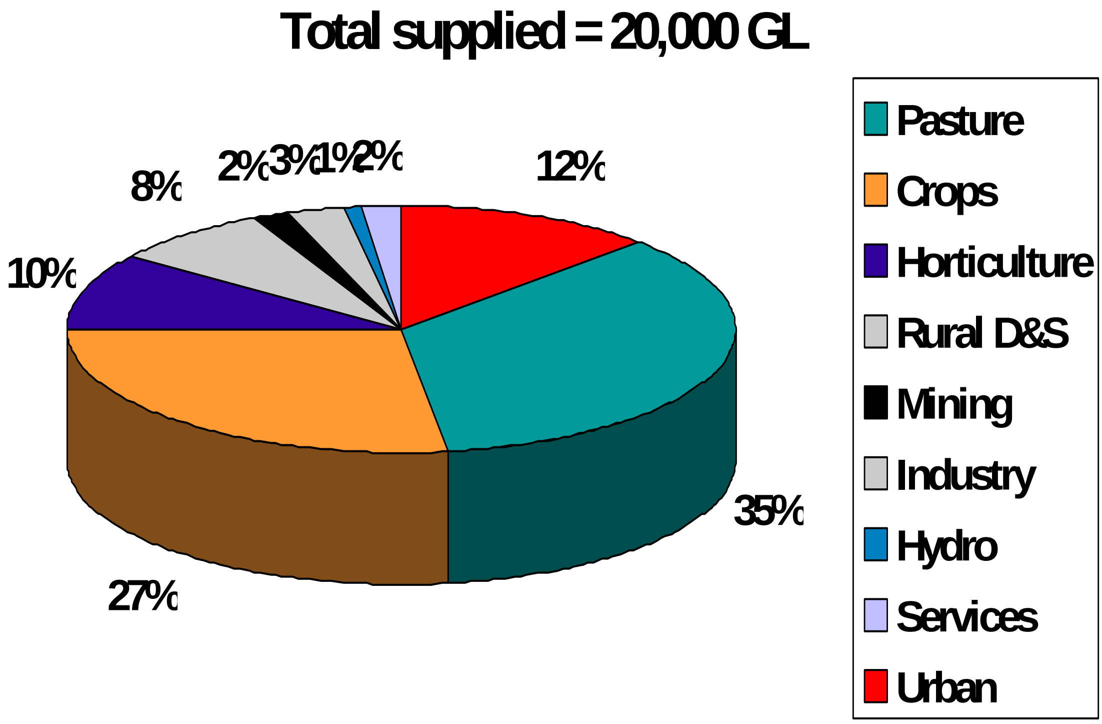
Rural use accounted for some 78% of the total. Irrigated agriculture dominated, accounting for around 72% of national water use. The industries using large volumes of water included dairy products, beef cattle, mixed farming/fat lamb raising, sugar, cotton, rice, wine grapes, fruit and vegetables. Together, these industries account for approximately a third by value of Australia's agricultural output in a normal year. They supply most of Australia's domestic consumption of the products mentioned, and are significant exporters.

The mining industry uses comparatively small volumes of water, but is of strategic significance to the economy. Much of the industry is situated in remote, arid areas. Therefore, providing adequate water supplies and preventing water pollution problems in the vicinity of mine sites is of great importance. In several regions the water needs of the mining industry are large in relation to the available resource.

Australia's cities are significant users of water for residential consumption and irrigation of parks, playing fields and gardens. This sector has been studied as a separate demand component. Manufacturing and service industries are largely served by urban water utilities, though self- extraction is often practiced outside of the urban areas. All these industries depend on good quality, reliable water supplies, supplied at an efficient price.

Water use is estimated to have been some 25% higher in 1995-96 than the 16,000 GL of water supplied in 1983-84 (Department of Primary Industries and Energy, 1985b, Volume 2, Tables 25 to 58). This will be a surprising result to many who believe that Australia has become conservative in its use of water. We estimate that nationally, approximately 1,500 Gl/year has been added to reticulated supply capacity from both dams and groundwater since 1983-84. About two thirds of this has occurred in Queensland. The remaining 2,500 GL/year has come from self-extracted sources, including groundwater and farm dams. Some increase in use was made possible by improvements in river regulation and distribution efficiency, though it is considered that this has not been a major factor over the last fifteen years.

**Figure 2:** Estimated industry shares of national water use in 1995-96
(Note: excludes self-extracted hyper-saline water used in the gold mining industry)




## 5. STUDY METHODOLOGY

The study used a simulation approach, which describes the relationship between trends in economic activity and water use in 18 study regions within Australia. Figure 1 shows the overall study design. It can be seen that there are four main streams of activity, dealing with: (a) modelling of the Australian economy, (b) estimation of resulting water use, (c) comparison of water use with resource availability and quality, and (d) allowance for future technical and institutional change.

There is a feedback loop from (d) to (a), which is used to generate alternative scenarios for the economy and water use. The "soft" part of the simulations is the specification of alternative scenarios, requiring explicit judgements rather than formal quantification.

The MONASH model of the Australian economy (Adams, Dixon and McDonald, 1994) provides a simulation of likely prospects for population and economic development. It is designed to examine the implications of different macro-economic scenarios, including

industry policies, at a disaggregated level of industries and regions, and was adapted to produce projections of economic activity between 1996 and 2020, based on best available evidence of trends for macro-economic variables and the response of individual industries.
The year 2020 was chosen as the study time horizon. A time period of some 25 years beyond the base year, 1995-96, could be relied on to generate some large potential changes in population and economic output, and thus highlight key issues. Also, that year would be just within the range of current plans. Few additional developments that are not already being actively considered by State governments are likely to be in place before the year 2020.

MONASH takes inputs on particular aspects of the economy prepared by specialist organizations. These included forecasts for macroeconomic variables, quantities and prices of agricultural and mineral exports, forecasts of changes in industry technologies and household preferences, and regional-level forecasts of the level of population and tourist activities. For this study, the model was used to project growth rates of real value added (or output) and employment for 167 industries and 18 regions. Data for the agricultural sector was finely disaggregated in order to examine likely changes in output for each of the water-intensive (i.e. either water using or water polluting) industries.

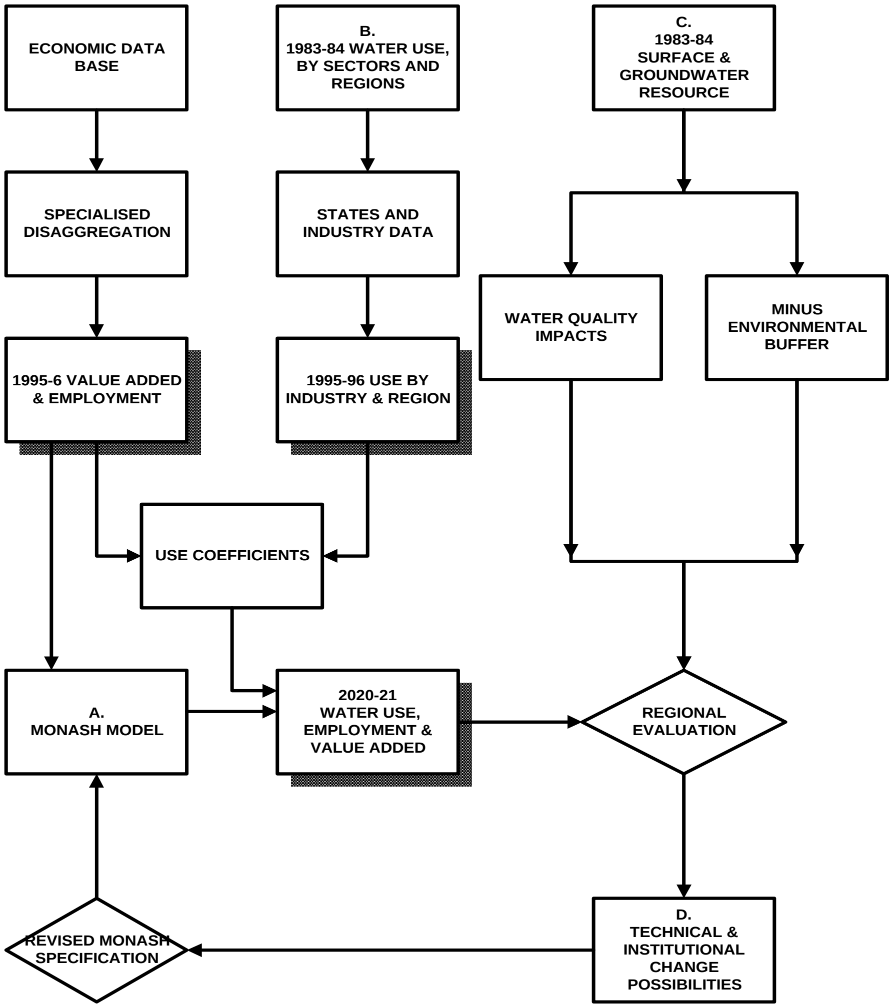
The overall relationship between the growth of the economy and the use of water is not linear. For example, according to our estimates, water use in Australia increased at about 1.9% per year between 1983-84 and 1995-96. By contrast, in the same period, the Australian economy grew at an average real rate of 3.4 % per year. In developing scenarios for the future, the coefficients of water use per dollar of value added in any economic activity were assumed to decline at the general rate of resource efficiency gain in the whole economy, namely at 0.6% per year. The basis for this assumption is that in the MONASH model there is an annual reduction of 0.6% per year in the “technical coefficients” which determine how much intermediate input is purchased by any industry.

Future demands of final consumers in urban areas, namely the residential and municipal sectors, were estimated separately based on trend analysis and known policies. Similarly, estimates of demand in rural areas for stock and domestic purposes were based on trends in rural populations.

Development of water use estimates for the base year, 1995-96, was a major part of the work effort. It involved up-dating the key water use statistics for the last previous national water use survey undertaken for the year 1983-84 and generating more disaggregated estimates of water use coefficients at the level of specific industries. This was done using the best available current data from State department sources, Commonwealth agencies, and many supplementary calculations.

Having projected the levels of population, economic activity and potential water use in each region, the simulated futures were examined to establish whether they would (or would not) be consistent with what is known about the water resource in terms of quantity and quality, competing (including environmental) demands, changing economic policies and management practices (including water pricing and water trading), and likely rates of adoption of innovations in the provision of infrastructure and water use technology.

**Figure 3:** Study Plan




## 6. SCENARIOS

In order to focus on the ways in which the economy and the water resource might interact in future, three scenarios for the Australian economy were examined:

- ***"Trend Projection"*** The economy continues to grow nationally and regionally in a manner consistent with past trends, without any constraint in terms of water infrastructure or water resource availability.

- ***"Non-Reform Scenario"*** Because of rigidities in water resource allocation, no irrigation industry can grow in water-stressed regions, and some irrigation activities would have to cease production as a result of water re-allocation to the environment or declining water quality. This scenario provides an illustration of what level of economic loss could occur if water resource scarcity were handled poorly. By "poorly" we mean that no attempt would be made to re-allocate water to its most economically productive uses. There would be no gains from water trade and in the absence of incentives, limited progress with water-saving technical innovations. Under this scenario, intensive irrigation industries within the Murray-Darling Basin, including rice, cotton, fruits, grapes and vegetables, would be constrained to remain at their 1995-96 levels of value added. In addition, the beef cattle and dairy industries of the Murray-darling Basin, were constrained to decline at a rate that would leave them, in real terms, at 85% of their 1995-96 output level by the year 2020, reflecting reduced water availability. It is implicit that any water freed by such a decline would be re-allocated to the environment rather than to other industries.

- ***"Continued Reform Scenario"*** Profitable and growing irrigation industries would obtain increased water entitlements through market processes and through the transfer of water from lower-valued uses. The output of some pasture-based industries would nevertheless grow through substitution of other inputs for water: in particular dry feed. Both water suppliers and agricultural water users in the Murray-Darling Basin would achieve a 1% per annum improvement in water use efficiency over the whole projection period in response to increasing market values of water.

The specification of the "Non-Reform" and "Continued Reform" scenarios in terms of industry impacts at the level of the 18 spatial units is shown as the "Regional Evaluation" box in Figure 1. Each spatial unit was considered individually.

Differences in gross domestic product between the three scenarios at the level of regions and the nation were then taken as a measure of the economic impacts of alternative strategies for water allocation and management.

## 7. RESULTS: TREND SCENARIO

The "Trend Scenario" produces a projected national water use of 32,550GL by the year 2020. Table 1 shows the additional demands projected in each region.

As the MONASH model tends to "anchor" industries in their current regions, the current concentration of irrigation in the Murray-Darling Basin plus the growth prospects of this sector causes the largest prospective increase in demand to be in that basin. However, as is shown in Table 1, the Murray-Darling Basin is unable to increase its water supply capacity. In fact basin

**Table 1**: Potential changes in water requirements 1995-96 to 2020-21 under the Trend Scenario

| Region | 1995-96 Usage (GL) | Demand Increment (GL) | Projected 2020-21 (GL) | Comments |
|---|---|---|---|---|
| Tropical North Queensland | 400 | 350 | 750 | Growth in water use is related to the growth of tourism and mining. The unit has ample resources to meet this demand. |
| Queensland Arid Centre | 80 | 0 | 80 | Usage in pastoral industry static or declining. Mining usage difficult to predict |
| Coastal Queensland | 2,740 | 2,770 | 5,510 | Growth in urban, industrial and irrigation sectors. A high percentage commitment of the resource is likely by 2020-21. |
| Coastal New South Wales, Victoria, Tasmania and the South East of South Australia | 3,540 | 1,880 | 5,420 | The water resource throughout these regions can cope with projected water demand comfortably, but pressure for environmental conservation of river systems will limit future diversions. |
| Murray-Darling Basin | 11,410 | 5,850 | 17,260 | Potential growth is evident across all irrigation sectors. However, the water resources of the basin are insufficient for supplying any of the additional quantity of water required. |
| South Australia beyond the Murray-Darling Basin | 360 | 160 | 520 | This region of sparse water resources relies on an extensive network of pipelines to import water from the Murray River. The economy is projected to grow relatively slowly, but major "shocks" such as new mineral or mineral processing would cause a hectic search for new sources of water. Re-use of wastewater from Adelaide is being developed to support expansion of irrigated horticulture. |
| South West and Goldfields Region of Western Australia | 1,010 | 1,170 | 2,180 | The Trend Scenario projection, of 3.0% per growth in aggregate water use, implies (a) diversion of southern-flowing rivers, (b) development of new sources of groundwater, (c) re-allocation of water away from pasture irrigation, (d) further long-distance pipelines to supply Goldfields needs and/or (e) development of seawater desalination or water re-use schemes. |
| Tropical Western Australia | 280 | 350 | 630 | The Trend Scenario is likely to under-estimate actual growth as new phases of the large Ord River Scheme are developed. |
| Northern Territory | 130 | 70 | 200 | The Trend Scenario possibly under-estimates the impacts of off-shore oil and gas developments and down-stream processing in the Darwin region. |
| Australia Total | 19,950 | 12,600 | 32,550 | |

Governments have indicated future reductions in the volumes of water supplied for economic use, in order to restore environmental flows.

Large increases in water use are projected in Coastal Queensland and Western Australia as a result of expansion of irrigation, mining, industry and urban populations. The intensive irrigation industries that have higher growth rates in the Trend Scenario are not well represented in the more temperate regions of the southeast coast and Tasmania. In these regions agricultural water is used mainly for supplementary irrigation. Hence, the overall growth rate for agricultural water use is expected to be lower than in other parts of the country. The coal industry in coastal New South Wales is projected to grow strongly, and this influences water demand. Urban demands have been assumed to be constant in per capita terms, and this keeps the demand down, as the south east coast has projected population growth rates that are below the national average.

Western Australia has the fastest growing State economy in Australia, with growth projected at around 3.9 per cent per year to 2020. The south west of Western Australia is better endowed than South Australia with rainfall and runoff. However, extensive clearing for dryland agriculture in the southwest has rendered many rivers brackish or saline. There has also been an undeniable climate change that has cut the divertible surface resource by as much as 50% over the last twenty years. Efforts are being made to encourage water use efficiency. Re-use and de-salination projects are being identified. The gold and nickel industries use significant quantities of locally-accessed, mainly hyper-saline groundwater, and demand is expected to increase in the long term.

The Trend Scenario suggests a significant growth in water demand in the Gascoyne and Pilbara regions, which lie in the dry tropics, from continued expansion of the large iron ore industry, oil and gas development and downstream processing.

In the Kimberley region in the wet tropical north of the Western Australia the Trend Scenario suggests continued rapid growth, from a small base, linked to further expansion of the Ord River irrigation area. The outlook is also for further growth of population and economic activity in the Northern Territory, based largely on developments in the energy resources, mining and tourism industries.

To summarise, in terms of pressure from current and future demand, the Murray-Darling Basin is the most “water stressed” region in Australia. The South West of Western Australia also faces water scarcity to the degree that re-allocation will become an issue within the time frame of this study. South Australia has for many years been in water-importing mode of operation, and will require growth in Murray River abstractions, continued efforts in groundwater exploration, water saving and/or water re-use if its Trend Scenario economic future is to be realized. Without pre-judging environmental requirements, other regions appear to have sufficient undeveloped water resource to meet their future needs.

## 8. NON-REFORM SCENARIO

The Non-Reform Scenario describes the potential economic repercussions of the “Cap” on water use in the Murray Darling Basin on the economy of the basin itself, and on Australia as a whole, *in the absence of complementary institutional or technical change*. It is emphasized that the Non-Reform Case is actually worse than is likely to occur, given that the COAG agenda has already started a program of institutional change that will help to alleviate resource limitations.

Table 2shows the projected growth rates for the affected industries in the Trend scenario, and their *assumed* growth rates in the Non-Reform Case scenario. It also gives percentage deviations for output in the final year comparing the Non-Reform Case with the Trend. From this table we see that the effect of our irrigation restrictions is to reduce pasture-based output in each region by around 55 per cent relative to the Trend in 2020, and to reduce intensive-irrigation output by between 43 and 60 per cent relative to Trend.

**Table 2:** Trend and Non-Reform Case projections for pasture-based and intensive irrigation industries in the Murray-Darling Basin(a)

| | Trend Scenario Average Growth (% /yr) 1996 to 2020 | Non-Reform Case Average Growth (%/yr) 1996 to 2020 | Difference: output deviation (%) 2020 |
|---|---|---|---|
| **Murray Darling: NSW** | | | |
| Meat cattle & calves | 2.8 | -0.5 | -54.4 |
| Whole milk | 3.1 | -0.5 | -57.3 |
| Total pasture-based | 2.9 | -0.5 | -54.7 |
| Rice | 2.3 | -0.2 | -45.1 |
| Cotton | 1.9 | 0.9 | -21.3 |
| Grapes | 5.3 | -0.1 | -72.1 |
| Plantation fruits | 0.5 | 0.1 | -8.6 |
| Citrus fruits | 3.6 | 0.3 | -53.9 |
| Vegetables | 2.7 | -0.2 | -49.7 |
| Total intensive irrigation | 2.6 | 0.1 | -43.3 |
| **Murray Darling: VIC** | | | |
| Meat cattle & calves | 2.9 | -0.4 | -54.0 |
| Whole milk | 3.2 | -0.3 | -56.7 |
| Total pasture-based | 3.0 | -0.4 | -54.6 |
| Rice | 0.0 | 0.0 | 0.0 |
| Cotton | 0.0 | 0.0 | 0.0 |
| Grapes | 4.2 | 0.5 | -57.3 |
| Plantation fruits | 0.6 | 0.2 | -7.5 |
| Citrus fruits | 3.7 | 0.4 | -53.4 |
| Vegetables | 1.5 | 0.5 | -21.4 |
| Total intensive irrigation | 4.0 | 0.4 | -55.5 |
| **Murray Darling: QLD** | | | |
| Meat cattle & calves | 3.3 | -0.4 | -58.1 |
| Whole milk | 3.6 | -0.3 | -60.6 |
| Total pasture-based | 3.5 | -0.4 | -58.6 |
| Rice | 3.0 | -0.1 | -51.9 |
| Cotton | 3.9 | 0.7 | -53.6 |
| Grapes | 6.9 | -0.5 | -82.3 |
| Plantation fruits | 1.4 | 0.3 | -23.7 |
| Citrus fruits | 4.5 | 0.5 | -61.3 |
| Vegetables | 4.4 | -0.6 | -69.6 |
| Total intensive irrigation | 4.1 | 0.0 | -60.3 |
| **Murray Darling: SA** | | | |
| Meat cattle & calves | 2.7 | -0.6 | -53.5 |
| Whole milk | 3.0 | -0.6 | -56.5 |
| Total pasture-based | 2.8 | -0.6 | -54.7 |
| Rice | 0.0 | 0.0 | 0.0 |
| Cotton | 0.0 | 0.0 | 0.0 |
| Grapes | 4.6 | 0.4 | -63.1 |
| Plantation fruits | -0.2 | 0.0 | 5.6 |
| Citrus fruits | 2.9 | 0.2 | -47.2 |
| Vegetables | 2.0 | 0.3 | -32.4 |
| Total intensive irrigation | 4.1 | 0.3 | -57.5 |

Table 3 reports Non-Reform Scenarios growth rates and deviations from trend for 60 sectors nationally.

**Table 3:** Non-Reform Case Scenario - Sector outputs for Australia 1996 to 2020

| | Sector | Average annual growth (%), to 2020 | Deviation (%) from Trend 2020 | | Sector | Average annual growth (%), to 2020 | Deviation (%) from Trend 2020 |
|---|---|---|---|---|---|---|---|
| | AGRICULTURE: | | | | MANUFACTURING: | | |
| 1 | Wool | 2.3 | 0.0 | 29 | Meat products | 2.7 | -8.5 |
| 2 | Sheep & lambs | 2.2 | -2.7 | 30 | Milk products | 2.0 | -26.2 |
| 3 | Wheat | 2.1 | 1.6 | 31 | Fruit & vegetable products, etc | 3.2 | 0.6 |
| 4 | Coarse grains | 2.9 | 0.7 | 32 | Other food products & tobacco | 2.1 | -0.4 |
| 5 | Pulses & oilseeds | 2.1 | 0.0 | 33 | Beverages | 3.6 | 0.8 |
| 6 | Total coarse grains & oilseeds | 1.5 | -6.5 | 34 | Fibres, yarns, derived products | 2.2 | 0.8 |
| 7 | Rice | -0.2 | -45.6 | 35 | Clothing & footwear | 1.2 | 0.3 |
| 8 | Meat cattle & calves | 2.0 | -24.4 | 36 | Sawmill prods., joinery, furniture | 3.1 | 0.5 |
| 9 | Whole milk | 2.1 | -22.3 | 37 | Pulp, paper & paperboard | 2.8 | 0.5 |
| 10 | Pigs | 3.3 | 0.0 | 38 | Products derived from paper | 2.9 | 0.0 |
| 11 | Stonefruit | 2.4 | -16.1 | 39 | Chemicals & their derivatives | 3.9 | 1.4 |
| 12 | Sugar cane | 3.4 | 0.0 | 40 | Petroleum & coal products | 3.0 | 0.3 |
| 13 | Cotton | 0.9 | -31.5 | 41 | Other products of nat. materials | 3.1 | 0.3 |
| 14 | Fodder crops | 2.8 | -3.9 | 42 | Metal products | 4.0 | 2.0 |
| 15 | Other export-related farming | 3.9 | -17.7 | 43 | Vehicles | 3.8 | 1.1 |
| 16 | Grapes | 2.9 | -32.3 | 44 | Electrical and electronic goods | 4.7 | 2.2 |
| 17 | Plantation fruits | 2.5 | -0.4 | 45 | Machinery | 3.9 | 2.3 |
| 18 | Citrus fruits | 1.2 | -46.0 | 46 | Other manufacturing | 3.4 | 1.4 |
| 19 | Vegetables | 2.7 | -5.6 | 47 | Total manufacturing | 3.4 | 0.4 |
| 20 | Poultry | 2.8 | -6.2 | | SERVICES: | | |
| 21 | Other agriculture | 2.9 | -3.8 | 48 | Electricity & gas | 3.2 | 0.2 |
| 22 | Total Agriculture | 2.4 | -12.7 | 49 | Water , sewerage & drainage | 2.6 | -0.3 |
| 23 | Forestry and Fishing | 3.1 | 0.7 | 50 | Res. building & construction | 3.4 | -0.1 |
| | MINING: | | | 51 | Wholesale trade | 3.3 | -0.2 |
| 24 | Ferrous metal ore | 4.3 | 4.5 | 52 | Retail trade | 2.5 | -0.9 |
| 25 | Non-ferrous metal ore | 3.9 | 2.5 | 53 | Repairs | 1.4 | -0.6 |
| 26 | Black and brown coal | 3.8 | 3.0 | 54 | Transport & communication | 4.4 | -0.3 |
| 27 | Other mining | 4.2 | 2.4 | 55 | Finance, business, prop. services | 3.8 | 0.0 |
| 28 | Total Mining | 4.0 | 2.7 | 56 | Public administration & defence | 1.8 | 0.0 |
| | | | | 57 | Health services | 2.3 | -0.5 |
| | | | | 58 | Other services | 3.2 | 0.0 |
| | | | | 59 | Total services | 3.4 | -0.2 |
| | | | | 60 | TOTAL ECONOMY | 3.4 | -0.4 |

The deviations follow straightforwardly either as the direct impacts of the limitations on agricultural output or from the consequent macroeconomic effects. Relative to the Trend Scenario, large contractions in output occur in Rice, Meat Cattle, Whole Milk, Cotton, Grapes, Plantation Fruit, Citrus Fruit and Vegetables; and in the closely related processing industries of Meat Products and Milk Products. Production of some other agricultural sectors also contract relative to base including Sheep and Lambs, Stone Fruit, Other Export-related Farming and Other Agriculture. Production of sheep and lambs is adversely affected by the decline in overall profitability of broad-acre Murray-Darling industries caused by the forced contraction in growth of their meat cattle production. The Stone Fruit and other export-related farming sectors are projected to have reduced growth rates because we have assumed that production of these products within the Murray-Darling Basin occurs on the same properties as the production of intensive-irrigated products. Other agriculture produces mainly agricultural services like sheep shearing, crop spraying and harvesting. The output of this sector falls in line with the overall fall in agricultural production in the Murray-Darling Basin. Other sectors projected to experience falls in production relative to the Trend are Water, Sewerage and Drainage Services, Retail Trade, Repairs and Health Services. The negative impact on the water services industry stems from the effects of the shock on irrigation usage.

Retail trade, repairs and health services suffer from the reduced growth in private consumption.

However, not all industries lose from the suppression of agricultural growth. Mining output is higher in the Non-Reform Case scenario than in the Trend, reflecting the beneficial effect on mining exports of the depreciation of the real exchange rate. Exchange-rate effects account for most of the other gains shown in Table 3, particularly in the non-food manufacturing industries that are export oriented and/or face import competition.

Table 4 reports results for the 18 regions. The comparative performance of the regions reflects three main factors:

- their reliance on irrigation agriculture;
- their reliance on secondary agricultural production adversely affected by the fall in growth of Murray-Darling Basin agricultural production; and
- their reliance on non-agricultural activities.

Among the Murray-Darling Basin regions, the South Australian part relies most on the directly affected agricultural sectors. The indirect, local-multiplier effects are also most strongly negative in this region because it has very little mining and manufacturing which benefit from the favourable exchange rate effects of the shock. Other Murray-Darling Basin regions experience less of a contraction in output relative to the Trend because they rely less on the directly affected agriculture and/or (in the case of the New South Wales part) have significant contributions from mining.

It should be pointed out that the value of agricultural production within the Murray-Darling Basin continues to grow, even under the Non-Reform Case scenario. This is because we assume continuing productivity gains in dryland agriculture. Nevertheless, growth in agricultural incomes would be seriously curtailed, as is demonstrated by Table 7.4.

**Table 4:** Non-Reform Case scenario - aggregate regional outputs

| | Region | Average annual growth (%), 1996 to 2020 | Deviation from Trend Scenario (%) 2020 |
|---|---|---|---|
| 1. | Queensland Coast | 3.6 | 0.01 |
| 2. | Queensland pt Lake Eyre Drainage basin | 3.5 | -0.55 |
| 3. | Queensland Carpentaria/Cape York | 3.4 | 0.11 |
| 4. | New South Wales Coast | 3.0 | 0.15 |
| 5. | Victoria Coast | 2.7 | -0.25 |
| 6. | Tasmania | 2.3 | 0.80 |
| | Murray-Darling Basin: | | |
| 7. | **New South Wales** | 2.3 | -3.85 |
| 8. | *Victoria* | 2.2 | -4.93 |
| 9. | *Queensland* | 3.0 | -7.92 |
| 10. | *South Australia* | 2.2 | -11.28 |
| 11. | South East Coast of South Australia | 2.6 | 0.07 |
| 12 | Adelaide & hinterland | 2.8 | 0.11 |
| 13. | South Australia Eyre Peninsula & North | 2.6 | 0.44 |
| 14. | South West of Western Australia | 4.0 | 1.01 |
| 15. | Goldfields and South East W.A. | 3.9 | 1.82 |
| 16. | Gascoyne & Pilbara | 4.0 | 1.64 |
| 17. | Kimberley | 3.9 | 1.08 |
| 18. | Northern Territory | 3.6 | 0.86 |

**Table 5:** Comparison of estimated agricultural value added in the Murray Darling basin in 1995-96 with Trend and Non-Reform Case scenarios in the year 2020-21

| | Total agricultural value added in 1995-96 ($ million) | Increase in value added under the Trend Scenario2020-21 ($ million) | Increase in value added to the year 2020-21: Non-Reform Case ($ million) | Growth relative to the Trend Scenario (%) |
|---|---|---|---|---|
| New South Wales | 3,320 | 2,860 | 1,480 | 52 |
| Victoria | 1,960 | 2,000 | 620 | 31 |
| Queensland | 1,020 | 1,130 | 540 | 48 |
| South Australia | 430 | 430 | 120 | 28 |
| Basin Total | 6,730 | 6420 | 2,760 | 43 |

Two other regions are projected to experience contractions in output relative to the Trend: the Queensland part of Lake Eyre drainage basin and Coastal Victoria. Both of these regions have significant shares of Meat and Milk Products in their manufacturing base. Large shares of the cattle and whole milk input to these industries originate in the Murray-Darling Basin.

The regions benefiting most from the Non-Reform Scenario are in Western Australia. In the main, these are mining-oriented regions and so benefit from some expansion in mining exports.

The forced reduction in agricultural output growth in the Murray-Darling Basin directly reduces Australian real GDP. This is the only reason for the deviation in GDP because Australia-wide employment of labour and capital are assumed to be unaffected due to labour market adjustment.

Reducing agricultural output leads directly to a reduction in exports of primary agricultural commodities and secondary agricultural commodities, including Milk Products and Processed Fruits and Vegetables.

However, our macro-economic assumptions do not allow the reduction in agricultural exports to generate a significant increase in the balance of trade deficit (we assume that changes in GDP are largely accommodated by changes in domestic demand). Hence, the reduction in agricultural exports is accompanied by depreciation of the real exchange rate, which improves the competitive position of all Australian producers versus their overseas counterparts, leading to an increase in non-agricultural exports. The reduction in agricultural exports from Australia increases world agricultural prices, while the increase in non-agricultural exports reduces other world prices. On balance, though, the increase in agricultural prices more than offsets the reduction in other prices, leading to an improvement in the terms of trade.

In our deviation simulations, we assume that real private consumption moves in line with domestically-accruing income. Domestic income is directly reduced by the fall in real GDP. Although the improvement in the terms of trade increases the spending power of the income, private consumption falls. Note that the *percentage* reduction in private consumption is larger than the percentage reduction in domestic income because the average propensity to consume is less than one.

**Table 6:** Non-Reform Case - selected macro-economic variable

| | Average annual growth (%/yr) 1996 to 2020 | Deviation from Trend (%) 2020 |
|---|---|---|
| Real GDP and its components: | | |
| Private consumption | 2.5 | -0.77 |
| Public consumption | 2.0 | 0.00 |
| Total investment | 3.3 | 0.00 |
| Imports | 4.3 | -0.02 |
| Exports | 6.0 | -0.36 |
| GDP (income) | 3.0 | -0.51 |
| Other macroeconomic variables: | | |
| Real exchange rate devaluation | 0.0 | 0.47 |
| Terms of trade | 0.1 | 0.11 |
| Real exports (agricultural) | 2.3 | -7.78 |
| Real exports (mining) | 4.5 | 3.49 |
| Real exports (other) | 7.0 | -1.23 |
| Real exports (tourism) | 8.9 | 1.23 |

Overall, the net effects on national economic welfare are small, with agricultural stagnation within the Murray-Darling Basin offset to a considerable extent by improved prospects for other export industries, contingent on exchange rate adjustments. According to these projections, the year 2020 value for GDP in the Non-Reform Case would be just 0.3% less than the Trend scenario, and real private consumption would be 0.5% less. Nevertheless, these small percentage deviations imply losses to the Australian economy in the order of $3.4 billion in the year 2020.

To summarize, the implication of the Non-Reform Case would be to severely depress the growth of income in the Murray-Darling Basin as a result of zero-growth scenarios for rice, cotton, dairy, fruit grapes and vegetables. On the other hand, at the level of the whole Australian economy, other industries and regions would benefit. However, the countervailing forces stimulating mining, manufacturing and services, are not strong enough to yield any net increase in GDP over the Trend. For this nil net gain the Non-Reform Case imposes severe economic penalties on the regional economies of the Murray-Darling Basin. South Australia, in particular, can hardly afford to be deprived of growth in one of the very successful sectors of its economy.

What are we to make of this conclusion? It will be tempting to those who see agricultural stagnation as the only way of releasing more water for the environment in the Murray-Darling Basin to point out that the net effects on GDP at the national level are tolerable. Nevertheless , they would have to acknowledge severe regional economic effects within the Murray-Darling Basin, and the additional environmental impacts of industries which would now grow faster, such as manufacturing and mining, and accept them as being worth incurring in order to gain additional environmental flows in the Murray-Darling system. But this economic penalty would be a high price to pay for achieving the desired environmental flows. There are better ways to manage the economy and the water resource to achieve both economic and environmental objectives. We shall examine one possible scenario in the next Section.

## 9. THE CASE OF CONTINUED REFORM

If possible, Governments would seek to avoid the losses of income resulting from the Non-Adaptive Scenario. However, the Trend Scenario demonstrated that continued growth of the irrigation sector in the Murray-Darling Basin would far outstretch the availability of the water resource there, unless there are radical changes in water allocation and outstanding technical improvements, leading to much more economically productive use of the water that is available.

It appears that enough water is currently used in low-value purposes to satisfy the growth requirements of high-value irrigation activities within the Murray-Darling Basin, if there were re-allocation. This could only occur within a market-based framework at prices that were attractive to both sellers and buyers.

The potential for transfers can be assessed by comparing the *current* amount of water used by pasture-based industries (i.e. in 1995-96) with the potential *additional* water likely to be required by the more intensive irrigation industries between 1995-96 and 2020-21. This is done in Table 7. It is seen that the total additional water requirement from intensive irrigation under the Trend Scenario projection is 2,780 GL, and this compares with total estimated use of 4,690 GL in pasture irrigation in 1995-96. Thus, on the basis of this crude mass balance, there is enough water currently being used in the pasture activities to supply the future needs of all the intensive activities. The pasture activities could potentially convert to dry-feed-based animal production, with relatively little loss of productivity, thus releasing large quantities of water. (They have not done so in recent times because during the drought the price of dry feed has been very high). A permanent transfer of 2,780/25 = 77 GL each year over the next 25 years would meet the requirements for additional water from the intensive activities. Total transfers were running at around 5% per year, or approximately 400 GL/year, in the mid-1990's, though the vast majority of these were temporary transfers.

When the required geographical distribution of water transfers is considered, the position becomes more complex. Additional demands of the intensive irrigation sector in South Australia exceed current pasture activities there. In New South Wales and Queensland the additional demands virtually equate with total current use for pasture production, leaving no water for pasture activities. Only Victoria has "spare" water available for pasture irrigation after the additional needs of the intensive sector have been satisfied.

**Table 7:** Comparison of additional water demands from the intensive irrigation sector in the Trend Scenario, with 1995-96 water use in pasture production, Murray-Darling Basin (GL)

| | NSW | Vic | Qld | SA | Total |
|---|---|---|---|---|---|
| Estimated pasture-based use, 1995-96: | | | | | |
| - Beef | 1,360 | 670 | 70 | 50 | 2,150 |
| - Dairy | 370 | 2,030 | 30 | 100 | 2,540 |
| - Total | 1,730 | 2,700 | 100 | 150 | 4,690 |
| Additional demand from intensive irrigation industries, 1995-96 to 2020-21: | | | | | |
| - Cotton | 940 | 0 | 70 | 0 | 1,020 |
| - Rice | 450 | 0 | 10 | 0 | 460 |
| - Fruits | 150 | 440 | 0 | 90 | 680 |
| - Vegetables | 40 | 20 | 0 | 40 | 100 |
| - Grapes | 170 | 250 | 0 | 80 | 500 |
| - Total | 1750 | 720 | 80 | 200 | 2,800 |
| Balances | -20 | +1,980 | +20 | -50 | +1,890 |

The position is also complicated by the commodity-composition of the additional demand. Despite our assumptions of moderate growth of the cotton industry in the long term, it provides the largest projected additional demand within the intensive sector. For climatic reasons, this demand is based largely in New South Wales with some projected growth in production in Queensland. But cotton growing cannot expand in its current locations without new inter-basin transfers, as there is no spare water in that part of the Basin. Water cannot be economically transferred to current cotton growing areas. For example, past investigations of an inland diversion of the Clarence River in northern New South Wales, have indicated disappointing cost-benefits. In the past there have been experiments with cotton growing in the southern Murray-Darling Basin, near Griffith, but rice proved to be more profitable. An agronomic problem for the more southern locations is that intermittent cold spells severely affect cotton growth.

Thus, it is concluded that growth of the cotton industry nationally at the Trend Scenario rate of 2.7% per year is more likely to be achieved by the establishment of new cotton growing areas, such as in the Fitzroy River Basin in Queensland, and in the north of Western Australia. If the additional needs of cotton are taken out of the equation, *as far as the Murray-Darling Basin is concerned*, then the remaining potential demands of the intensive irrigation sector can be met, both in hydraulic and market terms, by transfers of water out of pasture activities within each State.

The above discussion, of course, ignores the fact that the pasture-based activities are themselves projected to grow relatively strongly under the Trend scenario. The mooted transfers of water away from pasture production are therefore predicated on the voluntary surrender of water and by the substitution of alternative production methods -in particular by dairy and beef producers. Their willingness to make such changes will depend on the economic incentives to do so: either on-farm or by the sale of water entitlements at prevailing water prices. It seems highly likely that the combined effect of continued reduction in effective protection for the dairy industry, rising water market prices, increasing levels of cost recovery by bulk water suppliers and the availability of alternative animal production systems and locations for dryland production would convince enough pasture producers to trade permanent water entitlements.

Where would this new scenario of water market adjustment within the Murray-Darling Basin and spatial redistribution of the growing cotton industry leave the economy of Australia? We believe the outcome would look something like the following:

- There would be a transfer of water out of pasture irrigation into higher-value sectors, partly by permanent transfer trades, but also through large-scale improvements in the efficiency of water use on farms and in distribution systems. This "extra water" helps to meet environmental flow needs, but also means that the pasture sector no longer needs to sell quite so much water as otherwise would have been traded, and the intensive cropping sector no longer requires quite as much additional water to support its growth.

- Intensive irrigated cropping activities achieve the Trend growth in output nationally, but there is some re-distribution of these industries out of the Murray-Darling Basin. Intensive irrigated cropping industries achieve their Trend growth potential in all other regions.

- The cotton industry, which is currently located in the northern Murray-Darling Basin, achieves its growth potential nationally by expansion in coastal Queensland and the Kimberley region. The reasons for suggesting that cotton, more than any other industry, would experience a shift in its regional distribution are that (a) its profitability and growth potential indicate a large additional water demand, (b) it is excluded from the southern Basin by climatic factors, and (c) it cannot access significant amounts of additional water in the northern Basin. For the sake of illustration, two thirds of all new growth in the cotton industry occurs in Queensland and the rest in the Kimberley region.

- There is inter-state trading: the reason being that the demands from new growth in intensive irrigation exceed the latent supply from existing low-valued use in South Australia and western New South Wales, but not in Victoria.

Under the Continued Reform Scenario, despite the loss of water for pasture irrigation, value added continues to grow in the industries that are currently based on pasture, but not so fast as in the Trend. We suggest that the growth rate could be halved to around 1.5% real per year, as against around 3% per year in the Trend and negative growth in the Non-Reform Case.

Table 8 shows how the Continued Reform Case was developed out of the Trend projections of water use in the year 2020-21. The table shows projections for individual commodity groups, and by state. In all states the additional water demands of the intensive irrigation industries in each State were presumed to be supplied by transfers from the irrigated pasture sector in that State, with the exception of a small additional transfer from Victoria to South Australia. In presenting this table it is stressed that it is taken as a simulation of one possible outcome. In practice, our specific industry growth rates might turn out to be erroneous, while other trades might be possible. One example might be that the cotton industry in the Queensland part of the Murray-darling basin might be able to obtain water from pasture irrigators in that region. However, we can be confident that there will be some mixture of intensive irrigation activities that will be seeking to acquire water entitlements from low-valued water applications.

**Table 8:** Development of the Continued Reform Case assumptions for water use in the Murray-Darling Basin in the year 2020-21 (GL)

| | Estimated water use in 1995-96 | Trend Projection 2020-21 | Trend Increment | Continued Reform Case 2020-21 |
|---|---|---|---|---|
| **New South Wales** | | | | |
| Cotton | 1,970 | 2,960 | 0 | 1,970 |
| Rice | 1,740 | 2,200 | 460 | 2,200 |
| Fruit incl grapes | 254 | 572 | 318 | 572 |
| Vegetables & other | 153 | 249 | 96 | 249 |
| Pasture | 1,734 | 2,897 | -874 | 860 |
| Total | 5,851 | 8,878 | 0 | 5,851 |
| **Victoria** | | | | |
| Cotton | 0 | 0 | 0 | 0 |
| Rice | 0 | 0 | 0 | 0 |
| Fruit incl grapes | 632 | 1,330 | 698 | 1,330 |
| Vegetables & other | 191 | 250 | 59 | 250 |
| Pasture | 2,698 | 4,886 | -809 | 1,941 |
| Total | 3,521 | 6,446 | -52 | 3,469 |
| **South Australia** | | | | |
| Cotton | 0 | 0 | 0 | 0 |
| Rice | 0 | 0 | 0 | 0 |
| Fruit incl grapes | 149 | 312 | 163 | 312 |
| Vegetables & other | 126 | 170 | 44 | 170 |
| Pasture | 155 | 261 | -155 | 0 |
| Total | 430 | 743 | 52 | 482 |
| **Queensland** | | | | |
| Cotton | 70 | 139 | 0 | 70 |
| Rice | 0 | 0 | 0 | 0 |
| Fruit incl grapes | 0 | 0 | 0 | 0 |
| Vegetables & other | 4 | 7 | 3 | 7 |
| Pasture | 104 | 198 | -3 | 101 |
| Total | 178 | 378 | 0 | 178 |
| **Total Basin** | | | | |
| Cotton | 2,040 | 3,109 | 0 | 2,040 |
| Rice | 1,740 | 2,200 | 460 | 2,200 |
| Fruit incl grapes | 1,037 | 2,217 | 1,180 | 2,217 |
| Vegetables & other | 472 | 674 | 202 | 674 |
| Pasture | 4,691 | 8,222 | -1,842 | 2,849 |
| Total | 9,810 | 16,202 | 0 | 9,980 |

### 7.4.2 Projections

From Table 7.6 it can be seen that the Continued Reform Case produces an outcome for macro-economic variables in the year 2020-21 that is very little different from the Trend. The exchange rate and investment market mechanisms have compensated in part for this slightly reduced rate of growth in the agricultural sector, and this produces a shift in export composition out of agriculture and into other exports.

**Table 9:** Continued Reform Case: deviations from Trend for macro-economic variables in the year 2020-21

| Macro-economic variable | Deviation from Trend in 2020-21 (%) |
|---|---|
| Private consumption | -0.14 |
| Public consumption | 0 |
| Investment | 0 |
| Exports | -0.10 |
| Imports | -0.01 |
| GDP | -0.1 |
| Real wages | 0 |
| Employment | 0 |
| Exports: | |
| - rural | - 0.82 |
| - mining | +1.05 |
| - tourism | +0.50 |

Shows the implications for the eighteen spatial units. By assumption, the growth of beef and cattle production in the Murray-Darling Basin would be less than in the Trend, due to an assumed surrender of a part of current water entitlements. This would be partly offset by productivity improvement in a dry-feed-based animal production sector. This reduces agricultural output in the Murray-Darling Basin *relative to the Trend*. However, considerable growth in agricultural value added would have occurred both in the intensive irrigation industries and in beef and dairy production.

Relative to the Trend, the region that is most disadvantaged by the assumed embargo on expansion of cotton in the Murray-Darling Basin is the Queensland part of the Basin. This is not surprising, because that part of the Basin has a relatively small economy at present, and it is where a significant part of the cotton industry expansion would be located in the absence of water resource constraints. Even with a cap on diversions in this part of the Basin the cotton industry could possibly expand by obtaining water from pasture producers in that region. This is not taken into account in the Reform Case. However, the amount involved would be small in relation to total additional water needs of the cotton industry nationally. On the other hand, the regional economies of coastal Queensland and the Kimberley benefit strongly from the re-distribution of the cotton industry. The effect is particularly marked in the Kimberley given the small size of that region's agricultural economy.

Victoria also experiences a decline in agricultural value added relative to the Trend, but the deviation, of approximately -10% in the year 2020-21, has to be considered against a *doubling* of value added from Victorian agricultural output in the Trend, which would be achieved through increasing agricultural productivity in both dryland and irrigation sectors. That is, we are talking of a 90% increase instead of a 100% increase over the period considered.

**Table 10:** The "Continued Reform Case ": Percentage deviations from "Trend" sector outputs in 2020-21.

| | | Agriculture | Mining | Industry | Services | Total Economy |
|---|---|---|---|---|---|---|
| 1. | Queensland Coast | 2.28 | 0.84 | -0.05 | -0.02 | 0.06 |
| 2. | Queensland pt Lake Eyre Drainage Basin | -0.28 | 0.72 | - | 0.18 | 0.10 |
| 3. | Queensland Carpentaria/Cape York | -0.12 | 0.77 | -0.48 | 0.09 | 0.09 |
| 4. | New South Wales Coast | -0.29 | 0.85 | 0.14 | 0.03 | 0.06 |
| 5. | Victoria Coast | -0.21 | 0,83 | -0.06 | -0.10 | -0.09 |
| 6. | Tasmania | -0.07 | 0.84 | 0.35 | 0.15 | 0.17 |
| | Murray-Darling Basin: | | | | | |
| 7. | • New South Wales | -6.7 | 0.80 | -0.10 | -0.27 | -0.88 |
| 8. | • Victoria | -9.92 | 0.73 | -0.89 | -0.47 | -1.32 |
| 9. | • Queensland | -14.6 | 0.71 | -1.20 | -1.23 | -3.32 |
| 10. | • South Australia | -3.2 | 0.68 | -0.47 | -0.18 | -0.91 |
| 11. | Adelaide & hinterland | 0.07 | 0.67 | 0.21 | 0.11 | 0.13 |
| 12 | South East of South Australia | -0.15 | 0.71 | -0.74 | 0.21 | 0.06 |
| 13. | Eyre Peninsula & North of S.A. | 0.26 | 0.74 | 0.55 | 0.30 | 0.36 |
| 14. | South West of Western Australia | 0.31 | 0.77 | 0.45 | 0.24 | 0.31 |
| 15. | Goldfields and South East W.A. | 0.24 | 0.76 | 0.76 | 0.41 | 0.58 |
| 16. | Gascoyne & Pilbara | 0.21 | 0.77 | 0.25 | 0.36 | 0.54 |
| 17. | Kimberley | 73.15 | 0.72 | 0.30 | 0.47 | 2.58 |
| 18. | Northern Territory | 0.27 | 0.74 | 0.62 | 0.37 | 0.41 |

## 10. CONCLUSIONS

It has been demonstrated that the Australian economy *can* follow a trajectory that is very close to the Trend Scenario in terms of GDP and the regional distribution of incomes, *provided* that mechanisms and incentives are put in place to ensure water transferability and improved water use efficiency.

New strategies for the cotton industry are vital for continued performance. It is also possible that a similar shift could occur in the regional distribution of the sugar industry, with additional activity occurring in the Kimberley region as well as coastal Queensland. We have illustrated the need for market-based re-allocation of water within the Murray-Darling Basin. It is clear that it will be much more efficient for the market to determine final outcomes. Inter-State transfers between New South Wales, Victoria and South Australia should be a part of the solution.

Concerns about the availability of water, and a continuing belief that the resource can be used as an engine of social and economic development, Some interest groups have actively promoted investment to divert more water inland from the eastern coastal uplands, or to construct very-long-distance pipelines to bring water southwards from the wet tropics. The theme of further water development has been linked to the new railway from Melbourne in the south to Darwin in the north, a distance of some 6,000 km along a route passing through some of Australia's most productive agricultural regions.

There is also a contradictory view, which, far from seeking to increase water availability, regards many existing water uses as economically un-necessary and environmentally destructive. It has been argued that some irrigated agriculture yields a net economic cost to the nation, involving a transfer of wealth to a privileged group, based on historically high levels of subsidy. This school believes that only the social impacts of closing down some older irrigation regions should prevent us from doing so at a faster rate. This has been increasingly accepted since about the 1960's, when economists questioned the advisability of public investment in some irrigation schemes (Davidson, 1969).

Widespread evidence of environmental impact has been added to this economic criticism of past water development decisions. Many rivers have been severely depleted and the timing of their flows altered. Lakes, swamps, marshes and mound springs have suffered from reduced runoff and in some cases groundwater draw-down. Some ground water systems have been have been over-exploited for years and are no longer as productive as before. The quality of water has also generally declined as a result of salinity, nutrients and urban pollutants. Given the evident stress on the resource it has therefore been suggested that environmental needs and social equity (however defined) should now have priority. This view is frequently linked to a preference for the limitation of population growth, through a lowering of immigration quotas.

This paper concludes that the best way forward must lie between these two polar strategies. Most Australians recognize water as a scarce resource that must be used wisely. In an economic sense this means that it should not be wasted on “uneconomic” activities. But neither should there be a blanket ban on all new water development. The study identified opportunities for profitable irrigated agriculture, which are likely to emerge from Australia’s geographical and economic position in the world. The benefits of new or replacement investment in water infrastructure will still outweigh the costs in many locations. New development should be market-driven, and should be economically efficient. It should also take place within agreed environmental bounds.

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# THE VALUE OF WATER IN THE SOUTH AFRICAN ECONOMY - A REVIEW[1]

W L Nieuwoudt, G R Backeberg and H M du Plessis

## 1. INTRODUCTION

As South Africa is a drought prone, water poor region it seems probable that water shortages will redirect economic development. As water scarcity increases, the need to manage water as a national asset and for overall social benefit becomes imperative. During the past number of years the South African Water Research Commission (WRC) and the Department of Water Affairs initiated a number of economic research projects aimed at determining the value of water in different sectors of the economy and in different parts of the country.

The purpose of this contribution is to review existing information and experience in order to obtain the best current estimate of the value of water in different sectors of the South African economy and the role water plays in regional economies. Knowledge of basic human needs, the assurance of supply, the value of water in different sectors and basins can aid in demand management in times of shortages. This information is required to optimize scarce water resources for the social benefit of all people. In addition to this Command and Control (CAC) procedure, economic incentives and institutions can assist in promoting conservation of water within the ambit of the law. Economic institutions and incentives have internationally promoted conservation and the efficient use of water by using knowledge that is decentralized.

## 2. THE SOUTH AFRICAN WATER RESOURCE STRATEGY

The National Water Act (No. 36 of 1998) specifies that Government, as the trustee of the nation's water resources, must ensure that water is protected, used, developed, conserved, managed and controlled in an equitable and sustainable manner for the benefit of all people. The Act further requires that the Department of Water Affairs and Forestry (DWAF) should act as custodian of South Africa's water resources (RSA, 2002). The South African Water Act of 1998 guarantees basic human needs and ecological use (the reserve) as rights along with international obligations (relevant to where inter–country water schemes exist). Irrigation and other commercial agricultural activities are excluded from this allocation (Louw, p18, 2001; RSA 1998). The New Act thus gives priority to basic human needs and ecological sustainability above that of agriculture and other industries. The New Act respects water rights and farmers may continue using water until a call is made for the application of water licences. Water licences have a maximum span of 40 years and are subject for review at intervals not exceeding five years.

The implementation framework for the National Water Act of 1998 is provided for in the National Water Resource Strategy (NWRS). The NWRS has four objectives which include the establishment of the framework for catchment's management strategies. A catchment management strategy is the framework of water resource management in a water management area (RSA 2002).

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[1] This paper emanates from a consultancy undertaken by the senior author on behalf of the Water Research Commission and will be published as a WRC Report.

In the preamble to the Act it is clear that the approach to water management is to a large extent centrally orientated. However, Section 25(1) of the new National Water Act (1998) makes provision for the temporary transfer of water entitlement between users. It is possible that government and the private sector can act in a complementary way. A main feature of water markets in the Western USA is that decision making is decentralised (Louw, 2001). The Act contains important aspects which will support a water market; (a) a distinction is made between land and water rights and (b) managing of catchments will eventually be assigned to Catchment Management Agencies (CMA) and it will be possible, with the approval of the Minister, to include water markets as an allocation strategy in catchments.

A water market requires a well-tuned balance between government regulation and market forces. Without going into the conditions of such a market it may be stated that requiring that licences must be reviewed at intervals not exceeding five years will create uncertainty regarding long term investments in irrigation farming.

## 3. ECONOMIC PRINCIPLES

Water has two main uses, it is consumed directly as consumption good or it is used as a factor of production in agriculture, forestry and industry. The economic foundation of both demands differs and will be discussed separately.

### 3.1 Water as a consumption good

Residential demand is the only category where water is consumed directly. Residential water competes directly with other items in the household budget. Consumer choice can be modelled as utility maximization given a budget constraint from which a downward sloping demand for water can be derived. Some characteristics of water resemble that of other economic goods, implying that demand affects the price. Espey *et al*. (1997) survey of 124 estimates of price elasticity of demand for residential water supports this view. They report a median short-sum price elasticity of –0.38 and a long run of –0.64. This shows that residential water is not price responsive in the short run confirming its essentiality.

Apart from the time horizon, price elasticity is affected by type of use. Evidence from Europe, USA and Africa indicates that households are willing to pay much more for drinking water and basic needs than water used to irrigate gardens (Foster and Beattie, 1979; Zabel *et al.*, 1998; Rogerson, 1996). Veck and Bill (2000) record a similar result for Alberton–Thokoza in South Africa where the price elasticity of demand is estimated to be –0.13, for indoors and –0.38 for outdoor use. The lower elasticity for indoor use indicates that this use is less price responsive and more essential. From an empirical measurement perspective, total value of water for residential use can be quantified by the consumer surplus (area under demand for water but above the water price). The marginal value for water (marginal utility) which is its scarcity value is reflected by the price of water. A condition for economic efficiency in consumption is that marginal utility must be equated for all consumers which is achieved as all consumers in a given area face the same price for water.

It can be argued that Espey *et al.* (1997) evidence deals with luxury water use, and that it does not necessarily extend to basic-needs water. Quantity demanded is a function of willingness-to-pay <u>and</u> the ability to pay. While poor consumers may be willing to pay an infinite amount for basic needs water, they may be unable to do so and be excluded from the resource (McMaster and MacKay, 1998). Present legislation supports the basic needs position and includes water for drinking, food preparation and personal hygiene. A basic requirement of 25 litre per person per day is stipulated.

Several studies in poor communities have, however, indicated that poor people are willing to pay for water and that this willingness-to-pay indicates the opportunity for efficient allocation through price (Conradie, 2002). An extensive study of domestic water demand in low-income communities in the northern parts of South Africa finds that demand in squatter camps obey the same rules as demand in formal settlements. As in formal settlements, quantity demanded in squatter camps is a function of income, price of water, the presence of gardens, awareness of scarcity, time of the day, season, number of household members and the number of visitors (Van Schalkwyk, 1996).

### 3.2 Water as an input of production

Theoretically the demand for irrigation water is a derived input demand as irrigation water is a factor of production. An input demand is derived from the demand of the product (profitability of crops, etc), the production function (water plant efficiency), and the supply conditions of other factors of production (water saving technologies). The total income generated by the application of water (total value) can be measured by the integral of the area under the input demand function of water. The value of an additional unit of water can be expressed by the value of the marginal product. These concepts are shown in Fig 1 where DD is the demand for water, Qa the availability of water (supply is SS), A+B total value and B = Rent or Residual.

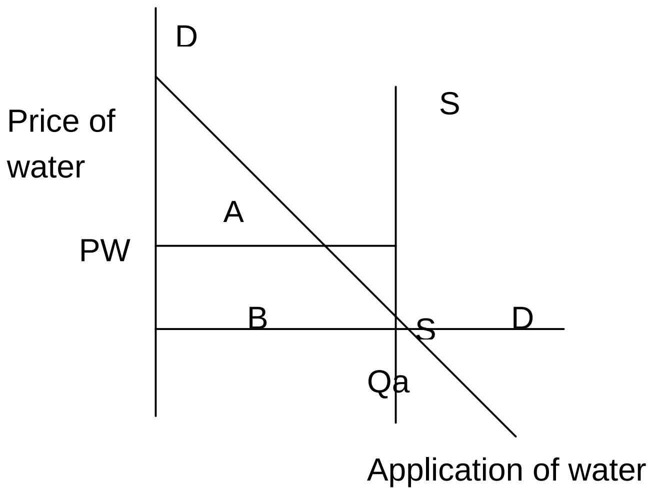


**Figure 1:** Resource demand for Water

In this situation no cost is shown for water. If costs exist then it will be deducted from value. The total per unit value is (A+B)/Q which is an average concept while the rent or residual value per unit is B/Q = Pw (which is a marginal concept). In a functioning water market, price of water rights is captured by Pw. These rights can be expressed as rental income (annual income) or a capitalised value (capital value of an asset). In a water market the price of water rights represents the contribution of water after all costs have been deducted including water charges. The total value (Area A+B) and marginal value (B) provide different information to stakeholders. In a Cost/Benefit Analysis the area A+B is compared with the cost of providing water (building dams) to ascertain whether benefits exceed costs. The marginal value is critical in utilising the resource in an efficient manner. For instance reallocation of use will promote societies' income if water has a greater efficiency of use (marginal value) in one area than in another.

Whether the total contribution or the marginal contribution is estimated in a study depends on the technique used. In a crop budget total cost is deducted from total income yielding the total and average contribution of water (Area A+B). Programming techniques provide information on the Value of the Marginal Product (VMP) of water given by the shadow price of the water constrained which is the marginal value (B/Q). The latter technique can also be used to derive the total and average value of water. Production functions provide information on the VMP of water although average value can also be derived. The Willingness to Pay (WTP) approach estimates average consumer surplus which is an approximation of market values and thus estimates marginal value B/Q. If water is rented then the trading price is B/Q or if it is sold then the selling price is the capitalised value of area B or B/Q (if expressed per $m^3$).

## 4. CONTRIBUTION OF WATER TO DIFFERENT SECTORS

In order to decide which sectors should be given preference in water allocation during scarcity, information is needed on the value of water in these sectors. Various sources of information will be critically evaluated.

### 4.1 Importance of water in supporting income and creating jobs

Agriculture is an inefficient user of water as it supports the lowest GDP per million $m^3$ while it creates the fewest jobs per million $m^3$. One cubic meter of water adds R1.5 in agriculture, R157.4 in industry, R39.5 in mining and R44.4 in eco-tourism (Conningarth Economists, 2001). Water adds the most value in industry, mining and eco-tourism and the least in agriculture, electricity generation and ecology. Large differences also appear in agriculture with the highest contribution per $m^3$ in livestock and game farming followed by orchards and lastly fodder crops. One million $m^3$ of water supports 250 jobs in agriculture but 1785000 jobs in glass products (BKS, 1999). These data do not show forward and backward linkages between sectors for instance between agriculture and other sectors which are important. Crop failures usually have ripple effects through the economy.

Some comments of caution are raised in interpreting these data. In a rationing situation (scarcity) water use should be allocated between sectors based on marginal benefits and not average benefits. These data are average relationships, derived from Input/Output tables. That is, water efficiency for the industry sector is high because output is high and water use low. Also, production in each sector is produced by many other factors and it can not be attributed to water only. It is, however, expected that supply assurance for water is high in the mining and industry sectors compared to agriculture. The input elasticity of demand for water is expected to be low in sectors where the cost of water is a relatively small share of the value of the final product and where water can not be replaced by other factors of production (Friedman, 1962 p153). A low price elasticity of demand implies that a high premium is placed on sufficient water and a high level of assurance.

The marginal contribution of water in industry is expected to be much lower than the R157.4 per million $m^3$ mentioned earlier. Water use by these sectors is not rationed in South Africa and these sectors are able to acquire as much water as they want at current municipal prices. That is, profit maximizing firms in the Industry Sector will purchase water from municipalities until the contribution that the last unit of water makes to the firm (VMP) is equal to the price of water (about R1.26/$m^3$ in the case of the Nelson Mandela Metropol). Economic logic thus indicates that the marginal contribution of water could be as low as R1.26/$m^3$. Some sectors place a higher premium on sufficient water and marginal contributions can not be the only criterion of allocation between sectors.

### 4.2 Importance of water in job creation

Although agriculture creates few jobs per unit of water compared to other sectors it generates more jobs per value of output than other sectors. For instance a R1 million production in agriculture creates 24 jobs in total (direct and induced effects. Mining creates 10.9 jobs per R1 million production and manufacturing 9.0 jobs per R1 million production. Agriculture also generates more jobs per 1 million rand investment (806) than the other sectors. This number has more relevance to irrigation agriculture than other branches of agriculture. That is, investment in dry land maize farming is constrained by suitable land area while investment in irrigation could create more jobs in the fruit and vegetable enterprises (land is often not the constraint but water).

Agriculture, however, requires large quantities of water as only 108 jobs are created per 1 million $m^3$ of water in agriculture while industry creates 4 269 jobs. The important mining sector creates 150 jobs per 1 million $m^3$ which is almost in the same order of magnitude as agriculture. South African agriculture is labour intensive, especially the irrigated sectors (fruit and vegetable farming).

In the allocation of water between agriculture and the other sectors it could be taken into account that industry can sometimes grow where water is abundant while some of the best fruit and vegetable growing areas are where water is scarce. Some will question this argument as Industry also requires other resources such as labour and infrastructure which may be available where water is scarce. Market forces will encourage industry location where resources including water are relatively abundant, thus the State should not subsidise certain resources.

## 5. VALUE OF WATER IN NON AGRICULTURAL SECTORS

Studies of water use in non agricultural sectors are: municipal use (Conradie, 2002), commercial forestry (Tewari, 2003), environmental use (Hosking *et al.*, 2002) and alien vegetation use (Hosking *et al.*, 2002).

### 5.1 Municipal water value

Conradie (2002) estimated demand functions for water for household, commercial and industrial consumption in the Nelson Mandela Metropolitan Municipality. Conradie (2002) estimates the marginal benefit of water to consumers at R2.40 /$m^3$, which is equivalent to an annual rental value of R21 600 /ha for a 9 000 $m^3$ allocation. Bulk sales of treated water to lesser municipalities are priced at R1.26 /$m^3$. The city purchases water from the Department of Water Affairs and Forestry at an annual rate of R0.256 /$m^3$. There is no doubt that, like irrigation, municipalities capture the residual value of the resource, but the reserve price at which agriculture will start losing water to municipal use is R1.26 /$m^3$ minus treatment costs in 1999 terms.

In order to increase income variability of households in the data set, observations from the more affluent residential areas and townships (low income consumers) were pooled. Using a regression model, the water price elasticity was estimated at –0.47 (t=-3.10) which is low and indicates that this use is not sensitive to price increases. A similar estimate (-0.40) was reported for Australia (Australian Academy of Technological Sciences and Engineering, 1999).

## 5.2 Commercial forestry

Water is the most important limiting factor of production in commercial forestry in South Africa. Commercial forestry uses water in two forms: evapotranspiration (ET) and streamflow reduction (SFR). In terms of stream flow reduction, water use is estimated to be in the region of 1.4 billion cubic metres per annum or roughly 8 percent of the total utilizable water in South Africa. Since commercial afforestation has been declared as a streamflow reduction activity (SFRA), it is to be regulated by means of a SFRA Water Use Licensing System in terms of Chapter 4, Section 36 of the National Water Act (No. 36 of 1998).

The value of the two uses of water (ET and SFR) in forestry was further estimated using two methods namely: the Residual Value (RV) method and the Marginal Value Product (MVP) method. The residual value method is based on the premise that the residual value obtained as total revenue minus total cost, including the compensation for capital and management, is attributed to water. The marginal value product method is based on the assumption that water is rewarded according to its MVP. Both approaches were used to estimate water values to selected sites of eucalyptus and pine in the eastern coast of South Africa. These two species were selected as they dominate South African forestry, especially on the east coast. Results of the estimates of water values are presented in Table 1. It is shown that water values estimated vary depending on method of estimation and type of use**.**

**Table 1:** A Comparison of different types of annual water values estimated in Commercial Forestry

| Name of Sites | ET value by RV Method R/cubic metre/yr | ET value by MVP Method R/cubic metre/yr | SFR value by MVP Method R/cubic metre/yr |
|---|---|---|---|
| Eucalyptus | | | |
| Kia-Ora | 0.06 | 0.34 | 4.44 |
| Tanhurst | 0.10 | 0.25 | 1.90 |
| Kwambonambi | 0.13 | 0.60 | 3.92 |
| Baynesfield | 0.04 | 0.04 | - |
| Average | 0.08 | 0.31 | 3.42 |
| Pine | | | |
| Richmond | 0.013 | 0.15 | 1.27 |
| Greytown | 0.008 | 0.11 | 2.20 |
| Usutu | 0.031 | 0.21 | 1.89 |
| Average | 0.017 | 0.15 | 1.79 |

(Tewari, 2003)

ET values estimated by the RV method for eucalyptus vary from 4 cents to 13 cents per cubic metre of water; 4 cents per cubic metre in low rainfall area such as Baynesfield and 13 cents per cubic metre in high rainfall area such as Kwambonambi site. The average value comes to 8 cents per cubic metre. The ET value for pine, estimated by the RV method, averages at 1.7 cents per cubic meter. Water value estimates for pine species are much lower than that estimated for eucalyptus. The difference can be explained in terms of the growth pattern of the two tree species; eucalyptus grows faster and uses water more efficiently.

The ET value estimates by the MVP method vary between 4 to 60 cents per cubic metre of water and are roughly 4 times the estimates by the RV method. The RV method measures the residual net value attributed to water after paying for all other inputs in the production process. As the MVP of water was derived from production functions (Table 1), it measures the value before other costs have been deducted. In the other studies reported in this paper the MVP was estimated from programming techniques after other costs have been deducted. The MVP estimates in Table 1 will thus be ignored in the further discussion in this paper.

This argument also applies to SFR values of water estimated by the MVP method. These values, nevertheless, need mentioning. SFR values vary from R1.90 to R4.44 per cubic metre, roughly 40 times the ET values estimated by the RV method. According to Tewari (2003, p56) runoff on natural vegetation is 20% and in a plantation 10%. This implies that the value of water in terms of SFR value is about 10 times the value in terms of ET. It is concluded that the value of water in commercial forestry is greater than its average ET value, estimated in Table 1. If the uncertainty of this estimate is accepted then a figure of 8c per cubic metre is suggested.

### 5.2 Environmental use of water

The value of freshwater inflows in the Keurboom Estuary was estimated using the Contingent Valuation Method (CVM) by Hosking *et al*. (2002). The method entailed asking respondents how much they were Willing-to-pay (WTP) to prevent the loss of environmental services provided by the estuary due to reduce freshwater inflows (Hosking *et al.,* 2002). Reduced inflow from the Tsitsikamma catchment could lead to estuary mouth closure. Inflows to the estuary have been reduced by infestation of water-consuming alien vegetation. The removal of this vegetation was initiated under the Working for Water (WfW) programme. In the WTP study the target population was identified as users of the estuary who included anglers, baiters, swimmers, water frontage/access, birdwatchers, bathers and scenic benefit.

The willingness to pay to prevent the negative consequences of cutting off freshwater inflow into the Keurboom Estuary was estimated at R274 per user (Standard deviation R262), based on a sample of 150. The total recreation value of water to the Estuary was estimated at R3626128 or 4.6 cents/m$^3$/a (Hosking *et al.*, 2002). This value is substantially less than the willingness to pay for water for farming namely 12.5c/m$^3$ (Hosking *et al.*, 2002). According to the researchers the benefits derived by those above the estuary were not included. Other benefits such as fire damage reduction and preservation of biodiversity were also not included. In this study the environmental value of water was estimated at about 5 cents/m$^3$/a. It can be expected that this value will vary significantly between areas.

## 6. VALUE OF WATER IN AGRICULTURE

In Table 2, irrigated area in agriculture and the direct contribution of water to agricultural income are shown for different agricultural enterprises. Irrigation water is essential to South Africa’s fruit industry, which ranks amongst the most important export commodities. The value of commercial crop production under irrigation is estimated at R14 700 million according to Table 2. This figure excludes enterprises such as wine grapes for which area under irrigation was not available. It is thus estimated that 30% of the value of SA agriculture is produced under irrigation. This figure appears similar to the contribution of water to rural value added in Australia which was also 30% (Australian Academy of Technological Sciences and Engineering, 1999).

Since agriculture is the most important consumer of water (consumes 54% of total use), studies in the following regions were undertaken; Fish-Sundays Scheme in Eastern Cape (Conradie, 2002), Berg River (Louw, 2001), Crocodile River Catchment (Bate *et al*., 1999), Lower Orange River (Armitage, 1999) and Eastern and Southern Cape (Hosking *et al.*, 2002).

**Table 2:** Estimated contribution of irrigation to commercial crop production, South Africa[1)]

| Crop | Area irrigated | | Production | |
|---|---|---|---|---|
| | x1000 ha | % of total area planted to crop | [2)] R Million | % of national production |
| Maize | 110 | 3 | 626 | 10 |
| Wheat | 170 | 12 | 739 | 30 |
| Other small grains | 52 | 3 | 16 | 6 |
| Potatoes | 39 | 70 | 1373 | 80 |
| Vegetables | 108 | 66 | 2296 | 90 |
| Table Grapes | 103 | 90 | 1504 | 90 |
| Citrus | 35 | 85 | 1462 | 90 |
| Other fruit | 95 | 80 | 4148 | 90 |
| Oilseeds | 54 | 10 | 199 | 15 |
| Sugarcane | 60 | 15 | 779 | 25 |
| Cotton (Lint) | 18 | 17 | 92 | 42 |
| Tobacco | 12 | 85 | 559 | 90 |
| Lucerne | 203 | 70 | 657 | 80 |
| Other pastures & forages | 104 | 15 | 250 | 25 |
| Total | | | R14 700 | |

Source: [1)] Backeberg and Odendaal, 1998
[2)] Value in 2000/01 (RSA, 2002).

### 6.1 Existing farming area

In this section the contribution of water is captured by its marginal contribution to net income (VMP).

#### 6.1.1 FISH-Sundays river scheme

The Fish-Sundays River is supplied by an interbasin transfer of 560 million $m^3$/year water from the Gariep Dam on the Orange River. During the past five years the Orange River delivered between 65 and 95 percent of the Fish-Sundays Scheme.

Conradie (2002) constructed linear programming models for 16 model types of farm situations in this area, also allowing for risk using MOTAD. In models where risk was ignored, the model simulated more specialization in crops than what is actually occurring. Inclusion of risk has lead to more diversification and a more realistic model. Estimates of the value of water were sensitive to assumed risk aversion values indicating that the degree of confidence that can be placed on estimates is not very high.

Estimates of the value of water also differ significantly amongst the different representative farms (Table 3). This is expected if transaction cost of water transfers is high. Table 3 shows that three farm types attach a zero marginal value to water. For the remainder, marginal willingness to pay for water ranges between R0.0003/$m^3$ and R0.2115/$m^3$. Municipal bulk rates for the area are R0.256/$m^3$. The current allocation of water is not efficient due to wide differences between areas. Table 3 also lists the purchase price of a cubic meter and a hectare's worth of water across farm types.

Table 3 indicates that citrus producers as a group are able to bid water away from fodder producers while water will migrate from the Fish to the Sundays River. As some resource areas have zero opportunity cost of water it is estimated that 77 million $m^3$/year or 13% of the resource can be redistributed away from irrigation at zero opportunity cost. Two thirds of the current allocation can be bid away at a price of R0.035/$m^3$.

**Table 3:** Marginal water values for the Fish-Sundays at current allocation

| Representative farm | Water rental | | Purchase price | |
|---|---|---|---|---|
| | R/$m^3$ | R/ha | R/$m^3$ | R/ha |
| Type 1 Upper Fish irrigation | 0.0011 | 15 | 0.02 | 297 |
| Type 2 Upper Fish stock farm | 0.0067 | 90 | 0.13 | 1 809 |
| Type 3 Upper Fish farm business | 0.0106 | 143 | 0.21 | 2 862 |
| Type 4 Upper Fish dairy farm | 0.0412 | 556 | 0.82 | 11 124 |
| Type 5 Middle Fish irrigation | 0.0003 | 4 | 0.01 | 81 |
| Type 6 Middle Fish stock farm | - | - | - | - |
| Type 7 Middle Fish farm business | 0.0120 | 162 | 0.24 | 3 240 |
| Type 8 Middle Fish dairy farm | 0.0427 | 576 | 0.85 | 11 529 |
| Type 9 Lower Fish irrigation | - | - | - | - |
| Type 10 Lower Fish stock farm | 0.0014 | 18 | 0.03 | 350 |
| Type 11 Lower Fish farm business | 0.0163 | 204 | 0.33 | 4 075 |
| Type 12 Lower Fish dairy farm | 0.0378 | 473 | 0.76 | 9 450 |
| Type 13 Sundays Small mixed | 0.1702 | 1 532 | 3.40 | 30 636 |
| Type 14 Large stable citrus | 0.2115 | 1 904 | 4.23 | 38 070 |
| Type 15 Small expanding citrus | 0.0815 | 734 | 1.63 | 14 670 |
| Type 16 Large expanding citrus | - | - | - | - |

Conradie (2002, p 148)

Thus equity objectives can be satisfied at zero or very low opportunity cost to commercial irrigation. Conradie (2002) concludes that the Fish-Sundays may be a possible source of cheap water that should be further investigated.

The total water value for the scheme is estimated to be R27 million in 1999 rand while irrigation shadow prices range from zero to 21c/$m^3$. The value of water in the small scale farming area (Tyefu) was also estimated. If the water tariff is included as a cost then the value is estimated as negative in this scheme.

### 6.1.2 Berg river basin

Louw (2001) developed a positive mathematical programming model to study the impact of water markets in the Berg River Basin. The novelty of the technique is that it is calibrated to simulate the base period which avoids the introduction of inflexible bounds. Louw (2001) showed that the capitalised marginal value of water differs from as low as R0.0/$m^3$ to as high as R20.0/$m^3$ within sub-sectors of the river basin. The median capitalised market value of water is estimated at R1.6/$m^3$ (rental rate of R0.21/$m^3$) if no trade is assumed and R0.30/$m^3$ if trade is assumed. Louw (2001) used a capitalization rate of 13% which appears high. The median capitalised water right is estimated in the base analysis at R8000 per ha (5000 $m^3$ per ha * R1.60/$m^3$) for a water right of 5000 $m^3$. The observed water rights in the Upper Berg ranged from R4000 to R6000 per ha which were lower than recorded in 2000. The significant differences in the value of water between areas within the basin indicate that significant gains are possible from trade between these areas.

## 6.2 New irrigation

### 6.2.1 Crocodile River Catchment

Bate et *al.* (1999) studied the trading of water in the basin and observed a capitalised value of water between 18.75c/$m^3$ and 22.75/$m^3$ (Table 4). A wide range of trade prices (rental value) for water were observed ranging from zero to 6 cents/$m^3$ with a modal of 2.5 cents/$m^3$. There were only a handful of buyers (four accounted for 90% of trade volume) but 45 sellers. Twenty-three permanent trades and 46 temporary trades occurred. Bate et al. (1999) concluded that the high variation in trade prices can be attributed to asymmetric information between large buyers and many small sellers, with a large buyer paying different small sellers different prices, including a zero price. A zero price trade does not imply zero value as the buyer must pay the water rates which are as high as 0.84 cents/$m^3$. Most of the trades (97% by volume) are from farmers in the upper/middle Crocodile selling to farmers in the lower Crocodile River. This is important as trades from up to down river increase stream flow and is desirable for the environment.

**Table 4:** Water trades in Crocodile River Catchment

| General Trade Information | Permanent | Temporary |
|---|---|---|
| Number of trades | 23.00 | 46.00 |
| Number of zero price trades | 4.00 | 23.00 |
| Area traded (ha) | 563.3 | 2140.69 |
| Volume of water traded (million $m^3$) | 5.36 | 21.04 |
| Trade price (capital value) of water c/$m^3$) | 18.75 | - |
| Trade price (capital value) of water c/$m^{3*}$) | 22.75 | - |

*Non-zero trade price Source: Bate *et al.* (1999)

The highest value of water was estimated in tropical fruits and the lowest in sugar cane. Sugar cane production, however, increased in spite of relatively lower returns per ha of land. This was attributed to the more stability in this industry with fixed domestic sugar cane prices. According to Bate *et al.* (1999) water traded on short term leases is likely to be used on this crop as it is a shorter term crop and production can be changed more quickly.

Bate *et al.* (1999) estimated gains from trade at R12.8 million annually. A negative externality of trade is that river flow may be reduced causing increased concentration of industrial sewage and farming effluent. However, several farmers only sought extra water as assurance against drought, so not all supplies will have been used. Bate *et al*. (1999) estimated that out of 12 million $m^3$ water traded 8 million $m^3$ is actually used. As is the case in other areas the cost farmers pay for water is substantially less than what urban consumers pay. The full economic cost (excluding financing) of providing water from the Kwena dam is 46c/$m^3$, while farmers pay 0.7c/$m^3$ and urban consumers R1/$m^3$. The latter users and tax payers clearly subsidise agriculture.

### **6.2.2** Lower Orange River

According to Moller (2003), a prominent farmer between Kakamas and Keimoes, water rights during February 2003 sold for between R8000 and R10 000 per ha (15000m$^3$) which average at 60c/m$^3$. All the water trades were of a permanent nature. No renting of water takes place as farmers need security of use for their long run investment in table and wine grapes. According to Engelbrecht as reported by Hosking *et al.* (2002) water rights in the Sundays River trade for about R 2000 per ha (quota is 9000m$^3$) or 22.2c/m$^3$. The market price of water is about a third in the Sundays River compared to the Orange (22.2c/m$^3$ compared to 60c/m$^3$) and water would move from the Fish/Sundays to the lower Orange if transfers are permitted. Moller (2003) further estimates that water would probably rent for about R450 per ha or 3cm$^3$/m (The rent of R450 per ha on an investment of R9000 per ha represents a return or discount rate of 5%). He further indicated that farmers can rely on the reliability of the river flow. Because of the latter, farmers have stopped planting low value crops which they could use as a water reserve in times of drought. Moller (2003) also states that selling prices of water are responsive to economic conditions (price of the product etc). Water prices in this area have more than doubled since the Armitage (1999) study. Armitage (1999) reported an average price (asset value) for water trades in the Lower Orange of R3407 per ha or 22.7 c/m$^3$. The average water price varies from as little as R800/ha to as high as R5000/ha. Closer examination of the data shows that there were fewer buyers (9) and more sellers (21) while the number of contracts per buyer varied from one to 14, while contracts per seller varied from one to two. Purchase prices vary significantly indicating that there may be asymmetric information (buyers are better informed about prices than sellers). The same phenomenon is observed by Bate et al (1999) for the Crocodile River Catchment. It appears as if this range has narrowed if Moller's (2003) prices are compared with Armitage (1999). This is expected to happen if farmers have better information.

A discriminant analysis undertaken between buyers and sellers of water rights showed that the most important variable discriminating between the two groups was that buyers were table grape farmers (F = 18.3) and secondly that buyers had a higher return per unit of water (F = 14.9). This shows that the water-market in the Lower Orange promotes the efficiency of water use.

## **6.2 Value of water in the Eastern and Southern Cape**

Water values were estimated in order to arrive at benefits from removing water consuming alien vegetation. This study was undertaken under the Working for Water (WfW) programme. The WfW programme is the biggest conservation project in terms of manpower use currently being undertaken in South Africa. Over 250 projects have been implemented since its inception in 1995 and during 1998, about 40 000 jobs were created through it (Hosking *et al.,* 2002). In this study the conservation value of water was approximated by its agricultural and urban use value (best alternative use value) in Table 5. The runoff from the Tsitsikamma mountain catchment that does not flow into the sea is used for irrigation farming

**Table 5:** Values of water for WfH projects in the Eastern and Southern Cape (2000)[1]

| Site | Value of water (c/m$^3$) | Valuation Method |
|---|---|---|
| Tsitsikamma | 12.5 | willingness to pay |
| Port Elizabeth Driftsands | 0.0 | potential user response |
| Albany | 0.0 | user response |
| Kat River | 15.7 | willingness to pay |
| Pott River | 0.0 | Non-scarce resource |

[1]Agricultural willingness to pay. Source: Hosking *et al.* 2002

and livestock watering. The actual user charge on this water is 5.3 c/m$^3$ which is an annual cost. According to Hosking et al (2002) this represents the true cost of supplying the water. The rental value (the reader can only conclude it is the rental and not capitalised value as it is not clearly stated), of agricultural water according to Willingness to Pay amounted to 12.5c/m$^3$ excluding storage and transfer cost (Table 5).

In the following areas water values were zero; Port Elizabeth Driftsands (no potential for municipal supply), Albany (high salinity content) and Pott River (not used for recreation). In the Kat River farmers were willing to pay 15.7c/m$^3$ for water. Hosking *et al* (2002) concluded that the cost of clearing alien vegetation on these sites will exceed the benefit if non metropolitan use is considered.

# 7. VALUE ATTACHED TO ASSURANCE OF SUPPLY OF WATER, WATER QUALITY AND TOLERANCE TO RISK

## 7.1 Assurance to supply and tolerance to risk

In the USA the urban sector attaches a high value to assurance of water supply. In Western USA, cities such as Denver buy senior water rights (high certainty of supply) from farmers and then rent the surplus water back to farmers at very low prices. The low estimates of the price elasticity of demand for urban water support this phenomenon that urban users attach a high value to assurance and a low value to additional water. Mirrilees *et al*. (1994, p2-1) also state that urban users require a high level of assurance. Conradie (2002) estimates the price elasticity of demand for household, commercial and industrial consumption as -0.47 (t=-3.10) in the Nelson Mandela Metropol. A low (numerically less than 1.0) price elasticity means that the marginal benefit of water increases steeply with scarcity but falls quickly with increased supply. As urban water in South Africa is purchased from municipalities one can approximate the marginal value of urban water by the prices paid to the municipalities (R1 to R2/m$^3$).

The linear programming models reported in this paper generally estimate fairly elastic input demands for agricultural water if the diagrams are studied (Conradie, 2002; Louw, 2001). These estimates will vary from area to area and from crop to crop but it may be possible in agriculture to use water saving technologies or switch to more water efficient crops. The fact that agriculture is also a more water intensive user than industry indicates a higher elasticity of input demand for agriculture (Friedman, 1962).

In agriculture high assurance of supply is needed where capital value invested in orchards and vineyards is high and crops are of a long term nature. Table grape farmers along the Lower Orange do not rent water but buy it. The reason is that the investment in table grapes is high (R250 000 per ha) and more assurance is required. More renting of water takes place in Australia in areas where annual crops are grown (Australian Academy of Technological Sciences and Engineering, 1999). Water marketing can promote assurance. In a study in the Crocodile River, the most important reason buyers of water rights have given is that they require a steady flow as they are concerned about drought (Bate *et al.*, 1999).

The water law that operates in South Africa and Australia (derived from riparian principles) does not provide farmers as much security of water use as in the case of prior appropriation water law operating in the Western USA. Under the prior appropriation water law, requirements of senior water right holders must first be satisfied before that of other more junior water right holders. Under riparian principles the apportionment of all irrigators is reduced by the same fraction when water flow is less.

To overcome the lack of assurance in water rights, South African farmers typically retain surplus water rights for drought years in the Lower Orange River where capital investment in table grapes is high. South African farmers may not be able to do this in future if non-use rights (sleepers) are lost. Another practice is to include a low income crop such as Lucerne in their production portfolio. In a drought year, water can be diverted from this crop at relatively low cost. If South African farmers lose sleeper rights then they can fall back on the second option. According to a prominent farmer (Moller, 2003) in this river reach (Lower Orange), the flow in this river has been fairly stable in recent years (due to dams) and these practices are not so common at present.

## 7.2 Water quality

Water quality is a major concern in certain areas and sectors in South Africa. For instance in the Eastern Cape, the Fish River is frequently flushed as the return flow is not suitable for irrigation.

### 7.2.1 Salinity in the Middle Vaal River area

The cost of salinisation in the Middle Vaal River area, an area of major problems was estimated by Urban Econ (2000). Utilising an Input-Output technique, direct and indirect costs of salinisation were estimated. As the average salinity level experienced in the area is 500mg/l TDS, a reduction below this is a cost saving while an increase above this level is an increase in cost. It is estimated that direct cost of R80.5 million will be saved if present levels drop to 200 mg/l TDS. Increasing salinity to 1200 mg/l TDS will increase salinity cost to R183 million. These cost data are not representative of other sectors of the South African economy as high urban mining and industrial concentration occurs in this area. The data, however, show that salinity is a major cost to urban water users, especially the household sector.

### 7.2.2 Sulphate pollution in the Witbank Catchment

South Africa has previously regulated pollution through Command and Control (CAC) whereby industries are prescribed the technology or processes that must be used. While this approach may have merits in some instances, a more cost efficient way is to provide polluters with an incentive to reduce pollution. Since 1994 South Africa's legal and policy framework has evolved so that it is more suitable to economic approaches such as the Polluter Pays Principle (Taviv *et al.*, 1999).

Taviv *et al.* (1999) studied sulphate pollution in the Witbank catchment and estimated that within a year revenue between R3 million and R9 million could be raised from pollution charges, which was less than the estimated cost of pollution. They estimate that full cost recovery can be achieved within four years. A main concern in South Africa is employment and to mitigate the loss of jobs if pollution is taxed it is recommended that firms should be given incentives to reduce cost in such a way that jobs are not sacrificed (Taviv *et al.*, 1999).

Another study on sulphate pollution in the Olifants River near Witbank was undertaken by Economic Project Evaluation (1998). The latter researchers differ in their approach to the pollution problem in the catchment. They alleged that this type of pollution is a non-point source (not easily monitored and measured). Market based research tools have proved to be effective in dealing with point source (easily monitored and measured) but less effective in dealing with non-point pollution as pollution (and culprits) can not be monitored with a reasonable degree of accuracy. In the latter study (Economic Project Evaluation, 1998), a marginal cost model to simulate green taxes and a simulation model to simulate tradable permits was used. Permits were traded within a geographic area also referred to as a bubble. The trading partners were five coal mines who are responsible for the sulphate pollution. The market price of permits for the two approaches (marginal cost and simulation) for a given level of pollution abatement was similar.

Taxes and tradable pollution rights have different impacts on polluters. Taxes can have a detrimental effect on profits and employment in some industries especially where the price of the product is set internationally. In the latter case the tax can not be partially shifted. Tradable permits also have welfare implications as those polluters who can modify their plant and equipment and sell permits are affected differently from those who can not and must purchase permits. The modelling exercise demonstrated economic efficiency of economic measures but it was recommended (Economic Project Evaluation, 1998) that a pilot study using tradable permits and green taxes be undertaken.

## 8. TOPICS THAT NEED FURTHER RESEARCH

### 8.1 Government/market partnership

Water allocation between sectors, areas and farms requires a partnership between government (DWAF) and markets (private enterprise). The government can not allocate water between farms as information to do it is not available in a centralised way. A study needs to be undertaken how this partnership can be facilitated, what information the State needs and what can be left to market forces. Currently water licences are to be reviewed within a maximum period of five years. The impact of such a short period on investment in say table grapes needs to be investigated. The State is concerned with socio-economic issues such as job creation while markets are more driven by profit. Even if the market approach is followed then many questions remain, for instance should the costly litigation that is so common in Colorado be avoided by giving DWAF powers to settle disputes of externalities.

The writers of this document were impressed with the knowledge of the people who are responsible for water transfers in South Africa but it is possible that markets may assist future allocation by using decentralised information. The transfers of water between basins, river reaches and sectors, however, require more input from DWAF because of externalities.

### 8.2 Water market institutions

Several of the studies recommend strengthening and support for a water market (Conradie, 2002; Louw, 2001; Bate *et al.* 1999; Armitage, 1999, Mirrilees *et al.* 1994). The studies in this report have shown that even the most sophisticated tools are blunt in trying to estimate the value of water (for example how can cost of risk in farming be measured to a high degree). The market does not only allocate water but provides an opportunity cost to water which in turn provides incentives for water conservation.

It is suggested that research, should focus on strengthening the market of water and how to keep transaction costs down. Water markets in South Africa are in their infancy and institutions need to be strengthened that also protect the environment. In all the studies undertaken huge differences in value of water between resources areas within the river reach are recorded. Discussions need to be held with all stakeholders to make sure that they support institutions.

Specific topics include:

(a) The feasibility of transfers between catchments such as the Orange, Vaal and Fish/Sundays rivers. All external impacts need to be studied such as impact on

(b) environment, on water and soil quality, on rural communities (employment) and threshold water required in source communities. Jobs may be lost in source area which may become ghost towns that must be traded of with the possible creation of new jobs in possible labour intensive fruit growing areas. If all water moves out of the Cradock area schools will close and the community will die and jobs lost. The high income crops may use all resources more intensively including labour. It is possible that salinisation and water pollution can be reduced if some water moves out of certain areas (Upper Fish River in Eastern Cape). Conradie (2002) showed that some water in this area has a zero value. The water market, however, only provides a partial solution to a more complex issue, in the sense that the market only maximizes water rents of buyers and sellers but not rents from infrastructure already developed in selling area. DWAF needs to provide a guiding hand due to complexity of externalities involved.

(c) Water transfers between forestry and agriculture may be possible but information is needed on complexity of issues. What are impacts on employment and what are other external impacts.

(d) Water transfers between agriculture and urban users could be feasible as is common in the Western USA. In the USA these transfers are often complicated as it leads to litigation if down stream users (farmers) are negatively affected. To avoid litigation many states in the USA rely on the impartiality of the State Engineer.

**(e)** Studies of water markets in the USA and Australia and lessons to be learned. This study could look at the following; should water be allowed to be transferred from down to up-stream as stream flow is reduced (not allowed in Western USA), should farmers be allowed to irrigate larger areas if they convert from flood to drip (this is allowed in SA and leads to increased consumptive use and reduced stream flow), should consumptive use be transferred and what about return flow (in SA and Australia diverted use is transferred while in the Western USA consumptive use is transferred while the farmer has no access to his own return flow) and is return flow an issue or should it be ignored in South Africa. According to Moller (2003) there is return flow even from drip irrigation in the Lower Orange. He contends that the quality of return flow is often better than the water applied as it is filtered. How water assurance can be accommodated in the market is important (for water security farmers with high capital investment often use surplus water on a low income annual crop).

### 8.3 Water quality

How to promote water quality and how to use Command and Control (CAC) as well as market incentives should be further researched. In Colorado the State uses Best Management Practices (BMP) but these also have problems.

## 9. SYNTHESIS

Input/output and multiplier analyses indicate that South African agriculture is an inefficient user of water in term of gross income generated per unit of water and also in terms of jobs created per unit of water. South African agriculture is, however, an important employer of labour as it is labour intensive especially in the fruit and vegetable growing sectors. Evidence is provided that indicates that non-agriculture generally places a high value on sufficient water but little value on more than what it already uses. From this it is concluded that water may have to be transferred in future from agriculture to non-agriculture but not at present (providing water for disadvantaged groups will always be a top priority in South Africa). Municipalities can (for example) only sell 4% more water in urban areas if they reduce the price by 10%. (The urban demand elasticity for water is about -.40). This means that the income of municipalities from water sales will fall drastically if they try to sell more water through lower prices. They may be reluctant to do that and the suspicion is that municipalities as monopoly suppliers of water, use price discrimination to increase revenues. From the above it is thus concluded that while a shortage or lack of water presents a serious hindrance to non-agricultural development, the converse is not true. That is, non-agricultural development cannot be stimulated simply by transferring water from agricultural to non-agricultural use,

Water values differ significantly between sectors, between geographic areas and within geographic areas. The following estimates of the rental value (annual value) of water were reported; Existing irrigation: Berg River (21c/$m^3$), Fish/Sundays River (0.0c/$m^3$ to 21c/$m^3$); New irrigation: Lower Orange (3c/$m^3$), Crocodile River (2.5c/$m^3$), Eastern and Southern Cape (12.5c/$m^3$); Forestry (8c/$m^3$); Environment (5c/$m^3$) and Urban (74c/$m^3$ and R2.40/$m^3$).

The problem of comparing water values between the geographic regions above is that different tools were used. The tools used are more appropriate to study water values for different resource areas within a given study area. For instance market trading indicates the capital value of water as 60c/$m^3$ in the Lower Orange (Moller, 2003) and 22c/$m^3$ in the Sundays/Fish River (Hosking *et al.*, 2002) which indicates water has a higher use in the former area.

It appears that DWAF has performed an excellent job in stabilizing water supplies in for instance the Orange River according to a prominent farmer (Moller, 2003) along this river reach. A partnership between Government and the private initiative can further promote water use efficiency. Water efficiency could significantly be enhanced if water transfers within river reaches are promoted. Water transfers should not only be permitted but institutions need to be created that promote transfers (within the ambit of the National Water Act). Institutions will also reduce the transaction cost of transfers. Socio-economic aspects and the impact on the environment of transfers need to be considered. The transfer of water values between major rivers such as the Orange, Vaal and Sundays/Fish River could promote water efficiency. The external impacts of such transfers require further study. In the latter instance water may move out of areas with poor soils (high salinity) to areas with good soils and high income crops. It is also possible that communities in the process will die and information is required on the maximum volume of water that may be transferred without having a material impact on the community at source. Conradie (2002) indicates that some surplus water may be available in the Sundays/Fish River. This may imply that less water needs to be diverted from the Orange to these rivers.

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# WATER SOURCES, USE AND DISPOSAL IN AUSTRALIA'S MINING INDUSTRY

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***ABSTRACT***

*Minerals are one of Australia's largest sources of wealth. Their production consumes a comparatively small proportion of the nation's limited water resources but associated processes have the potential to pollute (acid, cyanide, oxalate, caustic etc) any water returned to the environment. By a quirk of fate, most of the mines are located in desert or semi desert areas. The methods used by some mines to harvest and secure water resources are described, including the use of low quality water. Water balance and water management procedures will be described, showing the ultimate destination and consumption of water.*

**SUMMARY**

Minerals are one of Australia's largest sources of income, but use only a few percent of the water consumed in Australia. Since water is scarce and many mines are in desert locations, some novel means of harvesting water for mining use have been developed. This is justified by the comparatively high added value of water used in mining as compared with agriculture. However, many mining and processing procedures introduce or cause pollution of the water requiring it to be contained or managed or disposed in a controlled manner. Most is disposed by deliberate or consequential evaporation. Much is trapped or wasted on tailings systems despite improving methods of water recovery.
The paper describes seven mining projects chosen to represent a wide range of climatic conditions and some innovative water supply arrangements. The various methods of water disposal or water balance are described.

## 1. MINERALS IN AUSTRALIA

Minerals are one of Australia's largest sources of income. Both the actual production of minerals and the reserves of minerals are an enormous underpinning of our wealth (Table 1). Australia is indeed a lucky country.

**TABLE 1:** Some Australian Mineral Resources

| | World Rank | % World Production | % World Proven Reserve |
|---|---|---|---|
| Bauxite | 1st | 36% | 22% |
| Mineral Sands | 1st | 33% | 32% |
| Diamonds | 1st | 28% | 15% |
| Uranium | ? | 22% | 29% |
| Lead | 1st | 18% | 29% |
| Iron Ore | 3rd | 16% | 10% |
| Nickel | 3rd | 14% | 34% |
| Gold | 3rd | 12% | 10% |
| Zinc | 3rd | 10% | 15% |
| Brown Coal | 3rd | 8% | 20% |
| Black Coal | 4th | 7% | 6% |
| Copper | 5th | 7% | 7% |

Ref AGSC – Geoscience "Australias Identified Mineral Resources, 2001", Queensland Department of Mines & Energy "Mineral Information Leaflets"

Being of such fundamental importance, it would be reasonable to assume that mines would have some priority in the allocation of water resources, and in fact that is the case in some selected circumstances. Allocating water priority to mines is not detrimental to the community since this paper will show that their needs are comparatively modest.

## 2. WATER RESOURCES AND ALLOCATION

Australia has been described as the driest continent (excepting Antartica). We have the:

- Lowest average rainfall
- Highly variable and erratic rainfall
- Lowest runoff (11%) of rain
- Lowest river flow
- 92% of the river flow runs into the sea (mainly in the sparsely populated north)
- highest evaporation
- low groundwater recharge (1% of rain)
- one third of continent has virtually no runoff.

Yet Australia:

- stores more water per head of population than any other country (to cope with rainfall variability)
- has 22 megalitres per person per year (4th highest after NZ, Canada, Argentina)
- uses up to 100 L/day per person for showers ($^2/_3$ of people on earth have less than 60 L/day total)

Table 2 shows how much of the available water is needed for mining.

**TABLE 2 – Water Use in Australia**

| Use | % of Total (NSW) | % of Total (WA) | % Total Aust | Average Return Per ML | % of Land Area |
|---|---|---|---|---|---|
| Agriculture, riparian right | 91% | 40% | 78% | $200 | 76% |
| Town water, manufacturing | 7% | 30% | 12% | | |
| Industrial/Miscellaneous | 2% | 3% | 6% | | |
| Mining | 0.1% | 27% | 3% | $4000 | 0.5% |

The wide variation in figures is a function of the way in which figures are recorded rather than accurate measurement. For example, the real figure for mining in NSW is probably 2% whereas the quoted 0.1% appears to be only the quantity drawn from town supply sources. The WA figure for mining appears to include circulating water from closed loops within the process.

Overall the use of water by mining is a minor issue in the grand scheme of things.
In Australia, 78% of all water supplied goes to irrigation of 20,000 $km^2$ of land. Of this 80% is used in the inefficient flood irrigation method. For example, rice production uses 7% of supplied water and adds 0.02% of GDP. The estimates of the value of water vary widely according to various reports and the various methods of determining value. The average return figures in Table 2 are an average of several figures cited and should not be considered accurate. Nevertheless they show the widely reported trend that the return on water used in mining is at least one order greater than the return on irrigation.

However, mining does have the potential to cause significant environmental impacts on surface water supplies, groundwater systems and flora/fauna by producing or using:

- acid (from drainage of sulphide mines or stockpiles)
- caustic (as used in bauxite to alumina processing)
- cyanide (key component of many gold processes)
- salt (released from ore or concentrated by evaporation in tailings and storage systems)
- heavy metals (liberated from ore but not captured in process).

The management of water then becomes critical and can be a major constraint when water has to be contained or evaporated instead of a cheaper disposal to rivers or groundwater.

## 3. SOURCE OF WATER

The starting point is the finding of a reliable source of water which can give adequate supply even in drought. Figure 1 shows the average rainfall in Australia. The line of 400mm/a is important since anything less cannot provide crops. In northern Australia most rainfall occurs in summer at a time of high evaporation such that it is difficult to produce crops even in areas with 600mm rainfall. In general the lower rainfall areas also reflect increasing rainfall variability. For example, an inland town may have an average January rainfall of 20mm. It had 200mm in a thunderstorm 10 years ago and it hasn't rained since in January.

Figure 2 shows the major groundwater basins in Australia, most of which have a reasonable resource of groundwater. Inland basins generally have low recharge and may contain saline water, in some cases with an even higher salinity than seawater.

Figure 3 is a composite of Figures 1 and 2, but highlighting the areas in which there is neither reliable rainfall nor major groundwater basins.

Usually mines in the higher rainfall areas will use surface water whereas those in low rainfall areas would use groundwater supplies.

Sources of water for a mine can be generalised as:

- Town/Irrigation supply system
- Nearby rivers/lakes
- Damming of local catchments
- Site and mine runoff
- Rainfall on tailings ponds
- Groundwater
- Mine dewatering
- Water contained in the ore supply
- Seawater
- Desalination

Thereafter the generalities cease and there are many innovative solutions to obtain reliable supplies of water.

## 4. USE OF WATER IN MINING

The water used in mining generally falls into the following categories:

- Beneficiation (e.g. coal washing, improving ore grades)
- Processing (often with chemicals)
- Dust control
- Fire control (including water mixed with coal)
- Domestic (offices, camps)

Unfortunately, the majority of the water used is then lost to evaporation although sometimes a significant portion of it gets exported with products such as coal. The evaporation can be deliberate, i.e. cooling towers, cooling ponds, drying of products, calcining as part of process. There is also evaporation as a consequence of the use i.e. dust control, fire control, use on gardens.

Some water losses are largely uncontrolled. Typical examples are the water retained in tailings (0.3T per tonne of ore), groundwater losses from tailings storages (0.05T per tonne of ore) and evaporation from tailings (0.1T per tonne of ore).

Water used in processing is the major use in many projects. A typical mineral process will operate in the range of 20% to 30% solids i.e. for every tonne of ore being processed there are 3 to 5 tonnes of water with it. Often this slurry is then thrown out as waste or tailings after the valuable component has been extracted.

For a few mines, this disposal is the ultimate use of the water and it is then lost by evaporation or remains trapped in the tailings forever, or some is lost by seepage into the groundwater. Fortunately, these mines are a minority and most mines have a water recovery and return system on their tailings dams. This utilises the phenomena that many tailings will naturally settle to 50% or 60% solids, releasing much of the water to the surface, although some is still lost downwards to groundwater. The water remaining trapped is then in the range of 1.5 to 2 tonnes of water per tonne of ore. Hence there can be 1 to 3.5 tonnes of water released for re-use i.e. typically 50% to 70% of water going out with tailings can be potentially reused. Unfortunately in desert climates with typically 3m evaporation per year, a lot of this released water is lost to evaporation before it can be recovered.

Some projects even go to the trouble of constructing under drains beneath tailings storages to collect the downward moving water before it reaches the groundwater. This action may be prompted out of consideration of preventing harmful chemicals reaching the groundwater, with the extra water return being an added benefit.
Because of the contained chemicals (cyanide, salt, caustic, acid, etc) the majority of tailings storages are designed with sufficient freeboard so that they cannot spill into the environment in the event of storms. In wetter climates this need for containment becomes a significant constraint, requiring deliberate enhancement of evaporation with sprays or special evaporation basins, or alternatively some significant water treatment plants to destroy cyanide or to correct pH prior to discharge.

## 5. CASE EXAMPLES AND INNOVATION

### 5.1 Water Supply and Disposal

The following case examples are in a variety of climates and water supply situations, as can be seen from their locations in Figure 4. A wide range of solutions to water supply and disposal have been developed to suit each situation with many innovative methods of solving particular water issues.

### 5.2 Worsley Alumina

Worsley Alumina has substantial bauxite deposits on the inland side of the Darling Ranges in WA. This area has modest rainfall but it is erratic and due to over clearing of the land the rivers are brackish. For process purposes the owners sought high quality water and hence their alumina refinery is located 50km from the mines at the top of the Darling Ranges where there is consistent rain and high quality water. This location necessitated a 50km long ore conveyor, including the longest continuous section of conveyor line in the world at the time. It is one of the lowest cost producers of alumina in the world due in part to the good water system.

Water is the prime carrier of the process and is mixed with caustic soda at high temperature to digest bauxite. Cooling water is also required for the onsite combined steam and power station.

A local dam catches water from the refinery lease, providing clean water for some process activities and providing drought storage. Rainfall runoff from the tailings areas and plant area is likely to be contaminated by caustic soda and is transferred to a combined process water and cooling pond.

With rainfall nearly equalling evaporation and with water being harvested from large areas, it is necessary to find ways to satisfactorily remove surplus contaminated water from the system. Some water is evaporated from the tailings areas plus a special evaporation pond, whilst some water is permanently trapped in the tailings storage. Some water is also lost in the calcining of alumina hydrate to produce the final product.

The remaining water balance is then achieved by evaporation from the combined process/cooling pond using the elevated temperatures in the pond to provide an enhanced evaporation rate.

No water is disposed into the wider environment in order to avoid any possibility of contamination.

### 5.3 Argyle Diamond Mine

This is the largest diamond mine in the world (by quantity) and is located in an area where there is insufficient rain for crops and rain generally comes in summer storms. Fortunately one of Australia's largest irrigation dams is only 30km away, capturing an enormous catchment which is fed by several rivers and thus takes advantage of the storms wherever they may be in the catchment.

The diamond process involves crushing and gravity separation, requiring large quantities of water in the process. Significant quantities of water are also required for dust control in the mine.

The main supply of water is pumped from Lake Argyle, but there is also a local dam on site. As well as having its local catchment, this dam is also positioned to receive flows from mine dewatering and stormwater from mine drainage.

Water is lost from the system by evaporation from tailings and some water is also permanently trapped in tailings. There is a small discharge to local streams, the water being of high quality since the crushing, screening and sorting process does not add contaminants.

### 5.4 Morwell Brown Coal Mines

The Gippsland Basin in south eastern Australia is reported to contain 40% of Australia's fossil energy reserves in the form of offshore oil/gas reservoirs and onshore brown coal deposits. In the 80 years since coal was first mined 1.5 billion tonnes of coal have been removed plus 0.8 billion cubic metres of drainage water. Whilst there is ample water available in adjacent rivers due to the wet climate, boreholes have been installed to dewater the mines as the open cuts have become progressively deeper. Otherwise there would be heave and rupture of the floor of the mine and instability in the mine slopes.

The volume of water extracted for stability is in excess of requirements which are mainly for dust suppression and the wetting of exposed coal seams to suppress spontaneous combustion. Water is also required for cooling of the nearby power stations and for ash handling.

The remaining surplus borewater and runoff from the mine is cleaned in settlement ponds and is discharged to the rivers. Concentrated blowdown from the power station cooling system and surplus water from the ash ponds is too contaminated for river disposal and is sent via a pipeline to the ocean.

### 5.5 Cadia Copper/Gold Mine

Cadia copper/gold mine is located in an agricultural area where there is usually sufficient rainfall for crops although with an unreliable rainfall pattern. The mine needs to obtain water from a variety of sources including a purpose built dam on a nearby river, from treated wastewater from two nearby towns, from decant water on tailings areas and from rainfall runoff from tailings, mine and process areas.

Water is the principal carrier of the process, starting with crushing and grinding and then with the addition of cyanide and caustic to assist leaching of the ore. There is also a significant quantity used for dust control.
Since evaporation exceeds rainfall, water balance is achieved by evaporation from tailings areas and by some water being permanently trapped in the tailings.

The water system operates as a closed loop such that no water is discharged to the environment with the exception of surface runoff from clean areas.

### 5.6 Olympic Dam

This major underground uranium/copper/gold mine is located in a desert with high evaporations rates and negligible local runoff. Water is brought some 80km from one of the major groundwater basins in central Australia plus there is some water from dewatering of the mine. The borefields are in Australia's largest groundwater basin, recharged over 1000km away.

The main water use is in grinding, crushing and metallurgical processing, although there are other demands for the township built to serve the mine. The water becomes contaminated by acid and other chemicals used in the processing operation plus other heavy metals.

The saline and low pH water from parts of the process is evaporated in purpose built evaporation ponds which are lined with plastic. There are also significant evaporation losses from tailings with a small amount being permanently trapped in tailings.

There is no disposal of water to the wider environment.

### 5.7 Kalgoorlie Area

This is Australia's largest gold and nickel mining province, located in an area of semi desert. There is high evaporation and negligible local runoff, and the lack of water was a major burden in the early days of mining. Over 100 years ago a pipeline was built to carry water from a dam 600km away in the Darling Ranges near Perth. This feat stood as the longest water pipeline in the world for many decades. However, production has continued to increase in recent years demanding more water resources than can be made available by the pipeline and hence all mines in the area source most of their water from localised underground borefields. The quality of water obtained in these borefields varies from 40,000 mg/L to over 200,000 mg/L i.e. seawater quality to six times sea water salinity. As a result of using this water there are significant extra costs for chemicals, corrosion and scaling, whilst there are also treatment inefficiencies. Two current proposals being examined include the piping of seawater a distance of over 300km, this being better quality water than most of the water which is currently being used. Alternatively, the seawater could be put through a desalination plant near the coast and then brought as fresh water to the mines. There is another proposal to extract low quality water from a groundwater basin more than 100km away.

There are significant cost and environmental constraints with these proposals.

As with other mines, the main water use is for crushing, grinding and metallurgical processing. This uses the saline water which is further contaminated by cyanide, caustic and other process chemicals. This water is sent out with the tailings and is lost by evaporation with some contained in the tailings. The high salinity means that the rate of evaporation is much less than predicted from fresh water evaporimeters.

Better quality water from the existing pipeline is used for town water, dust control and specific parts of final processing.
There is virtually no disposal of water to the wider environment although a minor amount of better quality wastewater is disposed to local dry salt takes for evaporation.

### 5.8 Newman Iron Ore Mine

This is one of several large iron ore mines in an area of semi desert where stream flows are mostly non-existent except as a result of occasional storms or the tail end of cyclones. Water for processing purposes had for many years been obtained from aquifers which were being severely depleted due to extraction greatly exceeding the natural recharge.

A novel approach was developed whereby a dam was built across a flood plain of a river and two of its major tributaries. The dam system totals 10km in overall length, even though not exceeding 20m height. Water from occasional storms is caught, held until the sediment has settled and then fed to a series of recharge basins overlying the aquifer. The dam itself also overlies the aquifer.

The scheme has been in operation for 20 years and has been a major success. Approximately $^1/_3$ of the trapped water is lost in evaporation, $^1/_3$ seeps through the bottom of the reservoir into the aquifer and $^1/_3$ is delivered to the recharge basins.

Although storm flows are rare, they can be intense after a cyclone requiring three spillways to guard the dam. The main spillway is 600m wide, there is a 1200m wide supplementary spillway in an adjoining saddle and additionally there is a 300m wide “fuse plug” spillway to provide controlled release in the event of an extreme storm.

As the mine has become deeper there has been more water available from mine dewatering. This is used for dust control and beneficiation processes using gravity separation. The recharged borefields provide town supply and the balance of process water.

Water is lost by evaporation and entrapment at the tailings ponds. Some good quality water is disposed in local creeks and treated sewage water is used for irrigation of parks.

Acid generation from waste dumps has been a problem, requiring a special dam to collect drainage from the dumps before disposal in clay lined evaporation ponds.

## 6. SUMMARY

- Water use by mining is comparatively small compared with agricultural and town use.
- The value of the water used in mining is high compared with other uses.
- 
- Some novel methods for obtaining water have been justified by the high value.
- Desalination of seawater or other saline water is being examined as a source of water.
- Some processes involve adding chemicals such that the water cannot be discharged to the wider environment.
- For many mines, evaporation is the main method for disposal of contaminated water.

Future trends include changed processes and improved tailings systems to reduce the amount of water to be removed by evaporation.

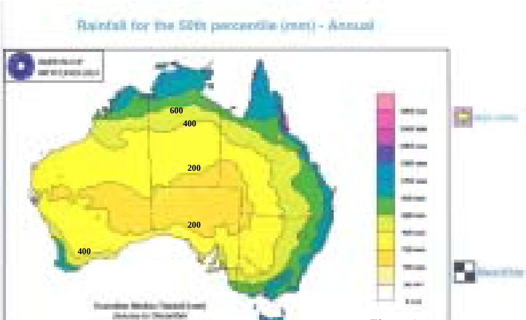

Figure 1

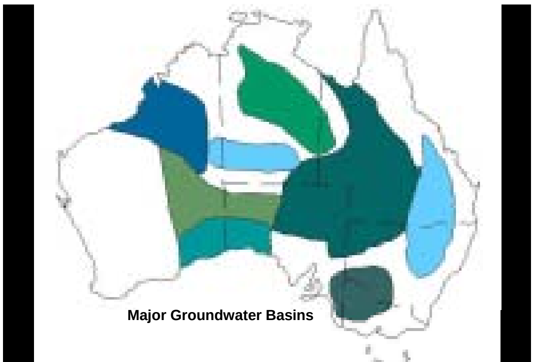

Figure 2

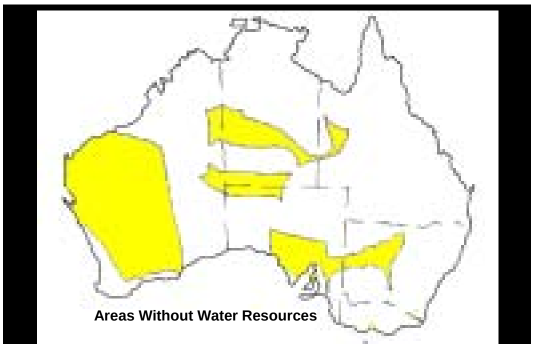

Figure 3

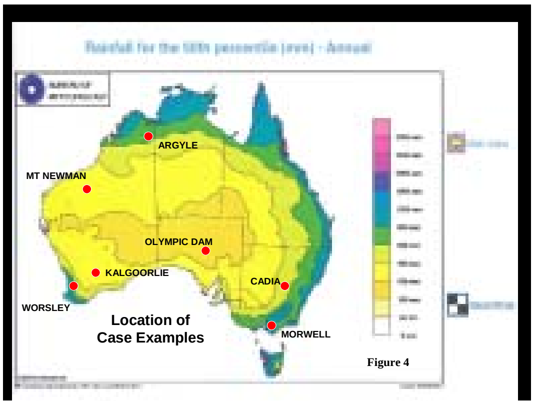

Figure 4

AUSTRALIA-SOUTH AFRICA WORKSHOP ON WATER RESOURCES
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# NON-COMMERCIAL VALUE OF WATER IN SOUTH AFRICA

**Marna de Lange**[2]

***ABSTRACT***

*The industrialisation of agriculture has driven water resources development in many countries of the world. But by the mid-1900s commercial development urged the review of the 1912 'Irrigation Act' in South Africa. The 1998 water law review reflected yet another expansion in the objectives of water resources management to include environmental concerns and explicit provision for 'basic human needs'. As the pressure on water resources mount, an increasing degree of sophistication is required to afford an appropriate weighting to water use sectors previously hardly recognised in planning. The paper considers the needs and significance of some newly recognised and other, still hidden water use sectors, particularly with regard to their potential to reduce poverty and inequality in South African society.*

## 1. INTRODUCTION

The dawn of democracy in South Africa after the *apartheid* years saw the review of all major policies and legislation, starting with the drafting of the National Constitution. Access to sufficient water is recognised in the Constitution as a basic human right. The White Paper on Water Policy for South Africa recognises water as an indivisible national asset, and maps out the role of national government as the custodian of the nation's water to achieve 'some, for all, forever'. Political will and strong leadership in creating the vision and setting the objectives for reform, were essential ingredients in initiating and sustaining the review processes, and is now driving implementation of the National Water Act and the Water Services Act. Leading scientists and experienced officials enjoyed a rare opportunity to formulate their convictions into national legislation.

### 1.1 A glimpse of indigenous water management systems in South Africa

Indigenous rules for water management in South Africa goes back many centuries and differed among nomadic, pasturalist and agriculturalist tribes. Generally, the land was regarded as a communal asset to be cared for and its value had to be maintained to sustain the communities living on it. In agricultural communities, land allocations included homestead plots and one or more fields for crop production, as well as communally owned grazing land. The homestead plot was the heartbeat of the rural home economy. The main water sources were rivers, wells and harvested rainwater. Families harvested rainwater run-off through terracing, and they dug wells where the natural conditions were conducive. Elders remember rivers flowing throughout the year and, when river levels were high for long periods, like in 1952, the water table was also very high. Then people would dig wells at their household plots, but when the water table dropped, the community dug wells next to the

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riverbanks and protected them so that they still had sufficient water. They also dug small dams near the fields, where the cattle could drink during ploughing.

Social systems developed and driven from the chief's kraal were aimed at ensuring that all were committed to food production. Issues discussed in the village *Kgoro* (Tribal Council) meetings included field activities, land planning and maintenance; care of the rivers and wells; construction of swails and gabions to stop erosion; and planning and implementation of land use strategies. Resources for land cultivation were abundant and soil erosion a limited problem, so rivers still had banks and silting was unknown. The rivers were an important source of food, through fishing and the reeds, grass, and variety of water vegetables growing on the riverbanks.

Annually before the rains started, and to mark the beginning of the New Year in the farming calendar, an environmental cleansing ritual was performed at the chief's kraal. The chief, councillors and traditional doctors were responsible to oversee the cleaning of the forest and *veld*, so that once the rains started, the water would not carry decaying carcasses and other pollutants into wells and rivers. Before the rainy season, traditional doctors performed another ritual, burning certain types of tree roots at the right time to attract birds to come and eat insect larvae before they hatched. The use of environmentally friendly products is also much older than the modern pre-occupation – *mosehlo*, a specific herb found growing under trees or in grass veld, was used as a dandruff shampoo.

Myths and storytelling were employed to transfer tribal rules from one generation to the next, such as acceptable sanitation practices instilled through the story that there once was a man who breached the community norm against squatting next to the drinking well. He grew a *motila* (a tail) so long that he could not wear a pair of trousers and became the laughing stock of the village, because he could only wear skin aprons.

### 1.2 European water management history in South Africa

The recorded history of 'integrated water resources management' in South Africa is as old as European settlement itself. In 1655, only three years after the arrival of Jan van Riebeeck and 'The Company' (i.e. the Dutch East Indies Company), a proclamation prohibited the use of river water for laundry purposes so as to avoid pollution of drinking water. Priority in use of water was given to households and mills and then to the irrigation of vegetable and fruit gardens. Six years later the Company 'nationalised' water, proclaiming priority for Company gardens and mills and for flushing Cape Town's open drains. Later, local farmer leaders gained authority to allocate water rights, provided Company interests received priority.

Nearly two centuries later, on English occupation in 1820, policy changes enabled full ownership of land, including water rights according to the riparian principle. Localised control of water allocation prevailed, but the Dutch-based system of local *landdrosts* was replaced by an evolving court system based on the British system. Following yet another political change through Unionisation, the 1912 Union Irrigation and Water Conservation Act continued to officially favour agriculture over industrial water uses, but this changed through the 1956 Water Act, which also saw a return to state control over water apportionment and development – initially of 'public water' sources and gradually also over 'private water' through the establishment of Government Water Control Areas and the issue of permits or 'quotas'. In the 1952 Commission, which underpinned these legislative changes, the idea of regional or basin management surfaced, as did 'environmental concerns' relating at the time to the water use of exotic trees planted for industrial purposes.

Public awareness of environmental issues grew rapidly in the early 1990s. This, together with major political changes with the abolishment of apartheid had a profound effect on the 1998

National Water Act. The current Act consolidates full government control of all water occurring in the hydrological cycle, abolishing the riparian principle and broadening the concept of ‘beneficial use in the public interest’ to include issues of equity and sustainability. This reflects yet another expansion in the objectives of water resources management to include environmental concerns and explicit provision for ‘basic human needs’. As the pressure on water resources mount, an increasing degree of sophistication is required to afford an appropriate weighting to water use sectors previously hardly recognised in planning. This paper considers some newly recognised and other, still hidden water use sectors, particularly with regard to their potential to reduce poverty and inequality in South African society.

## 2. NEWLY RECOGNISED WATER USE SECTORS

It is clear that the major changes in water legislation in South Africa over the past three centuries have been closely associated with the developing economy, significant political changes and evolving public opinion. Every major legislative review attempted to consolidate fragmented provisions across states or provinces and tried to improve clarity on the principles and practices that govern water allocation, development and use across the country. Every successive review reflected the broadening objectives of society, most recently with the explicit provision for environmental requirements and for more than a quarter of the population who lacked access to basic domestic water supplies.

### 2.1 Environmental requirements

One of the most important changes in thinking introduced in the 1998 Act, is the recognition that we need to protect the resource itself to ensure all other benefits from it. This underpins the creation of the Reserve and, at least in theory, removes ‘environmental requirements’ from the allocation debates. This paper will not dwell on the evolving science and practice of determining instream flow requirements, since a specific paper of this workshop is dedicated to that topic. The first draft of the National Water Resources Strategy (August 2002) sets the environmental requirements at approximately 20% of the available resource, although this may vary from 8 – 30% in respective rivers, and can also differ along the course of the river. Methodologies and guidelines have been developed to determine the environmental requirements of rivers, aquifers, wetlands and estuaries.

### 2.2 Basic human needs

The other, smaller, but fundamentally important part of the Reserve, sets aside water for ‘basic human needs’ of present and future generations. The right to water and food is entrenched in the National Constitution and the 1998 Act gives content to this right by prioritising the basic human needs provision. The allocation per person is not specified in law, but current policy sets this at 25 litres per person per day. The allocation is small compared to the available resource, but can pose a challenge in areas of high population density and water scarcity. However, in a developing country such as South Africa, the greater challenge lies in rolling out infrastructure to address the backlog in supply, especially to poor and remote communities.

South Africa has embarked on an ambitious programme to supply piped water to its entire population and has at the same time introduced the ‘user pays’ principle. Both the capital and recurrent costs of supply increase in remote, dispersed communities, while the ability to pay is typically very low in the rural areas. In townships, individually metered supply to large numbers of residents adds to the costs of supply and to the institutional requirements associated with billing and collection. These challenges and the introduction of Free Basic Water are requiring considerable technical and institutional innovation.

## 2.3 Water for productive uses by the poor

Improved supply of the 'basic human needs' reduces people's hardship related to lack of access and effort to collect water. The most recent category of water use under debate, but not yet explicitly recognised in law, policy or implementation programmes, is the water needs of the poor to enable basic economic activity. This debate needs to be seen in the context of high – and growing – unemployment in South Africa, a problem that is common to many developing nations. Further, in a dual economy such as South Africa's, the distribution of benefits of growth in commercial output – both agricultural and industrial – is highly problematic. There is no linearity between the growth in economy and employment and no prospects of major improvements in employment in the medium term, leading to a growing number of 'discouraged unemployed' – those who feel they cannot further afford the expenses associated with seeking employment. Redistribution through social benefits has proved extremely detrimental to the social and moral well-being of the nation and has a cascading effect on future generations. In this context, 'self-employment' through basic economic activities becomes an important poverty alleviation strategy and requires commensurate action from government to create an enabling environment.

From a study in twelve rural villages in Limpopo and Mpumalanga Provinces (AWARD, 2002), it was evident that the economic activity of the six villages with access to only 25 lpd, was approximately half compared to the villages with better access to water. Poor households engage in a variety of water-based economic activities, ranging from brick-making, food processing and hairdressing to the making of ice-blocks for sale. However, the most common practice when people have access to some additional water, is to grow vegetables and fruit for food, and where possible, to barter or sell surplus for cash income.

The example below is used to examine the potential for improved food security and income through yard production of fruit and vegetables, based on homestead rainwater harvesting and storage. But first it is necessary to examine current policies and the statistics on population and poverty to assess the potential demand and uptake of these practices.

The Integrated Food Security Strategy for South Africa, released in May 2002, sets the objective to reduce the number of food insecure households by half by 2015, by

- Increasing domestic production
- Facilitating food trade & distribution
- Diversifying income generation
- Improving food safety
- Improving safety nets and information

The methodology described below is specifically targeted at enabling increased domestic production by the food insecure households themselves, on land they currently have under their control (their homestead yards), as this is seen to have the most direct and lasting impact on food insecurity.

### 2.3.1 Context for the study: The South African family food crisis

In the thirteen poorest municipal districts in South Africa, that is, the 'poverty nodes' identified for the implementation of the Integrated and Sustainable Rural Development Strategy, 60% of all households are familiar with food insecurity, while roughly a third regularly suffer hunger. This sad state of affairs is borne out by the fact that the growth of a quarter of all children in South Africa is stunted through under- and malnutrition (Table 1).

**Table 1. Summary of Key Statistics in Rural Areas of South Africa**

| |
|---|
| 2 in 3 households have experienced food insecurity |
| 1 in 3 households regularly go hungry |
| 1 in 4 children are stunted through malnutrition |
| Half the population are younger than 15 years |
| Most hungry people live in rural areas <u>and have fields</u> |
| 1 in 3 households grow maize, at an average of 0.5 t/ha of a potential of >2t/ha |
| Only 1 in 7 households grow vegetables |
| Only 1 in 10 households grow fruit |
| Only 1 in 75 households' main income is from farming |
| 2 in 3 say they need water for irrigation, but rainwater harvesting is unknown |
| 1 in 2 households have < R800/month, 2.5% have nothing |
| Only 1 in 2 rural women find jobs, and 2 in 3 rural men |
| Only 1 in 15 kids study beyond Matric |

Interventions to promote productive water uses by poor rural South African households should in the first place aim to reduce risk and increase options for a food insecure family under its existing circumstances, namely on its household yard, its dryland field outside the village and in rare cases (<5% of rural households) a plot on an irrigation scheme near the village (see Table 2). This approach is based on the recognition that by and large these circumstances have prevailed for decades in rural South Africa and are not likely to change on a major scale in the foreseeable future. This also implies that it is not useful to spend time theorising about 'what is subsistence' and 'how much is needed', but rather take an approach of 'how can we assist food insecure families to rapidly increase and stabilise their productive use of the resources they currently have under their control'. As such, an initiative to address food security through yard production would be over and above on-going government land reform and farmer support programs, and would target all food insecure families in the rural areas (focusing on the poorest 800 000 households, or 4 million people), rather than emerging farmers only. This should be recognised as an integral component of inclusive rural development.

The simplistic 'development path' depicted in Table 2 was developed to target outcomes-based agricultural training more effectively (De Lange *et al*, 2002) and recognises the old Chinese proverb that 'a hungry person has only one problem…' Effectively, food security is the 'outcome' sought by households in Category A, and empirical evidence confirms how once this is achieved, the household's objectives rapidly expand and become more complex. Category B farmers focus on ways to increase production and engage sustainably with the market, while those in Category C typically strive to maximise profit, increase efficiency and bring under control the growing demands on their management time.

Agricultural extension and support programmes across Africa seem to assume interaction with the higher categories, but recognising food insecure households as a separate category with a very specific objective should enable us to target interventions more effectively.

**Table 2. Spectrum of rural households in the former homeland areas**

| | | | *Increasing cropping input costs and risk* | | | Grazing and livestock watering |
|---|---|---|---|---|---|---|
| | | | Homestead yards | Dryland fields | Irrigated fields | |
| ***Number of households (hh) in former homelands with current access to agricultural resources*** | | | ***2 400 000 hh*** | ***1 700 000 hh*** | ***56 000 hh*** | ***1 700 000 hh*** |
| ***Total hectares currently under control of these households*** | | | ***200 000 ha*** | ***2 000 000 ha*** | ***100 000 ha*** | ***12 000 000 ha*** |
| *Development path* | C | **Profitable commercial small-scale farmers** | | | | |
| | B | **Subsistence and emerging farmers** | | | | |
| | A | **Food insecure households *(35-60% of the South African population)*** | Target for IFSS | Target for IFSS | | |
| **Note:** Data is from the 1997 Rural Survey, Statistics South Africa. | | | | | | |

**Households gain access to food in one of two ways:**

i) through own production, or

- through having the money to buy food.

Employment opportunities and alternative strategies for income generation are important, but are scarce and thus not expected to address South Africa's widespread hunger and poverty in the short term. Recently the decline in employment and income of rural households[3]**,**

[3] "The percentage of people without work has almost doubled in the last five years" and "the percentage of households earning less than R670 per month grew from 20 percent in 1995 to 28 percent in 2000". *Cape Argus*, 27 January 2003, quoting recent reports by Statistics South Africa.

combined with unpredictable droughts and floods, has led to an alarming increase in vulnerability to food insecurity[4].

"Lack of water" is almost invariably indicated when rural people are asked why they no longer follow the tradition of planting vegetables, fruit and some maize around their houses. In South Africa, less than 10% of households plant food in the homestead yard[5], in contrast to most other African countries where this practice is very common, even in urban areas. Recent studies in South Africa show the significant untapped potential for food and income through homestead production based on rainwater harvesting[6], a practice that is used widely across Africa, but is largely unknown here. In Nicaragua, typically a quarter of the income earned by smallholder families derives from production around the house[7], while the figure is even higher in many Asian countries [8].

Household food security is now recognised as a matter of national importance and the Department of Agriculture is currently designing an implementation programme. In this paper we will show an example of yard food production and consider its potential impact on food insecurity, both through improved direct access to food and through improved income generation.

It is crucial to recognise that, quite apart from the use of municipal supplies, there are a range of water development options as yet unexplored by rural households for 'Water for Productive Use by the Poor'. We believe the first priority is water for food insecure families for food production and other productive uses (like poultry, brick-making, hairdressing, etc.) on their own homesteads, particularly through rainwater harvesting, storage and use, but also through the development and use of family wells and a range of inexpensive manual pumping technologies, such as rope pumps, treadle pumps and others. The re-use of household water should also be encouraged.

### 2.3.2 Elements of the study

In 2002 the International Water Management Institute embarked on several studies to document, analyse and understand Mrs Tshepo Khumbane's yard food production methods and their results. An ongoing parallel study is documenting and analysing her approach to the promotion of her food production methods among food insecure families in rural villages across South Africa and in Lesotho, now carried forward by the Water for Food Movement.
In winter 2002, two MSc students from the University of Pretoria, under the joint guidance of IWMI and the Agriculture Research Council's Institute for Soil Climate and Water (ARC-ISCW), recorded and analysed her production. The IWMI studies analysed the water supply and demand for her production system, investigated the soils, including improved soil water holding capacity, and recorded the varied preparation of her 52 vegetable beds and as a basis for future soil fertility assessments. Further, an M Tech student from the Technikon Pretoria, supervised by University of Venda, is currently analysing the dietary value of

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4 According to Statistics South Africa's *Measuring Rural Development Report, 2002* only around 30% of households in the thirteen poorest District Municipalities have "never experienced food insecurity". Nationally this figure is 50%.

5 *Report on the Survey of Large and Small-scale Agriculture*, Statistics South Africa and National Department of Agriculture, 2000.

6 Ongoing IWMI research on Intensifying Rainfed Agriculture in Africa.. See Appendix 1.

7 "A multi-sectoral approach to sustainable rural water supply: the role of the rope handpump in Nicaragua", paper delivered at the *International Workshop on Productive Water Uses by the Poor*, Muldersdrift, February 2003.

8 Personal communication, Randy Barker, Senior Advisor and former Director-General, International Water Management Institute, Sri Lanka.

MmaTshepo's production. She will compare these to the results of earlier Technikon Pretoria household diet studies of rural households in Limpopo, as well as to World Health Organisation standards on Recommended Daily Allowances.

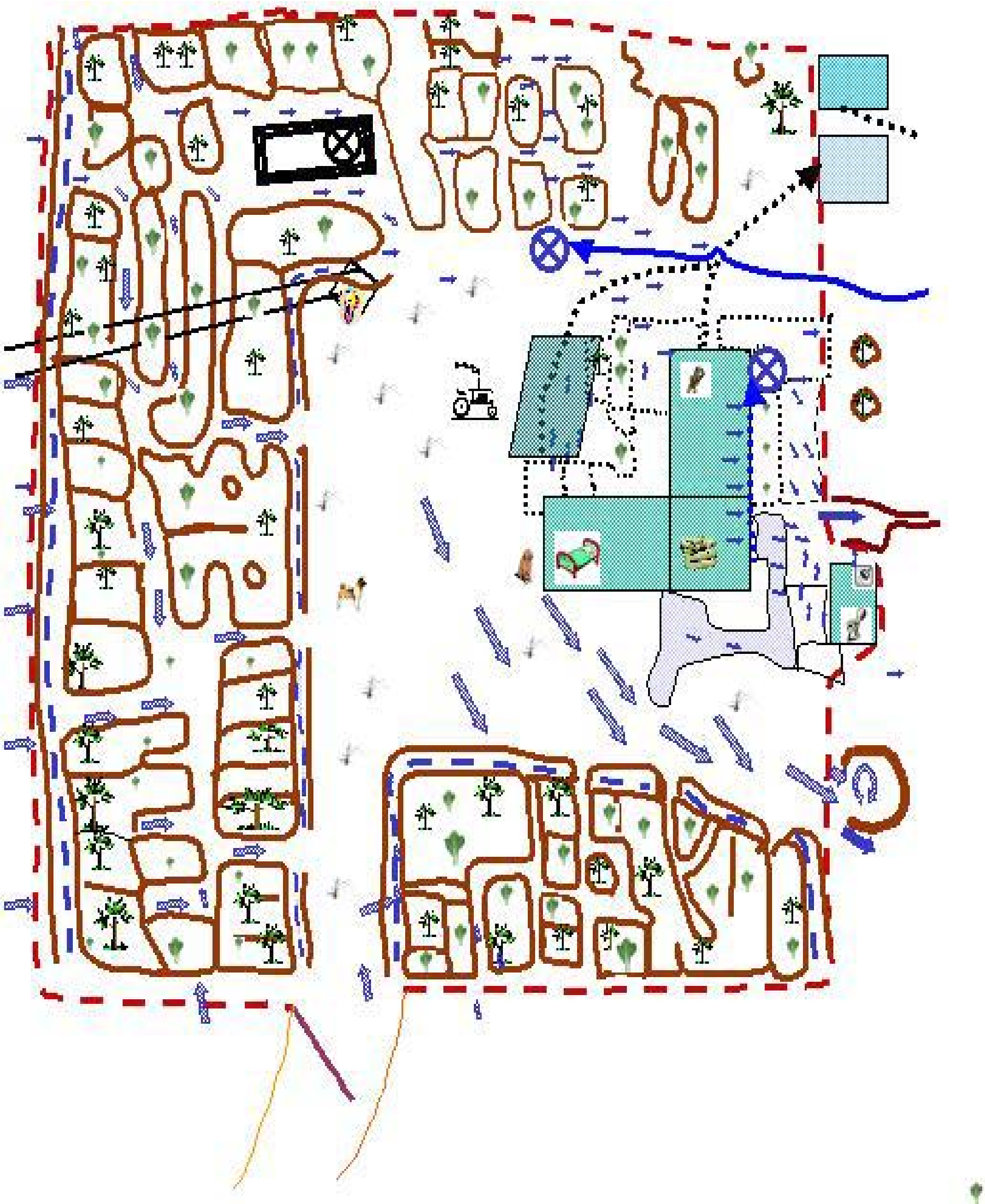
2.3.3 Results: Food produced on a township sized plot

MmaTshepo has laid out her homestead yard to be similar to a normal township plot, so that her results would be seen to be achievable by women from poor families. On a total area of 222 $m^2$, she grew more than ten types of vegetables and harvested a total of more than 1000 kg of plant material. In her intensive production system she achieved well above commercial yield levels, but her costs were very low. She has deliberately developed low cash demand production strategies to enable poor households to achieve food security even if they have minimal income.

When she moves to a new place (this is her seventh residence in South Africa), she first studies the flow of the rainwater run-off – she runs out of the house when everyone else runs inside to stay dry. When she understands the flow of the rainfall run-off water, she shapes the landscape to cut off, slow down, catch and store as much of the 'rolling river' for the few minutes that it lasts during and after every rainstorm.

The first feature of her design is a cut-off trench, right across the flow path of the rainwater rivulets. This cut-off trench typically runs along the full width of her property or township plot and collects all the water running down the hillside or down the street. With this trench, she slows down the flow of the water, so that her garden is protected from erosion. When the trench fills with water, it spills over at depressions (outlets) that she shapes along its length, into a network of meandering channels, and infiltrates the porous vegetable beds as the channels fill up. The 'channels' are in fact the footpaths between the vegetable beds, namely the undisturbed strips of soil that she leaves intact when she prepares her vegetable beds. The beds are bordered by ridges, which at the same time form the sides of the 'footpath channels'. These beds are odd shapes narrow enough so that they hardly ever need to be stepped on, preventing compaction. They are dug out to a depth of 1–1.5 metres and filled with raw organic waste, as described in more detail below. Because of the organic content, these beds can hold up to twice as much water as the sandy *in situ* soil. Once all the beds have filled up, the channels spill into the next long trench and channels that lead to storage pits and fruit trees planted on long organic trenches.

**Figure 3:** Layout of rainwater harvesting and vegetable beds for home food production



MmaTshepo's productions records for Winter 2002 are as follows:

**Table 3. Food and income from a homestead plot – Moloto, Winter 2002**

| *Crop planted* | *Land planted ($m^2$)* | *Food harvested [a] (kg)* | *'Months of food' for a family of six people [b]* |
|---|---|---|---|
| **Beetroot** | **30** | **120** | *7* |
| **Broccoli** | **23** | **90** | *3* |
| **Cabbage** | **12** | **96** | *8* |
| **Carrots** | **12** | **50** | *4* |
| **Cauliflower** | **10** | **35** | *2* |
| **Lettuce** | **20** | **30** | *1* |
| **Onion** | **50** | **225** [c] | *42* |
| **Peas** | **43** | **52** | *4* |
| **Spinach** | **14** | **126** | *4* |
| **Other** | **8** | **34** | |
| *TOTAL* | *222* [d] | *858* [e] | |

**Notes:**

[a] Where the harvest exceeded top commercial yields, the values were adjusted downwards accordingly. The objective was to achieve a realistic assessment of potential yard food production by poor families.

[b] This is the number of months that six people would each be able to eat one portion of this food per day from this harvest. Actual use would therefore extend over more months, provided the food is successfully stored. Alternatively, excess produce is sold fresh or processed.

[c] The actual value of the onions produced on 50 square metres in winter 2002 was R2 000, which was enough income to buy at least six months' supply of maize meal for a family of six.

[d] The total planted area of 222 square metres is approximately one-tenth the size of a normal rural homestead yard, and therefore accessible by virtually all households.

[e] Calculations of run-off and crop water requirements indicate that this level of food production through rainwater harvesting is achievable almost throughout the country in most years, even in low rainfall areas. Therefore, this need not depend on municipal water **supplies.**

**Please note**: *These figures reflect only the winter food harvest. Information will soon be available on crops planted during summer 2003.*

The sales and costs figures shown below were taken from MmaTshepo's accurate records for production and sales at her previous residence, a township plot in Ekangala, in 1990/91.

## Table 4. Production and earnings from yard production 1990/91

**Homestead agriculture - Fruit and vegetables**
***Records of production and earnings 1990/91***
Ekangala township Plot No 365
Size: (24m x 24m) = 592 square meters = 0.06 hectare
Water source: rainwater harvesting and grey water

**RECORD OF SALES: 1990/91**

| Crop | Trenches (1.5m deep) | Cash sales | Unit cost | Units | Description of unit |
|---|---|---|---|---|---|
| Tomatoes | 2 of 9m long, 1m wide | R 290.00 | | | |
| Carrots | | R 30.00 | R 1.50 | 20 | packets |
| Prunes | 1 tree | R 0.00 | | | |
| Onions | 1 of 9m long, 1m wide | R 300.00 | R 1.20 | 250 | kg |
| Naartjies | 2 trees | R 50.00 | R 5.00 | 10 | boxes |
| Lettuce | In tree basins | R 120.00 | R 2.00 | 60 | heads |
| Pumpkins | 6 basins of 14 pips | R 244.80 | | | |
| Pears | 2 trees | R 40.00 | R 20.00 | 2 | boxes |
| Beans | 1 of 9m long, 1m wide | R 199.50 | | | |
| Figs | 2 trees | R 45.00 | R 5.00 | 9 | boxes |
| Peaches | 15 trees | R 500.00 | R 50.00 | 10 | 50kg bags |
| Sweet potatoes | In tree basins | R 160.00 | R 10.00 | 16 | tins |
| Apricots | 3 trees | R 60.00 | | 3 | crates |
| Grapes | 6 vines | R 212.50 | R 8.50 | 25 | boxes |
| Spinach | 6 tree basins | R 650.00 | | | 9 month's supply |
| Lemons | 2 trees | R 20.00 | R 5.00 | 4 | boxes |
| Oranges | 4 trees | R 40.00 | R 5.00 | 8 | bags |
| Cabbage | 1 of 9m long, 1m wide | R 12.50 | R 2.50 | 5 | |
| Plums | 3 trees | R 110.00 | R 10.00 | 11 | boxes |
| Peas | 1 of 9m long, 1m wide | R 141.00 | R 3.00 | 47 | packets |

***R 3,225.30*** *SALES*

**RECORD OF COSTS: 1990/91**

| Trees | Number | Total Paid | Price |
|---|---|---|---|
| Peach | 15 | R 67.50 | R 4.50 |
| Plums | 3 | R 13.50 | R 4.50 |
| Figs | 2 | R 9.00 | R 4.50 |
| Grape vines | 6 | R 27.00 | R 4.50 |
| Pears | 2 | R 9.00 | R 4.50 |
| Prune | 1 | R 4.50 | R 4.50 |
| Apricots | 3 | R 13.50 | R 4.50 |
| Oranges | 4 | R 40.00 | R 10.00 |
| Lemons | 2 | R 20.00 | R 10.00 |
| Naartjies | 2 | R 20.00 | R 10.00 |
| Mulberry | 1 | R 0.00 | Own plant |
| Total | | ***R 224.00*** | |

| Preparation costs | Total Paid | Units | Description of unit |
|---|---|---|---|
| Trenches: 8 of 9m x 1m x 1,5m deep. | 0 | | |
| Kraal manure | R 33.00 | 1 | tractor load |
| Chicken manure | R 40.00 | 1 | tractor load |
| Total | ***R 73.00*** | | |

| Seeds 1991 | Number | Total Paid | Supplier | Detail |
|---|---|---|---|---|
| Tomatoes | 90 seedlings | R 15.00 | Florodale | |
| | 300 seeds | R 2.50 | Pyramid | Own seedlings |
| Lettuce | 200 seeds | R 2.50 | | Great Lakes |
| Seeding trays | 6 | R 6.00 | | |
| Beans | 2 pcts | R 4.40 | | Lazy Housewife |
| Carrots | 1 pct | R 2.20 | | |
| Pumpkins | 12 pips | R 0.00 | Sheridan Women OFS | |
| Sweet potatoes | | R 0.00 | | Own seed |
| Spinach | 1 pct | R 2.20 | | Fordhook |
| Cabbage | 1 tray | R 15.00 | | |
| | 1 tray | R 8.20 | | Own seedlings |
| Peas | | R 0.00 | | Own seed |
| Total | | ***R 58.00*** | | |

| Pesticides | Total Paid | Supplier |
|---|---|---|
| Tobacco leaves | R 1.00 | Groblersdal |
| Sunlight soap & paraffin | R 0.80 | |
| Total | ***R 1.80*** | |

***R 356.80*** *COSTS*

**TOTAL EARNED (Sales minus costs)** — **1990/91 season** **R 2,868.50** EARNED

*Hectare equivalent:* *R 47,808.33 /ha*

### 8.3.1 Application of the results – potential for improved food security

MmaTshepo has demonstrated that it is possible to successfully apply many of the traditional African food production approaches despite the congested nature of rural villages. The current thinking on how these production methods can be generalised is based on a number of independent but interrelated factors**.**

- In large parts of South Africa, the production of garden crops during the rainy season (summer) is often inhibited because of low or uncertain rainfall. Where the soils are shallow or very sandy, the problem is exacerbated, since insufficient water is stored in the soil profile to carry the crop through dry spells in the growing season. Further, many soils are subject to severe crusting that inhibits the ability for rain to infiltrate. If the soil is not adequate, the essence of the success of trench farming is that a new soil is created by backfilling with organic materials. With this method, soil ceases to be a limiting factor, meaning that this method can be applied virtually anywhere in the country.

- MmaTshepo's crop production is intensive and based on organic farming techniques that prescribe which crops can be planted together and which crops should follow next in order to keep costs low, and inhibit plant diseases and undesired insects without reverting to chemicals. This enforced attention to detail enhances yields and ensures production levels on a par with those attained by top commercial producers, but without the cash requirements and potential adverse environmental effects typical of chemical farming methods.

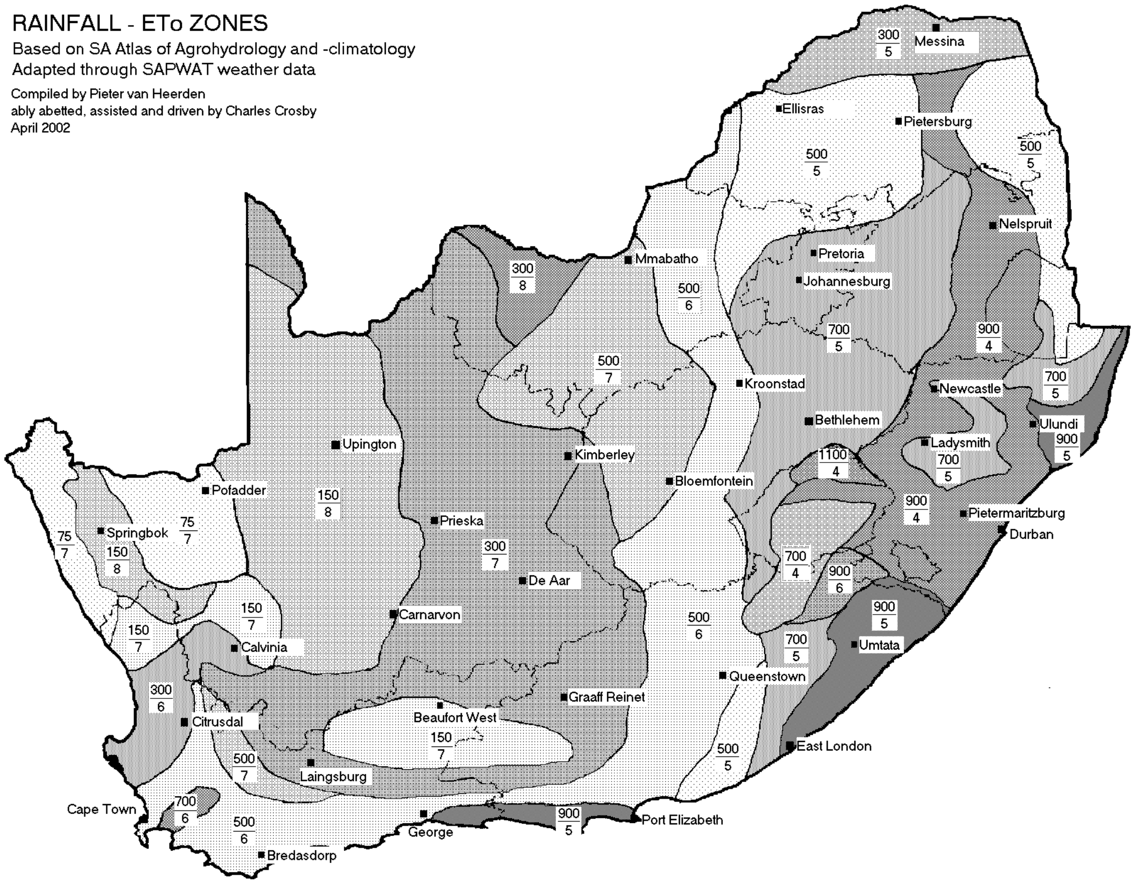
- In South Africa, as in many other parts of the world, there has been a tendency to over-estimate crop water requirements, but the use of the SAPWAT program has enabled more realistic values to be applied in practice. The program can express irrigation regimes in 'buckets per week', which simplifies irrigation planning in practice.

- Most of South Africa east of a North-South line running between Bloemfontein and Kimberley has an average annual rainfall greater than 500mm, with the exception of the arid area along the Limpopo river (see Figure 3). It is possible to garden productively throughout the whole area during the summer rainy season, by using MmaTshepo's methods of capturing rain in the water absorbing and retaining organic farming beds, with limited supplementation necessary from runoff from roofs and areas around dwellings. The development of the PLANWAT program now enables us to assess the potential for the successful application of rainwater harvesting for yard production anywhere in the country.

- Crop production in the dry winter season requires storage of summer rainfall. The advent of affordable manually operated water pumps (including treadle pumps) has increased options for pumping from underground storage tanks and small dams. The winter irrigation requirement is between 400-500 mm or approximately equal to the summer rainfall, meaning that an impermeable water harvesting surface (such as a roof or paved area) approximately equal to the area planted, is required to sustain production. Otherwise, assuming that runoff from "natural" catchment areas would be about 10% of the rain or 50mm, then 1000m$^2$ water harvesting area would produce enough water for 100m$^2$ under cultivation. This is a surprisingly small area and could amount to the area of road along the boundary of a residential plot.

**Figure 4. Map of South Africa: Ranfall - ETo zones**

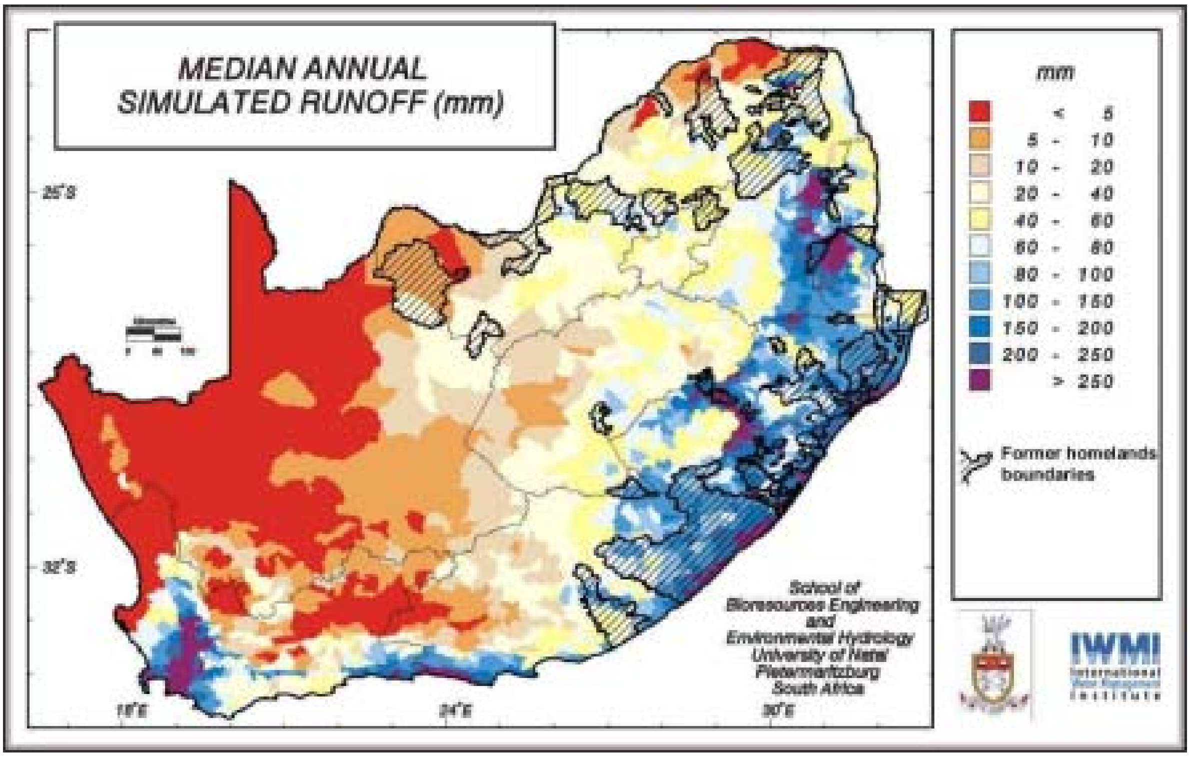
| Average annual rainfall (mm) |
|---|
| December ETo (Penman-Monteith) (mm) |




- The introduction of a cheap simple pumping procedure has important implications. It enables the "harvesting" phase (which must always have a considerable element of randomness) to be separated from the subsequent irrigation phase (which requires precision). Water can be stored and then delivered in small quantities by small-bore hose or pipe to the irrigation beds. Collection, particularly in the case of villages laid out in a grid pattern, is essentially an exercise in storm-water run-off planning and could be associated with gravel road maintenance. The diversion of small quantities of storm-water to on-property storage facilities should not present serious problems and could fill the dual role of water provisioning and planned road drainage.

- There is a wide range of storage possibilities, ranging from the conventional but expensive steel or fibreglass rainwater tanks commonly used for drinking water, to small "farm" dams. The storage can be above or below ground. Safety and health must also be taken into consideration. Cost and ease of construction are important factors.

**Figure 5. Map of South Africa: Median Annual Simulated Run-off**




## 9. OPPORTUNITIES FOR IMPACT

From the analysis above it is evident that basic economic activities of the poor have an immediate, direct and lasting impact on their livelihoods and that there is considerable opportunity to create an enabling environment for these activities to mushroom by removing perceived and real barriers to access to water, without unduly jeopardising the available resource.

In the short to medium term the following would need attention:

- In the context of water for productive uses by the poor, we need to change our thinking from a 'water demand management' paradigm to one that seeks to create water demand by the poor for poverty alleviation. This is an important precursor to compulsory licensing, which stands to further entrench the entitlements of advantaged users in the absence of effective demand from the poor.

- Recognising the *chronic and long-term nature* of food insecurity suffered by the majority of the South African rural population, the provisions of Schedule 1 need to be publicly promoted and extended in support of family food security, by providing open permission for rural households to harvest, store and use street run-off or any other rainfall run-off for productive uses on their homestead yards, and for households to collect water by bucket or manual pumping device from any river, dam or other water resource to which they have lawful access, for productive uses.

- There is a need to inventorise existing municipal punitive measures aimed at preventing over-use of municipal supplies and innovative monitoring approaches need to be identified and promoted that does not discourage food insecure families' use of alternative water sources for productive purposes

- Information on alternative water sources for productive uses by poor households needs to be collated and promoted, recognising the wealth of technologies and approaches available in international literature and especially from Sub-Saharan African countries

- The Department of Water Affairs and Forestry needs to clearly define its own role in *promoting* water use by the poor for productive purposes, which may include aspects such as awareness creation among staff, colleagues and rural communities; technical support and the supply of building material for interested households to create their own homestead water storage and use systems.

- We need a major programme, similar to the basic human needs and sanitation programmes, to mobilise households to develop their own homestead run-off water storage and use systems. This could be pilot tested at District Municipality scale, preferably in a dry area to maximise potential impact on food security and as a worst-case trial to minimise impacts on municipal systems and water resources.

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# EXCHANGE RATES FOR WATER TRADING IN THE MURRAY-DARLING BASIN

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***Abstract***

*Transfers of water within individual valleys in the Murray-Darling Basin have been allowed since the 1980's. Now, the Murray-Darling Basin Ministerial Council is seeking to expand trade, both temporary and permanent trade, wherever it meets efficiency, equity and sustainability objectives. However, designing and implementing a market for water entitlements that is efficient, equitable and sustainable, is very difficult.*

*The main problems with water markets arise from market failures. A simple system allowing people to buy and sell water with no outside intervention does not take account of issues such as losses incurred in supplying the entitlement at the new location, changes in security level or third party impacts such as return flows and environmental degradation. The cumulative effect of unconstrained trade could reduce the value of existing entitlements, decrease system reliability and jeopardise ecosystems. Applying an exchange rate, or conversion factor, to the traded entitlement is a simple and effective way to mitigate these effects.*

*This paper describes the conceptual framework for exchange rates and their application. A summary of exchange systems, and a preliminary view of their effectiveness, is also given. This research will ultimately be used to identify a preferred methodology for calculating exchange rates for the Murray-Darling Basin.*

## 1. INTRODUCTION

The case for water markets is simple: to allow water resources to be used where they are most highly valued. However, the complexities of designing a market quickly become evident when the physical realities of transferring water between users are considered. Issues such as security of supply, usage and conveyance losses can impact the volume of water used to supply a traded entitlement compared with an untraded entitlement. If these differences are not reflected in trading processes then there is potential for negative third party effects. This paper seeks to outline the key activities involved in a water trade, and demonstrate how different decisions can influence the volumes received by third parties. The intent of this paper is not to focus on water markets *per se*, but to analyse exchange rates as a mechanism for mitigating third party effects.

The Murray-Darling Basin covers around 14% of Australia's total area and is estimated to produce over 40% of Australia's gross agricultural output. Over 23 rivers flow across four states in the South-East of Australia, from Queensland in the north, through New South Wales and Victoria to South Australia. Also, over 1.5 million hectares of land are irrigated throughout the basin consuming an average of 10000 Gigalitres annually. Across the basin, 80% of major divertible resources are utilised, facilitated by a network of reservoirs with a combined capacity of 35 000 Gigalitres (Murray-Darling Basin Commission 2002).

## 2. WATER TRADING IN THE MURRAY-DARLING BASIN

An irrigator in the Murray-Darling Basin typically holds a legal entitlement for a nominal volume of water[9]. This nominal volume is stated on the irrigator's license but does not represent the actual volume that can be accessed in any given season. The actual volume that can be ordered in a particular season is governed by an percentage allocation, announced by the local managing authority at the beginning of a season, based on available supplies. In contrast to some other allocation systems, notably in the US West, available water is allocated evenly across all equivalent entitlements without any individual holding prior rights.

The relationship between the nominal entitlement and the physical volumes supplied are represented in the supply profile in Figure 1. This figure shows the average supply profile resulting from a 100 Megalitres (ML) water entitlement in the Sunraysia irrigation district based on observed streamflows and climatic data between 1891 and 2000[10]. The left hand column represents the nominal entitlement held by the irrigator, in this case, 100 ML. In this case, allocations would have been, on average, 99% of entitlements, resulting in an average allocated volume of 99 ML. The climate in many years reduces the need for full use of the allocation and hence, past utilisation has only been about 80 ML (last column).

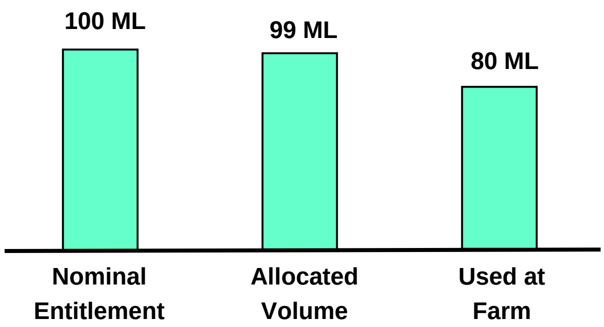


**Figure 1:** Supply Profile of Sunraysia District Water Entitlement

There are three possible ways in which water can be transferred: direct transfer upstream or downstream along a reach, substitution of upstream flows where a single storage supplies multiple reaches (upstream substitution) and substitution of downstream flows where multiple reaches each contribute to the supply of a downstream reach (downstream substitution). Figure 2 shows a simplified example of each mechanism. These examples assume there are no transmission losses in delivery, that each party receives their full entitlement (i.e. allocations are 100%) and that there are no other users in the system.

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[9] Entitlement types vary between uses (e.g. domestic, irrigation district, private diversion) and between states (Victoria, New South Wales, Queensland and South Australia).

[10] Source: Realm version 2.40a. System file Murray Model Murb311.sys (courtesy Department of Natural Resources and Environment Victoria, 2001)

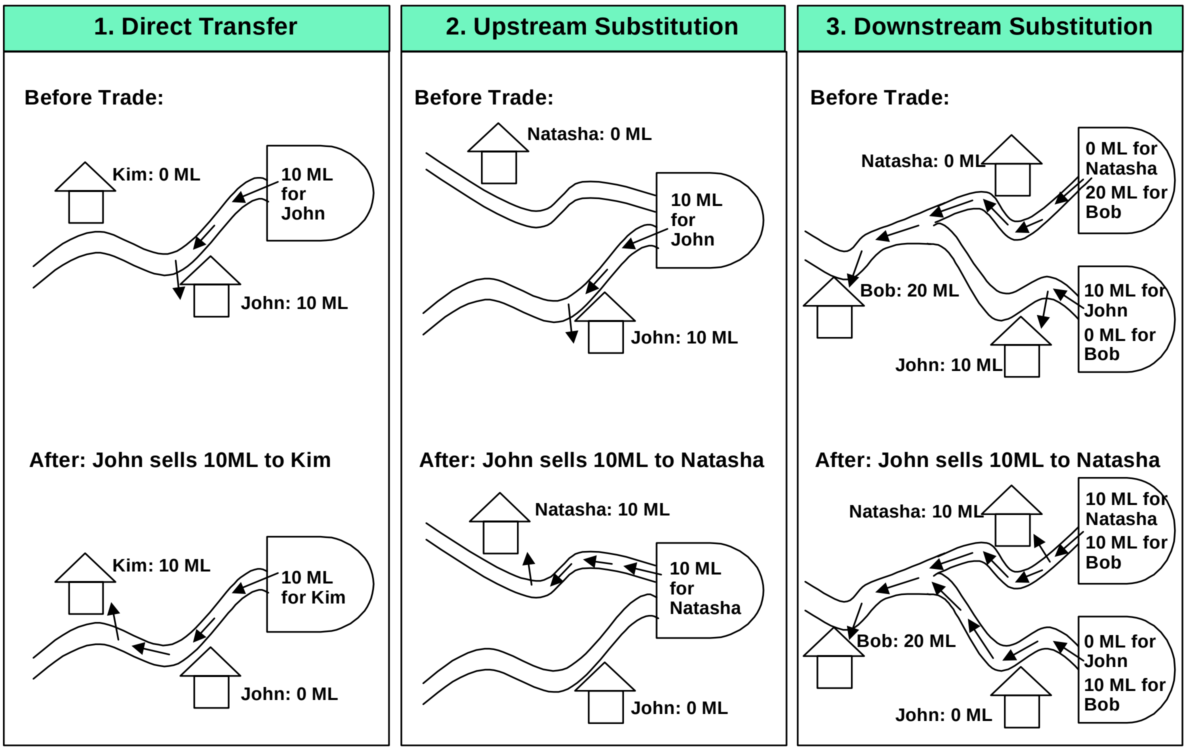


**Figure 2:** Transfer Mechanisms

When an entitlement is traded, up to six separate agents need to act: the individual buyer and seller, their relevant water management authorities and their relevant regulatory bodies. For a trade to occur, not only are the usual supply agreements required between a user and their local authority, but also three additional agreements need to be reached between buying and selling agents (Figure 3). Firstly, the buyer and seller must agree on an exchange. Secondly, the managing authorities of the buyer and seller must agree on the volume of water that will be transferred each season and how it will be supplied. Finally, and this only applies in the Murray-Darling Basin, a portion of 'Cap' must be ceded from the seller's system to the buyer's system. 'Cap' refers to the total volume that can be legally diverted from any of the Murray-Darling Basin rivers.

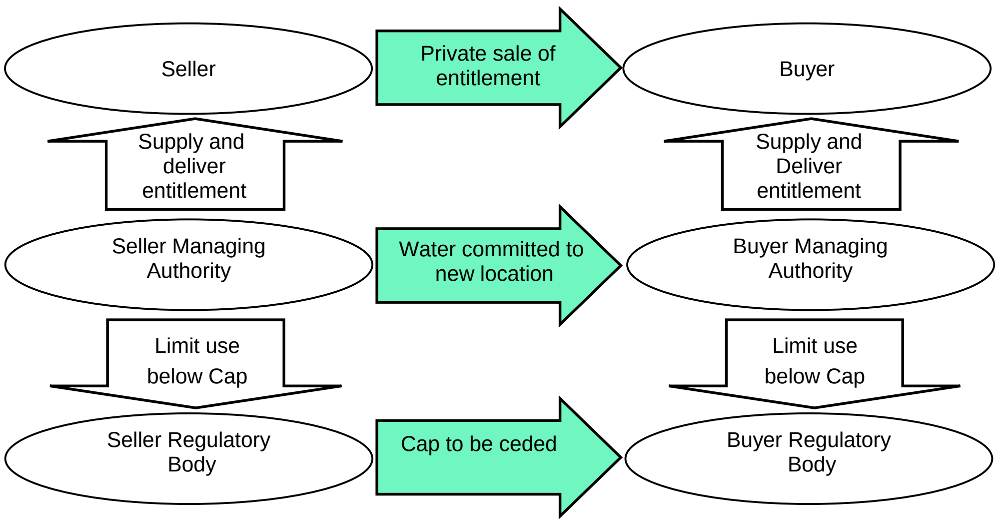


**Figure 3:** Water trading relationships

## 3. WATER MARKET FAILURES

Economics researchers have already described the potential for market failure as a result of externalities in water trading. Authors such as Howe et al. (1986) and Saliba (1987) have emphasized the potential for third party impacts to diminish the value of other entitlements. Since water rights are difficult to specify in an exclusive way, market transactions fail to account for costs imposed on third parties and market prices fail to reflect these costs. The sale of water nearly always, has direct impacts on third parties. This means that while markets may increase individuals' productivity from water, they may not maximise the collective outcome in terms of equity, sustainability and economic output. Thus, addressing third party effects is important for maximising overall outcomes.

In the course of each agent undertaking their role in the trade, third parties' entitlements can be affected. There are three possible impacts, namely seasonal allocations (volumetric reliability), delivery reliability and water quality. Each of these attributes could be subject to changes for better or worse. However, since the objective here is to avoid damage to third parties' entitlements, only negative outcomes will be examined.

Volume reliability effects are those that reduce the allocated percentage of an entitlement in a particular season. This has the consequence of reducing the number of seasons where a user will be allocated their full entitlement. For irrigators, the potential for ongoing reductions in allocations is of paramount concern; and with good reason. As trade has expanded, some entitlements that have never (or rarely) been exercised are now being utilised which is contributing to reduced allocations. Also, pressure to improve river health is likely to result in increased environmental flows, which will further consume Cap and reduce available water for irrigator's allocations. Therefore, it is critical that trade does not result in a further diminution of volumetric reliability.

Lower average allocations will arise where more water is used to supply the transferred entitlement than would have been had the entitlement not been sold, or where the upper limit on available water is reduced. There are seven possible drivers of reduced volumetric reliability:

- Security Levels: When the entitlement is purchased, the buyer is only purchasing the right to receive the physical volume of water that the seller did: the tradable volume. If however, the nominal volume of entitlement is not adjusted for differences in the average allocation the seller actually received; additional water might have to be supplied to meet the new entitlement. For instance, if the seller had an entitlement of 100 ML but only received 50 ML in an average season, a tradable volume of only 50 ML would be available. If the nominal volume were supplied from the selling valley rather than the tradable volume, additional water would be required and allocations in the seller valley would be reduced.

- Usage: If a transfer results in increased usage[11], it is possible that additional water may be required in the new location to service the transferred entitlement. Usage could increase for two reasons. Firstly, as a result of user preference, where an under-utilised entitlement becomes more fully utilised. This however, could happen without trade occurring and is not actually an externality of trade. Such increases in usage only need to be reflected implicitly when considering future security and Cap usage. Secondly, it is possible that the transfer of an entitlement results in lowering the probability of rain rejection, leading to higher usage. This factor is related to location, and thus, is a possible cause of volumetric reliability effects. The significance of this impact needs to be investigated.

[11] Usage refers to the percentage of a user's allocation that is actually diverted in a season

- Transmission Losses: Transmission losses could increase if conveyance distances are longer or channels are subject to greater seepage and therefore, require additional water to supply the entitlement.

- Environmental Flows: Where environmental flows have been defined, existing deliveries may be helping to meet them. So, when a trade occurs it is possible that flows might then need to be supplemented

- from available water, which could reduce overall allocations in the selling valley.

- Runoff Capture: The volume of runoff captured could reduce if there is an increase in demand for capacity in storages used to deliver orders resulting in increased spills and reduced volumetric reliability.

- Ceding Water: The managing authorities could also affect third parties when they cede water to supply the transferred entitlement wherever the volume of water ceded is different than that required for the traded entitlement. If there is a shortfall in either the buying or selling valleys, the allocations of other entitlement holders will be diminished.

- Cap: In a similar way, the selling regulatory authority needs to determine how much Cap to transfer to the purchasing regulatory authority. The major difficulty is determining how much Cap the seller would have been entitled to in the future. If too much Cap is transferred, the selling valley could experience lower allocations. If insufficient Cap is transferred, the same could happen in the buying valley.

Apart from third party effects on volumetric reliability, two other types of effects can impact third party irrigators as a result of trade. Firstly, any system change that reduces the likelihood that users will receive their water when they want it is categorised as a delivery reliability effect. Decreased delivery reliability occurs where demand for capacity at certain places and times exceeds the channel capacity at that place and time. Hence, deliveries become delayed and delivery reliability drops. The impact of an individual trade on delivery reliability is dependent on the total volume of deliveries. Where particular reaches are more heavily used, the marginal impact of an individual trade on delivery reliability will be greater.

The second effect is water quality effects, which is of concern wherever changes in instream water quality results in decreased productivity for downstream water users and reduces the health of instream environments. The magnitude of water quality effects are influenced by the volume and quality of return flows and the water sources used to supply traded entitlements. However, determining whether trade will result in positive or negative water quality outcomes is difficult since the transfer of an entitlement could simultaneously have both positive and negative effects.

## 4. FRAMEWORK FOR EXCHANGE RATES

The third party effects that impact volumetric reliability can be addressed through the design of an exchange rate system. Such a system applies a conversion factor to the traded entitlement volume to account for the impacts caused when the water is consumed in a new location. In other words, an attempt is made to provide ‘water currencies‘ so that traders can convert the value of a water volume provided in one location to its value in another place and time taking account of differences in security of supply, and losses as the water is transferred via rivers and channels. Exchange rates could adjust the entitlement volume to ensure that the traded entitlement can be adequately supplied, and to minimise third party impacts.

Volumetric reliability effects are those that reduce the allocated percentage of an entitlement in a particular season. Lower average allocations will arise where more water is supplied to a transferred entitlement than would have been had the entitlement not been sold, or where the available water is reduced. There are seven possible drivers of reduced volumetric reliability including differences in security levels, usage, transmission losses, synergies with environmental flows, spills from storages, available water and Cap. Exchange rates to address volumetric reliability effects could have a high level of efficacy since they ensure that an entitlement is supplied the same volume (on average) after trade as it was before.

A framework for exchange rates needs to encompass all of the parties involved in an entitlement trade. Clearly, the exchange rate between the individual buyer and seller is critical to 'doing the deal' and becomes a means to translate the volume of entitlement to take into consideration system losses, security of entitlements and other factors such as in-stream requirements and water quality. Additionally, each time an entitlement is traded into or out of a region, there are consequences for basin authorities and state authorities: for instance, with respect to storage accounts and the Murray-Darling Basin Cap on diversions. Thus, exchange rates need to apply typically at three levels: individual, accounting and Cap (Figure 4).

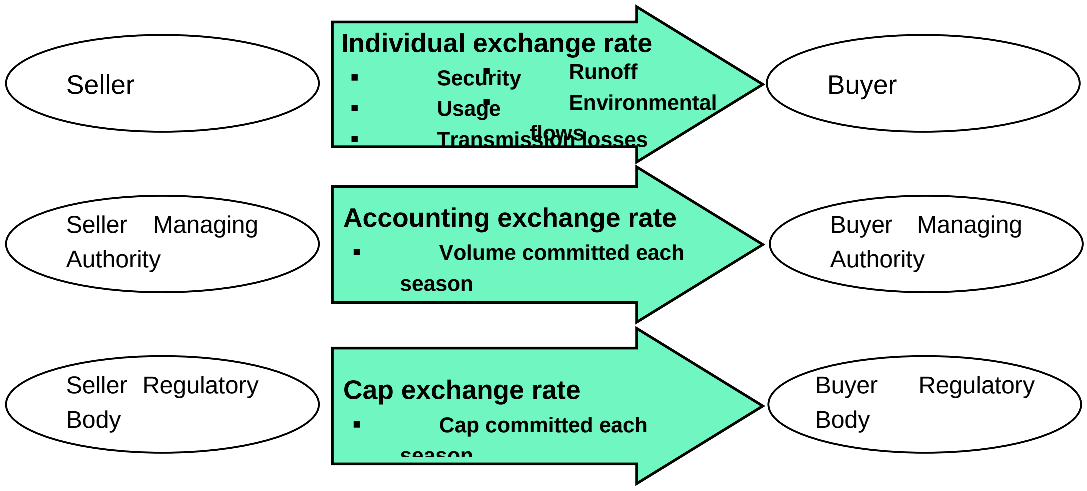


**Figure 4: Framework for exchange rates**

## 5. IMPORTANCE FOR STAKEHOLDERS

The challenge for stakeholders, the irrigation authorities and regulatory agencies, is to develop simple and consistent mechanisms to deal with third party effects. If the market becomes too complicated and transaction costs too high, efficient reallocation is unlikely to occur. Since exchange rates avoid third party effects by defining entitlements with simple conversion factors, they have emerged as a preferred option for dealing with third party effects. Exchange rates have already been used in a project trialing interstate trade and are now being used in Victoria for trade between regulated and unregulated systems. However, questions still exist as to the basis for calculating exchange rates.

This research focuses on clearly defining the role of exchange rates and defining the basis for calculating them. Analysis of exchange rates for intravalley, intervalley and interstate water trading will demonstrate the potential size of third party effects and the value of particular exchange rates. Additionally, this research will inform stakeholders of some risks involved in large-scale water trading and how best to manage them. Given the socio-political importance of water allocation, establishing exchange rates is likely to be very complex and sensitive. Independent analysis undertaken for this research will provide a foundation to aid stakeholders in their decision-making.

## 6. CONCLUSION

As water trading in the Murray-Darling Basin expands, so does the potential damage to irrigators' allocations from third party effects. A system of exchange rates can mitigate these effects and force buyers and sellers to recognize third party impacts. For this reason, exchange rates are emerging as the preferred solution by stakeholders. This research will add to stakeholders' understanding by clarifying the role of exchange rates and how they should be calculated.

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# MEETING THE WATER DEMAND FOR FUTURE GROWTH AND DEVELOPMENT: AN INTEGRATED PLANNING APPROACH

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## 1. INTRODUCTION

As a developing country South Africa's water related challenges for sustainable development are compounded by its historical past and by the fact that South Africa is a water scarce country. The biggest challenge regarding water and development in South Africa is the provision of basic water services to all, and in particular the poor. Although considerable progress has been made over the last eight years there are still millions of people without access to basic water and basic sanitation services. The provision of services to the poor is however only one of the challenges for sustainable development in the water industry. Other challenges relate to high level of non-revenue demand, the weak institutional capacity of the water services industry, the economic viability of service provision, environmental degradation of water resources and the availability of sufficient water resources. All of these challenges are associated with the objective of meeting the water demand for future growth and development in a sustainable and efficient manner.

The aim of this paper is to evaluate the new approach of Integrated Water Resource Planning (IWRP) and the role of Water Conservation and Water Demand Management (WC/WDM) in meeting the water demand for future growth and development in South Africa. The paper identifies the potential of WC/WDM in South Africa, identifies the constraints, makes recommendations on how to overcome them and determines the role of WC/WDM and IWRM in meeting the water demand for future growth and development.

Although the paper reflects on the water situation in South Africa for all water use sectors, it focuses mainly on the requirements of the domestic and business sector (urban sector). The reason for focusing on this sector is because it is the sector with the expected growth in water demand and because it is generally accepted that the water demand for the agricultural sector will not grow in the foreseeable future. Furthermore most proposed new dams and transfer schemes are recommended to meet the growing demand of the urban sector.

## 2. GENERAL BACKGROUND

South Africa entered a new phase in its history with the election of its first non-racial democratic government in 1994. It emerged from a history of oppression and division, exploitation and deprivation that left South Africa with significant inequalities. In parallel to the political background huge inequalities also exist with water allocation and the provision of water services. The promise of the new government is "a better life for all" and water is an integral part of that promise as it represents one of the most important fundamental requirements for sustainable development.

The Department of Water Affairs and Forestry (DWAF) has been very proactive in meeting the new challenge for water supply and by developing new legislation, policies and large programmes to address this. The two main areas that the Department is focusing on are described in the following two mission statements:

a) *Ensuring that water services are provided to all South Africans in an efficient, cost-effective and sustainable way.*

b) *Conserving, managing and developing our water resources and forests in a scientific and environmentally sustainable manner in order to meet the social and economic needs of South Africa, both now and in the future.*

### 2.1 Background regarding security of supply

South Africa is a water-stressed country with an average annual rainfall of less than 500 mm compared to a world average of about 860 mm. On average only some 9% of rainfall reaches the rivers, evaporation is higher than precipitation and extreme weather events such as droughts and floods are common. The water demand is continuously growing due to a developing economy, a high population growth rate (if the impact of AIDS is ignored) and meeting the backlog of water supply to people who previously did not have adequate access to water. Reconciling the growing demand with the available water resources is becoming more and more difficult as most of the optimal available water resources have already been developed and exploited.

Estimates published by DWAF (Workshop of National scenarios Nov 2001) indicate that although the total water available is larger than the total water requirements, there are a number of basins where there are water deficits.
Figure 1 below indicates that currently there are 9 basins were water requirements are greater than available water.

### 2.2 Background regarding WC/WDM in South Africa

The South African water supply industry up until about ten years ago, was managed within the supply side management paradigm and WC/WDM was not considered an option. Water was relatively cheap, and government's policy and approach was to develop as many dams as possible in order to utilize most of the available water. The need for WC/WDM would emerge primarily during the time of a drought, and the role of WC/WDM in the long term planning was not considered. As the building of dams and other infrastructure became expensive and other government expenditure programmes on social services gained more prominence, the role of WC/WDM become more apparent and a national Water Conservation drive was initiated in 1995. The new National Water Act (Act 36 of 1998) promoted Water Conservation and water use efficiency as one of the key principles. Subsequently various policies, strategies and guidelines have also been developed and a number of additional tools are currently been developed. A directorate of Water Conservation was established by DWAF during 1998 (now called the Directorate of Water Use Efficiency) with the mandate to promote and ensure the appropriate implementation of WC/WDM in South Africa. Currently there are some achievements in the field of WC/WDM particularly with the reduction of Unaccounted for Water (UaW) by municipalities but progress is relatively slow.

The WC/WDM policy in South Africa is based on the following three principles:

a) Water management and water services institutions should ensure that they reduce the level of leakage in any water works or water services works to an optimal level and implement measures that promote on an ongoing basis WC/WDM to their consumers and end users.

b) BAll consumers in South Africa should not waste water and should strive to use water efficiently. Water wastage can be defined as the use of water with out deriving any direct benefit. The non-efficient use of water can be described as water used over and above the accepted benchmark for a specific purpose or water used where very little benefit is derived.

c) WC/WDM should be considered as part of the water resources and water services planning processFigure 1 Water reconciliation scenarios in South Africa for year 2000

## 3. INTEGRATED WATER RESOURCE PLANNING (IWRP)

When there were limited available water resources the building of dams and transfer schemes were initially imperative for the economic growth and development of South Africa. Considering that currently South Africa has a highly developed water resource infrastructure it is necessary to consider whether the available resources are being used efficiently and effectively and whether it would not be more viable to invest in WC/WDM as an alternative augmentation option before any additional dams and transfer schemes are built. Identifying the opportunities of WC/WDM as an alternative option for reconciling water demand and availability, should be determined through a new planning approach commonly referred to as Integrated Water Resource Planning (IWRP).

The planning objective of the traditional planning methodology was defined by the projected water demand. The approach was to increase availability to meet the growing demand. With IWRP, the planning approach is no longer limited to a water resource perspective and looks at a number of other consequences that are associated with the reduction in demand. This includes potential economic savings in operating costs, and potential savings in the cost of other water supply related infrastructure such as treatment plants and reservoirs. It integrates all the components of the supply chain and tries to identify the best solutions from society's perspective.

IWRP is not totally distinct from what was previously been practised but it is does contain functions that are not generally found in traditional water supply planning. The are four main considerations which deviate from the past / current planning practises:

a) Integration of planning throughout the supply chain to achieve the best results to society (end consumer) and to meet **specific project objectives**. The traditional water resource planning practises focus on the best-perceived solution from a water resource perspective only.

b) Ownership and responsibility of the planning must not be limited to the water resource manager or water management institutions, and should require the involvement of all key stakeholders in the supply chain.

c) Evaluation criteria of the various options must be comprehensive and include social, economic, institutional and environmental.

d) Water demand-side management measures are considered as an alternative resource option and not a separate function or campaign.

A comparison between traditional planning and IWRP, is noted in Table 1.

Table 1: Comparison of traditional planning and Integrated Water Resource Planning[12]

| CRITERIA | TRADITIONAL | INTEGRATED RESOURCE PLANNING |
|---|---|---|
| ***Planning orientation*** | | |
| - Resource options | Supply options with little diversity | Supply and Demand-side management; efficiency and diversity encouraged |
| - Resource ownership and control | Centralized and utility owned | Decentralized; utilities, customers and others |
| - Scope of planning | Single objective, usually to add supply capacity | Multiple objectives as determined in the planning process |
| - Evaluation criteria | Maximise reliability | Multiple criteria, including cost control, risk management, environmental protection and social |
| ***Planning process*** | | |
| - Nature of process | Closed, inflexible, and internally oriented | Open, flexible and externally oriented |
| - Judgement and preferences | Implicit | Explicit |
| - Conflict Management | Conventional dispute resolution | Consensus-building |
| - Stakeholders Identity and focus | Utility | Multiple interests |
| - Stakeholders' role | Disputants | Participants |
| ***Planning issues*** | | |
| - Supply reliability | High priority | A decision variable |
| - Environmental quality | A planning constraint | A planning objective |
| - Cost considerations | Direct utility system costs | Direct and indirect costs, including environmental and social externalities |
| - Role of pricing | A mechanism to recover costs | An economic signal to guide consumption |
| - Efficiency | An operation concern | A resource option |
| - Trade-offs | Hidden or ignored | Openly addressed |
| - Risk and uncertainty | Should be avoided or reduced | Should be analysed and managed |

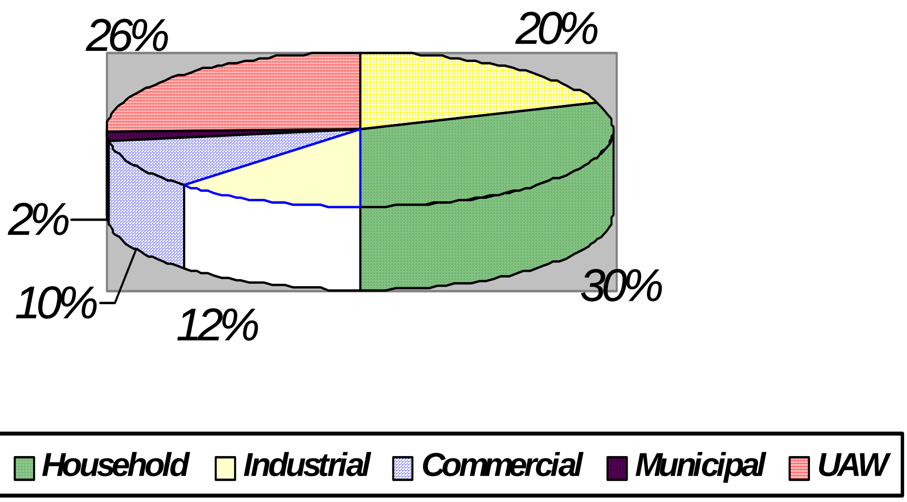
[12] Adopted from a paper by Janice A. Beecher; published in the June 1995 AWWA Journal :"Integrated resource planning fundamentals"

## 4. POTENTIAL OF WC/WDM IN THE WATER SERVICES SECTOR

The potential for WC/WDM exists because consumers generally use water for the service they derive from it and not for the water itself. Through new technologies combined with a change in behaviour water usage can be reduced significantly without necessarily affecting the desired outcomes or quality of life of consumers. WC/WDM should focus on increasing water use efficiency and reducing wastage. In South Africa there are opportunities for implementing WC/WDM to the common benefit of the consumer and Water Services Institutions.

The first requirement in determining the potential for reducing water usage is to carry out a detailed demand analysis. Currently there is no consolidated database of information regarding the water usage from Water Services Authorities in South Africa. Figure 2 below indicates estimated averages based on information obtained from Rand Water, Durban Water and Waste and Cape Town City Council.

**Figure 2:** Water use in the urban water use sector (National estimated average)




The following analysis illustrates the estimated opportunities in reducing demand in most water services areas. (Estimates are based on sectoral usage information illustrated in figure 2 and on general information obtained from WC/WDM studies in various urban areas.)

a) Reduction in distribution leaks

It is estimated that by implementing effective distribution management measures the Unaccounted for Water can be reduced from 25% to **12.5 %** of the total demand.

This can be achieved through adequate and proper operating and maintenance measures of the reticulation system. Pipe network replacement or rehabilitation should also be undertaken. An accepted general norm is to replace the pipe network every 50 years but this can vary according to a number of variables and circumstances. Related activities by Water Services Institutions can include the following:

i. Leak detection and repair
ii. Pressure management
iii. Effective zoning of the distribution system
iv. Repair of visible and reported leaks
v. Pipe replacement / management program
vi. Cathodic protection of pipelines
vii. Meter management programme
viii. Unauthorised connection programme

b) Reduction in plumbing leaks within domestic consumers

Studies in a number of areas such as Soweto and Khayelitsha have identified high levels of leakage due to faulty plumbing. The average water wastage through plumbing leaks is estimated as 20% of the total household water usage (water used indoors). By repairing 90 % of the plumbing leaks within domestic consumers the total consumption can be reduced by **5.4%.** Plumbing leaks include any leaks past the consumer connection and include leaks within the connection pipe, leaking taps, leaking toilets and leaking hot water geysers.

Repair of plumbing leaks can be achieved by the following related activities initiated by the Water Services Institutions:

i. Leak repair projects in the “former urban black townships” sponsored by water institutions (re-addressing the apartheid plumbing of Council houses)
ii. Communication and education campaigns
iii. Ensuring payment of services through credit control measures

c) Retrofit of existing plumbing fittings within the domestic and commercial water use sectors

On average it is estimated that by replacing existing plumbing fittings with more efficient fittings the household and commercial water consumption can be reduced by 40% and 30% respectively. This can be illustrated with the replacement of a normal 9 litre toilet cistern with a 6/3 litre dual flush toilet. The total theoretical saving between the two types of toilets is 60%.

The estimated saving by retro fitting 80% of existing plumbing fittings on household and commercial properties is calculated as **13 %** of the total demand.

Opportunities in retrofitting of plumbing fittings include fitting dual-flush or interruptible toilets, user-activated urinals, low flow shower heads and tap flow controllers, and aerators. Retrofitting can be achieved by the following related activities of the Water Services Institutions:

i. Retrofit projects in the “former urban black townships” sponsored by the water institutions (combined with leak repair projects described above)
ii. Communication and education campaigns
iii. Grant incentives schemes where water institutions will pay part of the costs to retro-fit to the consumer
iv. Regulations and by-laws
v. Marketing and research of new technologies
vi. Schools audits

d) Reduction in gardening water use

On average it is estimated that by increasing the efficiency of gardening water usage the total consumption can be reduced by **5%** or 25% of the total gardening water use. Opportunities in reducing water used for gardening include water wise plants, mulching, efficient irrigation systems, irrigation scheduling, rain harvesting and recycling of wastewater.

Reduction in gardening usage can be achieved through the following related activities of the Water Services Institutions:

i. Communication and education campaigns, including water-wise demonstration exhibits
ii. Block rate tariffs
iii. Regulations and by-laws
iv. Research of new technology such as linking soil moisture monitors to automatic garden irrigation systems
v. Grant incentives schemes for lawn replacement, and xera-scaping where water institutions can pay part of the costs to change existing gardens

e) Reduction in the demand by new consumers – reduction of natural growth rate

On average it is estimated that by increasing the efficiency of all new consumers the growth in water demand can be reduced by an estimated average of 30%. Opportunities in reducing water demand of new consumers include selecting appropriate levels of service for different communities, efficient plumbing fittings, efficient reticulation design practices and pre-payment meters.

Reduction of new demand by new consumers can be achieved by the following related activities of the Water Services Institutions:

i. Installation of pre-payment systems (if economically, technically and socially viable)
ii. Effective billing systems
iii. Communication and education campaigns
iv. Regulations and by-laws
v. Negotiations and incentives to developers
vi. Improved reticulation design and plumbing standards
vii. A high level of operation and maintenance, with rapid response to bursts and leaks

From the above general analysis it is calculated that the total opportunity in reducing water demand in the water services sector in South Africa is approximately 39% of the total existing demand. This estimate does not necessarily imply that it is feasible to achieve such water demand reductions and the feasibility of each inefficient component should be established through the principles of IWRP. Examples in various areas such as in the Western Cape regions however indicate that the cost of implementing all the above WC/WDM measures will be significantly less than the costs of building additional water resource schemes.

## 5. CHALLENGES IN IMPLEMENTING IWRP AND WC/WDM

The concepts and motivation for implementing WC/WDM and IWRP may appear quite simple but yet they are not adequately embraced and implemented in South Africa. A number of obstacles and constraints will have to be overcome, before the potential of IWRP and WC/WDM can be fully recognised. These are divided into four categories:

a) Inadequate integration in **planning** between institutions
b) Limited financial framework to fund WC/WDM activities
c) Resistance to change and limited understanding
d) Institutional challenges

### 5.1 Inadequate integration in the planning between Water Services Institutions and Water Management Institutions.

The current legislative model separates Water Services and Water Management institutions through the two new Acts, the Water Services Act (Act 108 of 1997) and the National Water Act (Act 36 of 1998). The main function of Water Services Institutions (WSI) is the provision of water services, and very little requirements and responsibilities are placed on them with regards to water management issues. The converse is also true with regards to Water Management Institutions (WMI). The legislative situation is not conducive to an integrated planning approach and planning solutions in the past were biased to benefit of various institutional perspectives and were not necessarily in the best interest of society. The following two examples illustrate where the planning objectives can differ between water services institutions, water management institutions and society. (The names of areas were excluded in the examples because they are meant to illustrate the point and not to judge decisions made by various institutions)

**Example 1**: Water resource planning had determined that various WC/WDM measures will have the same impact as augmenting the existing water resources in a specific area. These WC/WDM measures however would have cost more than building a new augmentation scheme and from that perspective it would appear the augmentation scheme is the most appropriate solution. The view of the service provider was that they also preferred the water augmentation scheme because the implementation of the various WC/WDM measures may lead to a loss of revenue, and may require an increase in the unit charge of water. The cost of implementing the WC/WDM will also increase the financial burden of the Service Provider. The reality however is that form the perspective of the end consumers, implementation of the various WC/WDM measures would have resulted in the cheapest option. The costs of WC/WDM measures would have been less than the combined avoided costs of building a further augmentation scheme; the avoided costs of further bulk supply infrastructure such as reservoirs and waste water treatment plants by the service provider; and the savings from the operating costs of water and waste water treatment, and transportation.

**Example 2:** A water resource basin study identified that after taking into account the water allocations of existing consumers the ecological reserve, there is still a significant amount of water left, and that this water should be allocated to the urban metropolitan area in an adjacent water basin. This conclusion was reached after comparing the overall economic output from the use of water by competing users. The study went as far as recommending the development of an augmentation and a transfer scheme to make this water available to the urban area. The conclusions and recommendations of this study were based on a water resource management perspective and completely ignored the water efficiency and effectiveness criteria within the urban area. Although nobody can dispute that in general the overall economic benefit obtained from the use of water is much higher in an urban area than by agriculture, the question that needs to be asked is, "will the extra allocation of water resources be of any real benefit to the urban area ?". The further allocation of additional water would have increased the cost of water unnecessarily, and this would have had a negative economic impact when compared with the opportunities of implementing various WC/WDM measures.

The important point that needs to be highlighted from the two examples noted above, is that the planning objectives need to be focused on the best overall interest of society and not from the perspective of one institution. The key-planning objectives of any component of the entire water cycle should start from society needs and not from the institutions. This does not mean that planning should ignore environmental or institutional issues, but it implies that they should not be the starting point. The second point that is illustrated from these examples is that water resource planning cannot be separated from water services planning. The optimal solution can only be achieved if water supply planning is integrated throughout the supply chain.

**Conclusion**

*The planning cycle for sustainable development in the water industry needs to be integrated incorporating social, environmental, institutional and economic requirements with the starting focus been to achieve the best interest of the general society.*

### 5.2 Limited financial assistance to fund WC/WDM

Funding opportunities in the water sector from international countries and local financial entities are mostly for capital projects. Funding institutions are reluctant to provide money for WC/WDM projects suggesting that such projects are not sustainable, particularly in 3rd world and developing countries. Funding capital projects is easier as there are tangible assets involved. A view expressed by one large international funding institution is that operation, maintenance and management of service delivery in 3rd world countries should be privatised and they have no confidence in government institutions to provide an efficient and effective service. Although there maybe a partial truth in such a statement, the end result however is that the supply side management paradigm is promoted in instances where WC/WDM maybe more beneficial to society.

What is perhaps not recognised by funding institutions is the unique and diverse situation of South Africa. South Africa unlike most other developing countries does have significant bulk infrastructure particularly in urban areas. Due to its social – political past however water service delivery and water supply was/is largely subsidised and inefficiently used. This is true for most water use sectors including domestic, industrial and agriculture. This implies that currently there are significant opportunities of implementing water efficiency measures and reallocating resource capacity for the further development of communities without services.

One example is water supply in Soweto. Limited water services, usually comprising a toilet and a tap for each stand can be found in most areas in the "former urban black townships" but the overall water supplied is very high. In the past adequate operation and maintenance of the reticulation system was not carried out resulting in very high levels of Unaccounted for Water UaW). Houses belonged to the Councils and were not adequately maintained also resulting in significant plumbing leaks.

The challenge by Water Service Providers such as Johannesburg Water (Water Service Provider) to implement adequate measures that will ensure effective, efficient and sustainable service delivery to areas such as Soweto are significant and need substantial financial resources. The reality however is that these challenges cannot be overcome overnight and if Johannesburg is to succeed they will need assistance. The challenge for resolving the water wastage and water leakages in areas such as Soweto should not be considered only a local authority problem but a national problem.

**Conclusion**

a) *The current approach by international funding agencies promotes the implementation of a supply side management approach that may have a negative impact on sustainable development in South Africa*.

b) *There are limited funding opportunities for WC/WDM measures. A national support and funding framework model to assist local authorities in implementing WC/WDM should be considered.*

### 5.3 Resistance to change and limited understanding of WC/WDM

Although considerable progress has been made in WC/WDM over the last few years, the appreciation and acceptance of WC/WDM in the water industry in South Africa has a long way to go.

One of the main constrains to WC/WDM being adopted in the water supply industry is the resistance to change and limited perceptions and understanding by officials of water supply institutions. A lot of senior water officials choose to misinterpret the opportunities of WC/WDM and generally focus on its potential negative aspects.

Some of the typical comments made by some officials are: “WC/WDM will reduce the opportunity of subsidising free basic water” and “WC/WDM will reduce the ability to pay for the Lesotho Highlands Water Scheme”. Although it is true that the implementation of wide scale WC/WDM may have these effects, it is incorrect to use these as reasons not to embrace and promote WC/WDM. A common trend of officials entrenched in the supply side management paradigm, is to always associate WC/WDM as one blanket initiative not recognising that it is a paradigm that can lead to a number of different initiatives. As with the supply side management you would not built all potential dams at once and you would prioritise their development. Similarly you would also identify and prioritise the type of WC/WDM measures that will have the most benefits. In the case of Gauteng and many other urban areas, it is obvious that the priority will be to focus on reducing non-revenue demand which is estimated to be higher than 30% of the total water demand.

Another common perception regarding WC/WDM is that WC/WDM will limit economic growth and negatively impact on the lifestyle of consumers. WC/WDM is considered by many as being a punitive and restrictive measure. A lot of the potential WC/WDM measures will result the opposite and can have positive impacts on the economy, the consumers and water supply industry. Besides the obvious benefits of reducing non-revenue demand consider the example of retrofitting plumbing fittings in a domestic and commercial environment. Such retrofits with technologically advanced products can reduce water consumption without affecting the quality of life or economic growth. In fact they can stimulate economic growth by providing business opportunities for the plumbing industry.

**Conclusion**

*The understanding of the role of WC/WDM is limited and often misinterpreted. To accelerate the process of introducing WC/WDM in the water supply industry, a more aggressive marketing programme must be adopted and implemented by the advocates of WC/WDM.*

## 5.4 Institutional challenges in the water service industry

Most will agree that the transformation in the institutional arrangements brought about by the new legislation framework will benefit the water industry and will go a long way in ensuring sustainable development. There are however still a few institutional related challenges which threaten the principles of IWRP and limit the opportunity of implementing WC/WDM that need to be resolved. Some of these are:

i. The relationship between the various institutions in the water supply chain

ii. The loss of expertise and slow capacity building of new personnel

iii. Inadequate regulatory environment for privatisation and concessions

5.4.1 The relationship between the various institutions in the water supply chain

There can be as many as six water institutions directly involved in the provision of water and sanitation services in the supply chain. These are depicted in the table below.

**Table 2:** Institutional role in the water supply chain

| | **Institution** | **Role** |
|---|---|---|
| **1** | **DWAF** | Development of water resources |
| | | Regulator |
| 2 | Catchment Management Agency (CMA) | Management of water resources |
| | | Allocation of water |
| 3 | Water Board | Abstraction, purification and supply of bulk water |
| | | Bulk waste water treatment services |
| 4 | Water Services authority | Key policy decision and accountable to government |
| 5 | Service provider A | Water service provider |
| **CUSTOMER** | | |
| 6 | Service provider B | Bulk waste water treatment |
| 7 | Water Services authority | Key policy decision and accountable to government |
| 8 | CMA | Management of effluent discharge into rivers |
| 7 | DWAF | Regulator |

Because there are so many institutions involved in the supply chain, there are often conflicting objectives that may ultimately restrict or even threaten effective, efficient and sustainable water services delivery. Some examples of these conflicting objectives are as follows:

i) Conflict between the Water Service Provider's objectives to increase profits and the need for WC/WDM.

ii) Difficulty in integrating planning between possible competing institutions (For example: Rand Water Board was competing in concession proposals with the company which won the management contract for Johannesburg Water.)

iii) Difficulty in integrating objectives due to the different area of supply by each institution. (For example the area of supply of a Water Board will be different to the area of supply of the CMA and will provide to a number of different Water Services Authorities.)

The biggest threat to sustainable development and IWRP due to the complexity of the supply chain, is the lack of adequate integration and co-operation that may exist between the various institutions.

**Conclusion:**

a) *The institutional arrangements of all water services providers should be reviewed and restructured if necessary, optimising bulk supply and distribution functions in terms of regional efficiency objectives.*

b) *Water Services authorities need to be more in control of the planning, operation and capital expenditure of a water services programme and should not allow the Water Service Provider to take complete ownership of such processes. By taking more control it will facilitate further integration of planning between other institutions in the supply chain and will alleviate potential competitive tensions.*

5.4.2 The loss of expertise and slow capacity building of new personnel

The institutional changes have seen a lot of expertise leaving the water supply industry resulting in significant gaps in the capacity of water institutions to perform their duties and meet the challenges of managing water services effectively and efficiently. There are also advantages in this transformation of personnel because it provides an opportunity to alter the management style which was previously technologically driven and lacked sound social, environmental and financial skills. There is also a lack of existing skills in the implementation of WC/WDM measures and the WC/WDM paradigm.

The lack of adequate capacity in water institutions is threatening the effective management in terms of economic, environmental, technical and social requirements that is ultimately having a direct impact on sustainable development and implementing the opportunities of WC/WDM.

**Conclusion**

*A comprehensive capacity building programme on effective and efficient management needs to be developed for all water related institutions.*

**5.4.3** Inadequate regulatory environment for concessions and privatisation

One of the objectives of the Water Services Act was to introduce the opportunities of privatisation and concessions in service provision. The motivation for privatisation was to inject much needed cash and to introduce more commercially orientated management into municipalities. Although the role of privatisation may not be disputed it is necessary to ensure that the profit motive of private institutions does not minimise the role of WC/WDM.

Private institutions are driven primarily by competitive forces. Without competitive forces however there is no incentive to minimise cost and private entities can increase their prices to meet profit targets rather than reduce costs. In the water service industry once there is a concession it is difficult for a consumer to change their service provider and it can be argued that the competitive forces do not exist. The key to effective and sustainable service delivery through privatisation and concessions is to develop strict performance criteria and a comprehensive regulatory framework. Such a framework does not exist in South Africa and although some legislation governing the relationship between Water Services Authorities and Service Providers exist, they are inadequate.

**Conclusion**

*Currently privatisation and concessions are seen as a positive step towards ensuring effective and efficient water service delivery. In the long term however privatisation and concession agreements could prove to be detrimental to WC/WDM and IWRP unless an adequate legislation framework is established to govern such agreements.*

## 6. THE ROLE OF WC/WDM IN MEETING THE WATER REQUIREMENTS FOR FUTURE GROWTH AND DEVELOPMENT

There are a number of methods to meet the water requirements for future growth and development. The following are some of the options identified in South Africa:

a) Water demand management and conservation
b) Surface water resource management (operation of dams) and conservation
c) Managing and use of groundwater
d) Re-use of water
e) Eradication of invading alien vegetation
f) Re-allocation of water
g) Development of surface water resources (e.g. dams)
h) Transfer of water

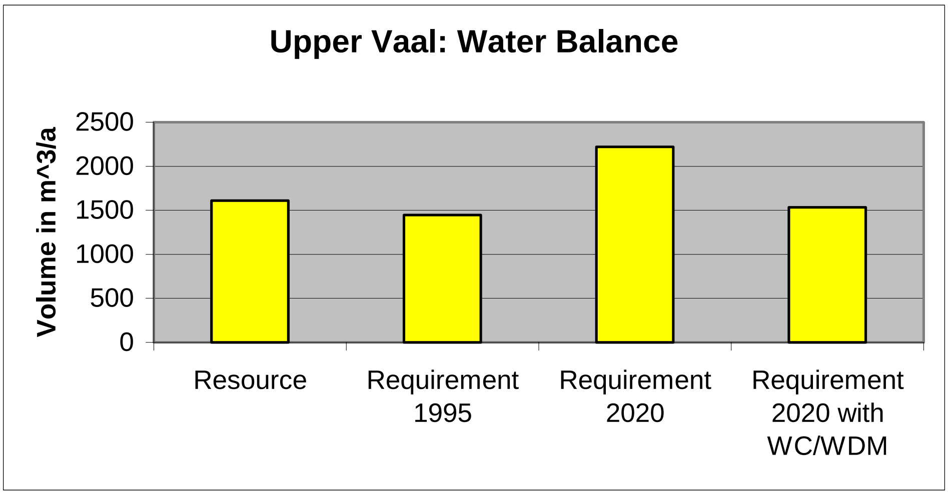
Although most of the above options can be evaluated using the traditional planning methods, the full appreciation of WC/WDM can only be recognised through an IWRP process whereby the planning parameters go beyond the scope of water resource considerations. It is estimated that WC/WDM measures is the most feasible solution to meeting the water requirements in the urban water sector. This was illustrated in the IWRP study carried out in the Western Cape whereby seven different WC/WDM measures were determined to be more feasible then any of the other options.

There are various potential scenarios of the role of WC/WDM in meeting the future water requirements for future growth and development depending on the outcome of an IWRP process within each basin and water supply system. Assuming that the full potential of WC/WDM in the water services sector is feasible, the opportunity of WC/WDM is to reduce the existing demand of water services by 40% without negatively affecting economic activity. Furthermore it is estimated that future growth in demand due to population growth (without the impact of AIDS) and economic activity can be reduced by an estimated amount of 30 % of the projected growth. Applying these estimates the projected water requirements in the following water basins have been estimated:

a) Upper Vaal WMA

   The Upper Vaal WMA supplies water to a large proportion of the Gauteng urban area. The urban water requirement is approximately 40 % of the total demand. Figure 3 below indicates that with out WC/WDM and assuming an estimate growth in demand for the urban sector of 3% per annum, the water requirements by 2020 will exceed available resources considerably. If the full potential of WC/WDM is achieved the water requirements by 2020 will however not exceed the current available water.

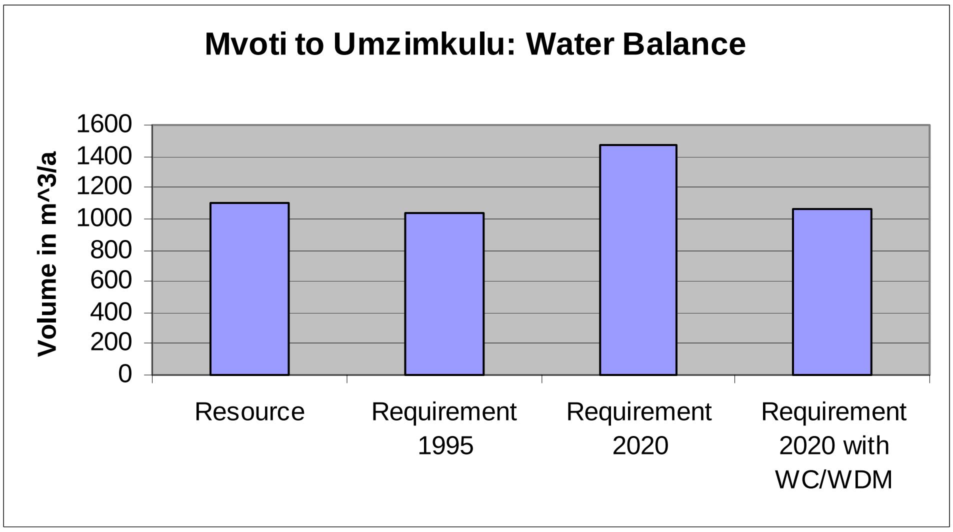
**Figure 3:** Upper Vaal Water Balance




b) Mvoti to Umzimkulu WMA

The Mvoti to Umzimkulu WMA supplies the Durban urban area in Kwazulu Natal. The urban water requirement is approximately 47 % of the total demand. Figure 4 below indicates that without WC/WDM and assuming an estimate growth in demand for the urban sector of 4 % per annum, the water requirements by 2020 will exceed available resources considerably. If the full potential of WC/WDM is achieved the water requirements by 2020 will however not exceed the current available water.

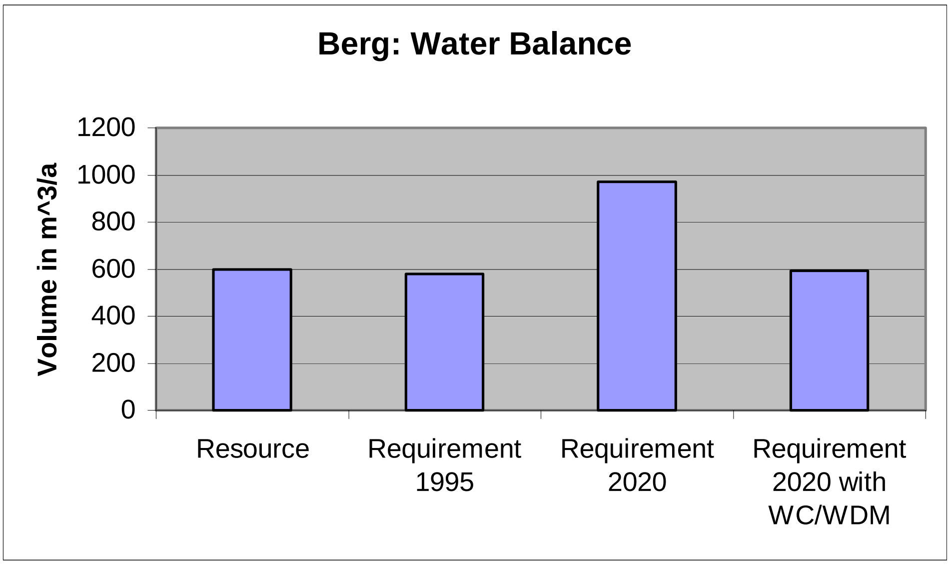
**Figure 4:** Mvoti to Umzimkulu Water Balance




c) Berg WMA

The Berg WMA supplies the Cape Town urban area. The urban water requirement is approximately 57 % of the total demand. Figure 5 below indicates that with out WC/WDM and assuming an estimate growth in demand for the urban sector of 4 % per annum, the water requirements by 2020 will exceed available resources considerably. If the full potential of WC/WDM is achieved the water requirements by 2020 will however not exceed the current available water.

**Figure 5:** Berg Water Balance




## 7. CONCLUSION

WC/WDM is often deemed negative, as being either restrictive or punitive and is therefore often regarded as a constraint or having a negative impact on economic development. The truth however is that if WC/WDM is determined and implemented through the principles of IWRP it can enhance economic efficiency and development and contribute significantly in meeting the water demands for future growth and development. It is estimated that water savings of up to 40% of the existing demand could be achieved and that WC/WDM could meet the future water requirements for more than 15 years.

There are significant challenges and constraints in the water industry that threaten the implementation of WC/WDM and adopting of an IWRP approach. Some of these gaps are as follows: Inadequate legislation/policies to ensure the sustainability of service provision projects and institutions; Inadequate institutional capacity; Lack of integration in the supply chain; A supply side management orientated service delivery industry.

South Africa has made some developments in the field of IWRP and WC/WDM but these needs to be intensified and institutionalised if the full potential of WC/WDM is to be realised.

Although there are still a few other but limited alternatives to meeting the water demand for future growth and development there is no doubt that currently WC/WDM remains an extremely viable option, if only an appropriate conducive framework of support exists and of greater importance, practitioners with the water industry adopt and embrace WC/WDM and IWRP.

## 8. ACKNOWLEDGEMENTS

I would like to express my most sincere gratitude and appreciation to my colleagues in DWAF particularly the Directorate of Water Use Efficiency ; my colleague and friend Mr. G Constantinides who has contributed significantly to the WC/WDM debate in South Africa, and this paper in particular.

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# THE USE OF SCIENTIFIC KNOWLEDGE IN THE DEVELOPMENT AND IMPLEMENTATION OF PUBLIC POLICY: EXPERIENCES WITH THE RIVER MURRAY ENVIRONMENTAL FLOWS ALLOCATION PROCESS SO FAR

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## INTRODUCTION

I believe that the type of scientific knowledge needed to inform public policy and water management varies over time, as the policy development and implementation 'journey' unfolds. Using environmental flows (e-flows) as an example, this 'journey' can be considered to have (at least) four key phases requiring scientific input:

Stage 1. Provision of evidence for degradation of river condition, and establishment of an environmental management need

Stage 2. Identification of probable causes(s) and agreement on possible management options (to inform policy development and, if required, legislation),

Stage 3. Negotiating and balancing social, economic and environmental needs and trade-offs to reach a final environmental flow allocation decision

Stage 4. Implementation of e-flow allocation, and measurement of ecological response (e.g. monitoring and assessment of river health)

The type of scientific knowledge that scientists must provide to governments and communities, and the manner in which it is communicated, varies depending on which phase of that decision making journey a scientist(s) is trying to inform and influence. In developing these ideas and arguments, I draw in particular on my experiences with the River Murray (Australia) environmental flows allocation process. The Murray is Australia's most economically significant river and its most 'iconic'. For the purposes of environmental flow policy development and implementation by the Murray-Darling Basin Ministerial Council, it includes the River Murray proper, and three major tributaries – the Goulburn, the Murrumbidgee and the Darling. These rivers, which together are over 5000 km in length, form the backbone of the expansive and profitable irrigation agricultural systems of the southern Murray-Darling Basin. All are part of the scientific, economic and social analyses being undertaken to decide on appropriate system-wide environmental flow allocations, and other river restoration investments.

**THE SCIENTIFIC KNOWLEDGE JOURNEY**

*Stage 1.* The first stage in any environmental public policy development is the establishment of a 'need' ie. a robust and convincing case for present environmental degradation or, in some cases, the very significant risk of future degradation. For the a river system such as the Murray, this requires provision of evidence of significant and on-going deterioration in river health. More often than not, river ecologists are instigators of this process. Curiosity driven research leads to development and communication of an evidence base that is intended to stimulate government acceptance and recognition of the need for a response. A point I will return to, is that river ecologists often take on the dual roles of scientific advisor and public environmental advocate during this needs establishment phase.

By and large the key role of objective science in the needs establishment phase is to provide quantitative **data and information** about the present ecological condition, and contrast it to historic (near) natural, or reference (present minimally impacted) condition. The aim is to establish a robust case for a declining trend in ecological condition, and support for the proposition that the current condition is ecologically unsustainable. Ideally, the scientific advice eventually will be formalised and reported through an agreed river health assessment framework. However, in the early days of needs establishment, it may be individual scientific publications that are tabled to provide a substantive 'body of evidence'. These may be reviewed and consolidated in a report by government scientists or consultants acting on behalf of government. Environmental NGO's may also use this scientific evidence to support their public and political lobbying.

Often included in this stage is the somewhat risky undertaking of environmental advocacy by the scientists involved. Their position may be stated thus "it is obvious from that data that there is a serious river health problem …..clearly, something must be done about it , no matter the cost". When I say this is a risky situation, I do not mean to imply that there is no legitimate opportunity for scientists to 'advertise' the seriousness of a particular environmental situation. Certainly many in the community will see scientists as legitimate "watch dogs" of environmental condition. But, it is important this watch-dog role is not confused in the minds of government and the public with the role the scientists may be playing in providing independent, objective evidence to community and government. Naiveté about the political realities of being involved in a debate as an advisor and advocate may lead to scientific advice being completely dismissed by government and stakeholder groups.

*Stage 2.* When a government decides to develop a policy, it is formally recognising a 'need' it has chosen to address. The policy will spell out, often only in broad terms, how it will respond to that need and allocate resources accordingly. For scientists, rather than talking about general issues of ecological trends and condition as in Stage 1, what is now required is advice on the reasons for the current unacceptable state. Hopefully, this advice will direct the response(s) that government might reasonably take to rectify the problematic situation. I say hopefully, because the history of science in informing major public policy issues in Australia is not glorious. In many cases, scientists are unable to agree on causes or the most practical and cost-effective means for addressing them. Production-focussed scientists tend to interpret environmental needs and appropriate responses in very different ways than ecologists. The public arguments that ensue may lead to the 'disengagement' of science and scientists from the policy development phase.

In Stage 2, rather than being providers of 'bare' data and facts about water quality and ecological condition, scientists must now provide **interpretive knowledge** about how key flow and non-flow drivers of the system have changed, and what their relative ecological significance is in the river management context. For the River Murray this interpretive knowledge was captured in a scientific 'Expert Panel' evaluation report to the Murray Darling Basin Commission (Thoms et al. 2000). The River Murray expert panel report detailed, on a reach by reach basis, the consensus scientific opinion on causes of degradation, including flow regime modification, habitat destruction, loss of connectivity, increased sediment and nutrient loads, introduction of exotic pests, *et al*. The information in the report was interpretive – based on review and synthesis of a myriad of published and unpublished papers and reports, combined with the personal experiences of the panel scientists.

The reliance on interpretation and synthesis by a panel of scientific experts has been a common step in Australian river management during the past two decades (see Cottingham et al. 2002a,b). By its nature, expert advice tends to reflect the personal values (particularly those relating to environmental protection) of those involved, as well as more value-free (objective) scientific thought. It also tends to be somewhat cryptic – without sitting down and talking to the experts face to face, it is hard to know exactly why certain conclusions may have been reached. The veracity and acceptability of expert opinion is largely predicated on the reputation, credibility and trust of the scientists involved. When scientists mix advice with advocacy, stakeholders may see their credibility as tarnished and be disinclined to trust their expert opinion, seeing it as "biased in favour of the environment".

*Stage 3.* Moving from policy development to resource allocation encompasses the key decision making phase of the process. Policies, by their nature, are general statements of government recognition of a need, and broad intention for response. They intentionally do not include specific details of how decisions will be reached eg. mechanisms for assessing environmental allocations, or how trade-offs will be reconciled. The likely effects of policy on individual and stakeholder group livelihoods are not always obvious during development. There may be a reasonable level of acceptance by irrigation farmers, for example, that a river is degraded and that some level of environmental flow allocation is needed. But it is a quite different proposition when a specific environmental flow allocation (perhaps large) is being considered, and the economic and social consequences of that become apparent. Consequently, scientific advice may be accepted without excessive critique in Stage 2 but this is unlikely to be the case during Stage 3.. In stage 3, stakeholder interest may be dramatically aroused, and the scrutiny of the scientific advice may rapidly expand. Certainly, this has been the case for the River Murray.

The key scientific tasks in Stage 3, are to, either, (i) predict the magnitude of the management response that is needed to bring about the target ecological response (river health condition), or (ii) (conversely) to predict the future ecological condition under a particular management scenario. Sometimes both are required, at different points in the decision-making process (this has been the case for the River Murray). In either case, the knowledge that is required in this decision phase is hence, **integrative and predictive** in nature. This is a challenge as river ecology is a comparatively immature branch of science, not rich in a basis for prediction, and especially not at a whole of river scale. The holistic paradigm of landscape ecology, and the predictive capabilities of river hydrology, are only just starting to influence freshwater ecology in Australia.

*Stage 4.* This is the action phase. The two key steps for scientists in this phase are: Step 1. Optimisation of the way in which the agreed environmental flow allocation will be implemented (bearing in mind practical constraints on distribution in large lowland rivers, or inter-annual effects such as droughts and floods, for example) This will require strong **modelling** knowledge and capacity, especially in river and floodplain hydrology. Step 2. When the optimised management actions (flow regime) is set in motion, monitoring is required to test the ecological response against that predicted. Strong **quantitative and statistical** knowledge is required to ensure the best monitoring programs are implemented, at the lowest possible costs. These must be based on testable hypotheses in relation to the management action, rather than on broad notions of river health.

Ideally, this is all done based on a sound understanding and acceptance of active adaptive management as an overarching principle.

**Case Study: Environmental flows allocation for the River Murray system, Australia**

How has all this worked so far in the River Murray environmental flows process? As noted above, in 2000 the first major report on threats to river condition was published (Thoms et al. 2000). Prior to that had been several government reports over two decades detailing a decline in numerous water quality parameters, in addition to numerous individual scientific research papers (perhaps best summarised in the book by Young et al. 2001). In 2001, the Ministerial Council of the Murray Darling Basin requested information on the flow regime required to deliver a 'healthy working river' Murray, according to a set of community-based ecological, economic and social objectives. Because there had not been good communication with the public during the 1990's – the needs establishment phase – the Council also requested a new report summarising all the scientific evidence for decline in river health for broader public distribution (Norris et al. 2001). This report was based on the framework adopted nationally for the National Land & Water Resources Audit (see www.nlwra.gov.au).

A subsequent report produced by a new scientific expert panel (Jones et al. 2002) adopted a simple risk based approach to the provision of environmental flows – it is summarised in table 1. The risk based approach adopted by the scientists was highly influential with managers and politicians. It was a paradigm familiar to them – risk management – and also avoided the (near-impossible) task in the time available, of specifying the exact flows required to achieve what was a vague set of river health objectives.

| **Key system level hydrological attributes (% of natural)** | **Probability of having a healthy working river** |
|---|---|
| ≥ two-thirds | **HIGH** |
| ≥ half | **MODERATE** |
| < half | **LOW** |

Caveats: The 'two/thirds natural' guidance level applies only to regulated and other impounded rivers. It is a target for river restoration, focussed on the River Murray, not a level for 'acceptable degradation' or 'sustainable diversion' of minimally impacted or wild rivers. The probability categories presume that the river offers suitable habitat and water quality for the growth and survival of native plants and animals. ~~As already noted, t~~The full benefits of environmental flow restoration will only be realised if river water quality, flood plain lands, and river habitat are also rehabilitated~~stored~~ or protected.

Table 1. Summary of simple risk based approach to environmental flows allocation for the River Murray (Jones et al. 2002)

Stage 3 – policy implementation - commenced in late 2002 and is ongoing at the time of writing . As it approaches the critical decision environmental flow allocation point in October 2004, the Ministerial Council is now asking for answers to a different question……" *what will be the ecological benefits , at both a whole of river and local scale that could be provided by* *additional flow volumes ranging from 350 through 750 to 1500 gigalitres, plus a range of structural (habitat) and operational improvements; and compare these with the current management scenario."*

To undertake this complex task, a new scientific reference panel (yet another!) considered a number of existing flow allocation assessment methodologies from Australia and around the world. These included the DRIFT Assessment Methodology developed by Jackie King and her colleagues in South Africa, Australia and elsewhere. The decision tool being used is a modified version of the environmental flow decision support system (EFDSS) developed by Bill Young and colleagues from CSIRO Australia in the late 1990s. It is now known as the Murray Flow Assessment Tool (MFAT). MFAT links modelled river and floodplain hydrological data with ecological conceptual models to provide a series of ecological habitat indices. It is less data intensive than DRIFT, and hence, less precise. But we expect to complete an assessment for the >5000 km of river length in less than 6 months, a task that would have been impossible using the DRIFT methodology. The interim panel report will be submitted in August 2003, and the final report in July 2004. Extensive public consultation will occur over the intervening twelve month period, leading up to the environmental flow allocation decision by the MDB Ministerial Council in October 2004. .

## SUMMARY

What, for me, have been the key learnings throughout this process?

1. In terms of how the scientific evidence is both developed and represented to all stakeholders, I think three T's are very important: **Talking**, and this means talking both amongst the scientists and scientists talking with the community; **Trust**, without trust even the best scientific advice in the world will not be accepted by stakeholders; and **Transparency** in the way the scientific information and knowledge is presented so that it is available for all to see and readily understand.

2. The laudable and necessary desire of scientists to provide independent and robust scientific advice does not abrogate responsibility for them to understand the socio-political context into which their advice is being provided. Scientists must understand the use their advice is being put to, and where the policy 'journey'is up to when they engage.

3. Most ecologists are 'problem definers' – they tend to answer questions through the formulation of more questions of ever increasing complexity. This can be a source of frustration for managers, politicians and the public. Of course, rivers are complex natural systems and providing specific answers to questions will always be very difficult. Nevertheless, ecologists need to do develop a culture of 'problem solving. This requires a certain type of leadership from whomever is given the responsibility of coordinating such (eg expert panel) approaches. Many times in the River Murray process, one of my greatest challenges has been to move some of the scientists involved from a sole focus on the problems that the system faced and why those problems had occurred, to a point where they can state how those problems might realistically be solved.

4. The comparative weakness of freshwater ecology as a predictive science is am impediment to it properly informing major public investment in river rehabilitation. This leads to an over-reliance on 'expert opinion' through processes that the public cannot easily scrutinise. As a leader of a large national river research organisation, I see the need to develop a strong ecological predictive capacity as a major strategic factor influencing our research direction for the next 5-10 years.

5. Another important learning, and probably one that it well known to scientific communicators already, is that the impact and acceptance by very senior government decision makers including federal and state ministers was heavily influenced by the supporting pictorial material that accompanied the expert panel technical report (Jones and Cartwright, 2002). Recognising the power of good pictures and good photographs ,in this case which show key aspects of river condition both now and in the future, was very powerful supporting the policy development and implementation journey. I suspect it will also be in supporting the decision making phase of this process between now and October 2004..

6. Finally, coming back to a point raised earlier, there is a very important need to separate scientific advice from advocacy. It is all too easy for environmental scientists, even the very best environmental scientists, to embed their views (albeit often unintentionally) about desirable ecological outcomes in the advice they are providing to government and the public. There is a very significant risk in doing this, of alienating key stakeholder groups and the public. Separating scientific advice from advocacy is critical.

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# THE ROLE OF ENVIRONMENTAL FLOWS IN WATER RESOURCES MANAGEMENT: PRINCIPLES, POLICY, DETERMINATION AND IMPLEMENTATION

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## INTRODUCTION

The era of “big development” of water resources is drawing to a close: the financial costs, and the often unforeseen long term social and environmental costs, both upstream and downstream, of large, engineered water resources developments are becoming prohibitive, while the potential for large new developments is becoming more limited as we reach the limits to utilization of currently available water resources which can be achieved with current technology. The emphasis has been gradually shifting to sustainable management of currently available water resources and rehabilitation of those that are degraded, supported by a recognition that water resources provide many more services than just water for abstraction: they also maintain varied livelihoods, many of which rely on the biochemical, biophysical and ecological processes occurring within aquatic systems, and they contribute to essential global and regional life support processes. The idea that water can have just as significant a value instream as offstream has been gaining ground in the last twenty years.

Internationally, water policy is shifting away from promoting offstream utilization of water to support economic development, towards achievement of a realistic and sustainable balance between the offstream and instream values of water. Allocation and water-sharing policies are shifting from allocation of the water itself towards allocation of the benefits or values of water, whether these be achieved through abstraction of water or maintenance of water within aquatic systems.

Many of the instream values of water are related to the provision of a suite of environmental goods and services which can be provided by healthy, functioning aquatic ecosystems. Maintenance of these goods and services at a particular level and quality is most dependent on the determination and delivery of water for aquatic ecosystems, in sufficient quantities, at the appropriate time, and with as close to natural a pattern as possible. Although other factors, including habitat degradation, pollution, invasion of alien species and over-exploitation by people, also influence the supply of goods and services from aquatic ecosystems, arguably it is the provision of adequate environmental flows which is the critical success factor in achieving sustainable management of aquatic systems.

## SUPPORTING POLICY FRAMEWORKS

The principles and policy frameworks for management of water resources on a whole-ecosystem basis have their bases in international initiatives such as Agenda 21, the World Commission on Dams, various UN conventions and treaties, and the World Summit on Sustainable Development. In many developing countries, the maintenance of natural aquatic ecosystem functions is often critical in supporting large numbers of people who are engaged in subsistence livelihoods, including subsistence agriculture, aquaculture and fisheries, which leads to an imperative to manage water resources as ecosystems. This is reflected in recent policy initiatives in several African countries (MacKay & Mutale, 2001).

To make water resources and water allocation decisions without considering the aquatic ecosystem and the environmental flows required to maintain the aquatic ecosystem is an approach which is deeply flawed. The report of the World Commission on Dams (WCD, 2000) has highlighted the need to determine and make provision for environmental water allocations, and to broaden cost-benefit studies to include all ecosystem goods and services.

National policy to support the allocation of water to meet environmental flow requirements, specifically to protect and maintain aquatic ecosystems, is fairly new in most countries where it has been implemented. Commonly the issue is addressed in environmental policy, legislation or regulation. However, experience is beginning to show that unless environmental flow requirements or water allocations for aquatic ecosystems are explicitly mentioned and given clear status in water policy and legislation, then although water requirements of aquatic ecosystems may be determined in the planning phase of water resources development projects and in environmental impact assessments, they are not likely to be implemented in practice. It is not sufficient to have the issue addressed only in environmental policy and legislation (MacKay et al. 2002).

## PRINCIPLES WHICH UNDERPIN THE CONCEPT OF ENVIRONMENTAL FLOWS

Aquatic ecosystems in southern Africa have become adapted to natural seasonal cycles and generally high inter-annual variability, and so are resilient to some degree. It is reasonable to assume that there is a relationship between the health status of an aquatic ecosystem and the abundance, variety and value of the goods and services which are provided by that aquatic ecosystem, in that a healthier aquatic ecosystem should be able to support a greater diversity or quantity of goods and services for humans. There has been ecological research directed towards quantifying the amount or flow of goods and services which are associated with different levels of aquatic ecosystem health, while recent research in the field of resource economics has been aimed at quantifying the value of those ecosystem goods and services in monetary currencies (Turpie, 1999). Thus the costs and benefits of managing aquatic ecosystems at different levels of ecological health can be assessed, and decisions about water utilisation can be made accordingly.

A healthy aquatic ecosystem is one in which the major ecological components of habitat and biota are present and all the major ecological processes are supported and functioning well. This includes natural processes such as decomposition and nutrient cycling, oxygenation and carbon sequestration, photosynthesis and primary production, grazing, predation and reproduction. An ecosystem does not have to be pristine to be healthy, although generally speaking the closer to natural a system is, the healthier it is likely to be.

In order to protect the health of an aquatic ecosystem, four components of the ecosystem must be addressed:

- a sufficient quantity of water must be provided, distributed in as close to natural a pattern as possible;
- water quality, including the physico-chemical and biological characteristics, must be maintained at appropriate levels to protect biota and their associated ecological processes;
- the character, extent and condition of instream and riparian habitat must be maintained, in order to provide sufficient habitat of a suitable quality to support viable biotic populations;

- the character, distribution and condition of biotic populations (fauna and flora) must be maintained, in order to maintain ecological processes which depend on these populations.

The overall health of the aquatic ecosystem will depend on the degree to which these four components are supported by water resources management and land management activities.

Measurement of ecosystem health is still a developing science, and many monitoring tools and techniques are now available which allow assessment of the health of an aquatic ecosystem in comparison to some reference condition (usually the natural, unimpacted condition) (Roux et al., 1999). Within the bounds of uncertainty, it is therefore possible to set quantitative objectives for aquatic ecosystem health, and then allow utilisation of water resources, such as abstraction and waste discharge, to the extent that the desired level of ecosystem health can still be maintained.

It is important to note that aquatic ecosystems are impacted directly, through consumptive uses of water resources, as well as indirectly through the effects of land use practices. It will not help to design and build a dam that can release sufficient water of the right quality at the right time to protect downstream aquatic ecosystems, if at the same time aquatic habitat is being degraded due to unsustainable land use practices, destruction of riparian vegetation, smothering by sediments as a result of catchment erosion, and loss of local species due to introduction of invasive alien plant and animal species.

## DETERMINATION

The determination of environmental flows remains a relatively new and still-growing science, requiring trans-disciplinary work between the engineering, earth sciences, life sciences, social and economic sciences.

There are two primary ways in which environmental flow requirements can be expressed:

- either as the amount and quality of water which must remain in a river, watercourse or water resource, at specific points in the water resource, in order to maintain a particular desired level of aquatic ecosystem health, or
- as the amount of water which may be abstracted from specific points in a river, watercourse or water resource and the magnitude of change in water quality which may be allowed in a river, watercourse or water resource, in order for aquatic ecosystem health to be maintained at a particular desired level.

In general, environmental flow requirements are expressed in relative terms, as the proportion of the virgin or present-day flow which must be maintained, or the proportion of virgin or present-day flow which may be abstracted, and the allowable deviation from natural or background water quality conditions. Although the aim in both cases is the same, i.e. to protect aquatic ecosystems and maintain a certain desired level of aquatic ecosystem health, the scientific process of determination may be slightly different depending on the approach that is taken.

In determination of environmental flow requirements, it is necessary to select quantitative, verifiable management endpoints towards which the ecosystem is managed. An endpoint usually represents a particular desired level of ecosystem health, expressed in terms of the water quantity, water quality, habitat conditions and biotic conditions required to meet that level. An environmental flow requirements would then be set which would achieve these endpoints.

For reasons of scale and resolution, the endpoints for management are generally habitat-related and expressed at the river reach level (DWAF, 1999). Since patterns of flow and water quality vary between headwaters and downstream reaches, it is not appropriate to set environmental flow requirements as a "single number" (such as the percentage of mean annual runoff) which applies throughout a river basin. The basin must be divided into representative reaches, each of which would require a separate determination and specification of the environmental flow requirements.

To be useful in developing operational rules for a river basin, any method for determination of environmental flow requirements must address the magnitude, timing, frequency and duration of flows, and must indicate both intra-annual and inter-annual variability. Generally, the ecologically important flows are (King et al. 2001):

- "maintenance" dry season low flows, which maintain ecological processes and critical habitats and refuges for biota during the low-flow season;
- wet season low flows, which maintain important wet-season ecological processes and habitats;
- intra-annual floods or freshets, which are often triggers for ecological processes such as spawning and migration, and which flush out poor quality water and small debris which may accumulate during the dry season;
- larger floods, which maintain channel geomorphological characteristics, flush out accumulated sediment and re-shape the cross-section of the watercourse.

Freshets and inter-annual floods play an important role in moving and distributing sediment in a river course or water resource. The geomorphological habitat is formed through a complex interaction between water and sediment. This interaction has its origins in sediment delivery mechanisms from the land surface of the catchment to the river, which are influenced by topography, soil characteristics, rainfall characteristics and land uses. Depending on what is happening on the land surface, and what the instream flow regime is, sediments can accumulate in certain places in the aquatic ecosystem and be lost from others, thus changing the balance between different types of habitat. The environmental flow requirements determination takes into account this interaction between sediment and water by requiring geomorphological studies to be conducted, the results of which are used to predict the outcome of certain modified flow regimes as regards sediment distribution, gains and losses in the aquatic ecosystem, and the subsequent impacts on availability of instream habitat.

## IMPLEMENTATION

While the scientific basis for determination of environmental flows is more or less agreed within the international scientific community, many issues remain to be addressed in the implementation of environmental flows. These range from political will, through inclusion of environmental flows in decision making and regulatory processes around water allocation, to the highly practical issues of delivery of pre-determined environmental flows, which can be especially challenging in unregulated river systems. A brief overview of some of the more technical aspects of implementation follows.

### (a) Dams, weirs and flow control structures

Most dams, weirs and flow control structures are built to store and deliver water to places where water is not usually found in one season or another, for example to provide water for dry-season irrigation. The resulting flow regime is thus often very artificial, and can have severe impacts on the downstream aquatic ecosystem. In the design phase of large dams, it is necessary to determine the environmental flow requirements, particularly the peak flood flow rates, in order to ensure that the dam can deliver the required flows at the required times. If the outlet structures are too small, the important flushing and scouring floods cannot be released, and this may lead to substantial changes in habitat downstream, including sedimentation and reed encroachment. If normal daily flow releases are too high, serious erosion of downstream habitat, changes in banks and incision of the river channel may result.

Large dams also cause significant changes in water quality downstream, especially when the water column becomes stratified in the reservoir behind the dam. If water is released from the bottom layers of a stratified reservoir, the resulting outflow is likely to be much colder than the surface waters and will probably have a low dissolved oxygen. These factors can cause severe mortality of biota in the downstream ecosystem. Many large dams are now designed to incorporate variable-level outflow structures so that water can be released from any chosen depth in the reservoir, depending on the downstream water conditions. Operating rules need to address this aspect of water quality, providing for monitoring of water quality at various depths in the reservoir and in the river downstream, in order to select the correct release scenario.

Dams and weirs also trap sediment and nutrients, leading to deficit of these in the downstream ecosystem. This may affect habitat, through net erosion downstream, and ecological processes through a lack of nutrients to support primary production. It is possible to design dams that can bypass some sediment, although the costs of construction will be increased.

Dams and weirs form physical barriers for most migratory species, which can lead to losses of key species if they are unable to migrate to and from breeding and spawning areas. Any dams and weirs should be designed to incorporate appropriate fish ladders or equivalent structures to enable the passage of migratory species.

Once environmental flow requirements have been converted into daily operating rules for a dam or for a river basin, there is a need to ensure that the required flows are delivered to the downstream ecosystem in a pattern that is as close to natural as possible. If river flows upstream of the dam rise due to a rainfall event, then the flow releases from the dam to meet the environmental flow requirements should be timed to coincide with this rise. Usually this will require real-time monitoring of river flows at a site upstream of the dam where the flow pattern is reasonably natural.

Similarly, if a natural drought occurs, then the environmental flow requirements during the drought period should be adjusted downwards in order to ensure that the downstream ecosystem also experiences drought conditions. A determination of environmental flow requirements usually includes flow specifications for maintenance conditions (i.e. normal rainfall years) as well as drought conditions. The natural stresses associated with drought conditions are necessary to maintain the health and resilience of the downstream ecosystem. However, once the natural drought has passed, instream flows should be returned to maintenance levels. Artificial prolonging of drought conditions can result in severe, irreversible changes to an aquatic ecosystem, particularly when a naturally perennial river is forced into a seasonal flow regime or a seasonal river into an episodic or ephemeral regime.

### (b) Managing run of river abstraction

Implementing environmental flow requirements can be especially challenging in an unregulated river basin where most abstraction is run-of-river. There may be little or no opportunity to compensate for abstraction by making dedicated releases from a dam for the downstream ecosystem. In this case, abstraction has to be managed, controlled and monitored in order to ensure that the environmental flow requirements are met.

Control options include metering of abstractions, and limitations on pump capacities or pipe diameters. While this may be practical in the case of large commercial water users, it may be extremely difficult for small-scale or subsistence uses of water. Yet if population density is high, the sum of many small-scale abstractions can represent a significant removal of water from the system, possibly compromising the environmental flow requirements. Water tariffs can be applied to encourage reduction in water use or more efficient water use, but awareness creation and education of water users are generally more effective in promoting understanding and support for the environmental flow requirements.

Customary law or water-sharing practices may provide important mechanisms for gaining and maintaining community buy-in to implementation of environmental flow requirements, since such customary practices have often been developed over long periods of time to suit local socio-economic and environmental conditions (MacKay et al., 2002).

**(c) Groundwater abstraction and baseflow**

In many perennial rivers, dry-season flows may be maintained largely or solely by inflows from groundwater or from the water stored in the soils of river banks. Excessive abstraction of groundwater via wells or boreholes in the riparian zone or close to a river may cause dry-season flows in the river (known as baseflows) to be reduced or to stop altogether.

In determination of the environmental flow requirements, some indication should be provided as to how much abstraction of groundwater can be allowed in the riparian zone or near the river without compromising baseflow in the river. There are techniques available to determine the contribution of groundwater to baseflow in a river: the simplest is hydrograph separation, a form of analysis of hydrological time series data; if higher confidence or resolution is required, then it may be necessary to carry out a geohydrological survey when the field ecology studies for the environmental flow requirements determination are conducted.

This issue will be particularly relevant in the Okavango River basin, since there is a strong and complex link between surface water and subsurface water, and uncontrolled abstraction of groundwater from aquifers that are near to or in hydraulic connectivity with surface waters could lead to significant changes in surface water flow and chemistry (McCarthy et al., 1991; McCarthy et al., 1993). The total allowable abstraction from the Okavango basin should be expressed in terms of the allowable groundwater abstraction from certain delineated aquifers as well as the allowable surface water abstraction from specific points in the system.

**(d) Tributary management and offstream storage**

Efficient and effective implementation of environmental flow requirements requires integrated planning at the river basin level. The siting of dams, weirs and flow control structures relative to the main stem of the river must be considered. Large dams on the main stem of a river generally have a more significant impact on downstream ecosystems than do smaller dams on tributaries. A recent trend internationally has been to discourage the building of large dams on the main stem of a river in favour of offstream storage reservoirs and smaller dams on tributaries.

The impacts of dams and weirs in a river basin can be mitigated to a degree if key tributaries are maintained in a relatively undeveloped condition. The flow contributions from these tributaries help to maintain a more natural flow regime in the main stem of the river. In addition, the undeveloped tributaries provide important ecological refuge areas, from which the main stem ecosystem can be repopulated in the event of loss of species due to natural disasters or accidents. An environmental flow requirements determination, if carried out at river basin scale, should address these issues and identify the key tributaries which should be protected and on which development should be limited.

## CONCLUDING REMARKS

The issue of determination and allocation of water for maintenance of ecosystem functions, particularly downstream of large water resource developments or in basins where offstream demand for water is high, remains fraught with politics, emotions and controversy.

Transparency in decision-making, whether it be in policy, in the process of determination of environmental flow requirements, or in the allocation of water to users in the subsequent implementation of environmental flows, remains the single most important criterion for success.

Other key aspects which must be addressed include:

- The need to keep the issue and the procedures as simple as possible;
- The need to demonstrate benefits as early as possible in order to ensure continued political and public support for environmental flow allocations;
- The need to build in flexibility to determinations of environmental flow requirements, in order to be able to review and refine determinations once more knowledge about the ecosystem becomes available.

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# MOVING TOWARD SYSTEMS UNDERSTANDING OF INTEGRATED WATER CYCLE MANAGEMENT

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***Abstract***

*The urban water cycle is currently managed as separate centralized water supply, wastewater and stormwater disposal processes that have endured for over 100 years. This paper discusses technical and institutional aspects of the integration of decentralised approaches into current approaches for urban water cycle management using rainwater tanks as an example. The efficacy of the current approaches to understanding decentralised water demand and supply management approaches is questioned. It is argued that a systems approach is required to understand and hence find optimum solutions for urban water cycle management that includes decentralised approaches used to supplement to current centralised management methods.*

## 1. INTRODUCTION

Integrated water management involves the incorporation of decentralised approaches to urban water management that includes use of rainwater and treated wastewater and demand management measures in domestic dwellings with centralised water supply, stormwater and wastewater disposal techniques [Coombes and Kuczera, 2002].

This paper discusses technical and institutional aspects of the integration of decentralised approaches into current approaches for urban water cycle management. The discussion is conducted using an example with 5 kL rainwater tanks used to supplement mains water supplies for hot water, laundry, toilet and outdoor uses. The efficacy of the current approaches to understanding decentralised water demand and supply management approaches is examined.

The philosophies for supply of water, and wastewater and stormwater disposal have remained largely unchanged over the last 120 years [Troy, 2001]. We are of the view that the Australian paradigm for urban water cycle management has compartmentalised the cycle into the provision of water supply, wastewater and stormwater services.

It is our contention that the current urban water cycle paradigm has resulted in sub-optimal outcomes for both the community and the environment. In this paper we document evidence of how the paradigm has failed us. We demonstrate that outcomes currently provided by the water industry in major urban areas can be unambiguously improved upon. We argue that it is not technology that restrains us but rather our understanding of the systems impacts of alternative technologies, including perception of system boundaries and constraints that clouds our vision of what is possible. Ultimately the adoption of integrated urban water cycle management approaches will allow provision of sustainable water services to the community.

## 2. THE URBAN WATER CYCLE AND SOURCE CONTROL

The urban water cycle starts with water extracted from streams and aquifers, stored in reservoirs and then processed to potable quality before delivery through an extensive pipe system to urban allotments. Some of this water is then used to transport wastes through a network of sewers to treatment plants which discharge effluent into receiving waters such as rivers, lakes and oceans. Rainfall falling on the urban allotment contributes to the urban catchment's stormwater that is collected by an extensive drainage system for disposal into receiving waters. A schematic of the urban water cycle is presented in Figure 1.

The management of water at the allotment scale is referred to as source control. The philosophy of source control is to minimize cost-effectively the consumption of mains water and the production of storm and wastewater. Source control can be implemented through retention of rainfall runoff from roofs in rainwater tanks, stormwater detention, on-site treatment of greywater (laundry, bathroom and kitchen) and blackwater (toilet), use of water efficient appliances and practices, on-site infiltration and aquifer recharge/recovery.

Some of these source control technologies have seen wide adoption, for example, the use of water efficient appliances and the growing requirement for stormwater detention in new urban development and redevelopment of existing areas. However, other source control technologies such as use of rainwater tanks and on-site infiltration have historically seen limited usage particularly in the major urban centres on the east coast of Australia. In recent times there has been a greater use of rainwater tanks in Australia's major cities due to renewed community focus on water conservation, adoption of source control approaches for stormwater management and the current drought.

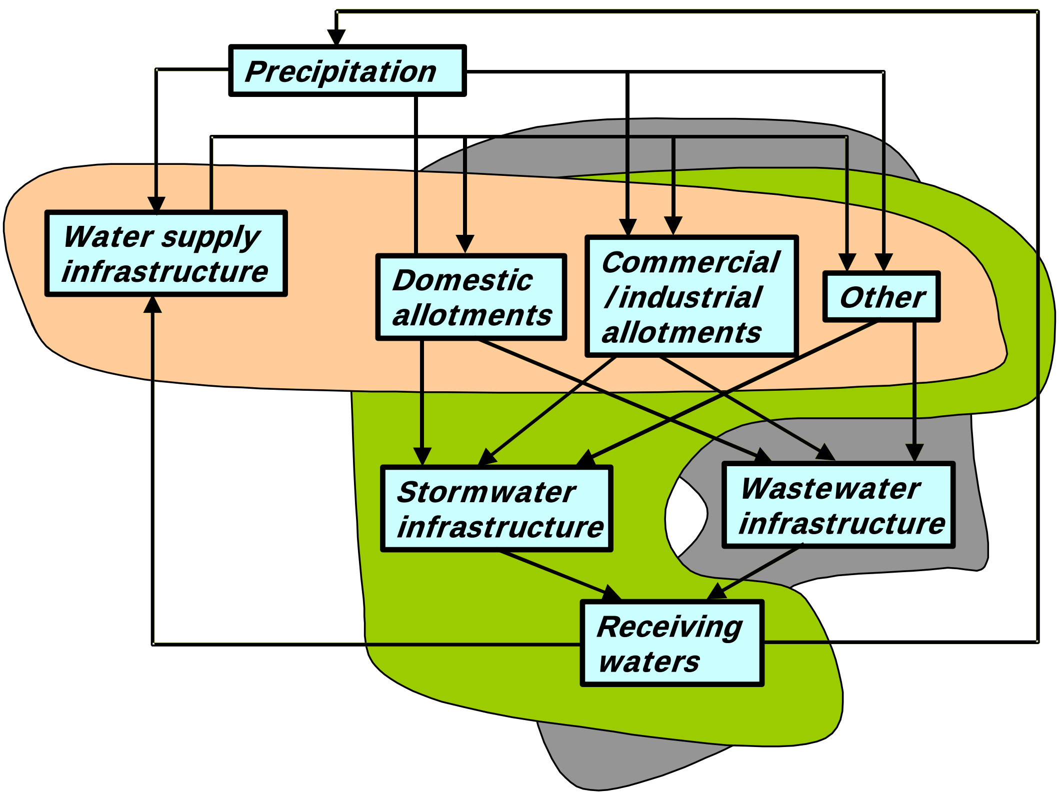


**Figure 1**: Schematic of urban water cycle depicting sub-system spheres of influences

Figure 1 shows the boundaries of the sub-systems responsible for water supply, stormwater and wastewater disposal. Interestingly, all three sub-systems intersect at the allotment where source control measures can be implemented. Source control measures (such as rainwater tanks) typically impact on more than one of the sub-systems. Consequently separate management of the sub-systems often obscures the benefits to the entire urban water cycle that can be derived from the use of a source control measure. Similarly resistance to the use of a source control measure by the manager of one sub-system can deprive the remaining sub-systems of benefits. The rainwater tank used on urban allotments is an excellent example of this.

Kuczera and Coombes [2001], and Coombes and Kuczera [2002] argued that a systems analysis of the use of source control measures, in particular, rainwater tanks, as part of the combined stormwater management and water supply systems is required to understand their impact on the urban water cycle. They further argued that institutionalised management of the urban water cycle as separate sub-systems has limited the scope of water cycle solutions depriving the community of substantial environmental and economic benefits that derive from the use of source control measures. Systems analysis of the urban water cycle is therefore required to examine the benefits of the use of source control measures at the allotment, subdivision and regional scales.

## 3. THE CONSTRAINED PARETO FRONTIER

The water supply, sewage disposal and stormwater management industries have historically only considered a limited set of solutions for water supply and stormwater management. Indeed stormwater, sewage and water supply solutions are typically considered separately. Many authors including Clarke [1992], Gippel [1988], Mitchell et al. [1997; 2002] and Coombes et al. [2000, 2002; 2003; 2003a] have shown that the use of rainwater tanks provided greater benefits to the community than the traditional water supply and stormwater management options. Yet, historically, the stormwater management and water supply paradigms have excluded the use of rainwater tanks as a solution. Traditional solutions for water supply, sewage disposal and stormwater management are selected from an artificially limited set of separate technical solutions that form a constrained solution space. To illustrate the significance of constrained solutions consider the example in Figure 2.

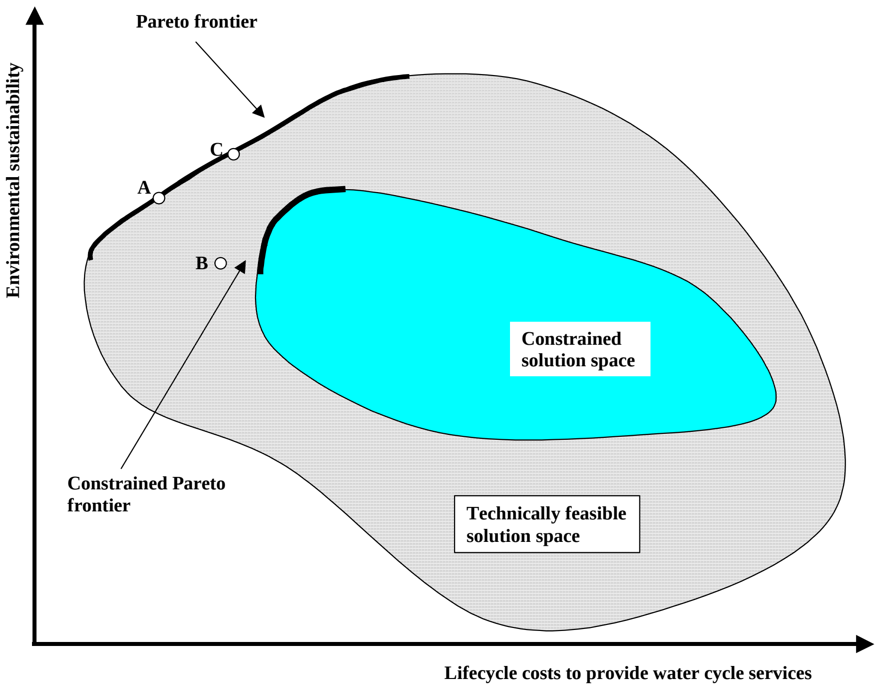


**Figure 2:** Conceptualisation of the constrained Pareto Frontier.

To keep our example manageable we start with the premise that the community requires the provision of urban water cycle services to a certain standard. For example, the urban community may require that water supply services are secure during all but the severest drought and the provision of potable water at an acceptable pressure. The community may require that stormwater be managed so that frequent nuisance flooding is avoided and damage in major flood events is mitigated. There are many ways that water cycle services can be provided at the required level of service. To rationally choose between competing options, the community may decide that these services be provided in a way that trades-off two objectives, minimise community lifecycle costs and maximise the sustainability of the ecosystems that underpin the water cycle services.

The light grey region in Figure 2 represents the performance outcomes of all technically feasible solutions that provide water cycle services to a certain standard. The Pareto frontier describes the solutions that the community should carefully examine in order to arrive at a preferred solution. Solutions that do not lie on the Pareto Frontier are unambiguously inferior. For example, solution A has lower lifecycle costs and better sustainability than solution B. No rational person would prefer B to A unless there are other objectives not articulated in the analysis. On the other hand, one cannot argue that solution A is better than solution C. Although A has lower lifecycle costs than C it has worse environmental performance. The community must examine the trade-off between A and C and in doing so implicitly value sustainability in monetary terms.

The darker grey region in Figure 2 represents a constrained technically feasible solution space which is a subset of the technically feasible solution space. The constrained space may arise because of institutional constraints that limit or prohibit implementation of alternative feasible solutions (such as rainwater tanks) or may arise because it is believed that the alternative solutions are not feasible.

The price paid for artificially constraining the solution space can be considerable. In Figure 2 the constrained Pareto Frontier is unambiguously inferior to some solutions on the unconstrained Pareto Frontier. For example, solution C produces lower lifecycle costs and a more sustainable outcome than any solution in the constrained space. Removing the "artificial" constraints on solutions will produce a more beneficial outcome for the community.

One of the major contributions of this paper is to show that the operation of the traditional water supply and stormwater management paradigms produces a constrained Pareto Frontier resulting in sub-optimal economic and environmental outcomes for the community. It is argued that the use of rainwater tanks can provide greater economic benefits to the community and reduced environmental impacts in comparison to the traditional water supply and stormwater management options. Yet, historically, the current urban water cycle paradigm has effectively excluded this solution from consideration.

## 4. DESIGN OF A RAINWATER TANK FOR DUAL WATER SUPPLY

Coombes and Kuczera [2001] developed a design for small rainwater tanks with mains water trickle top up, connected to residential dwellings in urban areas that will maximise water savings and stormwater management benefits. The required capacity will depend on number of persons in the household, water use, rainfall and roof area. Design of the dual water supply scheme (Figure 3) should make provision for:

- a minimum storage volume to ensure that water supply is always available
- a rainwater storage volume and
- an air space for additional stormwater management.

The minimum storage volume is the maximum daily water use that is expected from the tank (about 250 -750 litres). If the volume of stored water falls below the minimum storage volume, the shortfall can be overcome by topping up the tank with mains water to the required level. A simple float valve system can be installed to do this automatically.

The rainwater storage volume is the total volume available in the tank to store rainwater below the overflow pipe. The air space between the overflow pipe and the top of the tank can be used to provide 'stormwater detention', thereby delaying the delivery of excess roof water to the drainage system. The rainwater storage volume and the overlying air space both provide stormwater management benefits providing both retention and detention of roof runoff.

The configuration of plumbing required for rainwater tanks is shown in Figure 3. Water supply from the rainwater tank (such as for outdoor, toilet, laundry or hot water uses) is directed to the household via a small pump. When tank water levels are low, such as during hot, dry periods, the tank is topped up with mains water via a trickle system. The trickle top up system will reduce the daily peak demand on the mains water distribution network. In the event of pump or power failure the rainwater tank can be bypassed.

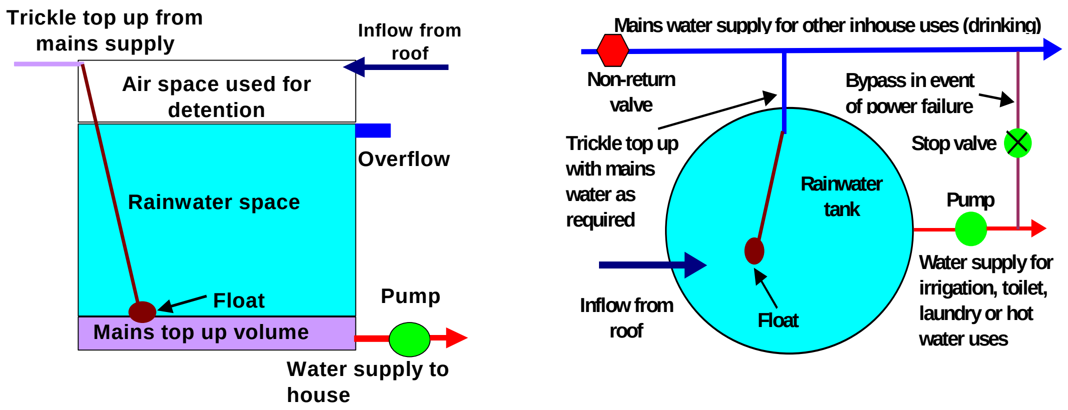


**Figure 3**: design details for a dual water supply system using rainwater and mains water

The airspace between the overflow pipe and the top of the tank also virtually eliminates the potential for backflow of rainwater into the mains water system in the event of a pressure loss in the mains water system. To further minimise the risk of cross connection between mains water and rainwater, the pipes from the tank are plumbed directly to appliances that are to use rainwater.

## 5. REGIONAL IMPACTS OF THE USE OF RAINWATER TANKS

Rainwater collected from roofs and stored in tanks to supplement mains water supplies for domestic consumption was shown by Coombes et al. [2002; 2002a] and Mitchell et al. [1997; 2002] to significantly reduce household mains water use. Importantly Coombes et al. [2000] and Spinks et al. [2003, 2003a] found that the quality of water supply from rainwater tanks was acceptable for hot water, toilet, laundry and outdoor uses. Coombes et al. [2002] found that the use of rainwater tanks will defer the requirement to augment the Lower Hunter and Central Coast water supply headworks systems by 28-100 years. In addition Coombes et al. [2003] showed that the use of 5 kL rainwater tank in the Greater Sydney region to supplement mains water supply for hot water, toilet, laundry and outdoor uses would defer the requirement for a new dam by up to 84 years.

Domestic above ground rainwater tanks were also shown by Coombes [2002] and Coombes et al. [2003; 2003a 2000] to reduce frequent stormwater discharges from urban catchments resulting in improved urban stormwater quality and decreased flood risks. The requirement for stormwater infrastructure was also reduced resulting in construction, depreciation and maintenance cost savings.

Given these significant results, it is important to provide a process-based explanation of why rainwater tanks can defer major infrastructure for the provision of urban water cycle services. Until recent times it was commonly assumed that rainwater tanks were of little benefit to the community because during drought the rainwater tank is empty and the consumer is totally reliant on mains water. This wisdom appears to be based more on belief than fact. There are a number of “hidden” processes by which rainwater tanks significantly reduce impact on water supply headworks systems. These are described below.

It is true that during drought major urban water supply systems rely on water storages. For example on the east coast of Australia droughts represent extended periods of below average rainfall. In the last 150 or so years the annual rainfall at Sydney’s Observatory Hill has dipped a few times to between 600 to 700 mm. Figure 4 presents a schematic comparing the efficiency of a water supply catchment and a roofed catchment feeding a rainwater tank.

Plots of annual runoff against annual rainfall for water supply catchments typically display a threshold effect. Once annual rainfall falls below about 500 mm annual runoff in water supply catchments is insignificant. In such years evapotranspiration and infiltration accounts for virtually all of the rainfall and the water supply system is almost totally dependent on water stored from more bountiful years. In contrast the roofed catchment, being impervious, only experiences a small loss at the commencement of each rain event. In addition, urban areas such as Sydney and the Central Coast in NSW typically receive more rainfall than water supply catchments. As a result, a rainwater tank can harvest significant volumes of water even during drought years.

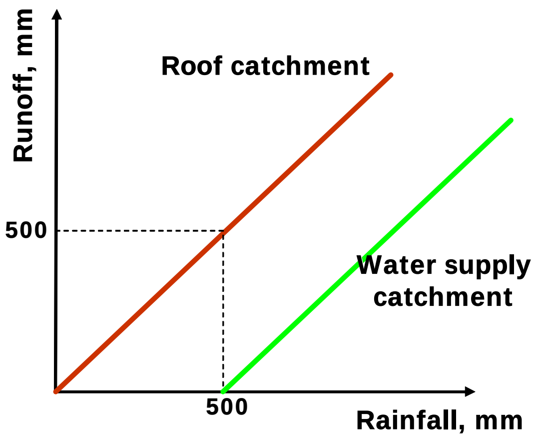


**Figure 4:** Harvest efficiencies of natural and roofed catchments.

Conventional wisdom assumes that rainwater tanks in urban areas only provide water for outdoor uses such as garden watering. As a result, the tank is only utilised during the growing season. If, however, the tank is used for toilet flushing, laundry and hot water, which represent a significant fraction (about 85%) of indoor usage, the tank is constantly being drawn down. This has two unexpected benefits. First, for small storm events much of the potential runoff is captured by the tank – that is why use of the rainwater tanks produces considerable reduction in stormwater runoff for small ARI storm events. Second, because toilet flushing, laundry water and hot water are sourced from the rainwater tank, the base load on the mains water system is reduced. As a result, reservoirs will fill more rapidly during periods of good streamflow. In headworks systems with over-year storage capacity, the reduction in base water demand provides a buffer against the effects of droughts and growth in water demand due to population growth.

## 6. WATER QUALITY FROM RAINWATER TANKS

There are many misconceptions about the quality of water from rainwater tanks. The early debate about the quality of water from domestic rainwater storages was propagated for economic reasons. Troy [2001], Armstrong [1967] and Lloyd et al. [1992] explain that early Australian water authorities were in debt. Acts of Parliament were created in the 1800s requiring the occupiers of all properties to pay for mains water supply even if they did not use it to ensure that government debt was repaid. The reluctance of the community to part with their rainwater storages had threatened the economic viability of the new centralised water supply paradigm. The legislated mandatory fixed charges ensured that citizens used mains water in preference to household rainwater tanks.

The arguments predominately used to discourage the use of rainwater are based on public health concerns although very few published studies or data are in existence to justify this position. Indeed over 3 Million Australians currently use rainwater from tanks for drinking [ABS, 1994] in urban and rural regions with no reported epidemics or wide spread adverse health effects. Fuller et al. [1981] and Mobbs et al. [1998] found that the quality of tank water was often adequate for potable uses. Note that Heyworth [2001] concluded, after an epidemiological investigation using 1000 participants, that people drinking chlorinated filtered mains water reported higher rates of gastrointestinal sickness than people drinking roof runoff collected in rainwater tanks.

Coombes et al. [2000; 2000a; 2002] reported that that rainwater collected from roofs in an inner city industrial area and stored in tanks was of acceptable quality for hot water, toilet and outdoor uses. Although roof runoff and the surface of stored water was sometimes found to be contaminated, the quality of water at the point of supply in rainwater tanks was significantly improved. Rainwater used in storage hot water systems (temperature settings: 50ºC to 65ºC) and instantaneous hot water systems (temperature setting: 55ºC) was found to be compliant with Australian Drinking Water Guidelines [Coombes et al., 2000a; 2002]. Spinks et al. [2003] confirmed that *E. Coli* and selected pathogens are rapidly eliminated from water heated to temperatures above 55°C by the processes of heat shock and pasteurisation. Note that Australian standard ASNZ2500.2.4 requires that hot water systems be set to heat water to 60°C to eliminate *Legionella Spp.* from mains water.

## 7. SYSTEMS ISSUES

The inclusion of decentralised solutions for management of the urban water cycle that are spatially distributed throughout urban catchments poses a new set of challenges to water resource planners. The effectiveness of decentralised approaches on managing the urban water cycle will be influenced by local conditions that can produce variable impacts on regional water demand, sewage and stormwater discharges. This section discusses the importance of accounting for spatially variable response of decentralised measures to manage the urban water cycle. The use of “average” responses, as is current practice, can introduce significant bias.

### 7.1 Water Balance Modelling

Source control strategies at the allotment scale can significantly reduce mains water demand on the headworks system, downstream stormwater impacts and reduce wastewater discharged into sewerage systems for treatment at centralised facilities. Coombes and Kuczera [2001] developed the PURRS (Probabilistic Urban Rainwater and wastewater Reuse Simulator) model to enable a detailed simulation of the household and cluster water balance allowing ultimate evaluation of the impact of various source control strategies on larger scale water cycle systems.

The model, shown in Figure 5, comprehensively simulates the allotment scale water supply, demand management, stormwater and wastewater dynamics. It employs continuous simulation using rainfall from pluviograph records or a stochastic rainfall model. Time steps are selected within the model to match the dynamics of the water balance. During storm events sub-minute time steps are required to adequately simulate the dynamics of the rainwater tanks and other stormwater source control measures. Note that the use of daily time steps in conjunction with average water demands can introduce appreciable bias and will not allow understanding of the impact of source control measures on the provision of urban water cycle infrastructure which is designed using peak demands and discharges. A novel feature of PURRS is the model of indoor and outdoor consumption. Outdoor consumption is highly variable and depends on the householder's perception of water stress experienced by lawns and gardens - PURRS uses a probabilistic behavioural model to describe these dynamics [Coombes et al., 2000c].

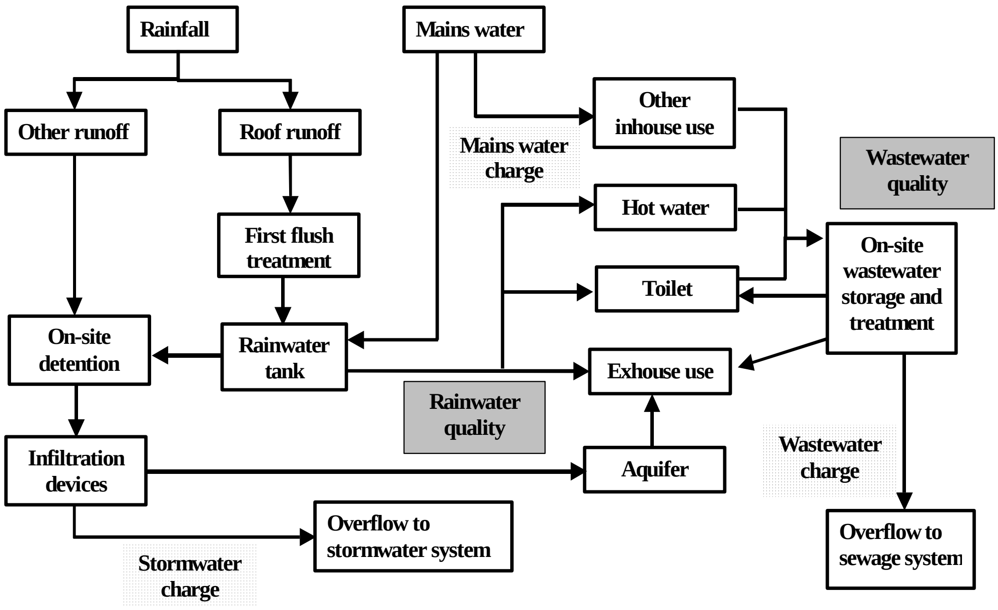


**Figure 5:** Schematic of PURRS allotment water cycle simulation model.

### *7.1.1 Household Water Demand*

Domestic outdoor water use such as garden watering, car washing and filling of swimming pools was seen by Coombes et al. [2000c] to be a recreational pastime that is dependant on human behaviour. It was hypothesized that outdoor water use behaviour is significantly modified by human reaction to daily temperature, days without rainfall and rainfall depth. Indoor water use was considered to be relatively constant. Coombes et al. [2000c] found that the probability of outdoor water use is expected to increase as the length of a period without rainfall increases and the volume of water used is a function of temperature and normal water use patterns. People are more likely to use water outside of the house when it is hot and dry, and in accordance with habits.

During a day with rainfall there is a smaller probability of water use and the volume of water used is dependent on the rainfall depth. There is a chance of outdoor water use when people perceive rainfall depth to be insignificant and, conversely, when rainfall depth is perceived to be large there will be no outdoor water use. When that rainfall depth is sufficiently high, people may not use water outside of the house for a number of days. This probabilistic climatic approach to simulating urban water demand at the allotment scale has significantly improved the reliability of simulating outdoor water demand ($R^2$ = 0.49 – 0.67) in comparison to traditional models currently in use ($R^2$ = 0.34 – 0.39). Figure 6 shows that the approach was able to simulate the strong seasonal outdoor demand trends experienced in the Lower Hunter region of New South Wales in Australia. The model differs from traditional models that rely on linear regression to physical parameters in that it is simulates behavioural reaction to climate variables (including rainfall and temperature) using a probabilistic framework.

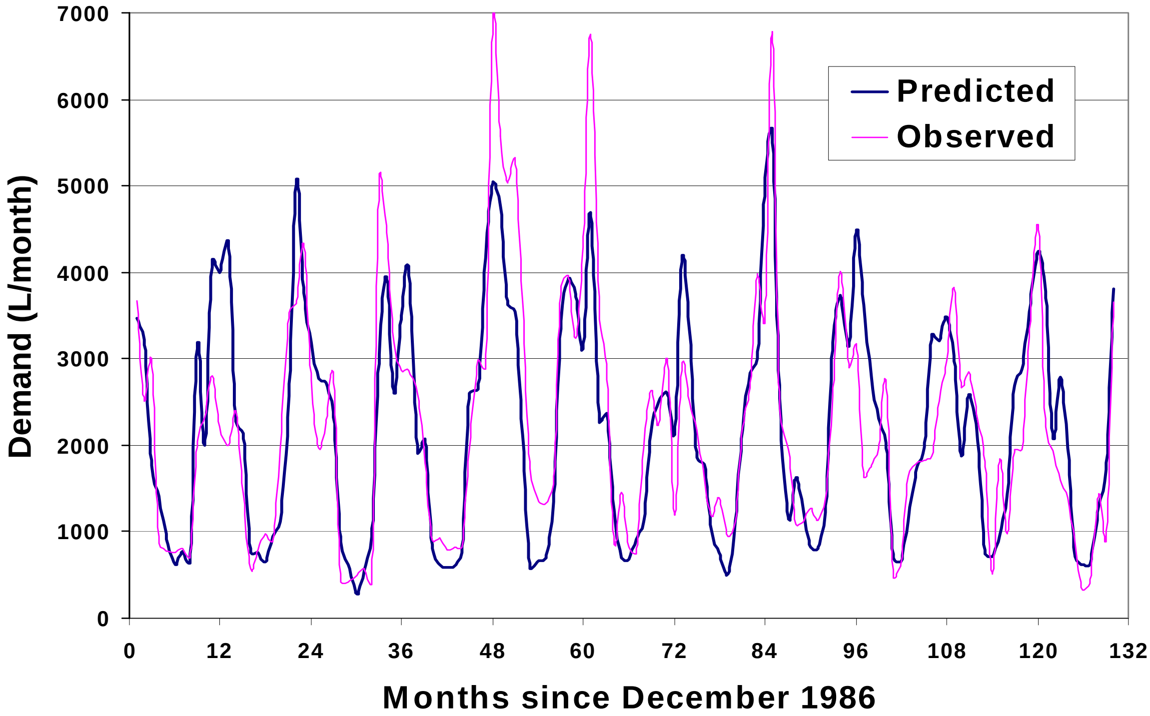


**Figure 6:** Time series of Observed versus predicted monthly outdoor water use for Mayfield.

Many authors including Maidment et al. [1985], Kuczera and Ng [1994], Zhou et al. [2000] and Coombes et al. [2000b; 2002] have established that urban water demand is dependent on seasonal and climatic variables. Maidment and Miaou [1986] established that water use in different locations was dependent on spatially averaged rainfall series, ambient air temperatures and established water use patterns. Coombes et al. [2000; 2002] found that urban water demand was spatially dependent on local climatic and socio-economic variables. In addition water demand in similar households with the same number of occupants with similar socio-economic status can have vastly different water usage as shown in Figure 7.

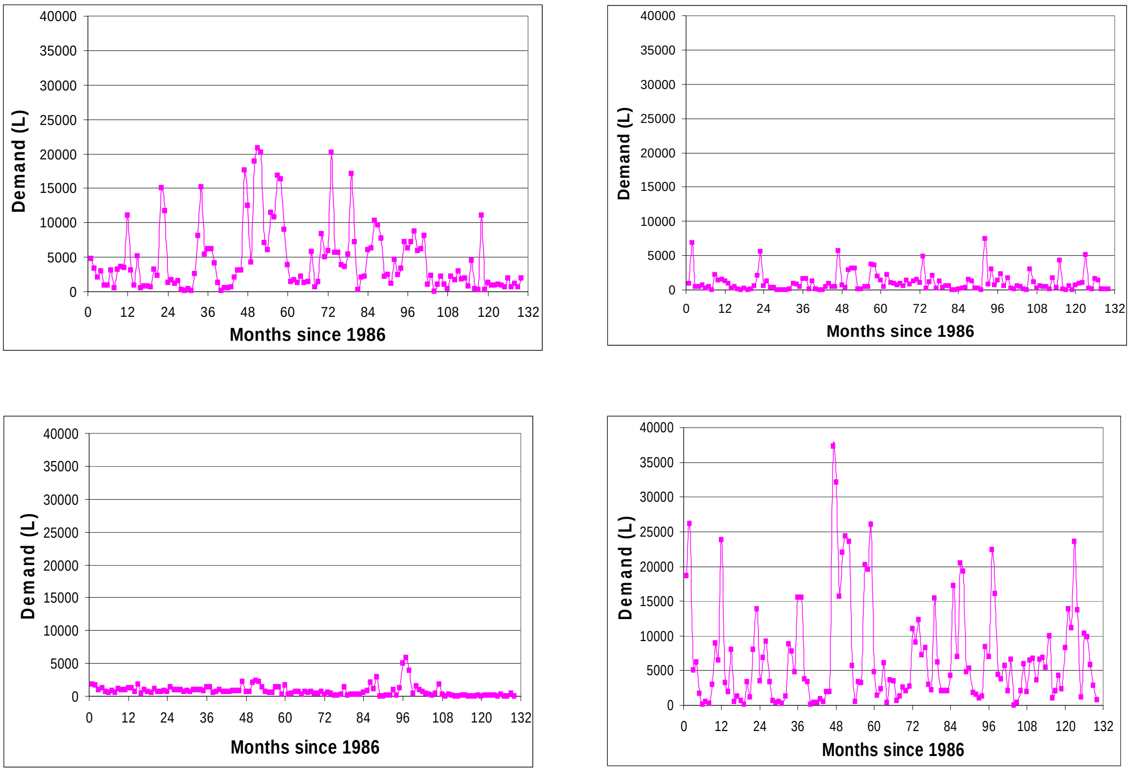


**Figure 7:** Water demand at 4 similar dwelling types with the same number of occupants with similar socio-economic status

It will be important to understand the variable impact of source control measures on water use in different household configurations and locations to enable regional understanding of the impact of source control measures on urban water demand. The use of probabilistic behavioural methods and understanding of socio-economic variance of domestic water use in allotments will improve this understanding. However methods will need to be developed that also account for the natural variation of household water use that is highlighted in Figure 7.

### *7.1.2 Yield from Rainwater Tanks*

Simulation of different allotment scenarios using rainwater tanks has revealed a nonlinear behaviour that makes questionable the assumption that an average household can be used to represent allotment water use behaviour [Coombes et al., 2003a]. Figure 8 compares average annual mains water savings for different sized tanks and different household occupancy for two Australian capital cities: Adelaide which has a Mediterranean climate characterized by hot dry summers and wet winters with an average annual rainfall of about 520 mm, and Brisbane which has a semi-tropical climate characterised by dry winters and wet summers with an average annual rainfall of about 1110 mm. Note that:

- Water savings do not scale linearly with tank size - as tank size increases the catchment area of the roof becomes limiting.
- For a given tank size incremental water savings decrease as the number of persons in the household increases. However, for the wetter Brisbane climate incremental water savings do not decrease as rapidly as for the Adelaide climate.

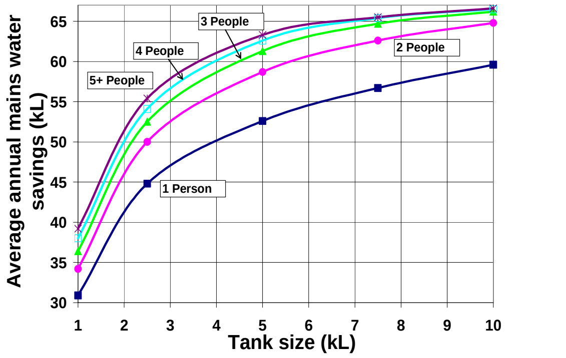


Figure ~~7~~8a. Mains water savings at dwelling with 200 m² roof areas in Adelaide

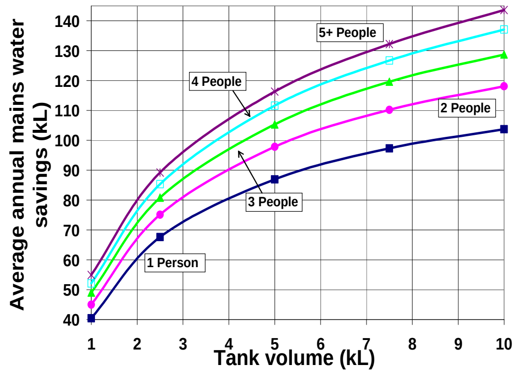


Figure 8~~7~~b. Mains water savings at dwellings with 200 m² roof areas in

The installation of rainwater tanks throughout a water demand catchment will have a highly variable impact on regional water demand that will be dependent on the spatial variability of rainfall, household water use, roof areas and the selection of tank sizes. It is unlikely that performance of an average house with a rainwater tank can extrapolate to reliable estimate regional water demand that includes the widespread use of rainwater tanks throughout a catchment that has spatially variable rainfall patterns.

## 8. TRADITIONAL APPROACH TO EVALUATION OF THE SECURITY OF WATER SUPPLIES

A schematic of a traditional approach to the evaluation of the security of urban water supplies is shown in Figure 9. Historical availability of water resources (streamflow) and water demand for the entire demand catchment are used to:

1. predict the likely future water demands generated by various population characteristics and

2. determine the maximum water demand (safe yield) that the water supply headworks system can supply with a given reliability.

Figure 9 shows that at some time in the future, the predicted water demand from the base case (D1) will exceed the safe yield of the water supply headworks system requiring the system be augmented in year A1. The impact of different demand management approaches (D2, D3) is estimated as a proportion of the base demand (D1) determining the timing of the expected augmentation of the water supply headworks system (A2, A3).

This analysis is usually undertaken using continuous simulation of a time series of historical streamflows and predicted water demand. Implicit in the analysis is an assumption that the pattern of historical water demands and streamflows will be repeated. It is unlikely that this approach can reliability account for future changes in the management of water demand and the availability of alternative sources of water distributed throughout the water demand catchment. Importantly these changes will alter the known joint probability relationship between historical water demand and availability of water with the potential to fundamentally alter the behaviour of the water supply headworks system.

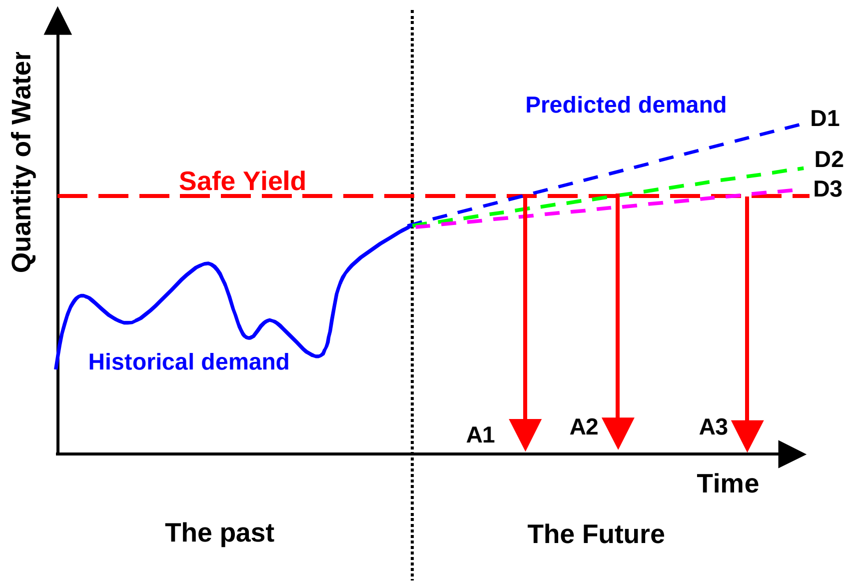


**Figure 9:** The traditional approach to the determination of the security of urban water supplies

## 8.1 The Impact of Using a Distributed Water Demand and Multi-replicate Analysis

To illustrate the potential unreliability of the traditional yield analysis we consider a case study based on the water supply headworks system for Sydney in New South Wales, Australia.

Figure 10 presents the Sydney water supply headworks system. Water is currently harvested from the Warragamba, Upper Nepean, Shoalhaven and Woronora river catchments that have a combined area of 16,850 km$^2$ [Sabet et al., 1991]. Streamflow from the Warragamba catchment is captured in Warragamba Reservoir that has a storage capacity of 1890 gigalitres (GL). Water from the Cataract, Cordeaux, Avon and Nepean Dams located in the Upper Nepean catchment is conveyed via a system of pipes, natural river channels, weirs, tunnels and aqueducts to Prospect Reservoir whilst also supplying various communities along the routes. The South Coast region is supplied with water from the Avon and Cordeaux Dams and Nepean Dam via the Nepean-Avon tunnel. Streamflow from the Shoalhaven catchment is captured in Lake Yarrunga and Tallowa dam where water is raised 612 metres to Wingecarribee Reservoir via Fitzroy Falls Reservoir when the water storage volume in Warragamba Dam is less than 65%. Water from the Wingecarribee Reservoir is distributed to Nepean dam and Lake Burragorang via the Wingecarribee and Wollondilly Rivers.

The Sydney system presently serves a population of over 4 million but by 2090 will need to serve 6.7 million. This growth in population will necessitate either augmentation of the existing system with the construction of a major dam at Welcome Reef on the Shoalhaven River or introduction of strategies to reduce mains water consumption. Coombes et al. [2003] and Coombes [2002a] provides detailed discussion of Sydney's water supply headworks system.


**Figure 10:.** Sydney water supply headworks system

Performance of the water supply headworks system and impact of urban water demand on streamflow in the water supply catchments was evaluated using the WATHNET network linear program for headworks simulation [Kuczera, 1992]. To preserve the climatic correlation between the urban and water supply catchments 2000 replicates of streamflow and climatic variables in the water supply and urban catchments were simultaneously generated for the period 2001 to 2090 using the methods described by Kuczera [1992] that employ a multi-site lag-one Markov model to generate annual values that were then disaggregated into monthly values using the method of fragments.

In this study reliability is defined as the probability that water restrictions will not be imposed in a particular year. Restrictions on urban water demand were triggered when storage levels in Warragamba Dam or Avon Dam fall below 60%. The reported effectiveness of water restrictions in the Sydney region during the 1992-1998 drought by Deen [2000] was used to develop restriction criteria and subsequent demand reductions for domestic outdoor demand. Water restrictions were only applied to domestic outdoor demand and non-domestic demand according to the rules described in Table 2.

**Table 2. Water restriction criteria for domestic outdoor demand**

| Demand category | Outdoor domestic | | | | Non-domestic | | | |
|---|---|---|---|---|---|---|---|---|
| Trigger storage (%) | 60 | 55 | 50 | 40 | 50 | 40 | 30 | 20 |
| Reduction in demand (%) | 33 | 57 | 75 | 100 | 5 | 10 | 15 | 20 |

Transfers from the Shoalhaven system are controlled by pump marks which are the storage levels in Warragamba and Avon reservoirs at which pumping from the Shoalhaven river is commenced. The pump mark, presently set at 65%, significantly affects the performance of the headworks system.

Because the case study considers scenarios involving use of rainwater tanks to reduce the demand on the headworks system it is necessary to integrate simulation of water usage at the allotment scale with the simulation of the headworks system. This is accomplished by use of a spatially distributed demand model. The Sydney region was divided into ten water supply zones with different climatic conditions (monthly rain depth, temperature and rain days) that coincided with trunk distribution system monitoring data provided by the Sydney Catchment Authority. These zones include: Prospect East, Prospect South, Prospect North, Blue Mountains, Orchard Hills, Avon, Nepean, Macarthur, Warragamba and Woronora. The following procedure was used to simulate 2000 90-year replicates of monthly mains water demand for use in the WATHNET headworks simulation:

1) Monthly daily average domestic water demand for different dwelling types within the various demand zones was estimated using climate and socio-economic data following the methods developed by Coombes et al. [2002] who developed regression models for domestic indoor and outdoor water demand using data for 130 households monitored over 12 years in the Lower Hunter region of New South Wales.

2) Different scenarios were identified for reducing mains water consumption. The base scenario represents the present state in which all consumption is satisfied by mains water supplied by the headworks system. Alternative scenarios involve different combinations of water-efficient appliance uptake and rainwater tank utilisation.

3) For each dwelling type and scenario a daily water balance using the PURRS model was performed using historical climate data. From this water balance simulation, daily mains demand was extracted and aggregated into monthly totals. These totals along with the corresponding historical monthly rain depth, rain days and average daily maximum temperature were saved in a resource file.

4) The resource file stores “historical” mains water demand at the allotment scale. To link this with the headworks simulation, the method of non-parametric aggregation [Coombes et al., 2002] was used to stochastically generate monthly domestic water use for each dwelling type in each climate zone. At each time step in the headworks simulation monthly stochastically generated monthly climate data is obtained from the WATHNET model. The resource file is scanned to find the historical month that is closest to this monthly climate data – this defines the mains water use for the dwelling type for that month. Using demographic data the allotment results are aggregated to estimate total domestic indoor and outdoor use for each zone.

5) Non-domestic monthly demand for each zone in the region is accounted for using a model of commercial/industrial water use and unaccounted-for consumption and losses developed by Kuczera and Ng (1994). The non-domestic water use model is calibrated to the difference between estimated domestic and total consumption from metering data and accounts for about 30 to 40% of total mains water use in each zone in the Sydney region.

The performance of this model was tested by comparing its predictions against trunk distribution system monitoring data from each zone. Figure 11 presents results for the combined Prospect zones. The model is able to reproduce satisfactorily the seasonal demand patterns in the combined Prospect zones. The coefficient of determination ($R^2$) for the calibration was 0.55. Similar results were obtained for the other water supply zones.

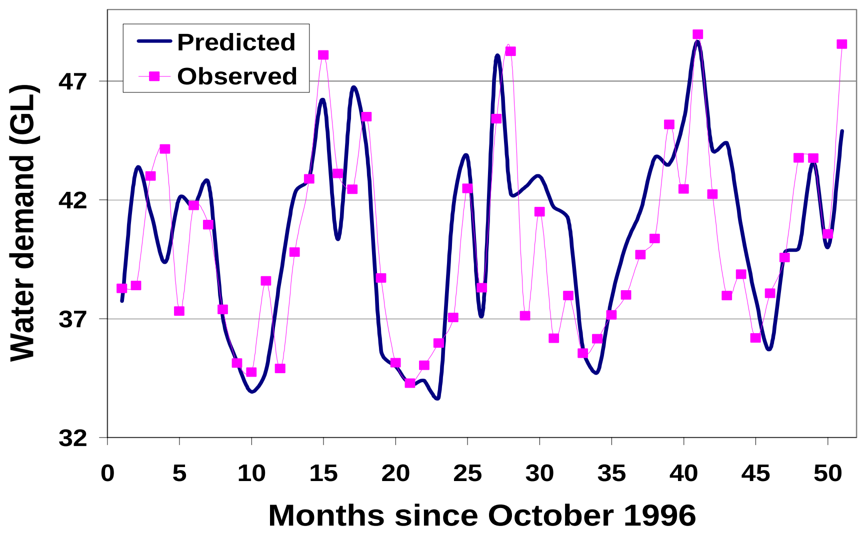


**Figure 11:** Demand model performance for the combined Prospect zones.

The safe yield of Sydney's water supply headworks system was estimated to be 648 GL/annum using the base scenario for urban water demand derived from the distributed methodology and the procedure for headworks simulation described above.

To test the effectiveness of the traditional yield analysis process for determining the security of water supplies the regional impact of installing 5 kL rainwater tanks is examined. Rainwater collected in the tanks will be used to supplement mains water supply for hot water, laundry, toilet and outdoor uses in 1% and 2% of dwellings. The average yield from the rainwater tanks in each of the water demand zones in the Sydney region is shown in Table 3.

**Table 3**: Climate, population and average rainwater yield data from each demand zone

| **Location** | **Rain depth (mm/yr)** | **Rain days (days/yr)** | **Water Demand (kL/yr)** | **Reduction in water demand (kL/yr)** | Population in 2001 (people) | Expected population growth (%) |
|---|---|---|---|---|---|---|
| Avon | 1273 | 146 | 203 | 101 | 256,600 | 0.51 |
| Blue Mountains | 1086 | 115 | 296 | 130 | 41,790 | 0.54 |
| Orchard Hills | 647 | 169 | 333 | 87 | 201,800 | 1 |
| Macarthur | 800 | 120 | 211 | 70 | 224,710 | 1.2 |
| Nepean | 902 | 146 | 203 | 72 | 25,511 | 1.98 |
| Prospect East | 1162 | 143 | 280 | 91 | 2,198,850 | 0.59 |
| Prospect North | 1162 | 143 | 273 | 90 | 576,580 | 0.94 |
| Prospect South | 1162 | 143 | 292 | 90 | 343,970 | 1.11 |
| Woronora | 882 | 134 | 233 | 92 | 100,160 | 0.42 |
| Warragamba | 300 | 158 | 204 | 49 | 10,190 | 1.72 |

From Table 3 it can be deduced that the use of 5 kL rainwater tanks to supplement mains water supply for hot water, laundry, toilet and outdoor uses will reduce mains water demand by an average of 33% or 90 kL/annum in dwellings in the region. Thus, in accordance with traditional yield analysis processes, it is assumed that each household in the region that installs a rainwater tank will have a reduction in mains water demand of 33%. Thus the impact of dwellings installing rainwater tanks on regional water demand $Rdem_t$ at time t was calculated as follows:

$$Rdem_t = NT_t(1-0.33)Bdem_t + (1-NT_t)Bdem_t$$
(1)

where $NT_t$ is the proportion of dwellings with rainwater tanks and $Bdem_t$ is the regional demand from the base scenario without rainwater tanks at time t.

The regional impact of installing rainwater tanks using the traditional yield analysis with the average reduction in regional water demand created by the tanks is shown in Figure 12.

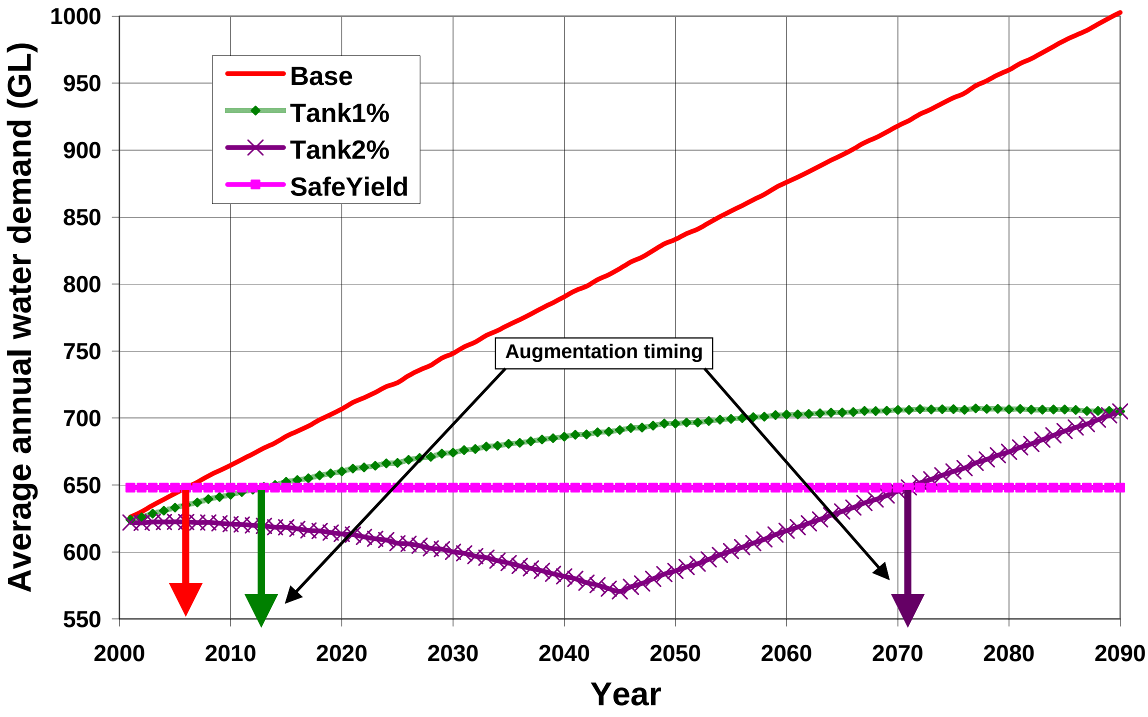


**Figure 12:** Traditional yield analysis of the water supply headworks system in Sydney

Figure 12 shows that using the traditional yield analysis augmentation of the water supply headworks system will be required in 2006, 2013 and 2071 for the base scenario, 1% per annum installation of tanks (Tank1%) and 2% per annum installation of tanks (Tank2%) respectively.

The security of the Sydney water supply headworks system that included rainwater tanks was evaluated using the distributed demand model and multi-replicate simulation presented in points 1 to 5 for the water demand zones shown in Table 3. The results from the distributed analysis of the impact of the rainwater tanks are shown in Figure 13.

When the traditional yield analysis (SafeYield in Figure 13) is incorporated with spatially distributed water demands augmentation of the water supply headworks system will be required in 2006, 2014 and 2090 for the base scenario, 1% per annum installation of tanks (Tank1%) and 2% per annum installation of tanks (Tank2%) respectively. However the use of spatially derived water demands and multi-replicate analysis results in a requirement to augment the headworks system in 2006, 2027 and 2077 for the base scenario, 1% per annum installation of tanks (Tank1%) and 2% per annum installation of tanks (Tank2%) respectively.

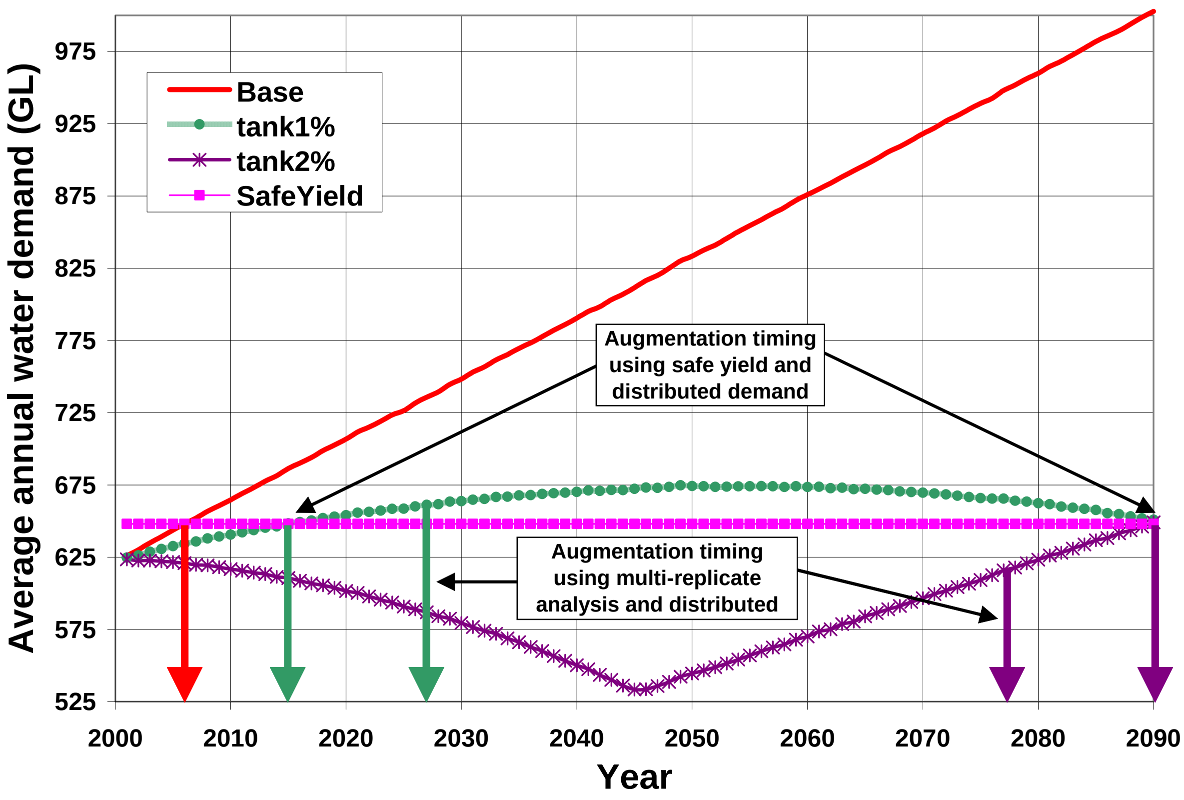


**Figure 13:** Multi-replicate analysis of the water supply headworks system in Sydney used distributed urban water demands.

The results show that the traditional yield analysis (Figure 12) has under-estimated the impact of installing 5 kL rainwater tanks on augmentation timing by 14 years for the 1% per annum installation rate and 6 years for the 2% per annum installation rate when compared to a multi-replicate analysis using spatially distributed water demand. The use of an average reduction in regional water demand attributed to rainwater tanks in the traditional yield analysis has under-estimated the reduction in regional water demands resulting from rainwater tanks. This is due to the variable performance of rainwater tanks in the different climate and socio-economic zones that are within the regional water demand catchment.

Figure 13 also shows that the use of the safe yield of 648 GL/annum and spatially distributed water demand to determine the security of the water supply headworks system resulted in the requirement to augment in 2006, 2014 and 2090 for the for the base scenario, 1% per annum installation of tanks (Tank1%) and 2% per annum installation of tanks (Tank2%) respectively. This is an under-estimation of the timing to augmentation by 13 years for the Tank1% scenario and an over-estimation of the augmentation timing by 13 years for the Tank2% scenario. The inconsistency in the results is due to the multi-replicate analysis accounting for a wide range of potential climate sequences in the headworks simulation thereby accounting for variations in initial conditions in reservoirs and rainwater tanks prior to dry periods.

Although the traditional yield analysis process has been presented in the most positive light by the use of the base water demand derived from the distributed modelling, it is clear that the traditional yield analysis and average assumptions about the impact of rainwater tanks on regional water demand could not reliably predict the impact of using rainwater tanks distributed throughout the water demand catchments on the security of the water supply headworks system. In order to understand the impact of source control measures on the security of water supplies the water industry will need to develop methods that can account for the spatial variance of urban water demand. Note that the use of the results from the simulation of the performance rainwater tanks in domestic dwellings using daily time steps and average assumptions was likely to have produced an even more unreliable result.

## 8.2 Distributed Water Demand and Security of Water Supplies

It has been established that urban water demand is dependent on seasonal, climatic and socio-economic variables. These variables will have spatial variance throughout an urban area. To accurately determine the impact of urban water demand on the security of water resources, the correlation between climatic conditions, domestic water use and streamflow must be maintained. In particular the correlation between hot dry conditions, high domestic water use and low stream flow and vice versa must be preserved because it is likely to have significant impact on the viability of streams and the reliability of water supply headworks systems.

The spatial variance of urban water demand is often ignored in analysis of water supply headworks systems in preference to the use of total regional water demand. However urban water demand was spatially dependent on local climatic and socio-economic variables. The use of demand and supply management measures such as rainwater tanks, wastewater reuse, pricing methods and demand management measures that act at the local scale are expected to further increase the spatial and day to day variation of total regional water demand. A schematic of socio-economic and climatic zones for urban water demand is shown in Figure 14.

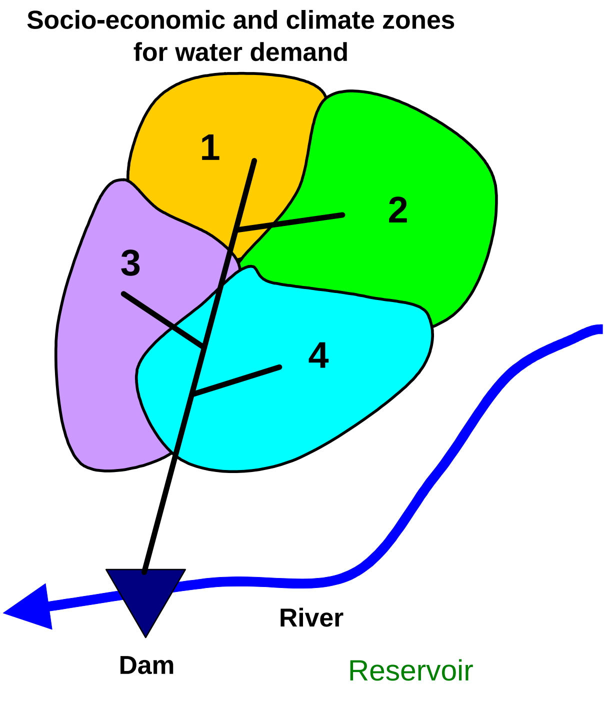


**Figure 14**: Urban water demand catchments with distributed water demand

It can be reasoned that regional water demand at the reservoir is a function of the water demands in sub-catchments 1 to 4. The water demands in sub-catchments 1 to 4 will be spatially varied dependent on dwelling types, population characteristics, and climatic and socio-economic parameters. The influence of these characteristics and parameters vary over time.

Water demand in each dwelling within a sub-catchment is a function of the installation of demand management (water efficient appliances), water supply alternatives (rainwater tanks, wastewater reuse and so on) and the socio-economic status of the household. The impact of these factors will vary with climate, time and population characteristics.

The security of the urban water supply is dependent on the availability of streamflow in the river, storage capacity of the reservoir and regional urban water demand. Streamflow varies with climate, time and other variables. For a given reservoir storage capacity, the security of the urban water supply can be determined from the joint probability relationship between streamflow in the river system and regional urban water demand. Whilst considerable effort is focused on the determination of streamflow characteristics, little attention is paid to the causative determinants of urban water demand. Indeed it is common practice to fit a regression relationship to global variables and historical regional water demand to develop a time series of regional urban water demand for use in the determination of the security of urban water supplies. This approach can be successful in situations where historical urban water demand has resulted from constant and uniform influences that will continue into the future. Unfortunately this situation is unlikely. Thus the current methodology for determination of urban water demand cannot rigorously account for the spatially varied impacts of source control measures (rainwater tanks, demand management, wastewater reuse and water pricing) rendering the determination of the security of urban water supplies unreliable.

## 9. CONCLUSIONS

Urban areas cannot continue to harvest increasing volumes of water from river systems whilst ignoring the resource potential of the rain that falls on those cities by discharging it to the environment as stormwater. Similarly we cannot continue to discharge increasing volumes of wastewater to the environment without attempting to utilise this resource. Integrated water management approaches that incorporate decentralised approaches to urban water cycle management are required to improve the performance of currently accepted centralized approaches by reducing the volume of water imported into cities, and decreasing volumes of wastewater and stormwater discharged to the environment.

It is our view that the urban water industry is operating within a constrained solution space that is a result of institutional arrangements and current engineering paradigms that have evolved to address separate centralized management of water supply, stormwater and wastewater disposal. The separate management of these sub-systems obfuscates the benefits of source control measures such as rainwater tanks, demand management methods, wastewater reuse and pricing measures on the entire water cycle system. In addition the focus on the performance of a management measure in a particular sub-system (such as water supply) may obscure the benefits to another sub-system (such as stormwater management).

This paper demonstrates, using rainwater tanks as an example, that the current institutional arrangements and engineering methods cannot reliably account for the impacts of integrated urban water cycle management approaches. The use of decentralised solutions for urban water cycle management poses new challenges to water resource planners. The determination of the security of a water supply headworks system that includes domestic rainwater tanks using the traditional yield analysis with average assumptions about the reduction in regional water demand created by the tanks produced unreliable results.

An assumption about the average reduction in regional water demand created by rainwater tanks can not reliably capture the spatial variation in the effectiveness of rainwater tanks due to local climatic and socio-economic influences that ultimately creates variation in regional water demand.

Analysis of the security of water supply headworks systems using a static system yield derived from a single replicate is also unreliable because the yield from a headworks system will vary for different supply options and the single replicate analysis cannot account for changes in the joint probability relationship between urban water demand and availability of water created by alternative supply scenarios.

This paper has presented a timely message: average assumptions cannot be used in the analysis of integrated water management schemes without introducing considerable bias. The adoption of integrated urban water management approaches to urban water cycle management will require the development of distributed demand models and a more detailed approach to simulation of these systems to produce reliable water resource plans.

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SUPPPLYING AND GROWING DEMAND

# FUNDING THE REPLACEMENT OF AGING INFRASTRUCTURE; ROLE OF PUBLIC/PRIVATE PARTNERSHIPS

Professor Danny Samson

ABSTRACT AND PRESENTATION

***ASTRACT – DANNY SAMSON***

*Public private partnerships have become an important way of establishing and maintaining many new and existing types of infrastructure. Victoria has taken a leading position in Australia in this regard. There are many considerations to be accounted for in these arrangements, including value, many categories of risk, revenue streams, relationship between public and private partners, roles and responsibilities. This presentation will outline the Victorian approach, which is applicable to water systems development. The principles behind it are sound and can be transferred to other contexts.*

Water industry opportunities for public private partnerships

Professor Danny Samson
School of Management
University of Melbourne

## PPP 'theory' (or at least rationale)

- Maximise return / risk profile
- Can be done by outsourcing / leveraging government efforts, capabilities and financial resources with those of the private sector
- Who has competitive advantage in BOOT projects such as Citylink? Consider B, O, O, T
- Align risk bearing with control and financial benefits, ie get the incentives right, for having all organisations strive to achieve aligned outcomes for the community and all stakeholders

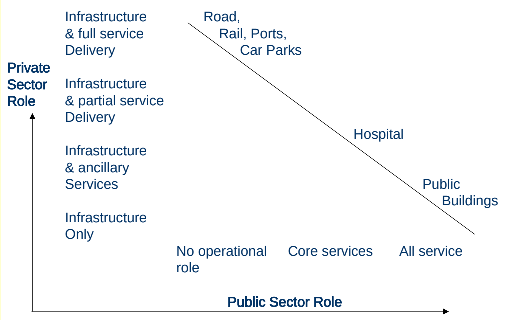
## Why shouldn't government "Do it all" (like in the good old days)

- **In "The Nature of the Firm" Coase addressed this question: Why are some activities carried on in firms and others in markets? His answer was simple: In the presence of transaction costs, it is cheaper, up to a point, to carry on activities within firms. Indeed, this is one raison d'etre for business firms.**
- **Similarly, PPP addresses the question, why should government necessarily produce the services it provides?**
- **Answer , sometimes it shouldn't, and many 'partial' models may make sense.**
- **Indeed, government 'doing it all' is a corner solution, not necessarily optimal, maybe never was**

## Why shouldn't government "Do it all" (like in the good old days)

- We can now take a much more sophisticated approach then Coase first imagined
- The analogy is just like in 'vertical integration', eg in the car industry. General Motors used to make almost everything that goes into the car. Now, GM uses contracts to **let specialists do what they do best**.
- PPP is all about smart outsourcing by government
- Government can be the service quality assurer, service provider, assembler of services etc, but doesn't need to 'own the factory' or fabricate all the parts
- Coase theorem is being rethought in the private sector too. EG Cisco is a networked organization. Cisco owns a bunch of contracts, technologies, customer / service relationships, doesn't make much at all

## Flexible Variety of Models/Contracts




## Payment

- For performance
- Private sector responsible for service delivery, payment conditional on performance, quantity & quality
- Private sector bears bulk of risk on service quality & quantity provision.
- Private sector bears primary risk of design, build, operate, obsolescence, residual value.
- Government bears risk of changing it's services, standards

## Risk Allocation

- **<u>The party (gov't or private) that is best able to control the risk aspect at lowest cost, should generally bear that risk</u>**.
- Recognises price of risk
- Complexity occurs when neither party can control risk (can still negotiate and price for risk)
- Overall aim is still to achieve 'best value for money'.

## Sound Leadership and Management: what is it ?

- Planning
- Leading
- Organising
- Control
- **How does Partnerships Victoria stack up on these**?

## Core Principles of sound leadership and management

- **Alignment of Values**
- **Distributed Leadership**
- **Integration of Effort**
- **Out Front**
- **Up Front**
- **Resourcing the Future**
- **Time Based**
- **Bias for Action**
- **Learning Focus**
- **Discipline**
- **Measurement/Feedback**
- **Customer Value**
- **Order Winners**
- **Capabilities**
- **Micro to Macro**

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## <u>Partnerships Victoria</u>
## Public & Private Sector Working Together

*"The provision of efficient and effective public infrastructure and related ancillary services through <u>Partnerships Victoria</u> will deliver benefits to all Victorians."*

- John Brumby MP
Treasurer

## <u>Partnerships Victoria</u>

- Government Policy: Launched June 2000
- Framework for integrating private investment into public infrastructure
- Focus on <u>whole of life</u> costing
- Full consideration of benefits & risk allocation
- Recognises that private sector can often deliver public infrastructure cost effectively

## Process Overview

**Once new public infrastructure need is identified, consider delivery options:**

- Government alone
- Government combined with private sector
- Private sector entirely

**Decision criterion:**

"Best value for money is meeting government service objectives."

## Scrutiny & Process

- Some 'core services' strategic for government to retain
- 'Public interest test'
  - Probity
  - Transparency
  - Other Criteria eg. Community interest, fairness, equity

## Policy Evolution

***From..*** pure outsourcing of physical assets (design and construct) of roads, prisons, hospitals, etc.

***To…*** additionally procure services related to infrastructure

## *Example:* Vic County Court

**Government procures services:**

- Courtroom availability, other spaces
- Building is privately owned/operated
- IT provided privately
- Government buys services
- Performance incentives (reduced payment for substandard services)

→ **New Focus on *services*, not *asset* construction**

## Decision Process

- **Core Services Question:** *Should government deliver some of the services (strategic reason)?*
- **Value for Money Question:** *Will private sector deliver Value for Money and how to optimise this?*
- **Public Interest Question:** *Does the project satisfy this? (eg. Security, privacy, accountability, transparency, equity)*

## Value for Money Drivers

- Risk transfer
- Whole of life costing
- Innovative solutions to service provision
- Asset utilisation: eg. Third parties

## As guidelines…

- Scale: contracts/projects > $10million
- Duration: long: eg. 30 years
- Services focus: measurable, pay for services
- Risk transfer: to private sector (substantially)
- Complexity: invites innovation in service delivery
- Market capability/appetite: business opportunity for private sector parties

## Partnership Basics

***Long Term Relationship!***

- Starts with sound planning & specification
- Business opportunity must exist
- Process certainty desired, ie lots of strucure
- Balanced bid evaluation (price and other criteria)
- Project resourcing must be sound
- Clear contract
- Contract management must be excellent
- Partnership: good faith, goodwill (cont'd…)

## PPP Features

**Private partner gets suitable ROI**

**Government gets services without capital outlay at fixed or known price**

**Asset future is defined after service contract ends: eg. Transfer back to government (or not).**

## Detailed Process

- Specify services used/ needed eg court, jail, hospital
- Appraise options
- Build business case
- Obtain projects funding approval
- Project development
- Bidding process, EOI, Project brief
- Project finalisation
- Final negotiation
- Contract management during operation

## Public Sector Comparator (PSC)

- Defined as theoretical whole-of-life, risk-adjusted cost of government delivering the output as specified.
- Benchmark for private sector bids in terms of value for money.
- Uses net present cost (DCF).
- Involves detailed risk assessment.
- Can quantify some but not all factors, recognise need for qualitative evaluation as well as financial.
- Generally expect to disclose raw PSC

## Risk categories can include…

- Design & construct
- Commissioning/operating
- Service underperformance
- Industrial Relations
- Maintenance
- Technology obsolescence
- Regulation/Legal change
- Planning
- Price
- Taxation
- Residual Value
- Demand for volume

*Who should bear risk? Control?*
*Control comes with freedom to manage/minimise*

# PPP in Victoria

**Tom Roper: May 1991**

Infrastructure Investment Guidelines foreshadowed:

- Water/sewerage
- Agriculture
- Energy
- Health, welfare, education
- Transport
- Leisure/entertainment
- Communications
- Justice/corrections
- Housing
- Industrial

**1991: Secretariat within Treasury recognised risk allocation as important.**

**RISK ALLOCATION ON INFRASTRUCTURE PROJECTS**

| AREA OF RISK | TRADITIONAL | POTENTIAL |
|---|---|---|
| **Planning** | Government | Government / Private sector |
| **Bidding** | Private sector | Government / Private sector |
| **Construction** | Government / Private sector | Private sector |
| **Operational** | Government | Private sector |
| **Demand** | Government | Government / Private sector |
| **Residual & Continued Use** | Government | Government / Private sector |

## Current Examples in Victoria

| Project | Description |
|---|---|
| Echuca/Rochester Wastewater Treatment Plan | The project involves private operator designing, building and operating an upgraded Wastewater Treatment Plant. The plant will comply with the necessary Environmental Protection Agency (EPA) standards and will meet anticipated requirements for the next 25 years. |
| Enviro Altona | The project involves redevelopment of the existing Altona Water Treatment Plant. The redevelopment will enable the plant to meet new EPA standards for discharge into Port Phillip Bay and cater for significant salt loads due to infiltration of the reticulation system. |
| Fibre Optic Cable | The project involves rollout of fibre optic cable to Regional Fast Rail destinations. The cable will cater for rail signalling and telecommunications requirements and any additional capacity will be commercialised to provide other wholesale or retail telecommunications services. |

(cont'd..)

| Project | Description |
|---|---|
| Spencer Street Redevelopment | The project will deliver a "state of the art" intermodal hub for passengers on country and metropolitan rail services, trams and regional buses. The project includes loungesm restaurants, shops and an airport-style concourse. |
| Berwick Community Hospital | The project involves design, construction, finance, and maintenance of hospital accommodation services for the Berwick Community Hospital. Opportunities will also be considered for the private sector to develop and operate complementary private health care services collocated with the hospital. The Government will directly provide patient care services. |
| Box Hill Hospital Carpark | The project seeks to engage the private sector to build a new multistorey carpark on the hospital site and operate the new and existing car park facilities. |

(cont'd..)

| Project | Description |
|---|---|
| Mobile Data Network | This project involves building a communications network infrastructure to carry data messages for the Victoria Police and the Ambulance Service in metropolitan Melbourne. MDN will facilitate the automation of incident despatch processes and provide remote database access for field officers. The project will form a building block for future communications projects that are part of the Statewide Integrated Public Safety and Communications Strategy. |
| Westgate Container Terminal | The project involves development of a third independent international container terminal in the Port of Melbourne. |
| TV and Film Studio | The project will see a private operator establish a Film and TV Studio to grow the local industry and attract new productions to Victoria. |

## SOURCES OF IMPROVED VFM

- There are many ways in which contractors for PFI projects could offer the public sector improved value for money. They include:

- Ensuring that assets are fully fit for purpose but no more, that is removing any tendency to over-design or gold-plate and removing the cost pressure from post-contract design changes
- Closely integrating design with operational needs so that the asset can be operated and maintained with maximum efficiency
- Increasing the efficiency of both construction and operation by applying existing expertise
- Making use of new technology and/or new, more effective business processes

(cont'd..)

## SOURCES OF IMPROVED VFM (cont'd..)

- Achieving economies of scale by enlarging the asset and sharing its use between the public sector and other customers (or between two or more public sector customers)
- Designing the asset to provide scope for other services to be sold to third party users
- Designing the asset to improve its resale value or its capacity to be transferred to new uses after the end of the contract
- Making easier the introduction of user changes where appropriate as a means of improving the match between supply and demand

## Value for Money (SIPP)

- Integrating operational needs in the basic design, thereby contributing to operational and maintenance efficiency
- Facilitating the introduction of user-charges, thereby achieving a better balance between supply and demand
- Providing innovative designs and avoiding over-specification ("gold-plating")
- Exploiting economies of scale from multiple operations
- Utilising knowledge of and experience with new technologies
- Designing the asset so as to exploit possible usage by third-parties or to increase residual value or flexibility in use
- Making possible the transfer of some risks from the public sector to those better able to manage the risks transferred

## Value for Money Factors

- ***Reduced whole life costs –*** the integration of infrastructure design, build and operation, facilitating private sector innovation in design, an avoidance of over-specification and improved maintenance scheduling
- ***Better allocation of risk –*** cost effective transfer of risk to the private sector, enabling efficiency benefits to be generated across the term of the contract
- ***Faster implementation –*** the transfer of design and construction risks, together with the principle of no payment until commencement of service delivery, will provide significant incentives for the private sector to deliver infrastructure projects within short construction timeframes. This is highly relevant in the context of the *National Development Plan 2000-2006*

(cont'd…)

- ***Improved quality of service –*** resulting from better integration of services with supporting assets, improved economies of scale, the introduction of new technology and innovation in design, and the performance incentives and penalties included in the Public Private Partnership contract
- ***Generation of additional revenue –*** more intensive exploitation of assets to generate additional revenues, for example from shared use of facilities or the sale of surplus assets

## PPP: Some Overseas Experiences

**CANADA** *(Canadian policy similar to Victoria)*

**Factors**: Cost saving
Risk Mitigation
Improved Service/innovation
Revenue enhancement eg. Export by private sector

**Risks**: Loss of control by gov't
Increased user fees
Political risk
Accountability
Lack of competition
Selection process bias

## UK

- **Private Finance Initiative (PFI)**
- **400 PFI's in force (£100 billion)**

**UK Audit office examined 121 PFI's:**

- Value for money generally 'good' to 'excellent'.
  81% satisfactory or better
  15% marginal
  4% poor

Most relationships between authority and contractor remained 'good'

## UK
*Lessons learned…*

- Needed spirit of partnership
- Successful partnership from start
- Sound clear risk allocation
- Clarity of contract
- Skilled staff are critical on both sides
- Seek to understand the other party
- Anticipate/plan for changes in contract
- Carefully monitor risks
- Open communication
- Monitoring must not be oppressive

## Scottish Approach
*Lessons learned…*

- Effective project management
- Specify requirement, but build in flexibility to the contract
- Hold contractor accountable
- Good, well-resourced team
- Use advisors effectively
- Accumulate knowledge, learn, improve
- Variety of contract forms possible

(Scottish Parliament Report – August 2001)

## Province of Nova Scotia
*PPP brings significant benefits*

Key Success Factors:

- Financial flexibility
- Technical
- Operational
- Acceptability to all
- Implementation
- Timing
- Private sector financing replaced public funds in capex.
- Critical choice of form of relationship
  - -Operations/maintenance
  - -Developer financing
  - -Turnkey
  - -Lease/purchase
  - -Build transfer operate
  - -Build own operate transfer
  - -Privatise: build own operate

## UK: IPPR Report (Institute Public Policy Research)

- Critical of PPP first generation (poor performance)
- Needs of citizens are paramount! (Not always paramount in how PPP's are structured)
- Making partnerships successful is difficult
  - - Finances
  - - Rational for PPP
  - - Strong government partner
  - - Responsible private partner
- Suggests improved practices are possible and must/will occur.

## UK: Response to IPPR (by Catalyst Group)

- Private sector profit motive adversely impacts cost, quality efficiency.
- No evidence of improvement in services (eg. Prisons)
- Private management of hospitals: problematic

Conclusion:

"No country in the world has delivered universal public services on the back of for profit providers. The costs are too high, the risks are too great and the markets are not and cannot be oriented toward social equity goals."

## Response to IPPR

- PPP is a form of borrowing: shifts burden to future
- Government could fund all initiatives
- Often few bidders ie: lack of competition
- Value for money elusive/illusory
- Public and private sectors are fundamentally motivated in different directions

## UK: Hospitals

**Private providers…**

- provide lower quality
- have higher admin costs
- provide inappropriate treatment
- are technically less efficient

➡ Same for UK nursing homes

## UK: Railtrack

**Demonstrated that public agency picks up cost of failure in contract**

- £2 million in fines in 3 years in UK
- Other evidence of 'Failure': 10 contracts terminated in UK (mostly cleaning & laundry in hospitals)

## Case Example…

Andersons took over and developed UK National Insurance Recording System (£44 million bid) in Feb 1997.

Andersons were to develop & operate for 7 years.

- 1500 unresolved problems
- 17 million unrecorded contributions
- Government paid compensation to claimants
- £ Billions of tax revenue lost
- Andersons paid £3.9 million compensation
- Ongoing problems

## PPP Planning and management

- Enhance the quality of the planning and management of project development and delivery.
- Setting up an operation from scratch.
- Respective roles of the responsible department and DTF. Planning, recruiting, training, motivating, communicating, maintaining records and information systems.
- Project management structure and project team structure.
- See Chapter 9 of the Practitioners' Guide.

## PPP Planning and management issues

- The risks that must be accommodated in planning a unique project – particularly a public sector project, where government commitment and community expectations may leave no room for variations in timing, costs or outputs.
- Management measures that will set a firm foundation for successful project delivery.
- Accommodating the Treasury responsibility for financial and commercial aspects and for government exposures generally.
- The management task - planning, recruiting, training, motivating, communicating, maintaining records and information systems, quality control, etc.
- Project management structure and procurement team structure.

## PPP Planning and management

- Project Development
- Key tasks:-assemble resources,
  - Steering committee, project director, probity auditor, procurement team
  - Project plan development
  - Further develop the PSC
  - Develop commercial principles
  - Consultation

## PPP Planning and management

- Assembling resources
- Project management structure
- Project director is CRITICAL to success
- Ensure the client is committed and stays informed
  - (hence reporting is important)
- Project management success
  - Perform : cost, quality (achieve specification), schedule

## Outputs

- **Outputs is what the whole thing is about!**
- By **outputs** we mean the quantity and quality of services provided by the assets and processes
- Outputs should be closely and specifically defined: specifications should be quantified wherever possible, tightly and unambiguously
- Partnerships Victoria is all about delivering outputs more effectively

## Outputs

- Outputs must therefore permeate and be central to every aspect of the process
- Outputs must be specified in terms that will support an effective procurement strategy and an optimal commercial arrangement.
- The output specification is present in all project activities. It is the focus of the business case, PSC, commercial arrangements, bidding process, contract management etc. It must allow innovation and motivation.

AUSTRALIA - SOUTH AFRICA WORKSHOP ON
WATER RESOURCES - APRIL 2003

# INSTITUTIONAL AND FINANCIAL ARRANGEMENTS FOR WATER RESOURCES MANAGEMENT IN SOUTH AFRICA

Bill Rowlston
Department of Water Affairs and Forestry, Pretoria

***Abstract***

*South Africa's National Water Policy (1997) and National Water Act (1998) have introduced profound changes to the ways in which water resources are managed. These changes include a progressive decentralisation of responsibilities from the Department of Water Affairs and Forestry, whose eventual role will be to provide the national policy and regulatory framework, to a suite of new regional and local water management institutions, and transfer of responsibility for infrastructure development, operation and maintenance to the new institutions.*

*The national raw water pricing strategy (1999) provides the funding framework for the new institutions, while the National Water Resource Strategy (in preparation) outlines possible arrangements for funding and financing the development of new infrastructure.*

*The paper discusses these changes, and explores some of the considerable challenges facing DWAF in implementing them.*

## INTRODUCTION

Since 1994, when South Africa's first democratically-elected government came to power, government policy has focused strongly on equitable and sustainable social and economic development for the benefit of all people. However, many of the laws in force prior to 1994, including the law relating to water resources (the Water Act, 1956), were not at all favourable to achieving these objectives. The National Water Policy for South Africa (DWAF, 1997), which was adopted by Cabinet in 1997, was introduced in response to the new direction of government policy, as part of the process of a thorough review of existing water law.

Development of the National Water Policy was preceded by the establishment of 28 Fundamental Principles and Objectives for a New South African Water Law (DWAF, 1997). Three of these are:-

- **Principle 22:** The institutional framework for water management shall as far as possible be simple, pragmatic and understandable. It shall be self-driven and minimise the necessity for State intervention. Administrative decisions shall be subject to appeal.

- **Principle 23:** Responsibility for the development, apportionment and management of available water resources shall, where possible and appropriate, be delegated to a catchment or regional level in such a manner as to enable interested parties to participate.

- **Principle 24:** Beneficiaries of the water management system shall contribute to the cost of its establishment and maintenance on an equitable basis.

These principles formed the basis for the development of institutional and financial provisions in the National Water Act (No. 36 of 1998) (NWA) (DWAF, 1998). This paper describes the proposed institutional arrangements for water resources management in South Africa, the system of water use charges by which the institutions' activities will be funded, and the proposals for financing new infrastructure developments.

## INSTITUTIONS FOR MANAGING WATER RESOURCES

The national government Department of Water Affairs and Forestry (DWAF) is currently responsible for all aspects of water resources management in South Africa. DWAF's activities include:-

(i) Developing and continuously reviewing and improving the national policy and regulatory framework for water resources management.

(ii) Routine management activities such as authorising and controlling water use, and monitoring the quality of water resources.

(iii) Assessing the availability of and requirements for water, and planning interventions to augment water availability (including water conservation and demand management initiatives, and the development of new infrastructure such as dams and inter-basin transfers).

(iv) Owning, operating and maintaining infrastructure.

One of the explicit objectives of South Africa's water policy and law is to progressively decentralise the responsibility and authority for managing water resources to appropriate regional and local institutions - existing and newly-created - in order, among other things, to enable water users and other stakeholders to participate more effectively in the management of water resources. Less obvious, but equally important, is the intention to create an institutional framework in which there are clear distinctions between the roles and functions of the various water management institutions, and in which the potential for conflicts within institutions is minimised.

DWAF's eventual role will be to provide the national policy and regulatory framework within which other institutions will directly manage water resources, to maintain general oversight of the institutions' activities and performance (the activities in (i) above), and to continue to undertake assessments of water availability and requirements at national scale (part of (iii) above). This regulatory and national water resources assessment role is incompatible with that of developing and owning infrastructure, and with routine water resources management activities, because it creates the possibility of conflicts between the regulatory parts of the organisation, and those responsible for implementation.

The principal new institutions envisaged are therefore:-

- Catchment Management Agencies (CMAs): Regional, catchment-based water management institutions, to undertake all functions relating to the protection, use, conservation, management and control of water resources.

- The National Water Utility: A national (albeit probably regionalised) organisation that will be responsible for planning and developing major new infrastructure, and for its day-to-day operation and management.

Existing irrigation boards, transformed to become water user associations (WUAs), will continue to distribute water for irrigation purposes, and will eventually take responsibility for managing the infrastructure on their schemes.

The proposed institutional framework is illustrated in Fig. 1, and the roles and responsibilities of the institutions are briefly described in the sections following.

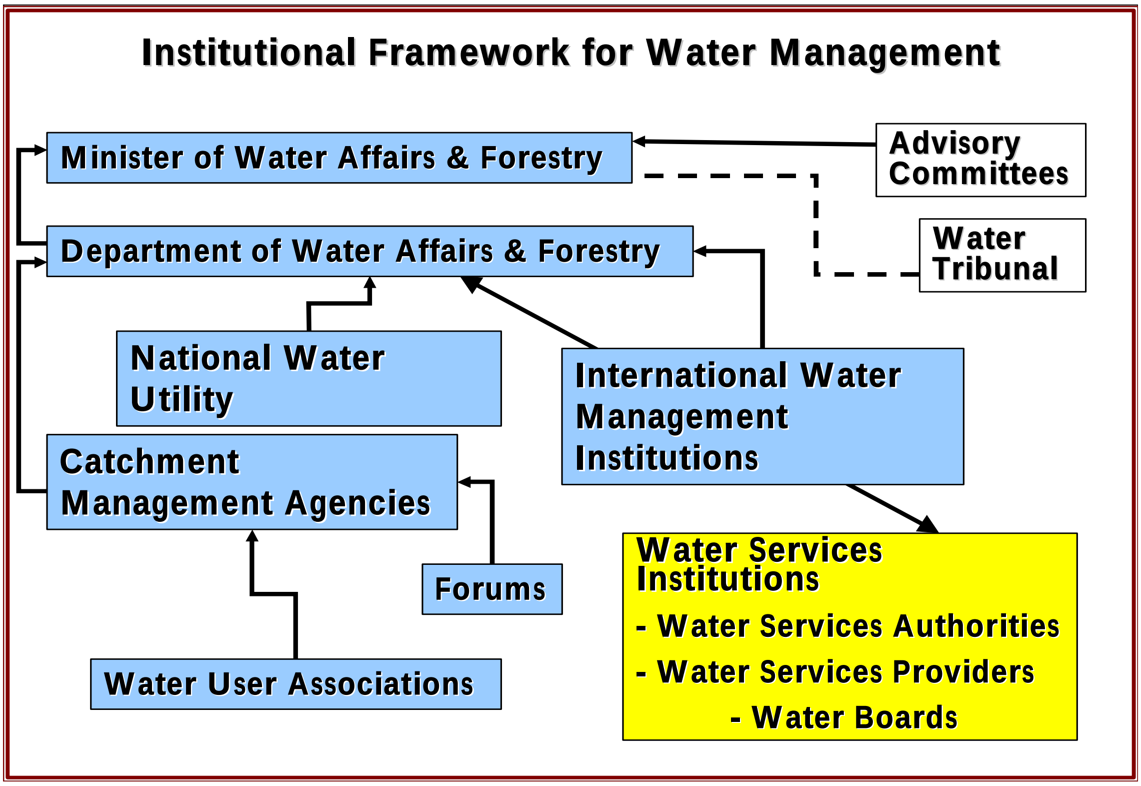


**Figure. 1:** Institutional framework for water management

**The Minister of Water Affairs and Forestry**

The Minister of Water Affairs and Forestry is the public trustee of South Africa's water resources on behalf of the national government. The Minister has overall responsibility for all aspects of water resources management, and all water management institutions are subject to her or his authority. For practical reasons the Act allows the Minister to delegate most of her or his powers and duties to officials or office holders in DWAF, and to water management institutions as they progressively build their capacity.

**The Department of Water Affairs and Forestry**

DWAF's current role, and the ways in which it will change as the new institutions are established, is discussed above.

**Catchment Management Agencies**

Catchment management agencies are statutory bodies with jurisdiction in defined water management areas. The internal boundaries of the 19 water management areas (that is, those not defined by international boundaries or South Africa's coastline) lie mainly along the divides between surface water catchments (a few, in the arid west, are defined by groundwater catchments), and are shown on Fig. 2 below.

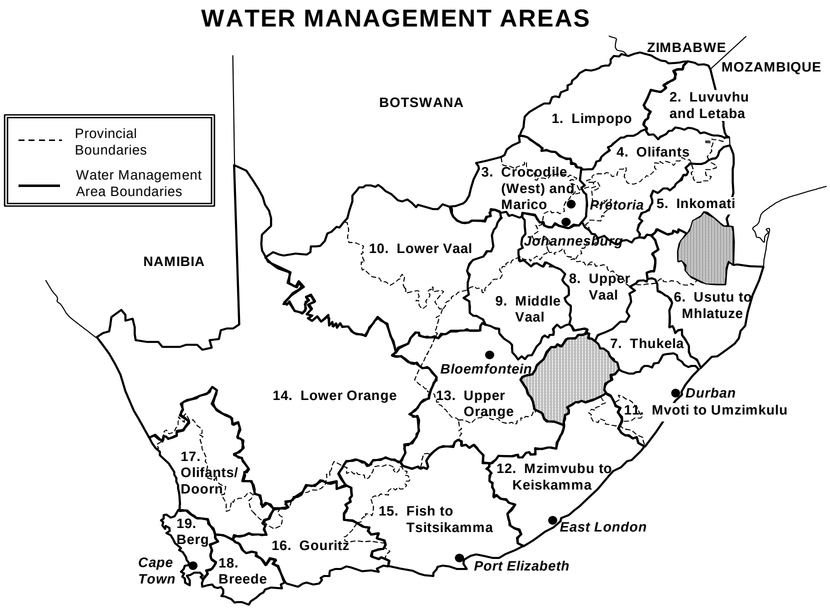


**Figure. 2:** Water management areas

A CMA is established when the Minister appoints a governing board, which must represent all relevant interests in the water management area, including provincial and local governments. However, prior to the board's appointment water users and stakeholders in the area are consulted in the preparation of a report which, among other things, analyses the agency's responsibilities, proposes an organisational structure and determines its financial viability against estimates of revenue from water use charges. This report must be approved by the Minister.

After its establishment a CMA takes responsibility for a number of initial functions described in the NWA. These centre on advising water users on water resources management issues, co-ordinating their activities, and. promoting public involvement in water resources management. Although the process of involving the public in establishing a CMA is time-consuming and expensive, it is essential because it contributes to establishing the legitimacy of the institution in its area of operation, assists the Minister in determining the composition of the governing board by identifying representative stakeholder groups, and builds a foundation for the agency to promote community involvement in water resources management.

Arguably the most important of the initial functions is the agency's responsibility to develop a catchment management strategy, which provides the framework for managing the water resources of the area and, among other things, determines the principles according to which available water will be allocated among competing user groups. The preparation of catchment management strategies is guided by the nationally consistent approaches to water resources management described in the Proposed National Water Resource Strategy (DWAF, 2002), which is developed by DWAF in terms of the NWA.

As the CMA builds its capacity additional powers and duties are delegated to it, until the agency is empowered to authorise water use, and determine tariffs for water use charges (see later). The CMA is then said to be a *responsible authority* in terms of the NWA.

Each water management area is different, with different requirements for water resource management and, within the constraints of the funding available from water use charges, a CMA has considerable flexibility in the approach it adopts to carrying out its duties. The governing board may choose to employ sufficient staff to enable the agency to carry out all of its functions in-house, or it may choose to appoint fewer staff members and appoint contractors, including other CMAs, for specific tasks.

Fig. 3 shows the proposed timetable for CMA establishment. The principal criteria for determining priorities for CMA establishment was the extent to which water resources in the water management area are under stress from over-utilisation. For each agency the process of making an establishment proposal and appointing the governing board is expected to take up to two years, followed by a five year period during which the CMA is progressively delegated additional powers and duties until it achieves responsible authority status. Completion of the process for all 19 CMAs is expected to take up to 12 years. Although a number of establishment proposals have been submitted to and are being assessed by DWAF, no CMA has yet been established. In areas where agencies have not yet been established, all powers and duties vest in the Minister, and DWAF will undertake their functions on the Minister's behalf.

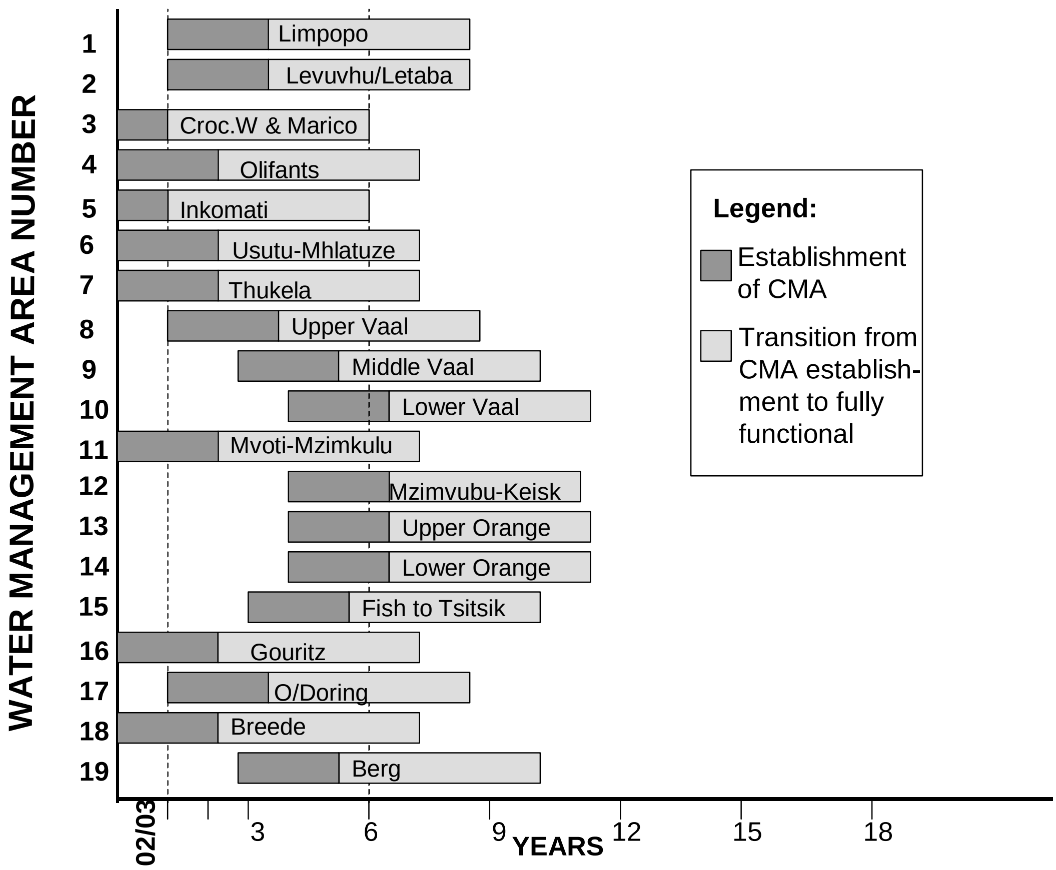


**Figure. 3:** Proposed programme for establishing Catchment Management Agencies

**Institutions for infrastructure development and management**

DWAF has developed, and owns, operates and maintains a number of water resources schemes, which comprise dams and related infrastructure such as pumping stations, pipelines, tunnels and canals. The schemes vary greatly in size. The infrastructure has an estimated (March 2001) replacement value of some R 38 billion, occupies some 2 500 departmental staff in its management, and costs about R 500 million a year to operate and maintain. During the next few years DWAF's present infrastructure responsibilities will be transferred to more appropriate institutions.

The responsibility for operating and maintaining schemes that are of local importance, or mainly serve one user sector such as agriculture or a single municipality, will be transferred to WUAs, water boards or local authorities as appropriate. With the agreement of National Treasury, the schemes may eventually be transferred into the ownership of the operating institution.

Fig. 4 shows the programme for transferring operating and maintenance functions for distribution infrastructure - canals and pipelines only: schemes involving dams will be dealt with later - on State-owned irrigation schemes to WUAs. The functions have already been transferred on 14 schemes.

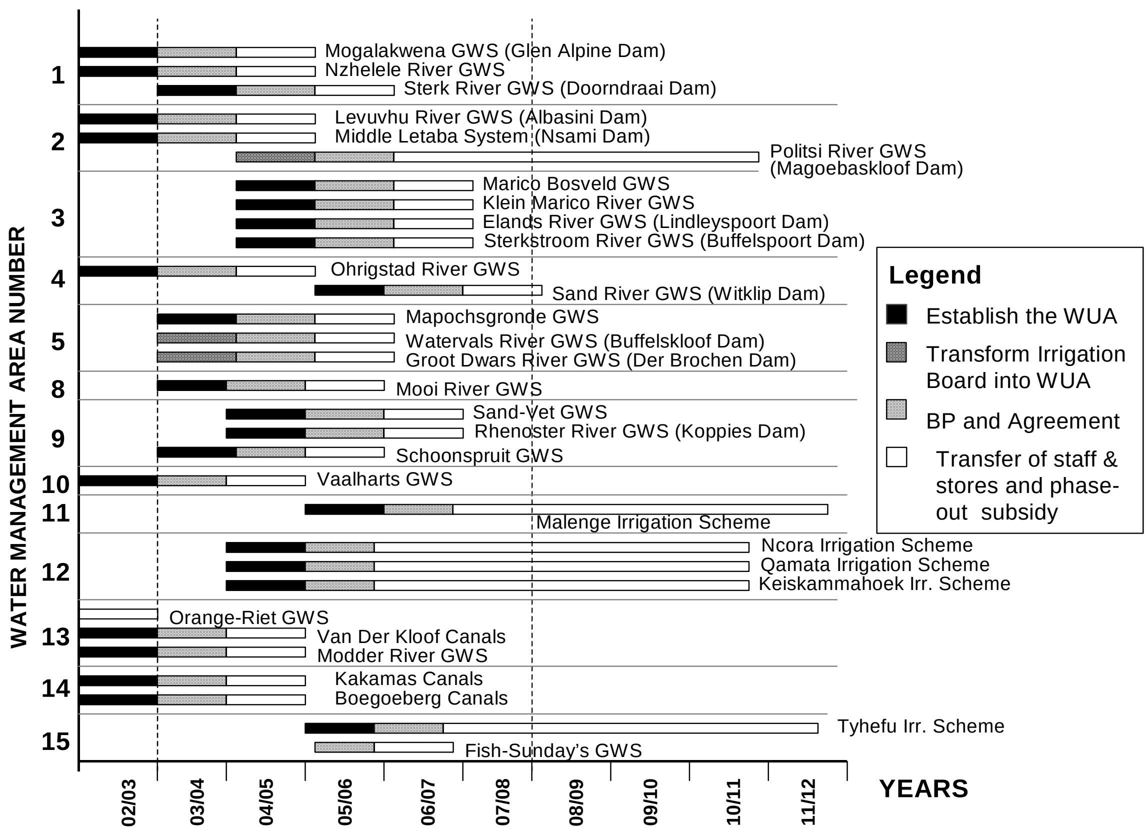


**Figure. 4: Proposed programme for transferring operations and maintenance functions to Water User Associations**

Other schemes are of wider importance because they transfer water across national boundaries or between water management areas, serve multiple user sectors or large geographic areas, comprise several interconnected catchments, or serve strategic purposes such as the generation of electricity to the national grid. Examples are large systems such as the Vaal, Umgeni, Amatole and Riviersonderend-Berg River systems, major water transfer schemes such as Thukela-Vaal and Orange-Fish, and major dams such as Gariep and Van der Kloof.

These schemes are regarded as national water resources infrastructure. After investigating various options DWAF has recommended to the Minister the establishment of a new national organisation - the National Water Utility - to manage national infrastructure, and to develop new infrastructure as required. The proposed Utility will have the advantage that, unlike DWAF, which has no powers to borrow money and may finance infrastructure development activities only from allocations from the national fiscus, it will be able to finance development by raising loans on the open market.

The proposal accords with the trend towards executing the State's role in direct service provision through appropriately-structured public organisations. The proposed utility will however be a public enterprise, and its establishment will not constitute privatisation of State-owned infrastructure. It is possible that the proposed Utility could be contracted to develop and operate infrastructure required by CMAs or WUAs.

**Water User Associations**

Water user associations (WUAs) have more restricted objectives than those of CMAs, both in scope and geographical extent. They are in effect co-operative associations of individual water users who wish to undertake water-related activities at a local level for their mutual benefit. Although they may be established for any purpose - the use of water for recreation, for instance - it is anticipated that the majority of associations will continue to focus on supporting agricultural water use. The NWA requires existing irrigation boards - there are more than 300 in South Africa - to transform themselves into WUAs by, for instance, building the capacity of emerging, previously disadvantaged farmers by including them into their areas of operation. In some cases existing management responsibilities may be extended to include other water uses, resulting in multi-sector associations.

WUAs operate in terms of a formal constitution, developed in consultation with individuals and organisations likely to be affected, and approved by the Minister. WUAs are expected to be financially self-supporting from water use charges determined and made in terms of the pricing strategy, and payable by members. A water user association falls under the authority of the CMA in whose area of jurisdiction it operates to the extent that the agency has received powers from the Minister to direct the association's activities. An association may receive delegated powers and duties from, or be contracted by the CMA to undertake activities that are within the scope of its constitution.

**Institutions for international water management**

Internationally-shared river basins comprise about two-thirds of South Africa's land surface [13]. The NWA, together with the Southern African Development Community (SADC) Protocol on Shared Water Courses, commits South Africa to sharing water in international river basins with neighbouring countries in an equitable and reasonable manner. Accordingly the Minister may, in consultation with Cabinet, establish institutions to implement international agreements in respect of the development and management of shared water resources, and on regional co-operation in water matters.

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[13] South Africa shares four major river systems with six neighbouring countries.

The Orange-Senqu system is shared with Lesotho (trans-boundary) and Namibia (contiguous).

The Limpopo River is shared with Botswana and Zimbabwe (contiguous), and Mozambique (trans-boundary).

The Incomati system is shared with Swaziland and Mozambique (trans-boundary)

The Usutu/Pongola-Maputo system is shared with Mozambique and Swaziland (trans-boundary).

A number of bodies exist, or are in the process of being established, to manage international relationships between South Africa and its river basin-sharing neighbours.

- A Treaty was signed by South Africa and Lesotho in 2000 to establish the Orange-Senqu River Basin Commission. Treaties are also being negotiated with Swaziland, Mozambique and Zimbabwe to establish a river basin commission for the Limpopo basin, with Mozambique and Swaziland to establish a commission for the Incomati system, and with Mozambique and Swaziland in respect of the Maputo River. Negotiations are expected to be finalised in the next two years. The commissions will be the focal points for giving effect to the SADC Protocol, and for implementing the SADC Regional Strategic Action Plan for managing and developing the water resources of the region.

- Matters of common interest on the various systems are discussed in a number of bi- and tri-lateral technical bodies that have existed for some years. Joint studies are also initiated and carried out via these bodies.

- The Lesotho Highlands Water Commission and the Swaziland / South Africa Joint Water Commission are project-related bodies that deal with matters relating to the Lesotho Highlands Water Project and the Komati River Basin Project respectively.

**The Water Tribunal**

The NWA has replaced the system of in-perpetuity riparian rights to water of the 1956 Water Act with a system of administrative permission - limited duration general authorisations and licences - to use water. The change was necessary to achieve more equitable access to water resources, but it is probable that disputes will arise as existing water uses and allocations are adjusted.

The Water Tribunal was established when the NWA came into effect in October 1998. It is not a water management institution in terms of the Act, but an independent body with a mandate to hear and adjudicate appeals, mainly against administrative decisions made by responsible authorities and water management institutions, on a wide range of water-related issues specified in the NWA. The Tribunal will also adjudicate claims for compensation, where a user considers that the economic viability of her or his water-using activity has been severely prejudiced by a refusal to grant a licence, or a reduction in water use on granting or reviewing a licence.

The Tribunal replaces the somewhat inaccessible Water Court which functioned in terms of the 1956 Water Act. It has jurisdiction everywhere in the country, and it may hold hearings in the areas where the cause of action arose. The Tribunal's operations are funded from the National Treasury.

**Challenges in implementing the new institutional arrangements**

Establishment of the new institutional arrangements for managing South Africa's water resources is still very much in its infancy, and it will be some years before all the institutions are in place and fully operational. Whether or not they prove to be "simple, pragmatic and understandable" and "self-driven" remains to be seen. In the meantime, DWAF is aware of some of the potential difficulties in establishing and operating the new arrangements, and is taking steps to address them proactively.

The anticipated time to establish all 19 CMAs is long - up to 12 years. Stakeholders are keen to see the agencies established and operational so they can "have their say" in the way the water resources in their areas are managed, but there are indications (from, among others, the public consultation processes for CMA establishment in some areas, and for the Proposed National Water Resource Strategy) that they are becoming frustrated with what they regard as unnecessarily long and complex processes to establish the agencies. The length of the establishment process also means that DWAF's regional offices, which are most profoundly affected by the gradual transfer of responsibilities (and, in all likelihood, staff) to CMAs, will be in a state of transition for some considerable time.

The current level of water resource management charges (see later), which will be the CMAs' principal source of revenue, are currently inadequate to fund the full range of necessary management activities. Whilst the intention is to increase tariffs to a level where they are sufficient for the CMAs' needs, the increases must be phased in to account for affordability. It is likely that CMAs will depend on allocations from the national fiscus for some time.

The boundaries of water management areas do not coincide with the administrative boundaries of provincial and local governments. Most CMAs will have to establish supportive and co-operative relationships with more than one provincial government, and a number of local governments. Developing and maintaining these relationships will not be easy, but they are of utmost importance to ensure, among other things, that water-related planning by the CMAs is consonant with provincial and local planning and development initiatives.

One of DWAF's responsibilities is to monitor and audit institutional performance. The NWA provides for a number of ways to do this, including review of business plans, annual reports and financial statements. The Minister may also issue directives to institutions in the event of failure to perform. Initially, until CMAs are empowered to oversee the activities of WUAs, DWAF will be responsible for a large number of institutions. At present there is insufficient capacity in DWAF for this task, and sufficient capacity must be developed. When CMAs become responsible for WUAs, provision must be made in their structures to monitor and audit WUA performance [14].

More than half of the water management areas cover internationally-shared river basins, for which the intention is to create river basin commissions in the next few years. A clear understanding needs to be developed of the respective roles of, and relationships between domestic water management institutions - DWAF and the CMAs - and the basin commissions.

## WATER PRICING

Historically there have been considerable inconsistencies in the application of charges for water use in South Africa. Whilst most urban and domestic users have generally paid the full cost of water provision, tariffs for irrigators using water from Government Water Schemes have, in many cases, not even covered the costs of scheme operation and maintenance, let alone made any contribution to the costs of capital, or infrastructure depreciation. One of the priorities of water policy and law is therefore to ensure that, within a reasonable time, the real financial costs of managing water resources and supplying water, including the cost of capital, are recovered from users [15]. The objective of the new approach to water pricing is to contribute to achieving equity and sustainability by promoting financial sustainability and economic efficiency in water use.

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[14] The NWA implicitly recognises water resources management capacity shortfalls in all areas of expertise in South Africa by allowing for phased and progressive implementation of its provisions over time. The Proposed National Water Resource Strategy briefly discusses a national capacity building initiative to address these inadequacies for the entire water sector.

[15] The exception concerns the NWA's Reserve, which is the water required to meet basic human needs (all households in South Africa receive 6 cubic metres of water per month free), and to maintain the ecological functioning of water resources.

**Pricing strategy for water use charges**

The NWA requires the Minister to develop a pricing strategy for water use charges. Charges are of three types, and are for:-

- Funding water resource management
- Funding water resource development and use of waterworks:
- Achieving the equitable and efficient allocation of water:

Water use is defined broadly in the NWA, and includes taking (abstracting) water from the resource, storing water, all aspects of discharging waste into water resources, land-based activities that may affect the quantity or quality of water in the resource, making physical changes to the physical structure of rivers and streams, and using water for recreation.

Each water management area us different, with its own mix of user sectors and requirements for resource management activities, and the Act allows tariffs to differ between different water management areas, and also between user sectors, provided there are sound reasons to do so, and equity is maintained.

**Charges for funding water resource management** are to fund routine management activities such as information gathering, monitoring and controlling water use, water resource protection, water conservation, some aspects of water quality management (see waste discharge charges), and dam safety control. This is a new charge introduced by the NWA to provide revenue for the CMAs. Prior to their introduction in financial year 2002/3 DWAF carried the majority of the cost as part of its routine management responsibilities.

The charges relate to all water used, irrespective of whether it is taken direct from the resource or supplied from a scheme, and are calculated on annual water use. In financial year 2002/3 tariffs for the 19 water management areas ranged between 0.32 and 3.37 cents per cubic metre per annum (c/m$^3$/a), for domestic and industrial use, 0.32 and 1.00 c/m$^3$/a for irrigation, and 0.30 and 1.00 c/m$^3$/a, for stream flow reduction caused by commercial forestry plantations. Tariffs for domestic and industrial represent full cost recovery, but an assessment of affordability indicated that tariffs for irrigation and forestry should be capped, at 1.00 c/m$^3$/a and the unit charge equivalent to R 10 per hectare respectively, and progressively increased in line with the increase in the producer price index.

**Charges for funding water resource development and use of waterworks** are to recover the costs of investigation, planning, design, construction, operation and maintenance of dams and related waterworks, pre-financing of development, a return on assets, and the costs of water distribution.

On Government Water Schemes tariffs have historically been subsidised, especially for irrigation, and they will be increased at different rates for different sectors, based on producer price index and the rate in inflation, until full cost recovery is achieved. Tariffs on schemes owned and operated by other water management institutions have generally achieved full cost recovery in terms of the pricing strategy.

Charges for resource management and for resource development and the use of waterworks are financial charges, directly related to the costs of managing water resources and supplying water from schemes and systems. The rather obscurely named **charges for achieving the equitable and efficient allocation of water** are economic charges, and relate to the value of water to particular users. The pricing strategy proposes the introduction of administratively determined charges, public tenders and auctions, but defers their implementation until the effects of full financial pricing have been evaluated. In the meantime the NWA permits temporary and permanent trade in water use authorisations, with close control under the licensing system.

Thus far the pricing strategy has been established for abstracting and storing water, and the reduction of stream flow caused by commercial forestry plantations. Limited capital and operational subsidies, and subsidies on water use charges are available to emerging farmers who are members of WUAs.

A **waste discharge charges system** is also being developed, and is currently the subject of public consultation. The proposed system is designed to supplement the more traditional regulatory, standards- and objectives-based approach to water quality management, by introducing financial and economic incentives and disincentives to:-

- Ensure that the costs of polluting activities are, as far as possible, borne by the polluter (internalised), and not passed on (externalised) to other water users who could be disadvantaged by the detrimental impacts of waste on water resources;

- Encourage the minimisation of waste discharge; and

- Promote efficient and effective water use.

Although the subject of ongoing debate, tariffs will probably comprise a base charge, and increasing pollutant load charges depending on the volume and nature of the waste.

**Challenges in implementing the pricing strategy**

Difficulties with implementing any new pricing arrangements are not unique to South Africa. With regard to water pricing in South Africa, difficulties are likely to centre on affordability and willingness to pay.

The previous pricing regime in which, for many users, the tariffs did not reflect the full cost of providing the service, did not encourage detailed understanding of the economics of all user sectors. In developing the pricing strategy DWAF undertook an overview of the affordability of the proposed charges in each water management area (hence the area- and sector-differentiated tariffs discussed previously), but it cannot be said with confidence that the relationships between water pricing and the economy are fully understood in detail. The irrigation sector in particular - the largest volume water user in the country, accounting for about 60% of all water used - insists that the new charges will prejudice the viability of its business, and it is clear that more detailed study is required to investigate the validity of the assertion. In the meantime tariffs have been set at levels appropriate to the present level of understanding of affordability, and will be raised as understanding improves.

Willingness to pay is closely related to perceptions of affordability, but also reflects the historical situation in which DWAF did not pursue payment of charges with any great vigour. Collection of revenue will prove to be difficult until users become convinced that DWAF, and eventually the CMAs, demonstrate that they are serious about cost recovery.

## FINANCING INFRASTRUCTURE DEVELOPMENT

Most of the major water resources infrastructure in South Africa has been funded from the national fiscus (some exceptions are discussed later), has been planned, designed and constructed by DWAF, and is owned and operated by DWAF. The institutional changes described previously will profoundly affect DWAF's direct involvement in infrastructure development and, as a consequence, will affect the way in which such developments are financed. DWAF has commenced a comprehensive analysis of the implications of these changes, but at present it is possible only to make general, qualitative observations about their effects.

**A new approach to infrastructure financing**

In terms of national government policy, infrastructure development should wherever possible be funded off-budget (that is, not from the national fiscus), on a project basis, through payments by users. One of the objectives of the current review of arrangements for developing and managing water-related infrastructure is to make recommendations for a coherent approach to the financing of capital investments. The establishment of a national water utility could significantly reduce the need for direct government expenditure on capital works, by facilitating off-budget funding.

The review is also investigating funding mechanisms for investments where long pay-back times or financially weak consumers do not allow a project finance approach to be adopted. Some government funding may continue to be required for developing such schemes, intended primarily for irrigation purposes, schemes for social or disaster mitigation purposes, or schemes to meet international obligations. Direct government funding will also continue to be required for the capital aspects of expanding the water resources monitoring network.

However, it should be noted that a substantial proportion of capital investment in the past decade has been financed off-budget, from sources other than the National Treasury. South Africa is not entirely without experience in this matter, and the development of the new approach was based on this experience.

The Lesotho Highlands Water Project (Fig. 5) is the largest project ever undertaken in Southern Africa. The scheme transfers water from the Senqu River system in Lesotho into the catchment of the Vaal River in Gauteng Province, South Africa, to augment supplies to urban and industrial users. The total cost, including finance costs, of Phases 1A & 1B amounts to about R 17.5 billion. According to the Treaty between Lesotho and South Africa the Lesotho Highlands Development Authority (Lesotho) and the Trans-Caledon Tunnel Authority (South Africa - TCTA) were responsible for sourcing finance locally and internationally by way of loans, credit facilities and other borrowings to cover the costs of construction, operation and maintenance. TCTA, a statutory international water management institution in terms of the NWA, also undertook the construction of the delivery tunnel from Lesotho into South Africa, and associated infrastructure in South Africa. TCTA is currently responsible for servicing the loans, from charges made by DWAF on water users in the Vaal System, and remitted to TCTA.

The Komati Basin Water Authority was responsible for arranging finance for, and undertaking the construction of water resources infrastructure in the Komati River Basin in South Africa and Swaziland, and is now responsible for servicing the loans from grants (subventions) received from the Governments of Swaziland and South Africa.

Dam development in the Usutu River, in the north-eastern part of the country, to facilitate power generation was partially financed by the principal user, the national electricity utility Eskom. Similar arrangements are being discussed with mining interests to finance the raising of the Flag Boshielo Dam on the Olifants River, also in the north-east.

**New infrastructure developments**

Although the first option in situations of water shortage will be to implement water conservation and water demand management measures, it will be necessary to construct more dams in future to support social and economic development.

Recently Cabinet has approved the appointment of TCTA to source finance for the construction of the recently-approved R 1.4 billion Berg River Project, which includes a dam on the farm Skuifraam, in the Western Cape Province. The scheme is primarily intended to supplement water for urban and industrial use in the greater Cape Town area, but some additional irrigation water will also be available. Approval of the project was given only after the City Council of Cape Town, who will be responsible for recovering water use charges from users, had agreed to implement a programme of water demand management in its area.

DWAF has identified, and published for public comment in the Proposed National Water Resource Strategy, 18 possible new publicly-implemented projects involving dam construction which may be needed during the next 25 years. Additional dam-related developments are mooted in the Proposed Strategy, but not discussed in any detail, because they fall beyond the 25 year horizon. Their total estimated cost is almost R 12 billion (2002 prices). Five of the projects are primarily for supplying water for irrigation (R 2 billion), with the remainder being mainly for domestic, urban, industrial or mining use (R 10 billion).

It is probable that the irrigation schemes, intended mainly to provide opportunities for emerging farmers, will not be sufficiently economically viable in the short to medium term to facilitate off-budget funding, and total cost recovery

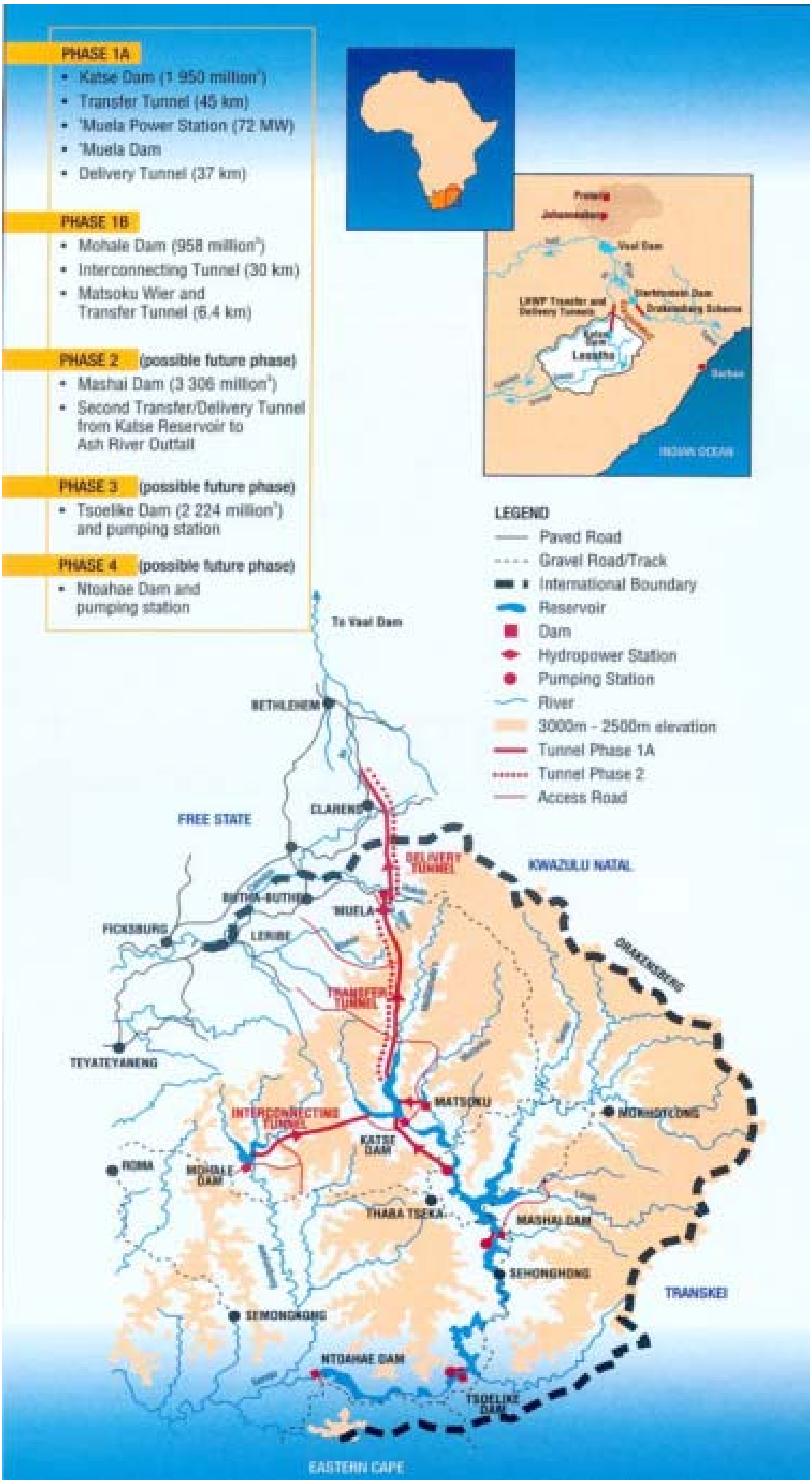


**Fig. 5: The Lesotho Highlands Water Project**

from water use charges. In these cases, should the schemes proceed, scheme implementation will be directly funded by the State. The other schemes, serving users who are able to pay the full water use charges, are more likely to be economically viable, and off-budget funding arrangements will be explored as the need for the schemes arises.

**Challenges in implementing a new approach to infrastructure financing**

If the new approach to infrastructure financing is to succeed, South African water management institutions will need to develop more expertise in project financing. At present there are few water-related organisations with the necessary understanding of the complexities of such arrangements, and South Africa relies on international support.

In addition, there is a perception, especially among civil society groups and trade union organisations concerned about the plight of the poor, that off-budget funding is a disguised form of privatisation of State assets. Some commentators believe that international investors will own the dams they are financing, and that their operation will be entirely for profit, to the disadvantage of the poor. (This perception is also held in respect of agreements between local authorities and private sector organisations to manage municipal water services). Irrespective of the validity of these fears, they will need to be carefully managed to achieve public acceptance.

The author gratefully acknowledges the permission of the South African Department of Water Affairs and Forestry to prepare and present this paper. The views expressed in the paper are the author's, and not necessarily those of the Department.

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# WATER ALLOCATION – PRINCIPLES, PRIORITIES & APPROACHES

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FULL PAPER

***ABSTRACT***

*Water allocation is a key element of South Africa's water reform process and forms part of the socio-political change that has taken place in the country since 1994. Its main objectives are the equitable allocation, efficient management and beneficial use of available water resources in the public interest.*

*This paper discusses three available allocation options via licences as entitlements to use water. These include: individual licensing; Catchment Management Strategies, incorporating Catchment Management and/or Water Allocation Plans; and Compulsory Licensing. The approach and methodology regarding the latter two options are currently under development.*

*The process has considerable socio-political and socio-economic implications and must be undertaken with great circumspection. Potential impacts are being factored into the process design. Other activities (technical, institutional, regulatory, etc.) impacting on the process are also discussed. Ultimately, the process must address the critical issue of poverty eradication and socio-economic development in South Africa.*

## 1. INTRODUCTION

South Africa has limited water resources that are unevenly distributed across the country and which are under pressure from development. The availability of these resources is further affected by natural cycles of drought and floods. National figures for water resources (which classify South Africa as water scarce) mask both this variability and the grossly inequitable access to water resources that forms a legacy of apartheid planning. Without effective management, and the equitable redistribution of water resources, targets for the delivery of basic needs and improved services to the poor will not be achieved and future economic development will be severely limited. Water resources are also central to the success of policies for land reform and support to emerging farmers.

Primary responsibility for water resource management rests with the national Department of Water Affairs and Forestry (DWAF). DWAF has developed a sophisticated policy and legislative framework for Integrated Water Resource Management (IWRM), which is enacted through the 1998 National Water Act (NWA). Implementation of different aspects of the framework is currently in progress.

Significant challenges include the need to deliver improved living conditions to the poor, while maintaining opportunities for economic growth and promoting the equitable redistribution of this scarce and variable resource. This is the focus of South Africa's water allocation program as part of its water reform process.

## 2. THE NEED FOR A WATER ALLOCATIONS PROGRAMME

South Africa does not have a clean slate to start its water allocations program with; however, provision is made to, at least, tidy up this slate. The credit for this must be given to the water law review process and the various role-players who actively participated in developing the National Water Policy for South Africa. The process culminated with the promulgation of two water statutes, namely, the Water Services Act of 1997 and the National Water Act of 1998. These statutes, in turn, reflect the principles of the supreme law of the land, namely, the Constitution of South Africa. The foundation principles of the NWA are: equity, efficiency and sustainability in relation to the manner in which water resources are protected, used, developed, conserved, managed and controlled. Public consultation and participation is a further statutory requirement for all activities prior to formalisation.

### 2.1. Equity, Efficiency And Sustainability

The NWA provides the framework for water allocations. It is intended that this framework be responsive to the needs of all South Africans who have a constitutionally enshrined right of access to sufficient water, “without the surrender to vested interests nor a water grab” (Kader Asmal, 1997 – Fundamental Principles and Objectives for a New Water Law for South Africa). The NWA was preceded by two water statutes; namely, the Irrigation and Conservation of Waters Act of 1912 and the Water Act of 1956. These laws allowed access to water on the basis of the Roman-Dutch riparian rights principle and the concepts of private and public water. With 87% of the land being in the ownership of the white minority population, access to water by the majority of black South Africans was restricted or denied. A land reform program, which commenced several years ago, was put in place to address this anomaly. However, although the riparian rights principle and the concepts of public and private water have been abolished, their legacy still endures and all lawful water use in terms of these and other relevant statutes are recognised by the NWA and must be accommodated within the water allocations program.

As a water poor country with historical legislation that made little or no provision for water conservation and demand-side management, the traditional approach to water resources management was supply driven. In this regard, DWAF was renowned for its dam building capabilities. While infrastructure development is still an important part of the DWAF core business, the focus is gradually shifting toward a demand side focus with water use efficiency, conservation and educational programs gaining more prominence. Capacity building projects for potential and new water users must address this issue from the outset by changing mindsets toward the way water is perceived. The old adage of “water is a gift from heaven to be used as desired” must be banished from the minds of water users. Accordingly, the DWAF slogan of “Some for All Forever” seems appropriate in the context of the country’s water situation.

### 2.2. Poverty And Productivity

Globally, access to and use of water is highly skewed. Even in the water rich areas of the world most of the water, and the pollutant effects of using water, lies in the hands of a relatively small and wealthy sector of the population. It is also increasingly accepted that sustainable development, and in fact the future of mankind, lies in improving access to water resources, particularly for the world’s poor. Inadequate access to water traps people into a cycle of poverty, poor health and pollution, which they find very difficult to break free of without active intervention. Poverty and the growing gap between the rich and poor are also increasingly seen as the greatest threat to global security and development. In South Africa, poverty is concentrated in the rural areas where nearly 75% of South Africa’s poor live and black South Africans comprise nearly 95% of South Africa’s poor.

The average per capita income in South Africa is one of the best in the developing world at 3020 US$ per year and an overall GDP of 150 billion and a population of some 40 million. However, this income is significantly skewed, with 11.5% of the population living below the international poverty line of less than 1US$ per day, and 36% below 2US$ per day. In terms of this income distribution we are one of the most unequal countries in the world, having amongst the worst social indicators of comparable middle-income countries. This income distribution is primarily a result of the apartheid history of the country, which not only robbed the black majority of a political voice but also distorted access to the economy and resources of the country through a whole gamut of repressive legislation.

The political dispensation changed with a remarkably peaceful transition to democracy in 1994. The onset of democracy in South Africa provided the opportunity for Government to revise legislation not only to repeal the old apartheid laws and create equal opportunities, but also to develop legislation aimed at addressing the crippling poverty affecting the lives of the majority of the population. The last nine years have therefore seen a plethora of new legislation not only aimed at equality, but also at taking proactive actions to redress past inequities. This was one of the key objectives behind the Water Law Review process, and promulgation of the National Water Act and the Water Services Act.

## 3. PROCESS DESIGN - ISSUES UNDER CONSIDERATION

Water allocations is a multi-faceted discipline, both within the water sector and outside of it. The flood of new legislation reflects the South African government's approach to addressing the issue of equity, sustainability and socio-economic development in the country, on all fronts. Accordingly, all spheres of government are constitutionally compelled to embark on every aspect of their activities in a spirit of co-operative governance. Thus, the approach with the water reform program is to link with other governmental programs, wherever possible and necessary at the relevant spheres, whether local, provincial or national. This is also in line with the government policy of co-ordination, integration and the optimal use of limited available material and human resources. One example of such a program is the Integrated Sustainable Rural Development Plan that focuses governmental resources and efforts in improving the quality of life of approximately half the South African population who live in rural areas by improving their access to resources and services.

### 3.1 Institutional and Regulatory Arrangements and Requirements

The two-tier approach to water resources management, described in the NWA, allows for matters of national interest to be described by the National Water Resources Strategy, the responsibility of the national Minister for Water Affairs and Forestry, while matters of regional and local significance are described by Catchment Management Strategies, which are developed by Catchment Management Agencies. The basic planning and operational units for WRM are catchments, wherein the unity of the hydrological cycle is recognised in its entirety. These provisions in the NWA guide the overarching approach that must be followed in water allocations planning by identifying the two major institutional water resources management role-players and the appropriate planning scales.

Furthermore, there are two temporal scales, or timeframes, that are important for the water allocations implementation program. Firstly, there are current structural, resourcing and functional constraints that seriously complicate implementation of the process in the short-term; and, secondly, there are structural, resourcing and functional needs that must be addressed in the medium- to long-term. An evaluation of the current situation and a projection for the future situation are therefore also critical planning elements.

All water use must ultimately be licensed, except that which is exempt. This will be done in a phased and progressive manner on a catchment-by-catchment basis, determined by the urgency of the exercise. The basic procedural approach for water allocations in the form of water use licences is described in the NWA and applies in all cases (Figure 1). The complex nature of the procedure, and its concomitant problems, requires that the process is simplified for ease of understanding by a wide range of stakeholders; but most importantly, that it can be implemented in a relatively non-contentious way.

The NWA also makes further provision for allocations to be undertaken as an intervention under certain prevailing conditions. This intervention, called Compulsory Licensing, can be undertaken for any aspect of water use as defined in the NWA, "in respect of one or more water resources within a specific geographic area". Essentially, it deals with the issuing of all licences in a designated area or catchment. Conditions that qualify for this intervention include the following:

(1) where it is necessary to achieve a fair allocation from a water resource which is (a) under water stress; or (b) when it is necessary to review prevailing water use to achieve equity in allocations;

(2) to promote the beneficial use of water in the public interest;

(3) to facilitate the management of the water resource; and/or

(4) to protect water resource quality.

Before Compulsory Licensing can be finalised, a number of building blocks need to be in place, including the registration and verification of existing water use, the National Water Resources and Catchment Management Strategies, the Classification of the water resource, setting Resource Quality Objectives and Reserve Determinations, international and strategic obligations and determining the water resource available for allocation. The interplay among these building blocks is shown in Figure 2.

The Compulsory Licensing procedure is more complex than that described in Figure 1, and involves the following steps (Figure 3):

(1) In the catchment selected for compulsory licensing, notice will be given inviting persons to apply for licences. Applicants may be required to submit additional information, technical reports, environmental or other assessments, which may be subjected to independent review.

(2) In determining water use allocations, all applications received must be considered and attention given to issues such as equity and poverty alleviation. A **proposed allocation schedule** will then be drawn up detailing how the available water will be allocated among the applicants. This information must be published in the Government Gazette.

(3) After considering all objections received on the proposed allocation schedule, a **preliminary allocation schedule** is compiled and, once again, published in the Government Gazette.

(4) After further appeals have been considered and the preliminary schedule amended, where necessary, the **final allocation schedule** is published in the Government Gazette and licences issued accordingly.

All available water need not be allocated and some may be reserved for future needs. Provision is also made for water to be allocated on the basis of public auction or tender. The envisaged Compulsory Licensing program for South Africa is depicted in Figure 4.

A third mechanism for water allocations is currently being explored. This is a compromise approach between Compulsory Licensing and Individual Licensing and requires the development of water allocations plans and schedules on a voluntary and co-operative basis among existing and potential water users as part of their Catchment Management Strategy. Much of the formality associated with the compulsory licensing procedure is circumvented, although intensive mediation among water users would become essential and process needs would remain similar.

### 3.2 Political, Economic and Social Aspects

Water is an important element of global politics at all scales and the potential threat of "water wars" has further highlighted the need for water use reform both on an international and national basis. Inevitably this means taking from the "haves" to give to the "have-nots" or allocating water among competing users.

Water use reform is therefore inevitable, not only on a global basis but also regionally and within individual countries. Water use reform must go beyond the provision of safe drinking water, and must include the provision of water for productive uses. However, the manner in which this is done is critical. While there are clear arguments for taking water away from the "haves" to provide the basic drinking and sanitation needs for the poor; taking water from existing productive users to emerging users has significant political, economic and social implications in the South African context. But these implications can largely be mitigated by proactive interventions to not only transfer the legal entitlement to use the water, but also to build the capacity to use the water productively. This program also proposes a framework for a process of transferring both the legal entitlement and the capacity to use water productively from the "haves" to the "have-nots" in South Africa.

There are obvious risks to a rapid and unmanaged process of water use reform. The re-allocation of water use entitlements must therefore be undertaken with caution and, apart from the social and economic implications mentioned above, should also be cognisant of potential legal implications of curtailing existing lawful water use. Short-term implications of water use reform must be balanced with the benefits of a better life for the rural poor, the impact of HIV/AIDS, and the impact this may have on the long-term economic benefits to the country.

**Figure 1:** Criteria to be considered for the assessment of water use licences (figure redrawn by James Perkins, 2002).

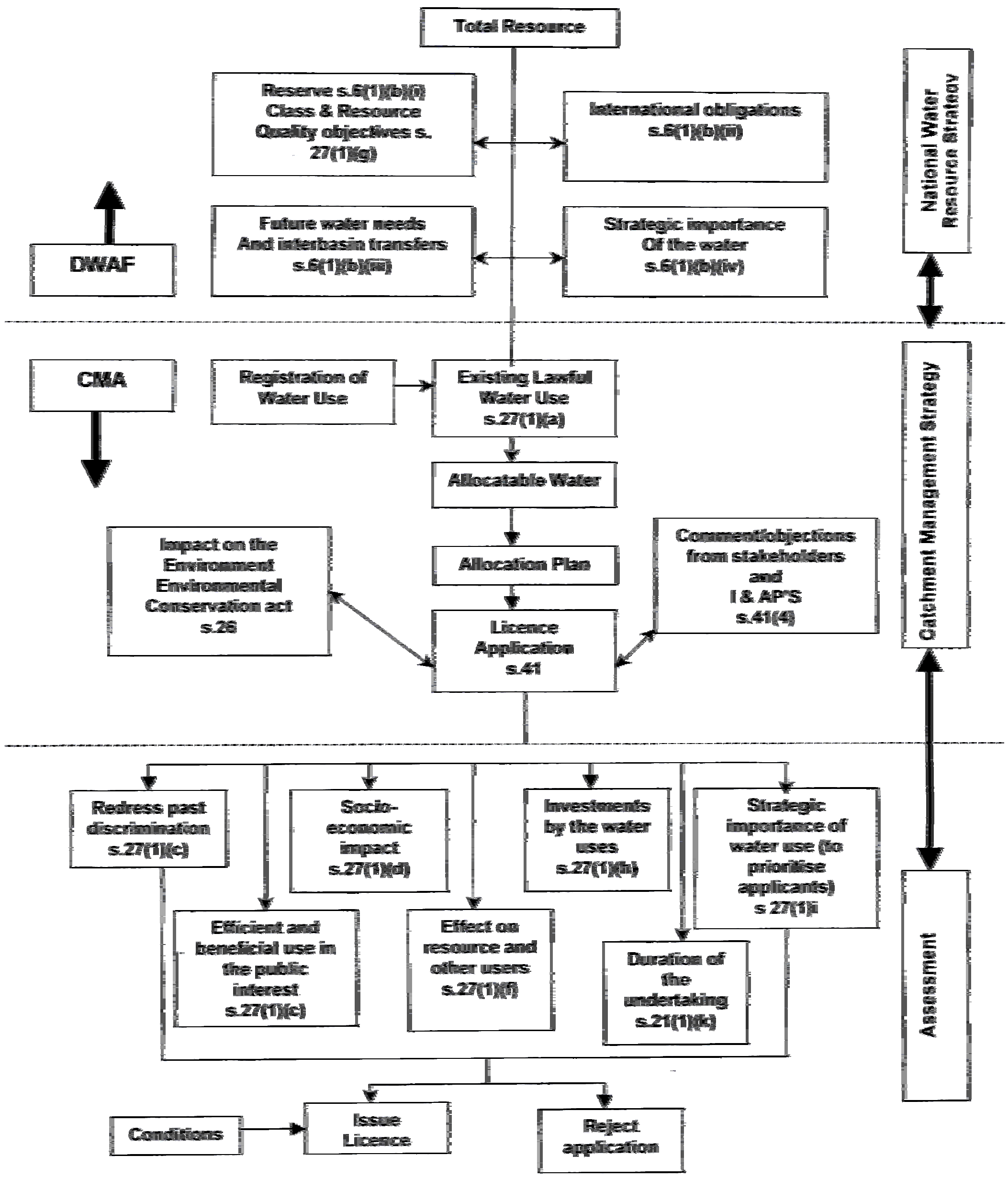


**Figure 2:** The Development of Reconciliation Options and Formalising IWRM (compiled by Johan van Rooyen, 2002).

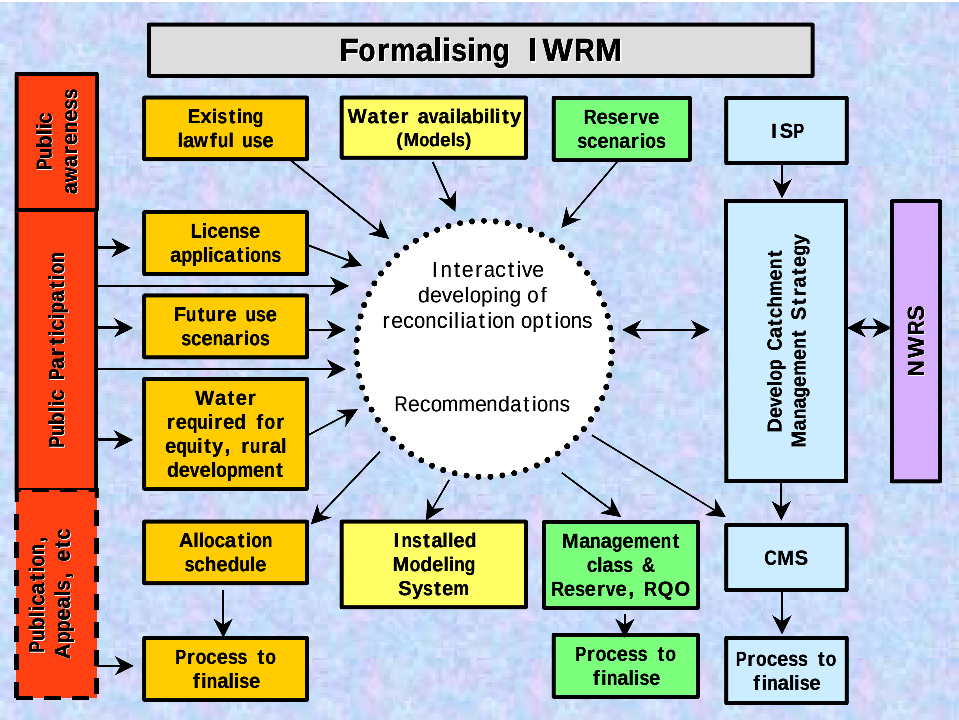



**Figure 3:** A proposed program for Compulsory Licensing in South Africa (TINWA, 2002).

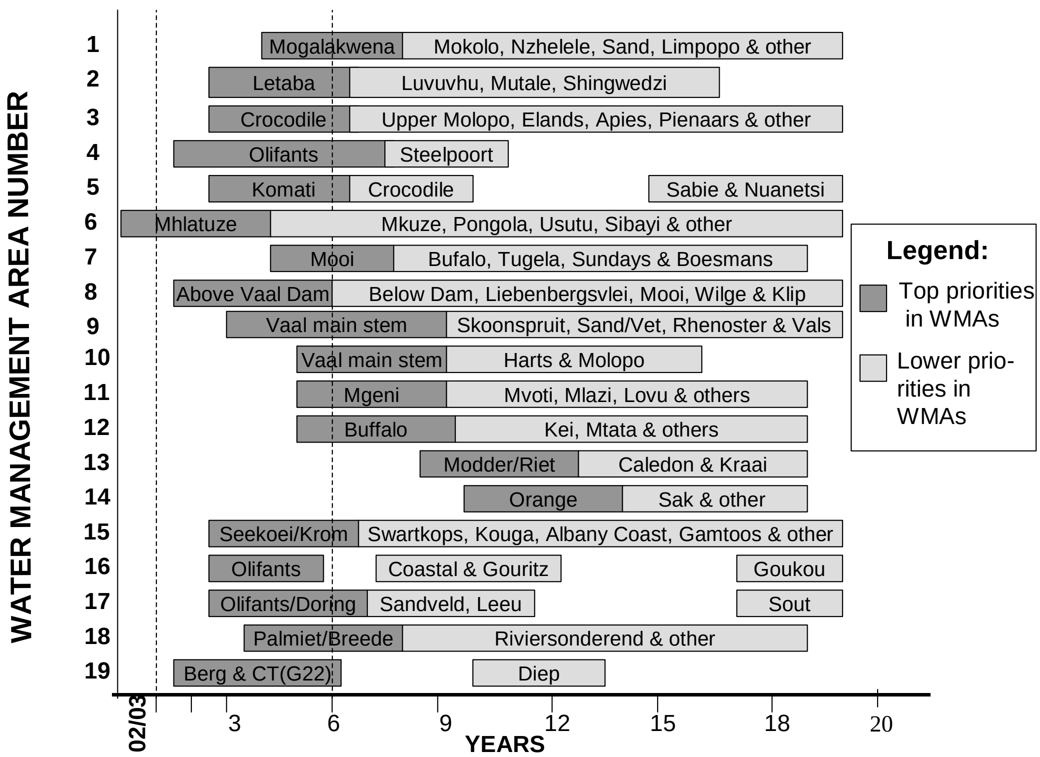
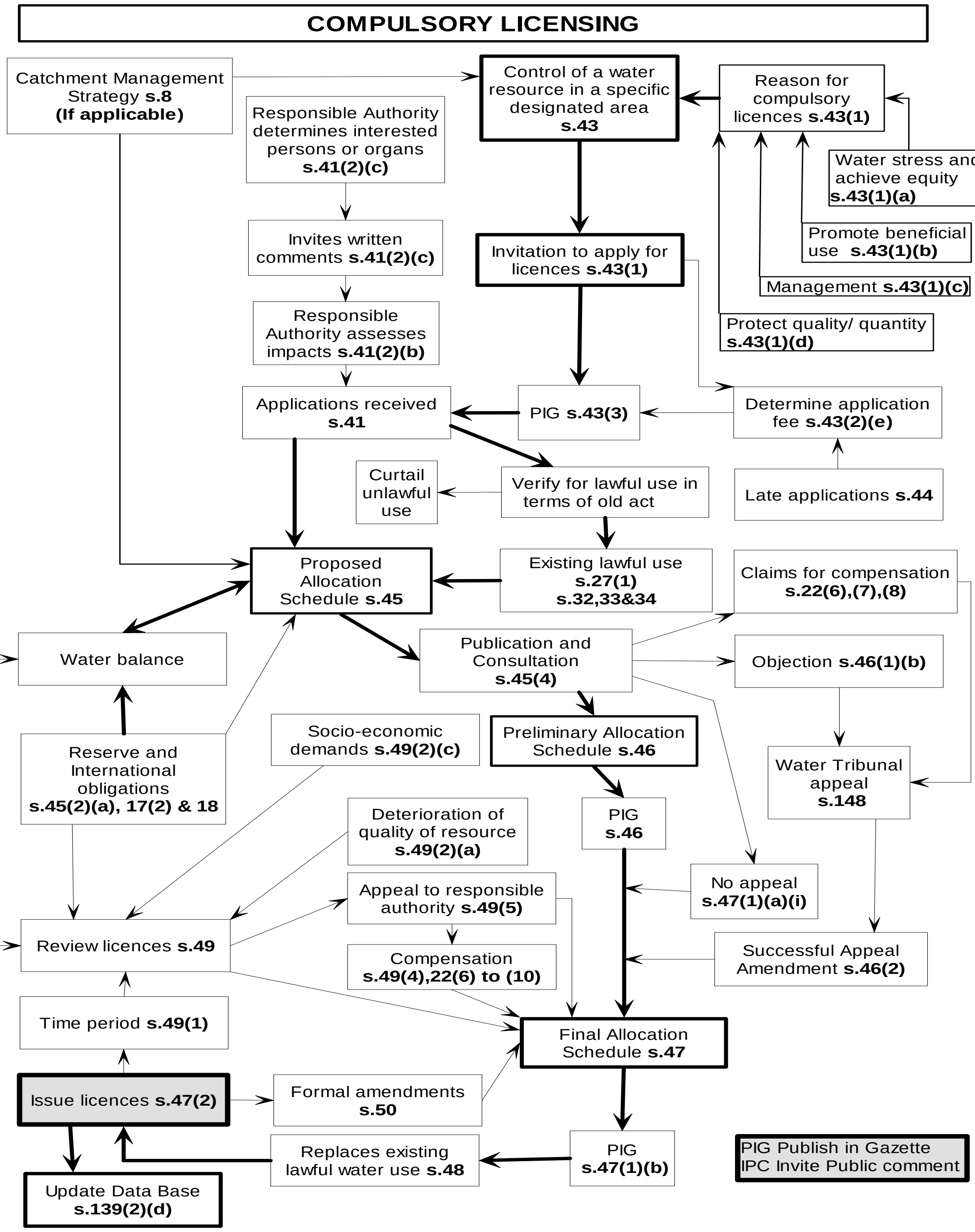


**Figure 4:** A process diagram for Compulsory Licensing. Cross-references to the National Water Act are indicated, where applicable (compiled by Johan Wessels, 2002).




## 4. APPROACH TO IMPLEMENTATION

The draft 1st edition National Water Resources Strategy (NWRS) has distilled a 10-step process for compulsory licensing and allocation of water use. These steps have been further elaborated into a flow diagram (Figure 3) that includes the determination of the Reserve and international obligations, and which indicates the links with the Catchment Management Strategy. These procedures are determined by the National Water Act, and the NWRS, and are legally binding. However, these processes are largely technically and administratively driven, where existing and potential users must make application, following which the responsible authority then identifies and develops solutions to conflicts, and submits these for public comment. Without careful consideration of how marginalized groups could participate, this process is likely to perpetuate the inequitable use of water resources. This program will therefore lend support to developing methodologies to include the rural poor in this process, as well as on building capacity within these groups such that they understand the process and recognize the need for participation.

These methods must ensure that marginalized groups are helped to identify their requirements over and above their basic needs. Such requirements will be linked with the rural development plans and with the Integrated Development Planning process. The rural poor will also be encouraged to identify needs that enhance and secure improved livelihoods by ensuring better access to the water resource. All users will also be encouraged to identify water quality needs with respect to their use. Moreover, the methodologies developed will include the development of guidelines that assist the responsible authority to develop allocation scenarios, to ensure a gradual move towards greater equity and realize tangible benefits to the rural poor; but which also balance the legal and economic impacts of curtailing existing lawful water use.

Multi-criteria decision-making processes developed using the Strategic Environmental Assessment methodology has provided a valuable strategic vision for this process and should inform this process. Similarly, DWAF's emphasis on Water Conservation and Demand Management and the need to shift towards more productive uses of water will be integrated into guidelines for developing allocation scenarios.

The water allocation program has at its outset a twelve-month development period for procedures, guidelines and methodologies, followed by a two-year pilot implementation phase and finally a one-year revision and refinement period. Where possible and pragmatic, lessons from the pilot will be used in implementing water allocations in other catchments around the country on a systematic basis during this four-year development period. Briefly, some of the factors that have a bearing on the approach to implementation are:

**Tools for reallocation**

Compulsory licensing is the tool for re-allocating water to ensure equity particularly in stressed catchments. Whilst the program will contribute to building the capacity of the rural poor to submit license applications, and to the process of developing the allocation schedules, the methodologies developed will also support allocation planning in unstressed catchments *via* the "normal" licensing process. Very importantly, the implications of using compulsory licensing in every catchment to level the playing field to achieve equity will also be examined.

**Testing of the methods**

The Team for the Implementation of the National Water Act (TINWA) and the draft National Water Resources Strategy have outlined a programme for compulsory licensing, indicating that the process will be piloted in the Mhlathuze catchment. However, other pilot catchments may be selected to test the water use allocation process in catchments displaying other characteristics that are not evident in the Mhlathuze.

**Compensation for curtailing existing legal use**

The National Water Act makes provision for compensation if existing lawful water use is curtailed and the economic viability of the undertaking is severely prejudiced – with certain exceptions. Nevertheless, many stakeholders have indicated that it is likely that DWAF would suffer claims for compensation following re-allocation. Lengthy appeals to the Water Tribunal could also slow the process of reallocation. This program will ensure that the methods developed are fair and consistent with the Constitution, the National Water Act and the Administrative Justice Act. Conditions under which compensation would have to be paid and the extent of compensation that will be needed will also be investigated.

**Merging with Resource Directed Measures**

Resource Directed Measures (RDM) specify the quantity and quality of water which is required to meet the needs of the Reserve and the Class of the Resource. The Class of the Resource and the Reserve must be determined before users can be licensed. With the Reserve being **the only water right** in the NWA, it is essential that the RDM and the compulsory licensing processes be integrated. The program will also investigate the implications of including water for food security as part of the basic human needs Reserve.

**The role of the Catchment Management Agency (CMA)**

The licensing of water use will ultimately be a CMA function. However, the responsibility for setting the Reserve, for setting aside a volume of water for future use, for international obligations and for certain strategic uses will remain with the Minister (administered by DWAF). There is consequently a need to investigate the institutional arrangements and integration of water use allocation processes between DWAF and future CMAs.

**Monitoring the socio-economic impacts of reallocation**

The program has included activities to monitor the impact of water allocations on the rural poor. It will also develop monitoring systems that can provide information on the racial and gender distribution of water use. However, measuring the impact on the rural poor will require socio-economic monitoring, which is expensive. DWAF already has significant financial obligations with respect to extending the existing monitoring systems and the viability of including socio-economic data as part of the routine water resources monitoring will have to be evaluated.

**Supporting the productive use of water**

This program will do more than simply make water available to the rural poor via the licensing process, but will also ensure that they have the capacity to utilize this water productively. There are options for providing capital and water use charge subsidies to the poor via the National Water Act. Similarly, close ties will be forged with the Integrated Sustainable Rural Development Programme and the Integrated Development Planning process at a local government level. This will help ensure that the necessary extension and financial support structures are in place to establish the productive use of water by emerging users.

*Merging with existing processes*

DWAF has made considerable progress with the development of methods for Integrated Water Resources Management (IWRM), Compulsory Licensing, RDM, Water Conservation Demand Management and Water Use Trading. This program will learn from these processes and will ensure that these processes are integrated with the water allocation process. The program will also support the development of methodologies that allow the gradual reallocation of water to emerging users to make productive use of the water, but which also limits the financial and economic consequences of restricting existing lawful use.

## 5. CONCLUSION

The National Water Act makes provision for the authorization of water use in 3 ways; **Schedule 1 use**, which includes relatively small quantities of water mainly for domestic purposes and stock watering, **General Authorizations**, which conditionally allow limited water use without a license, and **Water Use Licenses** which are used to control all other water uses. Water use licenses may be required for the abstraction of water (including underground water), storage of water, discharge of waste to water or the disposal of waste in a manner that may impact on the resource, and making physical changes to the structure of rivers and streams.

Water use licensing is consequently the tool that will be used to ensure equity in water use. In water stressed catchments all water use can be re-licensed via a compulsory licensing process. Given that inequities in water use exist in almost every catchment in South Africa, compulsory licensing could conceivably be considered in any catchment. However, the greatest challenges for re-allocation will emerge in situations were we do not have sufficient water, or where water quality is impacting on water use, and existing lawful use of water will have to be curtailed to meet the needs of equity. Cutting back on existing lawful use has complex political, legal and economic consequences, and the manner in which this is done is critical to sustainable development in South Africa.

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SUPPPLYING AND GROWING DEMAND

# COAG WATER REFORM OF THE URBAN WATER INDUSTRY IN AUSTRALIA

Dr John Langford

PRESENTATION ONLY

# COAG Water Reform of the Urban Water Industry in Australia

John Langford

Executive Director

Water Services Association of Australia



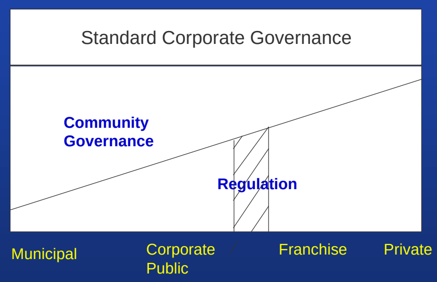
## Two Myths

1. Private sector is always more efficient than the public sector water industry
2. Private sector involvement in water services is a ‘bad thing’






## Where Do Australian Water Utilities Fit?






## Reform of Australian Urban Water Industry

- Keep industry in public ownership but go to brink of privatisation
- Pursue regulatory and industry reform
- Separate policy and regulation from the utilities
- Progressively build regulatory framework: environment, health, water resource and economic regulation
- Structural reform and corporatisation of the water utilities
- Pricing reform & removal of cross subsidies
- Stimulate reforms through National Competition Policy



## Structural Reform of Water Utilities

### Melbourne
- Horizontal disaggregation
- Comparative competition

Wholesaler

Retailer 1 | Retailer 2 | Retailer 3

### Hunter
- Vertical integration

Wholesaler

Retailer

### Brisbane
- Internal Service Contract

Brisbane City Council

Purchaser

↕ Contract

Brisbane Water: Service Provider

### Adelaide
- External Service Contract

SA Water Corporation Wholesaler

↕ Contract

United Water (Private Company) retail service provider & sewage treatment

## Corporatisation of Water Utilities

- Operating licence and statement of corporate intent from government
- Governance by a skills based rather than representational board
- Commercial and current cost accounting
- Subject water utilities to taxation and trade practices law as if a private company
- Pay dividends to owner (government)
- Benchmark performance
- Subject to regulation

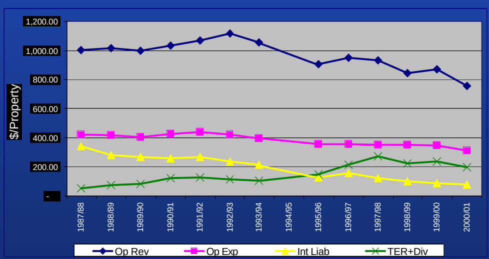
Water Services Association *of Australia*

## Pricing Reform & Removal of Cross Subsidies

- Removal of cross subsidies between classes of customer: industrial, commercial and domestic
- Elimination of property tax
- User pays
- Fixed access charge (based on size of water meter)
  - volumetric charge for all water used
- Support for low income groups
  - rebates for water efficient appliances and pensioner concessions

Water Services Association *of Australia*

## Trends in Revenue & Operating Efficiency




Water Services Association *of Australia*

## Improvement between 1987/88 and 2000/01 (Real $)

| | |
|---|---|
| **Operating Revenue** | **-24%** |
| **Operating Cost** | **-27%** |
| **Interest** | **-77%** |
| **TER & Dividend** | **275%** |

Water Services Association *of Australia*

## Trend To User Pays

(% of water revenue)

| | | 1989/90 | 2000/01 |
|---|---|---|---|
| Brisbane | Access | 80 | 13 |
| | Volumetric | 20 | 87 |
| Hunter | Access | 39 | 5 |
| | Volumetric | 61 | 95 |
| Sydney | Access | 71 | 17 |
| | Volumetric | 29 | 83 |
| Melbourne | Access | 75 | 18 |
| | Volumetric | 25 | 82 |

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## Sydney Water's Total Demand since 1950


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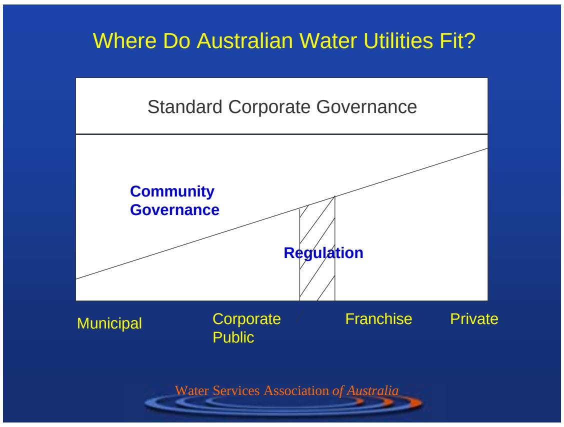
Where Do Australian Water Utilities Fit?
Standard Corporate Governance
Community Governance
Regulation
Municipal
Corporate Public
Franchise
Private
Water Services Association of Australia