THE ROLE OF CAPACITY-SHARING IN SOUTH AFRICAN WATER POLICY

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature :

Date :

ABSTRACT

A vast literature on the incompatibility of socio-economic development and environmental conservation (also referred to as sustainable development) has developed over the past few years. This study takes on the form of a critical, problem-driven discussion and evaluation of the applicability and viability of the concept of capacity-sharing to the current South African water management regime. Within the study, the complexities involved in the shift from a supply- to demand-oriented management strategy are examined in depth. This transition in strategy proves to be problematic for water policy makers and managers because of past management regimes and structures, measurement related problems, incorrect or insufficient definition of criteria needed for demand-oriented approaches and the emotional complexities regarding water use. Developments in water policy are currently at a point where problems are experienced regarding the practical implementation of proposed water demand-oriented policy.

The concept of capacity-sharing is explained and discussed in detail, leading to the identification of the applicability to three of the most important problems (basic contradiction within the 1998 National Water Act, initial allocation for market adoption and equity within the market) faced within the transition towards a demand-oriented approach.

This study found that the concept of capacity-sharing does hold applicability in addressing the above-mentioned three problems towards the transition to a demand-side management approach. Capacity-sharing, therefore, should be part of this timely transition and the state should make use of the advantages of this concept. To support this view, seven studies are proposed for further research to address the problems as mentioned in section 5.2 of the thesis.

UITTREKSEL

'n Uitgebreide literatuur aangaande die onversoenbaarheid van sosio-ekonomiese ontwikkeling en omgewingsbewaring (ook volhoubare ontwikkeling genoem) het oor die afgelope paar jaar ontwikkel. Hierdie studie neem die vorm van 'n kritiese, probleemgedrewe bespreking ten opsigte van die toepasbaarheid en relevansie van die konsep van kapasiteitsdeling binne die orde van huidige Suid Afrikaanse waterbestuur, aan. Die vele aspekte van die klemverskuiwing van 'n aanbod- na 'n vraag-georiënteerde waterbestuur-strategie, word ook beklemtoon. Hierdie oorgang is problematies vir waterbeleid-formuleerders en bestuurders as gevolg van vorige waterbestuur-ordes en strukture, meetbaarheid georiënteerde probleme, foutiewe of onvoldoende definieering van watergebruik-regte en die emosionele kompleksiteite van water. Tans, word probleme rakende die praktiese implementering van voorgestelde vraag-georienteerde waterbeleid ervaar.

Die konsep van kapasiteitsdeling word in detail verduidelik en bespreek waarvandaan die toepasbaarheid op drie van die belangrikste probleme (basiese kontradiksie binne die 1998 Nasionale Waterwet, aanvanklike verdeling van water gebruik regte vir opname binne die mark en die kwessie van regverdigheid binne die mark) vir die oorgang na 'n vraag-georiënteerde strategie geïdentifiseer word.

Die studie het bevind dat die konsep van kapasiteitsdeling wel relevansie ten opsigte van die bogenoemde drie probleme tydens die oorgang na 'n vraag-georiënteerde strategie, inhou. Kapasiteitsdeling behoort dus deel te vorm van die oorgangsfase na 'n vraag-georiënteerde water bestuur strategie en die staat behoort gebruik te maak van die konsep se voordele. Ter ondersteuning hiervan word sewe studies voorgestel vir verdere navorsing ten opsigte van die probleme soos geïdentifiseer in afdeling 5.2 van die tesis.

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For my mother, who planted the seed of inspiration for this study
and the rivers, which were it.

"In the end, we will conserve only what we love,
we will love only what we understand,
we will understand only what we are taught . . ."

- Baba Dioum
(Two Oceans Aquarium memorial plate, Cape Town.)

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INTRODUCTION

1.1 Background information

Natural resource management and, more specifically, water resource management, has developed into one of the most important political, social and economic issues of this age, and one of the main problems is the distribution of usable water resources for all users and uses.

Water-related issues are currently a controversial and relevant topic in South Africa due to the following underlying problems:

- A skewed distribution in the supply of usable water (poor communities often have no access to usable water).
- The agricultural irrigation sector is blamed for considerable misuse and for inefficient water practices.
- Pressure from environmentalists to guarantee minimum reserve flows to sustain the basic ecological functioning of catchment areas (National Water Act, 1998:A-31).
- The potential for new water supply development projects in South Africa is limited and costly.

These problems hold potentially negative effects for water security in South Africa. The problem of water security is essentially one of conflict between different uses and users in catchment areas, conflict between present and future generations of people, conflict between human resource development, consumption and other investments and conflict between economic prosperity and environmental conservation. This conflict can be reduced through bureaucratic (state intervention) or market processes or some combination of these. Controversy over the appropriate balance between market and regulatory approaches towards water allocation makes resource economics a relevant and dynamic sub-field of the discipline of economics.

As water resources develop from a "developing" stage towards a "mature" stage, the tension between market forces and broader social values becomes more prominent in state water transfer policies because of increasing competition (Groenewald, 1998:153). Economic development from extensive agriculture, irrigation and mining towards urban growth, services, tourism and industry, brings strong motivation and market incentives to transfer water from agriculture to meet the growing urban need (Louw, 2001:80).

Therefore, economists argue that market forces should play a greater role in water allocation-related problems. They emphasise the inefficiency of allocating water to low value crops while other non-agricultural users struggle to develop expensive new water supplies, because generally the cost of reducing agricultural water use is less than the cost of developing new water supplies. Furthermore, the transfer of only a small portion of the water used in South African agriculture would be sufficient to satisfy a significant proportion of the non-agricultural demand.

The establishment of tradable water use rights[1] could play an important role in improving the efficiency, equity and sustainability of water use patterns in developing countries. This would require well-defined tradable rights which would formalise and secure the existing water use rights held by water users; economise transaction costs[2]; force water users to consider the full opportunity cost of water; and provide incentives for water users to internalise and reduce many of the externalities inherent in irrigation practices. The institutional requirements, potential and feasibility of developing markets in tradable water use rights should receive increased attention from researchers and policy-makers (Groenewald, 1998:154).

Water markets are controversial both in theory and in practice but their potential benefits include greater efficiency and flexibility of water use and less state intervention and expenditure, while their drawbacks include social and environmental externalities, vulnerability to high transaction costs and examples of "market failures" (Bauer, 1997:639). However, before a water market could become active, a proper institutional framework must be in place to accommodate the practical workings of the market system.

The National Water Act of 1998[3] provides the institutional framework for the development of water markets in South Africa. Although the main reason for the Act is to address equity related issues, other important issues included are the development of a more efficient water allocation system which values water as a scarce resource, and the protection and conservation of the environment (Nieuwoudt, 2000:58). A remarkable shift from water supply management towards demand management is noticeable. However, this demand-oriented management approach presents several problems and limitations. These limitations in the current demand-oriented management efforts by the Directorate of Water Conservation and Demand Management can be summarised as follows (Gakpo and Du Plessis, 2001:7):

- Excessive state control over water management institutions still exists.
- Bureaucratic approval of water re-allocation is still necessary.
- Administrative pricing mechanisms still exist.
- Lack of institutional provisions for supply and demand management.

[1] Market transactions are undertaken for economic gain, based on the perception that water supplies will generate higher returns in their new use than in the former use. A third party (state) can gain some leverage on the transfer and start playing a role in water allocation decisions by decreasing these expected gains through imposing transaction costs on one or both parties and therefore have bargaining power (Colby, 1990:1186).

[2] Transaction costs are generally characterized as factors that prevent the efficient functioning of markets. Some are known and measurable while others are unknown and not measurable. In the water market paradigm, transaction costs usually consist of searching for trading partners, determining the characteristics of the water commodities, negotiating terms and prices for the transfer and obtaining legal approval for the transfer. Excessive transaction costs create artificial scarcity because the potential buyer of the right cannot afford the right due to high prices and the seller cannot sell the right due to high transaction costs. This artificial scarcity results in an excess supply of water (Colby, 1990:1185).

[3] Which repealed more than 35 previous acts.

- Lack of appropriate arrangements to facilitate trading of water (defining exclusive rights and providing the needed incentives).
- Unclear water transfer arrangements still remain.

Since most of the controversial issues regarding changes to be made to accommodate demand management policy have already been addressed in the literature, the last two of these limitations are of particular importance for this study, because the practical implementation of demand management policy will be the next problem area in this transition process. The co-operation between the public sector and private sector will be essential for the successful implementation of demand management policy.

Successful water institutions require co-operation between the public and the private sectors and the ideal institutional framework needs an approach that will integrate the public and private sectors and give market forces the chance to facilitate the allocation of water. The concept of capacity-sharing is the key to this process.

1.2 Capacity-sharing and the implementation of demand management policy

Capacity-sharing is an institutional arrangement that guarantees water use rights for allocating water among multiple users. These rights are exclusive, transferable and enforceable by law (Gakpo *et al*, 2001:91). The concept originates from Australia where a distinction was made within the market of water per se and water use rights (the right to buy water). With the separation of land and water rights in South Africa, the concept of capacity-sharing becomes an attractive alternative in handling uncertainty and potential conflicts within water management, because it facilitates the trade in water use rights and make a clear distinction between the market for water per se and the market for water use rights.

Capacity-sharing has been identified as an option that could play an important role in the transition towards a demand-oriented water management strategy. Capacity-sharing respects the needs of emerging water users (especially small-scale farmers) and therefore promotes equity. The concept fits into the proposed ideal institutional framework of Gakpo *et al* (2001:87) (refer to figure 4.1) and can also accommodate water banking for addressing social equity, while saving on transaction costs.

The relevance of capacity-sharing for this particular study lies in the fact that the concept could be used to make useful suggestions for engaging practical problems experienced in the practical implementation of demand-oriented water policy.

1.3 Statement of purpose

The focus of this study will be to investigate, in a critical way, the theoretical basis of the viability of "capacity-sharing" in addressing problems regarding the practical implementation of decentralised water management in South Africa. This will be done by identifying three of the most important problems (namely: a contradiction within the 1998 National Water Act, an initial allocation for implementing tradable water use rights and the equitable functioning of the market) that stand in the way of the practical implementation of demand-oriented water policy. The relevance of capacity-sharing in addressing these problems will be investigated in order to test the viability of the concept. However, this cannot be done without a detailed description and evaluation of the complexities of current water management-related problems.

The following questions refine this broad statement of purpose:

- Does capacity-sharing sufficiently accommodate the basic principles of efficiency, equity and sustainable water resource development as mentioned in the National Water Act of 1998?
- Is it possible to formulate a pricing strategy for the equitable and efficient allocation of water in South Africa that will also be institutionally accomplishable?

1.4 Rationale of the study

The consequences of water management and policy decisions are frequently difficult or impossible to predict because of the many complex interactions between technological, physical, institutional and socio-economic factors. This complexity, together with the objectives of sustainable resource development, decentralisation[4] and an equitable water allocation led to a situation where some difficulties are experienced in the process of implementing the proposed demand-oriented water policy. To add to this problem the National Water Act (1998) emphasised that the concepts of "efficiency" and "equity" should be transparent in water management strategies, but some vagueness is to be found in the description of the implementation of the above-mentioned concepts.

The purpose of this study is therefore to serve as a point of departure on testing the viability of the concept of capacity-sharing within the practical implementation of demand-oriented water policy in South Africa. This should

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[4] The concept of decentralisation strives to let all water users participate in the management of the resource. However, caution must be used because one of the weaknesses of decentralisation is a lack of the consolidation of power. This could lead to a situation where no authority has the final decision-making power and therefore no decision will be made at all. Capra (2002:76) mentioned that the economist, John Kenneth Galbraith distinguishes between three kinds of power. Firstly coercive power that wins submission by inflicting or threatening sanctions, secondly, compensatory power by offering incentives or rewards and thirdly, conditional power that changes beliefs through persuasion and education, and the art of politics is to find the right mixture of these three kinds of power in order to resolve conflicts and balance competing interests. The consolidation of power is therefore necessary to keep conflicting interests at manageable levels and to retain social order.

prove to be useful if government should decide on capacity-sharing as a viable option for water management in certain areas.

1.5 Literature Review

Current literature and research on capacity-sharing has been conducted mainly in Australia. Norman Dudley (University of New South Wales) (Dudley, 1988a; 1988b; 1990a; 1990b; 1992; 1994; 1999; 2002; Dudley and Musgrave, 1988; Dudley and Braynt, 1995) features as a prominent figure and is also the person who has done the most research on the practical implementation of the concept of capacity-sharing within catchment areas and reservoirs.

Within the South African context, capacity-sharing has been dealt with at an institutional level and some comparisons have been made between mathematical programming techniques that could be used in the implementation of the concept (Viljoen *et al*, 2000:1). No research project focusing on some specific problems regarding the implementation of demand-oriented water management, were found. Therefore, this study will be aimed at examining the concept regarding the practical implementation of demand-oriented policy in order to reduce uncertainty on the viability of the concept as a decentralised water management option.

1.6 Theoretical Framework

A theoretical framework, methodology and model of the concept of capacity-sharing have been suggested by Dudley (1988a:633-640 and 1988b:641-648) and Dudley and Musgrave (1988:649-658). Updated versions of the articles in 1988 are to be found in Dudley and Bryant (1995) and further readings on the concept of "capacity-sharing" are to be found in Dudley (1990a:381-402; 1990b; 1992:757-778 and 1994). Several problem areas have been identified, but the researcher is of opinion that the work of Dudley can be used as a point of departure to test the concept of capacity-sharing within the South African context.

1.7 Research design

Research design refers to a plan that guides the process of research activity. Within this study the research design will be build around semi-structured interviewing, the collection of documents, the attendance of various relevant conferences and informal discussions.

1.7.1 Semi-structured interviewing

The semi-structured interview is an important source of data production in interpretive and evaluative studies. The purpose of the interview is to provide descriptive data in the interviewee's own words and to access that which is unobservable. Semi-structured interviews therefore provide opportunities for responding to both predetermined questions and free responses. Semi-structured interviews are the ideal method for producing in-depth and detailed information that cannot be provided by other sources. Denzin and Lincoln (1994:367) argue that interviews provide better quality data if there is a relationship of trust between the interviewer and the interviewee. They recommend that relationships of trust should be developed with interviewees through empathy, sensitivity to context, appearance management and the development of shared interests.

Interviewing is therefore one of the most common and powerful ways available to help the researcher understand the human "self". It has a wide variety of forms and uses and the most common type of interviewing (also to be used in this study) is the face-to-face verbal interchange, but it could also take on the form of face-to-face group interviews, mailed or self-administered questionnaires and telephone surveys.

The semi-structured interview was used in this study for obtaining detailed information regarding demand-oriented water policy and the three problems (as mentioned in the statement of purpose) to be addressed by capacity-sharing.

1.7.2 Informal discussions

Informal discussions mostly took place during conferences and proved to be a useful in gaining insights on the research problem. Information shared in informal discussions provided insights into the opinions of other researchers within the field. This provided valuable information for delimiting the study.

1.7.3 Collection of documents

Documentation provides additional information to what may be accessible through observation and interviewing. It further helps to clarify other data, and includes records, files, internal and external communications, agendas, policy documents, forms, reports, news articles, journal articles, textbooks, published speeches and so on. Through the research study, documents applicable to the focus of this research were collected. Documents, drafts of writing material like conference papers, research reports and project proposals on South African water policy, as well as documents on international water policy, provided rich sources of insights for constructing the broader socio-historical and socio-economic contexts of the study and also substantially build the researcher's personal field of reference. It also helped with the interpreting of the study within the broader context.

1.7.4 Conferences attended

The three main conferences attended by the researcher were the 2001 and 2002 annual conferences of the Agricultural Economic Association of South Africa as well as the 2002 annual conference of the Forum for Economics and the Environment. The attendance of conferences and parallel working sessions were of great value in meeting people who shared the same passion and interests regarding water management. This was the ideal situation for the development of personal bonds ("networking") with important people within the field.

1.8 Chapter outline

This study is primarily concerned with a critical evaluation of the potential viability of the concept of capacity-sharing within the current South African water management regime. The present chapter is followed by a literature review on relevant issues related to water as an economic commodity, water policy and policy reform and water allocation strategies. The literature review (chapter 2) starts broadly on issues like the definition of water rights, valuing water as an economic commodity, the opportunity cost of water and sustainable water resource development by making use of integrated management strategies. Thereafter, the emphasis moves to water policy-making and water allocation strategies. Chapter 3 presents a detailed description of the capacity-sharing model (as a specific type of water use right allocation strategy) followed by a discussion on the viability and practical implementation of the model. Chapter 4 evaluates the viability of capacity-sharing with regard to the applicability to policy-related problems related to the practical implementation of demand-oriented water policy in South Africa. The final chapter consists of conclusions and recommendations for further studies.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

This chapter will serve as a point of departure to direct and help the reader to form a suitable context for this study. The basic point of departure for the study is the National Water Act of 1998. Within the act, sustainable development and equity are defined as central guiding principles in the management of water resources (National Water Act, 1998:A-15). Therefore, this literature review will start with a review of water rights under the National Water Act of 1956, followed by a summary of the National Water Act of 1998. A discussion on sustainability within the context of water management follows the section on the review on water rights since sustainable resource utilisation is one of the guiding principles of the 1998 National Water Act. This will be followed by a discussion on water as an economic commodity, because the study supports the use of the market mechanism to achieve the efficiency and equity related objectives as mentioned in the National Water Act of 1998. The accomplishment of these objectives is dependent on the follow through of an integrated approach towards water resource management thus leading to a discussion on integrated catchment management. From there, the emphasis moves on to the institutional changes facilitating an integrated approach towards water management. The literature review ends with a discussion on the legitimacy of the introduction of water markets as an alternative water allocation mechanism. Within this discussion, a clear distinction will be made between water markets for water per se and markets in water use rights. Once this distinction is clear, the reader will be able to understand the concept of capacity-sharing[5] as an instrument in facilitating trade in water use rights.

2.2 Review of water use rights in South Africa

This section will not give a detailed discussion of the old and the new South African water law, but an overview of the most important and relevant characteristics for this study.

2.2.1 The National Water Act of 1956 (Act 54 of 1956)

Backeberg (1994a) deals extensively with all the important issues pertaining to water rights, which were contained in Act 54 of 1956. This section is largely based on this work and is included for the sake of completeness.

The National Water Act of 1956 (Act 54 of 1956) incorporated and amended many of the historical developments in water law over a period of 300 years. It was an amalgamation of certain of the legal principles of Roman Dutch Law and English Law, supplemented by rules developed in South Africa. It was based on the riparian right doctrine of

[5] Throughout this study, the work of Scott and Coustalin (1995:961-979) will found many similarities with the concept of capacity-sharing.

English Law. Another 33 acts dealt with water use rights to use water out of specific schemes or works within certain demarcated areas. The power to exercise authority lay with the Minister of Water Affairs. Water rights were not contained within the act as the act only contained the mechanisms for determining and obtaining water rights. The section of the 1956 Water Act that deals with water rights was based on two principles:

- The first was the distinction between two water-use categories, namely private water and public water (this was mainly due to the influence of the Roman Dutch Law). Public water flowed in a known and defined channel and was capable of irrigating two or more pieces of land, which were original riparian grants to that stream. Private water was water not derived from a known and defined channel, and that it was not capable of irrigating two or more pieces of land that were original grants. The normal flow of a stream was limited to the maximum quantity of water available for beneficial irrigation during peak demand, but without storage, usually during the three to four months immediately preceding the raining season. Surplus water could be used for beneficial irrigation only after it had been stored.
- The second principle was a distinction regarding water rights per se. Rights to use groundwater and public water differed between areas not declared as government water control areas and areas declared as such. No property rights to public water existed, but only a right for certain persons to use the water subject to certain conditions. In an area not declared as government water controlled area, all the owners of land held common property rights to all the water in that stream for irrigation and/or urban use (this was mainly due to the influence of the old English Common Law[6]). In an area declared as government water controlled area, the right to use the groundwater and public water, was vested in the Minister of Water Affairs, subject to the beneficial exercise of certain rights.

The system of surface water rights, comprising 90% of usable water resources in South Africa, was based on riparian ownership. This linked water rights to land ownership or use. According to the 1956 Water Act, there were no ownership rights and decision-making powers regarding the transfer of rights rested with the Minister. However, a gradual relaxation of central control over water management occurred from the mid 1980's[7].

The newly elected government (in 1994) believe that the new Water Act should contain sufficient enabling legislation to allow an appropriate catchment management authority to be set up for a catchment. This would allow leading agencies to facilitate the development of appropriate frameworks for catchment management plans; allow the regulatory authority to enforce permit conditions and aspects of the management plan and set up appropriate

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[6] The rights to private water (excluding ground water) could not be affected by declaring the area as a government water controlled area. An owner of land with groundwater in such an area (not declared as government controlled) had the sole and exclusive use of such water. It could therefore be argued that there were unlimited property rights to these waters (this was also due to the old English Common Law) (Backeberg, 1994a).

[7] Some of these relaxations included changes in water management that have influenced the limited transfer of management responsibilities to farmers on state irrigation schemes and the deregulation of certain water management decision-making powers to the Department of Water Affairs and Forestry officials in certain catchment areas (Backeberg, 1994b).

consensus-seeking and conflict mediatory mechanisms. In the governments' view, the revised Water Act should allow the minister to issue regulations on a catchment-specific basis regarding (DWAF, 1996:52):

- The geographical boundaries of the catchment.
- Resource management objectives of the catchment.
- The nature of the process for developing the catchment management plan.
- Agency and stakeholder responsibilities for implementation of the plan.
- Legal status for the catchment authority.
- Conflict resolution processes.
- Monitoring, auditing and reporting requirements and responsibilities.
- The time scale and process for review of regulations.

2.2.2 The National Water Act of 1998 (Act 36 of 1998)

The National Water Act of 1998 (Act 36 of 1998) identified sustainability and equity as the central guiding principles in the protection, use, development, conservation, management and control of water resources. These guiding principles recognise the basic human needs of present and future generations, the need to protect water resources, the need to share certain water resources with other countries, the need to protect social and economic development through the use of water, and the need to establish suitable institutions in order to achieve the objectives of the new Act. These objectives were to be achieved through an administration system that should be self-financed primarily by the users of the water resource.

The National Water Act of 1998 stipulated that all existing claims to water rights should be registered within a reasonable time period. On completion of the registration process (January 2001) and the establishment of a comprehensive database on water users, the starting point for the pricing strategy would be the water management area. Through geological assessments and the use of hydrological models, the Department of Water Affairs and Forestry would calculate the available water for each water management area. From this quantity, four deductions would be made to determine the total water that could be allocated:

- Private usage as defined in schedule one of the Act (National Water Act, 1998:A-177). This section represents reasonable usage for domestic, small gardening (not commercial), watering of animals (not commercial) which graze on the concerned land within the grazing capacity, emergency and waste discharge purposes as well as sewerage systems such as in rural and local government areas[8].

[8] Irrigation and other commercial water use activities are therefore excluded from this deduction.

- The reserve component which is made up of two sub-components namely a basic human need sub-component[9] and a long-term ecological sustainability sub-component[10].
- International obligations, which are relevant where inter-country transfers exist.
- Inter-basin transfers in certain areas where a charge will be levied in this regard depending on the circumstances and objectives of the inter-basin transfer.

The above-mentioned quantities will be excluded from the pricing strategy, which, by implication, implies that the users of the remaining water (including irrigation users) will subsidise the provision of the above deductions. The Minister of Water Affairs and Forestry will then determine a water pricing strategy for the remaining water use. This pricing strategy may contain a strategy for setting water use charges for:

- Achieving the equitable and efficient allocation of water (for example correcting past injustices and ensuring optimal utilisation, which implies an increase in water prices for agricultural purposes).
- Funding water resource management (for example catchment management agencies).
- Funding water resource development and the use of waterworks (for government water schemes).

The general approach to the pricing strategy will thus be one where the water user has to pay the entire cost of provision, management and the servicing of the water resource and waterworks, whichever applies to the specific water management area. In essence, this means that agricultural irrigators will also pay for bureaucratic structures for the administration of water.

The following key aspects have been identified with regard to the National Water Act of 1998:

- The concepts of sustainability and equity serve as the dominant guiding principles in the protection, use and management of all water resources.
- The National Water Act of 1998 specifies a reserve flow, which is the first priority over and above the agricultural and industrial uses.
- Water property rights have shifted from private landowners to the state. The separation of land and water (and the substitution of water rights with a water use licence) will have a negative impact on land prices. This will have a negative impact on the net wealth of irrigators and the security position of financers. However, the Act respects the existing water rights and farmers may continue using water until a call is made for the application of licences.

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[9] This sub-component provides for basic human needs and includes water for drinking, food preparation and personal hygiene. An unofficial estimate of 25 litres per person per day will be allocated for this need.

[10] This sub-component will ensure that sufficient water of suitable quality will be reserved to sustain the basic ecological functioning of the water resource.

- South Africa has been divided into 19 Water Management Areas, each consisting of Catchment Management Agencies (the agency will be responsible for managing the supply of water) and Water User Associations (the association will be responsible for lobbying for water use rights).
- Certain specified areas may, however, use water without a licence within specified limits and if these limits are exceeded, registration will be required. All other significant water users that are excluded from this authorisation have to register for water usage. (If a specific user fails to register, it will have detrimental effects on the allocation of water licences at a later stage. If a user has not registered existing water use rights, he will be treated as a new applicant when the licensing process commences.)
- Given that the water licenses have a time span of 40 years and are subjected to a reviewing process at intervals not exceeding 5 years, long-term planning and investment decisions within agriculture are complicated. This is especially true for long-term crops and irrigation equipment.
- From now on water supplied by the Department of Water Affairs and Forestry will be priced at its true economic cost[11]. This implies that the farmer will have to pay the capital, operating and maintenance costs of the entire water supply system and consequently water tariffs can be expected to increase.

2.2.3 Limitations in the National Water Act of 1998

The two basic limitations of the National Water Act of 1998 include the dualistic nature of the Act and the lack of security and incentives for decentralised water management. Chapter 4 will build on this section as the most important part of the study.

2.3 Sustainability and water resource management

Paul Hawken (1993) argues that commerce and sustainability are antithetical by design (not by intention) and that the commercial systems of the future should be more like biological systems – self-sustaining, non-wasteful and self-generating. Only big businesses have the power to reverse ecological destruction and he outlines realistic ways of redesigning commerce so that everyday acts of work accumulate environmental benefits. Rather than a management problem of efficiency ("doing things right") we have a design problem of effectiveness ("doing the right things") – a flaw that runs through many businesses. The question therefore is, can we create profitable, expandable companies that do not destroy, directly or indirectly, the world around them?

Capra (1997:289) supports this argument and argues from a natural science paradigm that "reconnecting with the web of life" means building and nurturing sustainable communities in which we can satisfy our needs and aspirations without diminishing the chances of future generations. For this task, lessons could be learned from the study of ecosystems, which *are* sustainable communities of plants, animals and micro-organisms. He argues that in order to understand these lessons, we need to learn the basic principles of ecology. Capra (1997:290) mentions that we

[11] This concept seems to be justifiable, but it proves to be difficult to implement in practice.

need to "revitalise" our communities (including our educational, economical and political communities) so that the principle of ecology becomes manifest in them. Capra acknowledges the differences between ecosystems and human communities[12] and emphasise that we cannot learn anything about human values from ecosystems, but we can learn from them how to live sustainably[13].

Based on the understanding of ecosystems as autopoietic[14] networks[15] and dissipative structures, it is possible to formulate a set of principles of organisation that may be identified as the principles of ecology. This could be used as guidelines to build sustainable human communities[16] (Capra, 1997:290-295)

The **first** of those principles is *interdependence*. All the members of an ecological community are interconnected in a vast and complex network of relationships. Understanding ecological interdependence means understanding relationships. It requires the shift of perception (that is a characteristic of systems-thinking) – from the parts to the whole, from objects to relationships, from contents to patterns. A sustainable human community must be aware of the multiple relationships among its members.

The **second** principle is the *cyclic* nature of ecosystems. A major clash between economics and ecology derives from the fact that nature is cyclical, whereas economic systems are mostly linear. Businesses take resources, transform them into products and waste and sell the products to consumers who discard more waste when they have

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[12] According to Capra (1997:290) there is no self-awareness in ecosystems, no spoken language, no consciousness and no culture – and therefore no justice and no democracy; but also no greed and dishonesty.

[13] An interesting analogy could be found between sustainability in "nature" and "equilibrium" within economic theory. Sustainability in nature strives to find a balance between all parties involved to sustain their functionality in perpetuity. Capra (1997) mentions this as a constant striving towards a "bio-balance" (or it could be defined as a strive towards a homeostatic situation). Ironically, when all natural systems are in perfect homeostasis or balance, absolutely no activity will occur. (If for example, your own body were in perfect homeostasis, you would be dead!). Therefore, the "constant striving towards a perfect balance" is what keeps all life-forms on earth functional, yet when this balance is reached, no functionality will occur. "Constant change" is therefore essential in order to be sustainable, therefore, it is impossible to try to make once-off changes even within the economic policy paradigm and expect to achieve equilibrium (sustainability). The ability to change and to adapt to changing conditions implies sustainability and emphasises the importance of interdependency between all functional parties within a specific defined population. The same basic idea holds for the market equilibrium argument, except for the fact that micro economic theory states that at market equilibrium, optimal functioning of the market system will be found (optimality). Ironically, this idea translated back into "nature" terms means death (no activity at all). Perhaps this is the human niche: to keep the whole system in disequilibrium in order to remain sustainable. (This argument is supported by Cilliers (1994:20 and 200) and forms the basic argument for following an integrated approach to water demand-oriented management.)

[14] Refer to Capra, (2002:13, 30 and 71) for more detail on autopoietic systems.

[15] Capra (2002) notes that all living systems are organised along the idea of a network. In this book, Capra developed a unified, systematic understanding that integrates the biological, cognitive and social dimensions of life and demonstrates how life at all levels is interlinked by complex networks. There are two developments that will have a defining impact on the future of humanity. Both have to do with networks and both involve radically new technologies. One is the rise of global capitalism, which is concerned with electronic networks of financial and informational flows; the other is the creation of sustainable communities based on ecological literacy and the practice of ecological design, concerned with ecological networks, energy and material flows. The goal of the global economy is to maximise the wealth and power of its inhabitants; while the goal of eco-design is to maximise the sustainability of the "web of life". These two goals are contradictive and the great challenge of the twenty-first century will be to change the value system currently underlying the global economy to one compatible with the demands of human dignity and ecological sustainability. Environmental economics and more specifically water-related issues feature in the above-mentioned complexities and research within this field should be effective in order to find some answers to these problems.

[16] Cilliers (1994:7) identified ten essential characteristics regarding complexity within functional systems and "translates" these characteristics into socio-economic terminology to form an alternative paradigm in viewing complexity within the social-economic context. The arguments and reasoning followed within this study find an analogy within the work of Cilliers (1994:10-12).

consumed the product. Regardless of the reduce, re-use and recycling efforts of environmentalists, sustainable patterns of production and consumption need to be cyclical, imitating the cyclical processes of nature. This is not the case in most market economies. The free market does not provide consumers with proper or complete information, because the social and environmental costs[17] of production are difficult to quantify and are therefore not part of current economic models. Private profits are made at public cost in the form of the deterioration of the environment, general quality of life and at the expense of future generations. The marketplace simply gives us wrong information. There is a lack of feedback and basic ecological literacy tells us that such a system is not sustainable.

The **third** principle is *flexibility.* The flexibility of an ecosystem is a consequence of its multiple "feedback loops" (diversity) that tend to bring the system back in balance (dynamic balance) whenever there is a deviation from the norm due to changing environmental conditions. Disturbances happen all the time and thus the net effect is continual fluctuation. Change is what keeps an ecosystem functional and allows it to maintain itself in a flexible state, ready to adapt to change. The more a given variable is kept fluctuating, the more dynamic the system, the greater its flexibility and the greater is its ability to adapt to changing conditions[18]. In human communities, ethnic and cultural diversity may play the same role. Diversity means many different relationships and many different approaches to the same problem. However, diversity is a strategic advantage only if there is a truly vibrant community, sustained by a web of relationships. If the community is fragmented into isolated groups, diversity can easily become a source of prejudice and friction, but if communities are aware of their interdependency on others, diversity will enrich all the relationships as well as the community as a whole. In such a community, information and ideas flow freely through the entire network and the diversity of interrelationships and learning styles will enrich the entire community (Capra, 1997:295). The above-mentioned argument stresses the importance of effective and efficient communication between communities.

The **last** principle is *conflict resolution.* The principle of flexibility also suggests a corresponding strategy of conflict resolution. In every community, there will be conflict that cannot be resolved in the favour of one or the other side (for example communities need stability and change; order and freedom; tradition and innovation). Rather than by rigid decisions and rules these conflicts are much better resolved by establishing a dynamic balance. Ecological literacy includes the knowledge that both sides of a conflict can be important, depending on the context. The contradictions in the community are signs of its diversity and vitality and thus contribute to the system's viability.

The ability of all nations or societies to develop and prosper is partially tied to their ability to properly develop, utilise, protect and sustain their water resources. Ultimately, the achievement of these objectives is dependent on the implementation of an appropriate management system that ensures the long-term sustainability of both the water resources and their uses. In this context, well-managed water resources allow industrial development, transportation

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[17] "Eco-auditing" is a new strategy, which is concerned about the environmental consequences of flows of material, energy and people within a company, and therefore tries to accommodate the true costs of production (Capra, 1997:293).
[18] There are however, limits to tolerate change within flexible systems. There is always the danger that a whole system would collapse when a fluctuation goes beyond the adoption capability of that system.

of goods, agricultural production, public health protection, enhancement of recreational opportunities and the production of energy, while environmental degradation is minimised. Therefore, one of the highest priorities of all countries should be the development and maintenance of the most efficient and equitable water resource management system possible.

The process of water management involves managing the complex interrelationships and interactions between ecological systems, land use activities and water which control and characterise the water resource. The people who use the resource, as well as the people and institutions who are responsible for developing and managing the resource, have to be included in the process. Current international trends towards policies of "sustainable development" and "sustainable resource management" reflect a growing commitment to the principle of stewardship at all levels of strategic and operational management (DWAF, 1996:8).

Sustainable development of water resources in South Africa entails the adoption of three successive steps in water management (DWAF, 1996:10):

- *Identification* of the system characteristics, which involves the specification of the characteristic features of the water resource system relevant to the different problems encountered. (These features consist of the bio-physical, economic, social and environmental characteristics of the system.)
- *Prediction* of the behaviour of the system, which corresponds to determining how the system will respond to certain actions taken by man (including pollution discharges into water bodies, urbanisation, changes in agricultural practices, the building of structures which confine or condition the behaviour of water resources within the system and implementation of management actions).
- *Management* of the system, which involves selection and implementation of the best strategy to attain certain objectives, where the management decisions are based on the previous steps of identification and prediction.

The Department then intended to develop a management plan for each catchment area, which would help to ensure the equitable distribution of water resources between different water use sectors. It was anticipated that a suitable "catchment authority" would then be created to undertake the operational management within the catchment. This "catchment authority" would represent each water use sector in the catchment and would be responsible for executing the management plan under the supervision of the Department. The market mechanism will play an important part in the executing of the above management plan. Sustainability in the market is, however, not without problems. The perceived value of water will determine the sustainability of the use of that water. However, market prices fail to a greater or lesser extent to reflect the "true[19]" values of water in a variety of uses and it is therefore important to estimate (with expected values of water in alternative uses) the "true" value of water in order to achieve

[19] The term "true" value is a hypothetical concept and refers to the value of water (for different uses) after taking into account all the opportunity cost and externalities associated with the use of the resource. Also, refer to footnote 73 for detail.

a more sustainable use. Research which focuses on the determination of the opportunity cost of water will be important to determine the expected value of water in alternative uses. The next section will discuss water as an economic commodity in more detail.

2.4 Water as an economic commodity[20]

Almost all economic activities degrade water resources (therefore creating externalities[21] that are mostly negative) and thus we have a responsibility regarding the conservation of the finite available freshwater resources. According to the "user pays principle" (Pigram, 1993:1315) water users may pay for storing water, for transporting it to where it is used, for treatment of the water and for the disposal of return flows. Arguments for "user pays principles" are based on the cost of supply without the consideration of the ability of users to pay. Too little consideration is given to users' willingness to pay vs. their ability to pay and whenever the distribution of water entitlements does not match the demand, a true economic value of water will not be reached. It is therefore unlikely that users under a water use rights regime will be able to afford a full user-pay regime. Water policies should also be blamed for not promoting efficient water use in urban areas and for irrigation purposes. Examples of such inefficient water pricing policies include (Louw, 2001:33):

- The use of average cost pricing mechanisms rather that marginal cost pricing[22].
- The use of decreasing block rates for water pricing where the last unit of water used is cheaper than the initial blocks.
- Cost recovering for providing water services through property taxes rather than through charges based on water usage. Full cost recovery pricing, combined with improved institutional arrangements, has the potential to encourage water use efficiency through the transfer of water use rights to the highest value use possible.

The above-mentioned pricing practices provide inaccurate "price signals" to consumers which give the false impression that water is an "abundance resource" and in most cases will lead to an overuse of water. It may also result in an imbalance between investment in water-supply infrastructure and water conservation.

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[20] A clear distinction should be made between a market for water as an physical substance and a market for water use rights. The price determining forces playing a role in these two types of markets hold some similarities, but are not completely the same.

[21] Externalities are essentially activities whose full cost or benefit is not incorporated into an economic decision, hence they lead to sub-optimal social allocation. It could be seen as positive or negative factors, which have an effect on the market, but are difficult to quantify. An externality operates outside the market but with a certain effect on the functioning of the market. Externalities include: reduced water supplies and return flow for other water right holders, diminished economic activity in communities from which the water is taken, lower river flows and degradation of water quality, wildlife and recreational opportunities.

[22] Marginal cost pricing is the cost of providing the last unit (volume), and in practice, the average cost is mostly less than the marginal cost per unit, resulting in an incentive for not using water efficiently. Goodstein (1999:48) and Hosking (2002) provide a simplistic but relevant discussion on marginal benefit analysis. However, when marginal costs show a significant seasonal variation, seasonal pricing must be used instead.

The next three sections will describe three important factors pertaining to water as an economic good as well as the interaction between them.

2.4.1 The cost of water

According to Nieuwoudt (2000:60), water can be priced either through (a) tradable water by making use of the market mechanism, (b) opportunity cost through administrative pricing or (c) some other method such as actual operating cost. However, if water is transferable then the market will attach an opportunity cost to water, which is the preferred strategy within the international economic literature (Livingston, 1995; Thobani, 1997 and Howe, 1996). In the absence of a water market, the value of water is incorporated in the land value and as no volumetric price is attached to water, no incentive exists to use water as a scarce resource.

According to Dudley (1990b) the main roles (or arguments for putting a price on water) of water pricing are to:

- Communicate to each user what is the current highest value of water to other users (in other words the opportunity cost).
- Recover at least some of the operating and capital costs of the water supply and distribution system.
- Determine when the current value of water has risen to the point that supply supplementation is called for.

The price itself consists of various components and it would be naive to consider only the direct costs involved in providing the water service to the relevant users. However, due to the complex nature of the "product", economists constantly have to deal with a measurement-related problem[23] and imperfect information when trying to put a "real" value on the resource. As far as this thesis is concerned, the "real" price of water is made up by the full direct supply cost of the service[24] *plus* the opportunity cost[25] associated with the alternate use of the same water resource *plus* the externalities[26] imposed on others. Within the context of a water market, the above-mentioned value could be taken, but the transaction costs while trading the water use right should also be added. The next step would be to quantify the above-mentioned price determinants of water and currently no proven method of doing so, exists. The next two sections will discuss a few methodologies for estimating the price of water and the value of water in alternative uses.

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[23] Challen (2000:200) emphasises the measurement related problems regarding transaction costs.

[24] This cost will include the infrastructure-related costs associated with the supply of the service to consumers.

[25] Determining the opportunity cost of water is controversial due to the wide variety of uses of the resource. It becomes increasingly more difficult to determine an opportunity cost for a product with few or no substitutes. The only "substitutes" that water does have is in the form of "substitute uses" and each use of water is user-specific which cannot be standardised for easy comparison to other uses, making it difficult to measure. According to section 3.2.3, the opportunity cost of water equals the market price *minus* the transaction costs.

[26] Externalities in this regard are any form of impact which may have an effect on the use pattern and price of the resource which is not accommodated within the market system. These externalities could be negative (pollution) or positive (the use of clean water for free) and could be sub-divided into economic and environmental externalities.

2.4.2. Methodologies for estimating the value of water

The values for water could be either average or marginal values, it could be use-specific or for a mixture of uses or be for the long-term or the short-term. It is therefore an oversimplification to try to put a single value on water, because of the great variation in possible uses. The "best" option would only be valid within a specific context and given time period[27]. This thesis will not focus in detail on the several methods that could be used for estimating the value of water in different end uses, because the type of use will usually determine the methodology used. Therefore, a whole range of methodologies could be found within the literature[28] that deals with the estimation of the value of water in different uses. Some of these methods include (James, 1993:63):

- The use of standard methodologies like the travelling cost method, hedonic regression and contingent valuation.
- The estimation of demand curves[29] and the measurement of the areas under them.
- The estimation of production functions[30] and loss in output as a result of a loss in available water.
- The estimation of the costs involved of providing the service if the existing resources are unsatisfactory.

Tietenberg (1994:53) notes that ordinary cost-benefit analysis could also be used in valuing water, but emphasises that it is difficult to conduct a true valuation and quantification of all cost and benefits associated within the analysis.

Moilanen and Schulz (2002) introduced three different welfare functions to determine the relationship between the price of water (mainly for residential uses) and social welfare within a water tariff structure (administratively planned water management strategy). A "standard additive utility model", a "weighted utility welfare model" and a "Rawlsian welfare function" were used. These models demonstrated how the welfare function is decisive for the determination of a suitable tariff system. However, within the context of this thesis the market as a price setting instrument will be the main focus and not administratively planned tariff systems.

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[27] The value of a specific volume of water is therefore bound to the context and time-period of use.

[28] Within the list of references, the work of Bush *et al* (1987), Louw and Van Schalkwyk (2000) and Goodstein (1999) will mention some of the methodologies used.

[29] Arriaza *et al* (2002) recently conducted an interesting study where they made use of a multi-criteria decision-making strategy in order to simulate the price sensitivity (response to prices due to policy intervention, but not transaction costs and externalities) to water of irrigation farmers in southern Spain. They used utility theory and a method that does not require interaction with decision-makers in order to elicited utility functions of three groups of farmers. Utility was measured as a function of the first two moments of the distribution of total gross margin and the utility functions were then used to derive a water demand-curve for each of the three groups of farmers. Unfortunately, they did not include transaction costs and externalities in the study, which make it less applicable to "real word" situations. However, their method could be used as a point of departure for the simulation of policy scenarios for local water markets.

[30] Production function analysis is mostly used within agriculture where crop-water production functions and farm-crop budget analysis (including linear programming) are used. Irrigation water values are heavily dependent on crop prices. In crop budgeting and linear programming, the value of water is also dependent on non-water input costs. As the prices of other inputs increase, the estimated value of water decreases, as long as crop prices and irrigation efficiencies remain constant. Subsidised inputs lead to distortions and affect the estimated value of irrigation water. The value will be underestimated to the extent that these negative effects are not incorporated into irrigation water values when using other valuation methods.

According to Hearne and Easter (1997:191) the value of water within a market mechanism is predominately determined by the "willingness to accept" compensation for not using the resource in its current use, but in an alternative use. Goodstein (1999:131) mentioned that the "willingness to accept" normally proves to be higher than the "willingness to pay" because the receiver will be made marginally "richer" when compensated for the resource.

Louw (2001:37) mentioned a number of important aspects in the interpretation of the values of water (these characteristics are also emphasized by Colby *et al,* 1993:1572):

- Water has four main dimensions (quantity, quality, timing and location) that influence its value for different uses. Of these four, quantity is the most widely used, however, since water uses are subject to diminishing marginal utility, the larger the quantity at a given time and locality, the lower the marginal value.
- The quality of water is important for most water uses disregarding the fact that it stands secondary to quantity within market price negotiations. Water quality also influences both the value of the water and the cost structure. Drinking water has to be of the best quality and provides high value to the consumer. However, water for personal hygiene, gardening, industrial cleaning, cooling, transportation and agricultural irrigation has different levels of value and therefore willingness to pay.
- Timing can have an important influence on water value. Irrigation water for example is more valuable when applied during periods of critical plant growth and during droughts.
- The value of water will vary among locations, because relative to its value, water is expensive to transport out of existing natural drainage systems. (Within a drainage system, allowance should be made when comparing values of off-stream and in-stream water.)

Brennan and Scoccimarro (1999:81-83) supported Louw (2001) and Colby *et al* (1993), mentioned that value-in-use depends on the timing and reliability of water supplies. Timing is especially important within irrigated agriculture and a lack of reliable water supplies in centrally managed water reservoirs could lead to a lower willingness to pay the full cost of irrigation water. According to Tisdell (1996), the improvement of the reliability and timing of water supplies needs additional investments in storage capacity and/or pumping facilities. These costs could account for as much as 20 % of the net value of output from these crops and indicate that farmers' willingness to pay for reliable and timely water supplies is quite high. Therefore, those institutional and financing arrangements which improve reliable water supplies are likely to be more sustainable for improving water use efficiency than those which only focus on cost-recovery.

2.4.3 The opportunity cost of water

Opportunity cost of water could be defined as the value of a given volume of water in its next best use or the potential amount of utility lost by making a choice of water use. In other words, opportunity costs address the fact that by using a specific volume of water, the user is depriving another user of the water at that specific moment in time.

Given that the second user has a higher use-value for the water than the current use, the opportunity cost to society (due to this "misallocation" of water) would be that difference between the current use and the potential "better" use of the water. In the absence of the consideration of these costs, water will be undervalued, which leads to serious misallocations between users and disrupts long-term investment strategies.

Any form of uncertainty that affects the supply and demand of water will add to the opportunity cost of water[31]. This is where the market mechanism comes to the fore, because water buyers' willingness to pay and water sellers' willingness to accept water is an indication of the opportunity cost of the specific unit of water under consideration. In other words, the opportunity cost of that unit of water could be defined by the water market price (after the process of price negotiation) for that unit *minus* the total transaction cost and the externalities of the water use.

The opportunity costs of water are therefore generally reflected in market decisions and prices. However, in-stream flow and water quality values are most often poorly accounted and modifications in water right transfer approval criteria would be required to ensure that in-stream flow and quality values are accounted for when market transactions are considered. These changes would, however, raise the costs of implementing a market transfer (transaction costs) and could prevent other transfers that could have been economically beneficial for the user and the surrounding community. Therefore, tradeoffs exist between the benefits of protecting third party and public interests and the cost of doing so. Water trade policies must find a balance between transaction costs and opportunity costs in order to neither "over regulate" (so that efficiency gains provided by market transfers are eroded) nor "under regulate" (so that significant externalities are ignored when transfers take place). However, to find this balance requires information that is costly and/or does not exist because alternative uses and allocation processes have not been tried. Water management therefore plays an important role in determining the opportunity cost of water.

2.5 Water resource management

Water resource management can be defined as the systematic use of a set of technical and non-technical measures designed to ensure the effective and efficient management of water resources. The primary goal of water resource management must be to optimise the relationship between the availability of water and utilisation of the resources(DWAF, 1996:28). The sustainability of a country's resource-use depends on sound governance and appropriate sets of property rights that are all interconnected in one dynamic system (Tisdell and Roy, 1997:28).

Vaux (1986:1135) distinguished between three approaches to water management. Louw (2001:20) support this by saying that there are three main categories of water management:

[31] The only time when the opportunity cost of water will be zero is when there is no shortage of water in the long-term and when the transaction costs regarding water are equal to zero.

- Water supply management
- Water demand management
- Integrated[32] water management

Louw (2001:20) pointed out that historically most governments have attempted to solve the growing demand for water resources by following a water supply management approach. This approach has been costly in terms of capital investment and has involved the building of new dams and water infrastructure to satisfy the growing demand for water. South Africa has been no exception. However, as the water economy "matures" the supply-developing possibilities decrease and the developing costs increase (Groenewald, 1998:153). Few countries in the world could afford to continue with a supply-oriented strategy and gradually, as water development possibilities have become scarcer, a demand-oriented management strategy has developed.

Demand-oriented strategies focus on efficiency gains within the existing water-use system. Such efficiency gains may be realised through improving the co-ordination of water resource management, enhancing the flexibility of reservoir operations, expanding the conjunctive use of ground and surface water and taking advantage of new analytical and forecast systems.

The principle objectives to be achieved through water demand management are:

- Restraining the demand for capital (for water infrastructure development) at a time when available funds are limited and borrowing is expensive.
- Promoting the efficient use of water, thus easing competition for water resources and helping to minimise the pressure on the natural environment.

The actions needed to achieve these objectives are not restricted to water authorities. Most importantly, it requires changes in community attitudes and behaviour. It will therefore be important to promote an understanding of the factors affecting water use and to encourage an active community interest in the use of water. Efficiency gains could offset or postpone the building of large and costly structures. Demand management measures are also important because they often have short payback periods and lead to reduced capital and operating costs for water supply and wastewater treatment facilities.

However, water demand strategies are not always acceptable to users, particularly irrigation farmers, who see it as a restriction of their freedom to cultivate anything they wish and who usually argue that it will result in income reductions. The government, on the other hand, is obliged to provide water to a wider range of the population and

[32] Dinar and Lee (1995) did a review on integrated approaches to river basin planning, development and management. They compared different modelling approaches (refer to chapter 4 for detail) and reviewed existing models in terms of a set of categories ending with discussion on important barriers to effective planning and management. Throughout the paper, a integrated approach towards water management is emphasised and therefore, this study will also follow this approach.

has the responsibility of ensuring that limited water resources are used in the most efficient and effective way while also ensuring food security.

Winnpenny (1997) argues that water demand management implies taking into account the value of water in relation to its cost of provision and introducing measures that require consumers to relate their usage more closely to those costs. It implies treating water more like a *commodity or product*, as opposed to a "taken for granted" public service. Water must therefore be treated as an *economic good*.

The conceptual basis of integrated catchment management relies on the recognition that the different components of the hydrological cycle are linked to each other, and each component is affected by changes in every other component (interdependency). Therefore, they cannot be managed effectively as separate and disconnected units. The National Water Act of 1998 calls for an integrated approach[33] towards water management because interventions will not always produce with certainty the intended outcomes, and this has direct implications for catchment management in general. This dilemma leads to the following principles (DWAF, 1996:22) or critical factors for effective integrated water resource management:

- An *integrated approach* is required to properly assess and link together the processes that cause biophysical and ecological changes in catchment systems with economic variables.
- An *adaptive management approach* is needed, which responds to changes in information regarding catchment conditions and allows corresponding adjustments to management actions and strategies. This will allow continuous optimisation of resource allocation (personnel, equipment and funding), while at the same time being effective enough to promote the overall goal of sustainable water resource use in a changing environment.
- The social organisation for catchment management needs to be based on an *active partnership approach* and joint strategic planning to achieve outcomes which are acceptable to all participants and which ensure sustained use of the resource.
- *Institutional arrangements* for facilitating the social and economic roles required in catchment management as part of a formal process of water resource management, which is supervised by the Department of Water Affairs and Forestry.
- An *effective catchment management plan* is necessary for management to be successful. It must set out agreed policies, provide leadership, define roles and responsibilities, communicate effectively and mobilise resources.

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33 Systems-thinking forms part of an integrated approach towards water management and provides a distinctive, holistic view of a situation and the problems that are associated with that situation. Systems-based methodologies provide a practical approach to decision-making that deals with complex problems in a disciplined balanced way. A systems-approach pays considerable attention to the identification and diagnosis stages of decision-making by taking a holistic view of the situation and the diagnosis of the problem is deffered until sufficient awareness and examination of the situation has taken place to avoid the error of imposing inappropriate solutions (Jennings and Wattam, 1998:53).

In South Africa there has been a noticeable lack of success in the ability to integrate all these processes and functions into a coherent whole. This could be the result of the fact that integrated catchment management is a relatively new concept in South Africa (DWAF, 1996:21).

To conclude the discussion on integrated catchment management, a few points can be made regarding the level of commitment and types of arrangements that would be required to implement this approach in South Africa. It is clear that the objectives for adopting integrated catchment management will influence the type of approach that eventually will be implemented in South Africa. These objectives include (DWAF, 1996):

- *Devolution of authority and responsibility*

  If the Department's objective is to devolve more of the operational management functions down to local level in order to relieve pressure on the available manpower resources and to achieve a higher level of management efficiency, then it may be appropriate to set up statutory catchment boards with the power to raise levies, issue permits for discharge and abstraction and enforce permit conditions.

  The advantages of such an approach are that responsibility, accountability and authority are held at the catchment level and this is in line with the philosophy of the present government. Decision-making[34] can then take place at catchment level, assuming that catchment boards (or catchment management agencies and water using associations) are structured in such a way that all stakeholders are represented (DWAF, 1996:40).

  There are however also disadvantages to this model. *Firstly*, the appropriate expertise, experience and judgement are not likely to be available within stakeholder communities at catchment level to play their expected role in the decision-making processes of integrated catchment management. It is also unlikely that South Africa will find skilled people in the short and medium term to fulfil this role. *Secondly*, the activities and administration of the catchment management agencies would probably have to be financed from the local tax base, possibly with additional help from the central and provincial government, but sufficient funding may not be always available. *Thirdly*, given that many of South Africa's river catchments are shared across provincial and state boundaries (therefore inter basin transfers are common) there will be a substantial amount of administrative coordination required. This may be problematic if authority for water allocation is devolved to individual catchments or provincial level (DWAF, 1996:49).

[34] Decision-making of all kinds rests on assumptions about the to predict the future. This ability is hampered by the "chaos of reality" which characterised by the absence of regularities which prevent the accurate prediction of the future. This fact should make researchers aware of some limitations in their approaches to resolve problems (Jennings and Wattam, 1998:311).

- *Improved resource management*

  Given that one of the objectives of water management in South Africa is to improve the long-term management and protection of water resources, the Australian[35] model would probably serve as the best basis for implementing integrated catchment management in South Africa.

Clearly, if integrated catchment management is to succeed in South Africa, there must be a greater acceptance of the need to properly empower people so that they can participate in a transparent decision-making process. This will require a dramatic change in attitude and approach, both from the public and water managers. South Africa does have the opportunity to facilitate this change as an integral part of the socio-economic reconstruction of the society, but will not succeed if the approach is not supported the by legal, institutional and administrative frameworks.

Ideally, South Africa should look at a gradual shift from a situation where integrated catchment management is regulated by central and regional government levels, but still with some stakeholder consultation like Australia. This would allow for sufficient time for learning and the development of an appropriate skills base for the successful implementation of an integrated approach. On the ground, this could take on the form of priority catchments and working initially with a catchment forum, or something similar. This forum could then gradually be developed in to a catchment committee, taking more responsibility and accountability as local capabilities are developed and enhanced. The next step would be the development and constitution of a catchment authority, whose legal, executive and fundraising status would depend on the needs of the local situation.

2.6 Integrated catchment management and land reform

Given the limited employment opportunities in the formal sector of the rural South African economy, many of the poor depend heavily on the natural resource-base for their day-to-day survival needs. Their living standard is therefore closely related to the well-being of their natural environment. However, poverty, overpopulation, lack of education and slow technological development together with a strong short-term oriented consumption pattern, usually results in environmental degradation. Van Zyl, *et al* (1996:237) argues that poverty among the rural population and a past

[35] Refer to Louw (2001) for detail on the Australian model. The Australian alternative looks promising for South Africa. This approach relies on active community and stakeholder participation in the management of natural resources and leaves a guidance and supporting role for the government to play. An advantage of the Australian model is that planning and actions are community-based. All stakeholders play an active role in management, from the institutional level down to the individual landowner. Broad policies and objectives for water resources management can still be set at central government level, and these serve as a framework within which catchment agencies may do their operational management decision-making. However, a disadvantage of this approach may be that integrated catchment management is seen as a long-term process, where implementation is a gradual and slow process of learning, negotiating, planning and action (it is a lengthy process). In addition, this model should be adapted to deal with the complex and sensitive water allocation issues within the South African context. The Australian model requires the following:

- A core of skilled personnel at central and regional government level to initiate, facilitate, assist and guide catchment agencies with a national policy towards integrated catchment management.
- Access to technical support through scientific and engineering strategies for dealing with resource management issues.
- Improved collaboration between state departments and agencies involved in resource management.
- Long-term commitment of funding and personnel to support each catchment agency.

property right regime that allowed almost unrestricted use of natural resources by favoured groups in society, poses the most serious environmental threat in low-income developing economies and should therefore be confronted (by improved access to land) in order to protect the environment.

Integrated catchment management could play an important role in co-ordinating the planning and implementation of land reform and management. The current water care initiatives encourage the establishment of strong partnerships between government agencies and communities, this could also be used for developing an integrated land management programme for South Africa. Currently within land reform disputes, certain land areas are preferred over others due to water availability on that piece of land. (The fact that there is water available on the piece of land under consideration plays a direct role in the monetary value of that land.) This study suggests an alternative form of defining water use rights for adoption in the market system. Water use rights will be independently defined from land property rights and this would have a definite effect on land prices and therefore land reform disputes.

2.7 Institutional change and economic performance

The foundations of economic systems are rooted in political and legal systems and in general in the institutional structures of a society (Tisdell and Roy, 1997:28). These institutions could be defined as "collective actions in control, liberation and expansion of individual action" (Commons, 1931:648 as cited in Armitage, 1999:6).

Within the context of a water economy, institutions are defined as sets of values, customary rules, water rights and water laws. Together, these form "the rules of the game[36]" with respect to market control over water. They are capable of creating order and certainty for users to facilitate the achievement of economic and social goals while also creating incentives for efficient resource use.

Van Zyl and Vink (1997) studied the effects of two different water policies on the farm sector. These policies could be grouped under "command and control" methods[37] as mentioned in Goodstein (1999:11). Van Zyl and Vink (1997) compared increases in water tariffs (price limitation) with water restrictions (supply limitation) as two policy alternatives, to determine their effects on output, prices, welfare and employment. Both control measures should have a negative effect on producer surplus, but the extent of the effect was unknown. To know the producer sensitivity on each of the policies could be useful for water authorities to make a choice between these two alternatives, depending on the objectives of the authorities. Applied to the Western Cape, Van Zyl and Vink (1997) identified a noticeable shift away from intensive irrigated production to more extensive production and a decrease in producer welfare under both policies. Irrigators seemed to be more sensitive towards water restrictions than water tariff increases, because a large tariff increase is required before it has any effect on producer welfare. It seemed that a water restriction also restricts the management options to a greater extent than tariff increases, and therefore

[36] Chapter 4 refers in more detail to the "rules of the game" and other related equity issues.
[37] Feichtinger (2001:23) mentioned that a strong analogy could be found between "command and control" environmental policy and control measures for criminal behaviour (law enforcement). Refer to Feichtinger (2001) for more detail.

have a greater negative impact on producer welfare. Under the increased tariff regime, the effect on consumer surplus fell disproportionately on the poor, but was mitigated by an increase in employment. However, they found that under the water restriction regime, the loss in welfare and other negative effects fell disproportionately on the poor as employment decreased as producers switched to more extensive production patterns. This has negative implications regarding any type of equity-related policy intervention and should be kept in mind when planning an appropriate policy intervention. The study also showed that none of these suggested policies would realise a net social gain and the question remains in searching for appropriate policies with net social gains and sustainable properties.

As seen above, the term "economic performance" is associated with economic efficiency and equity goals. That is, we are not interested in improving irrigation allocation systems to merely make them more efficient, but also to improve them in the context of the decision-making of the small farmer (in order to accommodate the equity objectives as mentioned in the National Water Act of 1998). The rationale for this argument lies in the fact that if irrigation allocation systems for the small farmer could be improved, the operation and production activities of the small farmer would improve and the small farmer will become more self-sufficient. More food will be produced, a higher level of income could be achieved and a more equitable income distribution could be reached (Bromley, 1982b:1). Equity goals are therefore closely related to small-farmer activities. It is therefore necessary to have a look at the situation of small farmers within any form of policy development if equity issues are to be considered. It is important to accommodate these small farmers in a theoretical framework which allows the analysing of the current decision-making behaviour of small farmers, and to relate that behaviour to the way in which their irrigation supply system operates.

2.7.1 Policy, institutional change[38] and property rights

According to Bromley (1995a:1), the formulation of environmental policy in South Africa can only succeed if three ideas are kept in mind. The *first* is that natural resources are a function of accepted social relations at any moment in history. In other words, what a society regards as a "natural resource" is socially determined. The *second* idea is that the definition of property rights is necessary for policy formulation. The *third* idea focuses on the concept of "individualism". Economists say that only the individual counts, and then they construct models that try to prove that an individualised world leads to "efficiency" and "social optimality". This economic view de-legitimises traditional and community-based structures and behaviour and is not compatible with an integrated philosophy.

The relationship among these three ideas is obvious: the market drives "value", individual choices drive the market and property rights over natural resources must therefore be individualised (privatised) in order to protect

[38] Ultimately, any form of institutional change within water resource management could in a large part be explained in: (1) the demand for institutional change, which is associated with the willingness to pay to reduce static transaction costs associated with achieving particular economic objectives relating to water resources and (2) the supply of new institutions, which is constrained by dynamic transaction costs arising in the costs of the transition from one institutional structure to another (Challen, 2000:147).

environmental resources and to promote "efficiency". This relationship could be illustrated by looking at the degradation of communal (traditional) owned land and water resources. When natural resources are regarded as private property it should ensure that they would be managed wisely. Economic efficiency is claimed to be an objective guide to sound environmental policy and therefore state intervention in the market would be considered unnecessary and inefficient. Criticism of the above-mentioned argument could be based on numerous negative externalities associated with private ownership as a point of departure, leading to the conclusion that complete private ownership is no assurance that environmental problems will not arise.

When the *first* idea of Bromley (1995b:1) is considered, it becomes clear that political power, culture and social norms play an important role in the process of defining and valuing natural resources. Different cultures will define different natural resources as valuable. It is difficult to define and value water resources according to Bromley's argument, because the value of water is congruent with the specific use thereof. Without getting involved in value judgements, it is important to let context and time play a role in defining which natural resources are to be regarded as valuable to a specific culture. Therefore, the determination of the value of an environmental resource comprises two issues:

- Whose interests count when the state formulates policies regarding environmental resources.
- Which aspects of the environmental resource management those individuals choose to value.

Therefore, one of the essential elements of environmental policy-making is to work out *who* matters in the policy formulation process and then *what* matters to those who have been identified.

The *second* idea of Bromley (1995b:1) focuses on the definition of property rights to facilitate policy formulation. Bromley (1995b:4), emphasises the concern with the "social construction of scarcity" as the result of social rules which control the use of natural resources in such a way that an artificial scarcity of the resource develops. Under the National Water Law of 1956, groundwater belongs to the owners of the land above, and only some privileged groups could own land in South Africa. Groundwater may not be scarce in an absolute physical sense, but if a person does not own land (or if a person cannot own land) then groundwater is scarce in a social sense. Furthermore, it is known that farmers (i.e. not necessarily landowners) as well as the urban sector have a "right" to groundwater. The legitimacy of this "right" could rightfully be questioned: "What is this right?" and "Where does it come from?" When a party does have a right, it means that the party has the power of the state to enforce the outcome of the specific right in favour of the holder. Therefore, a right could be seen as secured form of protection. Different people or groups of people have different interests in particular outcomes. These people or groups will try to have laws passed that favour their interests best. Given the competing nature of different laws to be passed, the individuals or groups who are able to have their law (social claim) passed will have their interests protected by the state.

It is important to note that "property" is not an object (land and water), but rather a stream of benefits arising from the control over objects (or ideas). This stream of future values comprises the *property* of such interest. The magnitude of the stream of benefits will vary depending on the extent of managerial discretion for the owner of the right (the more restricted the control over the benefits, the less value it has for its owner). It is therefore clear that social entitlements arise to give certain interests the needed protection for the use of a specific natural resource. This suggests that property rights are created to serve particular social purposes. Therefore the question arises, how does the state choose in an objective way between alternatives and what is to be considered as fundamentally fair and how does one judge these property regimes in terms of nature and content? The fact is that the state often passes laws that favour its particular interests.

The *third* idea of Bromley (1995b:1) is concerned with the problem of individualism and the choice among different policy regimes. This could be seen as a more normative dimension of property right analysis because ideologies and value judgements underlie the choice of a policy regime.

Given the above-mentioned arguments, environmental policy-making is about disputes over different natural resource use regimes. At the one extreme is the economic logic of individualism and at the other end the social logic of larger scale to reduce the number of decision-makers across which external effects might travel (Bromley, 1995a:9).

According to Tisdell and Roy (1997:30), four broad categories of property rights can be identified in the literature:

- Private property in which all rights to the given property applies only to that individual.
- State property in which property rights rest with the state.
- Common property in which an identifiable community of users controls the property.
- Open-access property for which access is free and open to all.

Without going into a detailed analysis, one could say that different property regimes have their own compelling logic. In some cases, private property is the most useful social arrangement for scarce resources, and sometimes common property is the best option. There is no magical "one size fits all" property structure. The appropriate property regime depends on the purpose and the requirements involved. In some cases, a combination of the two will be appropriate.

Within the South African water policy context, it is essential to reassess what is regarded as a natural resource and to decide whose interests are to be served by the limited water supply. This reassessment will confront the attitudes and privileges of the current privileged parties. It will challenge the conventional ways of thinking about natural resources and question the ownership and control of these resources.

Public policy, according to Bromley (1995a:14) is about three ideas: intentions (or purpose); rules to accomplish that purpose, and the means of realising behavioural changes to bring compliance with new rules. For the development of appropriate water policy in South Africa, policy-makers must decide whose interests are to be served and precisely what those interests are. From here, it is possible to redesign rule structures (institutional arrangements) that will direct policy in a new direction.

It therefore is a question of: Who has which rights, when.

2.7.2 Evaluating institutions

Challen (2000) addresses institutional reform for water resources, arguing that in most social sciences, there is diversity in economic schools of thought as to how institutional change can be described and how institutions can be evaluated. Because neoclassical economics remains the mainstream of economic thought, the bulk of literature in resource economics reflects this view. However, Armitage (1999:11) mentions that standard neoclassical economic theory is abstract and incapable of dealing with current real world problems. (This is supported by Challen, 2000:1-11).

A fundamental methodological question concerns the grounds upon which alternative water institutions should be evaluated. There is a critical and substantial difference in the philosophical basis used in neoclassical and institutional economics. Neoclassical economic analysis rests on methodological individualism[39] and, according to this view, the "public interest" does not exist. Rather, economic analysis must rest solely on the subjective preferences of the individual decision-maker, aggregated through market forces. In contrast, institutional economics relies on "methodological collectivism" and is typically more holistic. Institutionalists incorporate some notion of the "public interest" as part of the parcel of individual and social welfare (Livingston, 1993:816). However, this type of model is often broadly inclusive, highly complex, detailed and messy, because problems are viewed in an interdisciplinary and integrated way.

2.7.3 The neoclassical approach

According to Bardhan (1989:3), neoclassical economics is concerned primarily with the allocation of resources through the forces of demand and supply in a market economy, without the full consideration of the complex institutions on which contracts in the actual market depend. However, the existence of political, legal, monetary and other systems is acknowledged by neoclassical economics, but are either regarded as having neutral effects on economic processes or are taken as given and are specified in a way that suggests that institutional influence is of minimum importance, thereby setting aside institutional change as a subject for economic analysis.

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[39] Refer to the *third* idea of Bromley in the previous section.

In theory, neoclassical economics uses the "Walrasian general equilibrium model" as an analysing instrument for studying small segments of isolated systems. Prices and quantities are determined in a market by equating demand and supply, while imperfect information and uncertainty are not considered. A competitive economic system, in the context of the general equilibrium[40] model requires the following for the achievement of a first best *pareto optimum* configuration: (a) zero transaction costs and individuals acting completely rationally, (b) individuals and firms are both profit maximisers, and (c) institutional arrangements play no role in determining equilibrium solutions (Armitage, 1999:12).

According to neoclassical theory, the three marginal equivalences needed for *pareto optimality* are satisfied at market equilibrium. These are: (a) the marginal rates of substitution for all consumers are equal (b) the marginal rate of input substitution is equal for all producers and (c) the marginal cost of production is equal for all producers and is equal to the price of the product (Armitage, 1999:13).

The First Theorem of Welfare Economics states that each competitive equilibrium is *pareto efficient*. A social state is *pareto efficient* if no individual's position can be improved without causing a worsening in the position of another individual. Taking the assumption of zero transaction costs, then the initial allocation of property rights is irrelevant in terms of efficiency because these rights can be traded free of transaction costs until a *pareto efficient* allocation is reached[41]. Consequently, the concepts of efficiency and equity become separable under the neoclassical assumptions (Bardhan, 1989:5).

Any form of market disturbance within the Walrasian model results in the instantaneous attainment of a new equilibrium because with no transaction costs, the adjustment costs are zero. Therefore, no effort is required in the exchange process, prices will allocate resources to their highest valued use and economic efficiency is ensured. As a result, prices are taken as exclusive indices of individual and social welfare and as criteria of the efficiency of allocation and the optimality of decision-making (Armitage, 1999:13).

However, the major shortcoming of the neoclassical approach lies within its assumptions. The assumption of zero transaction cost is of particular relevance for this study. Under real world conditions, every trade agreement involves a contract that must be defined and enforced. Transaction costs are then costs of specifying and enforcing the contract that underlies the exchange. These costs include search and information costs, bargaining and decision-making costs and policy and enforcement costs, as well as risk and uncertainty associated with transfer of rights due to imperfect information (Colby, 1990:1185). These costs can be divided into *ex ante* and *ex post* costs. Drafting,

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[40] Capra (2002:28) also notes the analogy between living systems and economic systems which need a state of disequilibrium in order to be functional (as mentioned in footnote 13). The argument regarding the efficient functioning and the achievement of *pareto optimum* solutions at a state of equilibrium, is also questioned. This study is of the opinion that economic systems certainly could not be viewed independent of these interactions and efficient functioning of an economic system will not be reached at a state of equilibrium because no functioning (interaction) will be necessary when a system is at a state of true equilibrium.

[41] The Coase-theorem supports this belief (Goodstein, 1999:53-54).

negotiating and safeguarding an agreement are *ex ante* costs. The problem of moral hazard, cheating and shirking lead to *ex post* costs, which includes contract enforcement and risk. Transaction costs are likely to increase as the number of individuals who are participating within the market increases, when the level and sophistication of technology increases or when a degeneration in social conventions (that reduce risk) occurs (Armitage, 1999:14).

The initial distribution of property rights influences the initial distribution of wealth and income in society by determining who benefits from income flows generated by the use of resources[42]. When transaction costs are present, the allocation of property rights becomes critical. A primary pillar of neoclassical economics is the separation of equity and efficiency. This is not valid for this situation, because the terms of contracts in various transactions, which directly affect efficiency of resource allocation, now depend crucially on ownership and property right relations.

Neoclassical models are therefore rich in theoretical simplicity and rigor. They are reductionist in their attempts to describe problems and solutions in terms of market principles. Unfortunately many economic problems cannot be reduced to a matter of markets and prices alone.

Therefore, the attractive normative criterion of *pareto optimality* cannot be used to analyse institutional change. According to Bromley (1982b), policy change is by nature redistributive, because institutions establish all initial endowments and any change will result in losses as well as gains (therefore not be *pareto optimal*). The controversial criterion of *potential pareto optimality* could be used as an alternative to evaluate change that involves losses. According to this form of optimality, a change is efficient when those who gain could compensate those who lose (actual compensation is not required) and still be better off. Standard benefit-cost analysis rests on *potential pareto optimality* in that the goal is to "maximise discounted net benefits, to whomsoever they accrue" (Livingston, 1993:816).

According to Bromley (1990:86) the *potential pareto optimum* criterion of economic efficiency as suggested by Livingston (1993) does not pass the test of consistency and coherence within economic theory, nor do such measures accord with what public decision-makers seek in policy advice from economists. However, such efficiency measures are, nonetheless, durable components of the ideology of economics in general and benefit-cost analysis in particular.

The ultimate test of efficiency can be seen as agreement on changes in rules governing market exchanges. If individuals agree to institutional changes and trade is voluntary, then the new institutional arrangement may be considered as more efficient than the previous arrangement. Agreement between the parties involved signals that individuals perceive the previous arrangement to be inferior. Since individuals are driven by self-interest, the

[42] It is therefore important to have a "fair" initial distribution prior to the activation of the market mechanism. This argument will be discussed further in chapter 5.

institution that evolves because of change will allocate resources in a more efficient manner. Artificial restraints placed on exchanges between parties via a political agency preclude an observation of the true test of efficiency: the agreement between parties. As a result, the resource allocation arising under such a situation can only be presumed to be inefficient (Buchanan, 1989:98).

2.7.4 The institutional approach[43]

Institutionalists[44] have recognised that economic processes cannot be adequately explained as self contained and self sustaining systems, isolated from a social and physical environment. Rather, institutionalists view an economy as an open system in perpetual dynamic interaction with a complex social, political and physical environment. Economic processes receive important organising impulses from this environment and in return exert their own influences on the environment. In other words, a definite interdependency exists between these two environments (Armitage, 1999:15).

Institutional economics could be described as an understanding of the structure of the institutions that constitute the market and the structure of property rights that determine which individuals' interests shape demand and supply within the market. Institutions must therefore be included as an endogenous variable in the economic system.

Institutionalists view transaction costs, and the institutions that evolve to minimise them, as the key to the performance of an economy. The levels of these costs determine the degree to which individuals can profitably exchange property rights for mutual benefit.

Livingston (1993:815) studied the normative and positive[45] aspects of institutional economics and the implications for water policy. Institutional economics provides an alternative framework for analysing existing and proposed water policies. Livingston, with the normative model, employs the concept of institutional value, rather than efficiency. Water policies are judged based on whether they foster the long-term viability of economic and ecological systems, not on whether they maximise the net present value. The positive model used by Livingston (1993:815) is holistic and more inclusive than standard market models.

While economic efficiency is described by the concept of *pareto optimality* within the neoclassical paradigm, the only way in which the outcome of the exchange processes can be evaluated is through the revealed choice behaviour of

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[43] This study supports the institutional model mentioned by Livingston (1993) and this school of thought will be used throughout this study. This institutional economics paradigm is supported by the field of new institutional economics as mentioned by Kherallah and Kirsten (2002) and also by Challen (2000:3-7).

[44] The original institutionalists such as Thorstein Veblen, John Commons and later John Galbraith, tended to reject forms of atomism and abstraction and instead assume approaches of investigation and writing that were descriptive, anti-formalitave, holistic, behaviouristic and collectivistic (Challen, 2000:5).

[45] Livingston (1993:819) notes that positive models enhance the understanding of real world events and causal relationships regarding water issues and could be used for predicting future changes up to a certain degree. Normative models could be useful in developing recommendations for desirable water institutions.

individuals to potential exchanges. Each individual will have different perceptions attached to a potential exchange of rights, and there is no way for an external observer to determine whether or not the observed level of exchange falls short of some idealised norm. Efficiency of resource use within an institutional setting is thus ensured, as long as exchange is voluntary to market participants. This implies that resource allocation is shaped by institutional arrangements and efficiency is comparable only *between* institutions and not *within* an institution.

2.8 Water allocation systems

Rosegrant and Binswanger (1994:1613) ask what water policies can lead to efficiency increases in irrigated production while reducing resource degradation in the irrigated areas and releasing water for growing non-agricultural use. They suggest four broad categories of policy prescriptions that could be employed: technological solutions, reform the public management of irrigation systems, communal irrigation management and the establishment of tradable property rights. The first three prescriptions have been widely utilised internationally, however the last strategy of tradable rights has not been vigorously pursued.

It is important to make a clear distinction between a market for water as a physical substance and a market for water rights (or water use rights, as it will become clear later in the thesis). A market for the physical substance of water focuses on the allocation of water via the market mechanism. Therefore, volumetric units of water are traded between willing sellers and buyers until the demand is balanced out with the supply. In this regard, the state normally acts as the dominant seller (because all water inherently belongs to the state) and water users (like irrigation farmers and municipalities) as the dominant buyers. The market price (or spot price) of the volume being traded is only partially determined by supply and demand forces, because the main force for price determination originates from the state, which implies that the state already determined the "ideal" price[46] of water for a given use-category. This proved to be problematic, because given the inelastic nature of water demand for the bulk of the water users, most of them are price-takers and therefore the state finds itself in an monopolistic position with scope for unrealistic price settings. With the state as the dominant price-setting force, questions regarding the method of price-determination used by the state given the equity and efficiency objectives in the National Water Act of 1998, also comes to the fore.

A market for water rights (this thesis prefers to use the term water use rights, because the utility derived from water is in reality a derived demand for the particular use of the physical substance) focuses on the allocation of water use rights via the market mechanism. It should be made clear that this is a market where rights to buy water is traded, and not the volume per se. It is therefore impossible for a specific user to buy a greater volume of water as specified by the current use rights held by that specific user. Price-setting within this market is to a greater extent determined by supply and demand forces, because the state is not the dominant end user in the market system.

[46] The state is responsible for the construction and maintenance of the water allocation system and these costs will be recovered from water sales to the users of lawful water use rights.

According to Livingston (1995:209) the balance between market and administrative allocation mechanisms will vary between countries and the degree to which either dominates, is determined by the following:

- The development stage of the economy and experiences with command and control mechanisms.
- The organisational skills and leadership abilities of water users and the state.
- The technical skills, client relationships and unbiased ability of government agencies to evaluate economic gains or losses from water transfers.
- The scale of the reallocations considered, with small transfers favouring market interaction between individuals and large transfers requiring involvement of the state.

Within South Africa, the market for water as a physical substance is certainly not a new idea given the trade in riparian water rights under the National Water Act of 1956. The National Water Act of 1998 facilitates the trade of water use rights, but a great degree of uncertainty remains with regard to the practical implementation thereof. Capacity-sharing presents some possibilities for the implementation stage of a market for water use rights and chapter 4 will give more detail in this regard.

2.8.1 Requirements for tradable water use rights

The efficient construction of any market requires the following conditions for trading to take place. Firstly, well-defined property rights, secondly an effective communication system and thirdly the physical possibility for trading to realise the negotiated transfers. Each of these will be discussed in the following sections.

2.8.2 Institutional requirements

Sampath (1992:968) notes that water rights are generally based on three systems: riparian rights, public allocation and prior (appropriative) rights[47]. Riparian rights link ownership of water use to ownership of adjacent land. Public allocation involves administered distribution of water. Prior rights are based on appropriate doctrine under which the water right is acquired by actual use over time. None of these systems satisfies the conditions for well-defined property rights to water. Riparian rights are the most restrictive of transfers because they limit use of water to adjacent land but even appropriative rights can be highly restrictive, building in a bias toward maintaining possible existing inefficient water uses.

Well-defined property rights define and delimit the use rights of the holder relative to other users and to the rest of society to the use of a certain amount of water (which is defined in terms of stream flow shares or volumetrically). If

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[47] This right implies that the first person to divert water from a stream and apply it to a beneficial use has the superior right to keep doing so (McCormick, 1994:953).

these rights are poorly defined, market processes cannot be relied upon to allocate water resources efficiently. It is therefore crucial that the state, as far as water markets are concerned, should define, allocate and enforce property rights in water. Government policy therefore plays a critical role in defining the institutional setting for market operation and provides the basis for market activity (Backeberg, 1994a). These property rights can take on the form of licences to use ground water from private wells or to surface water supplied through public irrigation systems. The quantity specified in the right can be determined according to historical use, but whether these rights will be traded in the market system depends on the buyer's willingness to pay, the seller's current water productivity level (willingness to accept compensation for the resource) and the transaction and opportunity costs involved.

According to Colby (1987:1116) the definition of rights and duties of water users relative to one another and to the rest of society, provides a basis for market exchanges. In order for market participants to estimate the value of a water use right, they must be able to form expectations regarding the future benefits associated with owning the water use right and the degree to which the right is protected from impairment by others. Only on that basis can they make economically rational decisions about water use and transfers. If property rights are not well defined, the consequent uncertainty will reduce the expected value[48] of the rights and the incentive to engage in trading. To produce efficient resources allocation through market transfers, the definition of property rights should satisfy the conditions of specificity, exclusivity, transferability, comprehensiveness and enforceability (Bush *et al*, 1987:619).

Scott and Coustalin (1995) identified five characteristics of property rights that are relevant within this context:

- duration
- flexibility
- quality of title or security
- transferability or assignability
- divisibility

These characteristics can present problems in the establishment, definition and enforcement of property rights. Within this design of water use rights, it is important to note that the more detailed the definition of the right, the greater the transaction costs and heterogeneity of rights and hence the more difficult it will be to organise a market (Howe *et al*, 1986).

By contrast, Colby (1987:1116) states that water rights are heterogeneous, each consisting of a bundle of legal and hydrological characteristics which affect the value of the right and its price. For example, according to Bush *et al*

[48] Statistically, an expected value of a variable (within this context it is economic gain) within a predefined population (population density function or range of possible outcomes) could be defined as the sum of the products between all the possible outcomes and their corresponding probabilities. In other words, the expected value is a **weighted** (because the variable is not random) average of all possible outcomes of the variable (Gujarati, 1992:36-38).

(1987:619-623), the reliability of water deliveries, water quality and institutional restrictions on location, season and purpose of use, have been shown to influence water use rights prices in specific market areas.

It is therefore important to consider the relevant criteria for defining water use rights carefully and in such a way as to avoid an excessively detailed right, because markets operate more efficiently when the commodity being traded is homogeneous.

An often-cited prerequisite for an efficient market is the establishment of completely specified, enforceable and transferable property rights (Rosegrant and Binswanger, 1994:1615-16120). When property rights are clearly specified, water users have a secure basis on which to make long-term investment decisions. If all values associated with water are encompassed in property rights, then market prices will also reflect social values and the holders of water use rights will face the full opportunity costs of their water use and transfer decisions. Transferability ensures that marginal values for water (net of transfer costs) are equal between different uses and users by allowing water use rights to be re-allocated whenever re-allocation would generate positive net benefits. Completely specified, enforceable and transferable property rights are the ideal **institutional** conditions for efficient market performance.

A water market also requires an effective administrative system that will prevent abuses of the system. Government agency performance in the administration of water transfers is necessary to legally sanction water trading, enforce legislation or regulations and resolve disputes among users (Livingston, 1995:207-208).

However, a market for transferable rights does not have only institutional requirements and the efficiency of the market will be determined by the compatibility of institutional with other kinds of requirements.

2.8.3 Effective communication

Publicly available information on the supply and demand characteristics of water use rights must include the means of identifying willing buyers, sellers and intermediaries or water brokers and the means for entering into enforceable contracts. Hydrological information is also required to permit the right to be defined. Various types of information are therefore essential for rational decision-making by water use rights holders. This implies the existence of suitable data and monitoring systems and it is at this point that the equity issue again comes to the fore because most small farmers do not have access to effective communication systems.

The irrigation community should be aware of entitlements at the time of the water licence sale. The price and amount of water being transferred should be accessible to the public (details of water use rights transfers should be transparent). This will promote fairness in the market, and traders selling or transferring water allocations for personal profit (which will not be used for the benefits of the irrigation community) should be fined accordingly.

2.8.4 Infrastructure requirements

Before the transaction, it is important to verify whether the transfer can be realised in terms of delivering the water to the desired location. A flexible infrastructure enables sellers to transfer water to buyers at reasonable costs and for this reason water transactions take place within the existing distributional systems. However, an effective information system could save transaction costs by linking local buyers and sellers to avoid water being transported over vast distances.

2.9 Important issues regarding water markets

Rosegrant and Binswanger (1994:1617-1622) listed nine of the most important issues regarding the implementation of tradable water use rights:

- Increasing benefits from reallocating water – where the main argument focuses on the fact that as economies grow, and water demand increases, the benefits from water allocation will rise exponentially.
- Transaction costs and institutional requirements for alternative mechanisms of reallocating water – transaction costs certainly decrease the expected gains from water transfers, but are in general not totally prohibitive. The question should rather be how do the transaction costs of market allocation strategies compare with alternative allocation strategies.
- Markets in water use rights vs. water pricing – the two major advantages of tradable water use rights include a reduction in information costs, because the market, composed of water users with expert knowledge of the value of water as an input in the production process, would bear the costs and generate the necessary information on the marginal value product and opportunity cost of water. Secondly, tradable water use rights would formalise existing rights to water rather than being seen as an expropriation of these rights and is therefore politically more feasible than water pricing.
- Property rights and externalities – appropriately defined property rights will to a large extent cause users to internalise externalities.
- Private vs. communal property rights – tradable water use rights can be assigned to communal groups (or Water User Associations[49]) as well as to individuals.
- User involvement in investment decisions – government will still remain the sole financier of large irrigation schemes, but the establishment of tradable water use rights is conducive to farmer input and will provide strong incentives for cost effective investments in irrigation if the rights are issued before the development of such a scheme.
- Variability in water supply and the design of water use rights.

[49] A detailed discussion on Water User Associations could be found in the National Water Act of 1998 (1998:A-117). Scott and Coustalin (1995:972) refer to a river "corporation".

- Inter-sectorial competition for water – there was great concern regarding the outflow of water from agriculture to urban uses. This however, did not realise because a small transfer from agriculture to the urban sector is adequate. (The urban sector is currently seen as a "low volume-high value" user.)
- Tradable water rights, market power and equity – evidence from Pakistan and India showed that greater availability of alternative ground water sources increased competition and lowered water prices. Therefore, policies encouraging the development of water markets should improve access of the poor to water and not hinder it.

Apart from this theoretical literature on the gains of institutional change, there are also a few studies which tried to quantify the potential gain from changes in a particular segment of water institutions like water markets, inter-regional transfers and water quality institutions (for example the work of Vaux and Howitt, 1984; Dinar and Latey, 1991 and Hearne and Easter, 1997). There are also a few studies that provide a rough estimate of the opportunity cost[50] or potential social gain of change in water institutions as a whole (for example the work of Hearne and Easter, 1997 and Saleth, 1996). There have also been attempts to estimate directly the transaction costs of reform (Colby, 1990; Easter *et al*, 1998; Connor and Perry, 1999; Louw, 2001 and Viljoen *et al*, 2000).

The present approaches towards estimating both the opportunity and transaction costs of institutional change in the water sector remain partial, for they do not adequately account either for the segment-specific institutional needs of different water sub-sectors or for the component-specific cost variations across the components of water institutions[51]. Variations in the opportunity and transaction costs make institutional changes easier in some contexts, but difficult in other. For example, it is easier to formulate and declare a water policy than to design a water law. Similarly, it is much easier to develop both water policy and water law than to create new or reformed administrative structures needed for an effective translation of legal adaptations. Since institutional change is continuous, the easier reforms initiated in the early stages brightens the prospects of further and higher-level institutional changes. This means that there is a functional linkage between the transaction costs of reforms and the opportunity costs of earlier reforms. Although these linkages appear to be abstract and theoretical, their practical influence within the political economy of the reform process should not be underestimated (Dinar and Saleth, 1999:5).

Since the magnitude of net benefits from institutional changes in the water sector is a direct function of the degree of water scarcity, the economic incentives for institutional change increase with every increase in the level of water scarcity (as induced by factors like population growth, economic development and climatic change). Increasing water scarcity also magnifies the real and economic costs of inappropriate water sector policies (for example treating water

[50] The problem with opportunity cost pricing is that the supply and demand of water are seasonal and variable and opportunity costs vary accordingly and could not be estimated. A further problem is that water needs to be metered while opportunity costs are subjective and cannot be objectively observed (Nieuwoudt, 2000:63). (The market solution to pricing water at opportunity costs is tradable water rights.)
[51] The components include: Water law, water policy and water administration (Dinar and Saleth, 1999:4).

as an "open access" resource and subsidised water provision), which can be approximated by the gap between the scarcity value of water and the prevailing water charges.

Besides the opportunity costs of institutional change, the water sector is also strongly influenced by some factors[52] that originate from outside the water sector. Macro economic reform emphasises the fiscal implications of opportunity costs of institutional change. In contrast, socio-political reforms in South Africa since the 1990's reduce the transaction costs directly because the institutional changes in the water sector form part of a system-wide reform. The opportunity cost has also been magnified further by water-related natural phenomena like droughts, floods and salinity. This means that the original opportunity costs of the water sector need additional support to prompt and sustain the process of institutional change (Dinar and Saleth, 1999:5).

Transaction costs are generally characterized as factors (externalities) that hamper the efficient functioning of markets. Some externalities are known and measurable and others are unknown and not measurable. In the water market paradigm, transaction costs usually consist of searching for trading partners, determining of the characteristics of the water commodities, negotiating terms and prices for the transfer and obtaining legal approval for the transfer (Louw and Van Schalkwyk, 2001 and Hearne and Easter, 1997:188). Excessive transaction costs create artificial scarcity because the potential buyer of the right cannot afford the right due to high prices and the seller cannot sell the right due to high transaction costs. This artificial scarcity develops in an excess supply of water. Lund (1993:3103) investigated the probability of an unsuccessful transaction due to high transaction costs. He found that seeking water transfers becomes more attractive to potential water purchasers and the probability of a successful transfer increases, if more of the transaction costs for water transfers are incurred after a transfer and if the costs of delaying implementation of alternative water supplies are small.

Connor and Perry (1999:2833) studied the effect of water quality externalities as a result of market water transfers. They allowed for both positive and negative externalities, mostly regarding return flows of irrigation water. Their study describes conditions[53] when water trade is most likely to generate positive and negative water quality-related externalities. They also draw policy conclusions about the kinds of institutional rules best suited for balancing trade-offs between gains to trade, water quality externalities and transaction costs. One of the key implications of this research is that certain property right schemes (treatments of return flow externalities) and hydrological conditions are conducive to the possibility of negative water quality externalities. Therefore, water right schemes including the protection from return flow externalities are likely to protect water quality in streams (because water transfers under such circumstances will generally reduce effluent loading), but will not reduce the flow (dilution capacity) of the stream. In contrast, "capital asset" water use rights (which allow the sale of the right to divert with no explicit return

[52] Including macro economic adjustment policies and social-political liberalisation and reconstruction programs (Dinar and Saleth, 1999:5).

[53] These conditions include the following: When water trade causes both reductions in water body loading capacity and dilution capacity, and the pollutant loading percentage increases, negative externalities regarding water pollution will occur. In other words, negative water quality externalities will only result from water trade if the percentage reduction in water dilution capacity (resulting from water trade) exceeds the percentage reduction in pollutant loading.

flow protection provisions) do not preclude the possibility of negative externalities (Connor and Perry, 1999:2837). Hanley (1995) also researched the potential of using water markets to control water pollution. His study showed that empirical evidence exists that water markets do indeed prove useful in controlling pollution.

The transferring of water use rights implies a negotiating process where the two parties negotiate to meet each other's needs. According to the Coase theorem (Goodstein, 1999:61), it does not matter which party the original property right belonged to, the outcome of the negotiating process (which can be explained in terms of marginal benefit analysis) will always be efficient. This will be the case with zero transaction costs and no free riding. The reality proves otherwise, because asymmetrical information is always present and the ability to impose transaction costs on the other party represents bargaining power in the negotiating process.

Market transactions are undertaken for economic gain, based on the perception that water supplies will generate higher returns in their new use than in their former use. A third party (government) can gain some leverage on the transfer and start playing a role in water allocation decisions by eroding these expected gains through imposing transaction costs (policy-induced transaction costs on one or both parties). For policy-induced transaction costs to facilitate efficiency, government must arrange incentives such that reallocation occurs *only if* the social benefits of the transfer exceed the social costs (social welfare is maximised when water transfers occur to the point where the social marginal benefits equal social marginal costs). Given the public good nature of water uses and the externalities associated with water transfers, private marginal costs are likely to be separated from social marginal costs (Colby, 1990:1186). Transaction costs could therefore promote efficiency, causing private decision-makers to account for social costs by taxing transferors through policy-induced transaction costs.

Colby (1987:1114) discusses another important factor to keep in mind when decisions regarding market efficiency are at stake. She raises the question of how market performance should be evaluated. The underlying answer to this question is conceptually simple. Knowingly, if the benefits of a transfer outweigh the costs, the transfer is regarded as "beneficial". The underlying theory and practical methodologies of measuring and weighting benefits and costs in order to make a decision, however, are controversial and complex. A thorough evaluation of market processes should answer two questions. First, do increased returns to water use and any other benefits associated with the transfer outweigh the social costs of market activities? Secondly, is there an alternative water allocation process that would yield greater net social benefits? The answers to these questions depend on the measurement technique used and it is therefore important to consider a variety of measurement techniques before making a choice.

2.10 Market failures and institutional barriers to water marketing

Neo-Classical economic theory suggests that under specific conditions, markets will yield accurate incentives and promote efficient resource use. However, these conditions are restrictive and when particular conditions are not met, markets do not yield appropriate incentives and "fail" to achieve efficient resource use (Livingston, 1995:204).

Randall (1983:147) studied the phenomenon of "market failure" and noted that there are indeed certain kinds of goods that the open market fails to deliver in an efficient manner. He mentioned the criteria of exclusiveness and rivalry and suggests the use of these to distinguish whether a certain economic good is suitable for the market or not. Water per se as an economic good cannot be characterised by these criteria, because it will vary according to use. Consumptive uses are certainly exclusive and rival, but most non-consumptive uses are non-exclusive and non-rival.

McCormick (1994:953) investigated institutional barriers to water marketing. He mentioned that the lack of articulation of public interests in the water resource itself leads to incomplete definition of the private rights to water and it is those private rights that are sold and leased within the market. Therefore, the willingness to define the nature and extent of private interests in water supplies will determine the development and level of efficiency of any water market regime.

Five characteristics exist which may prevent market prices from representing the social values of water. These characteristics include the physical characteristics of water, imperfect competition, externalities, uncertainty and equity-related issues. The *physical characteristics* of water violate a number of economic and institutional conditions for effective market functioning. Three central conditions necessary for efficient market allocations of the resource include: (1) certainty regarding the resource supply, (2) perfect divisibility and (3) independent use characteristics. Certainly in the absence of suitable institutional control, these conditions are not met in the case of water resources. *Imperfect competition* occurs when one or more users, suppliers or government have the power to significantly affect the market prices and conditions for water transfers. In this case observed prices may deviate from the maximum willingness to pay for marginal units of water. *Externalities* occur when water transfers positively or negatively affect third parties and these effects are not taken into account in market transactions, and prices will therefore not reflect full social values. Water systems always involve interdependency therefore the withdrawals and consumption of one user and the changes it causes in water quality, affect others. Externalities are pervasive. Thus, a market system in water use rights cannot perform efficiently without some kind of supervision. According to Brennan and Scoccimarro (1999:70), the "no injury rule" – avoiding damage to other users when water is first appropriated or later traded – must be enforced by a supervisory agency. *Uncertainty* reduces the willingness to pay because the buyer of the right cannot estimate the expected value of the use with certainty. *Equity* issues and distributional considerations may affect the appropriateness of observed prices as measures of social values, therefore water transfers will have an impact on the economic activity of communities receiving the water.

Market efficiency requires that the rights to water be non-attenuated (explicit, exclusive, enforceable and transferable). The common property nature of water and the difficulty in clearly defining water use rights, implies that water trade may affect third parties. The public good characteristics of some water uses imply that parties affected by these trades may not always be represented in the market. Adequate definition of property rights to the resource are essential in terms of quantity, reliability, security of tenure, conditions of use and water quality. However, even where these conditions exist or can be created, market performance can be flawed. According to Pigram (1993:1318), some theorists would deny that property rights to water would ever be sufficiently defined to permit a market system to operate. One of the reasons is because water is a "mobile" resource and not fixed like land. The right to a given specific volume of water is constrained in space and time and for a specific purpose. (This is also one of the main reasons why capacity-sharing is attractive, because the share is not limited to a specific volume of water but to a percentage of the storage capacity of the reservoir as well as a percentage of the inflow into the reservoir.)

Regarding the ability of water markets to distribute (or allocate) water efficiently, there are two reasons within the South African context why water markets do not release water for alternative use (Nieuwoudt, 2000:58). *Firstly*, most of the water trades take place between non-users of water and intensive users of water. It will therefore take time before all "sleeper rights" (water not in current use) are activated. *Secondly*, irrigation farmers in South Africa are permitted to irrigate a larger area if they adopt water-saving technology. Although this water-saving technology will reduce water application per hectare, the total amount of hectares will increase and therefore no absolute water saving will be realised. Agricultural water markets are therefore increasing the use of water and at the same time promoting the conservation thereof. This seems confusing. Nieuwoudt (2000) recommends that water transfers be based on *consumptive use*[54] if return flows are significant.

It is advisable to retain a certain level of state intervention in any water market in order to keep a balance between a total free market and a fully bureaucratic controlled system. This emphasizes the importance of putting into place an acceptable institutional arrangement for managing, firstly, the transition towards a more market-oriented system and secondly, the sustainable management of water resources. This raises the question of the appropriate mix of incentive-based mechanisms and "command and control" approaches to achieve these goals.

According to Bauer (1997), pro-market policies have both strengths and weaknesses in different areas of water management. At their best they implement the fact that water is an economic good with economic value. Such policies can raise economic efficiency through financial incentives and flexible resource allocation that is most likely to be effective at the local scale involving similar types of water uses. Water markets can also facilitate long-term trends in regional economic development such as urbanisation at the expense of agriculture, although this is often politically controversial as well. However, water markets are unable to handle broader problems such as multiple

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[54] Consumptive use is the volume of water that the farmer withdraws from the irrigation scheme minus his return flows back into the drainage system.

uses, environmental and third party effects, river basin management and conflict resolution. It is here that environmental sustainability and social participation meet the economic value of water in all of its competing uses. Such problems are theoretically and practically difficult and complex and can rarely be solved by a simple exchange of rights and when private bargaining breaks down, they highlight the importance of wider legal and political institutions.

Lastly, it is important to realise that the conversion of the current water management strategy to a water market is a slow evolutionary process. The initial steps should be consistent with the final design of the system. Starting small gives the institutions and parties involved time to adjust to the new system, and since most of the initial efforts will be precedent-setting, it will take time to work them out. Once the precedents have been established, the process will become smoother, quicker to respond and better able to handle large numbers of transactions.

2.11 Conclusion

This discussion concludes the literature review. It should be clear at this stage that the problem of achieving efficient and equitable water management is complex and sensitive partly due to the historical context and the emotional reactions of the bulk of water users. The next chapter will focus on capacity-sharing as part of an integrated demand-oriented approach to water management.

Chapter 3

DEMAND-ORIENTED WATER MANAGEMENT STRATEGIES

3.1 Introduction

The shift from supply- to demand-oriented water management strategies should be evident in the preceding literature review. The focus of this chapter will be on the development-path of the concept of capacity-sharing as well as the detail explaining of the concept.

Neo-Classical economic theory served as the original point of departure from where the "single decision-maker" approach was developed. As the most restricting assumptions under this approach were dropped, alternative approaches to demand-oriented water management were born. The volume-sharing and later on the capacity-sharing of reservoir water are examples that will be discussed here in detail. It should be noted that capacity-sharing will not be the final and "best" form of demand-oriented strategy, as the water management is a dynamic and multi-contextual field.

3.2 A single decision-maker approach

The work of Dudley (1988a and 1988b) and Dudley and Musgrave (1988) will be used as the basic point of departure to investigate the legitimacy and role of the concept of capacity-sharing within the current South African water management context.

The main issue, which Dudley (1988a and 1988b) and Dudley and Musgrave (1988) focused on, was concerned with the efficient management of water resources in terms of profit maximisation (in the broader sense) and the sustainable use of water resources. These two concepts seem contradictory, but when the concepts of capacity-sharing and equity issues come to the fore, this apparent contradiction will be resolved.

Dudley (1988a) developed a *single decision-maker reservoir management model* that made use of data produced from a *soil-water plant-growth model* (the so-called "Narribri"-model, which is mentioned in Dudley, 1988a:635) to produce its data. The single decision-maker reservoir management model consists of three sub-models. The *first* is a computer simulation sub-model, the *second* is a dynamic programming model and the *third* is another computer simulation sub-model. The purpose of the first simulation sub-model is to calculate expected gross margins and state variable transition probabilities for each combination of state- and decision-variable levels being considered.

The purpose of the dynamic programming sub-model is to select values of the decision variables (for example maximum area to keep under irrigation in the immediate stage) for each state and stage combination. This will maximise expected net benefits over the remainder of the planning horizon. The purpose of the second simulation sub-model is to simulate the effects of using the optimal decisions (derived by the dynamic programming sub-model) for each of a range of discrete irrigable areas (Dudley, 1988a).

One of the main functions of this model is to examine trade-offs between increasing mean annual net revenue and increasing standard deviation of annual net revenue as irrigated areas are progressively increased.

According to Dudley (1988a:633), irrigation systems throughout the world have the following four characteristics (which were not included in the literature on how best to operate irrigation systems) and are applicable for South African conditions:

- The demand for and supply of water is highly variable over time. "Demand" within this model is the quantity of irrigation water required per time period (for example per month) to maintain a specified minimum soil-water level for given areas of specific irrigated crops. "Supply" is the quantity of stored water available for use per time period. (Note that price does not play a role in Dudley's definition.)
- Seasonal water supplies are difficult to forecast, often being dependent on reservoir catchment rainfall after the irrigation season has begun.
- The frequency of droughts justifies the storage of water in reservoirs, often for more than a year. This justifies the construction of storage facilities to reduce the impact of water shortages to economically tolerable levels.
- Land suitable for irrigation is plentiful in relation to the available water and has relatively low value in alternative non-agricultural uses.

Each of the above-mentioned characteristics has an influence on the stochastic nature of irrigation water supply and demand. (Pigram (1993:1313) also emphasizes the stochastic nature of the supply of Australian water resources.) Dudley (1988a:634) argues that these four characteristics of irrigation management represent a general case. It is more likely that the supply and demand characteristics for arid environments take on a more deterministic nature. This general case was dealt with by Dudley (1988a:635) by proposing that there is a hierarchy of short-, medium- and long-term decisions to be made which should all be optimal if the expected net benefits from the use of irrigation water within a catchment are to be maximised. The problem of asymmetrical information was overcome by assuming a **single decision-maker** who has the power to make decisions about when and how much to irrigate as well as the timing and size of controlled releases from the single reservoir in the catchment.

Dudley's (1988a) objective in the paper was to provide a basis for comparing the results obtained from a single decision-maker model with a more realistic multiple (a reservoir manager or catchment management agency and individual irrigation farmers) decision-maker model. The main assumptions of the *single decision-maker approach* were (Dudley, 1988a):

- A reservoir irrigation system is assumed in which a single reservoir supplies water by a direct channel to storage facilities within the irrigation area (much like the Olifants River canal scheme in the Western Cape).
- No water other than releases from the water reservoir is available for irrigation (such as downstream tributary flows).
- The irrigation area storage is of sufficient capacity to ensure that all releases from the reservoir are retained for irrigation and that irrigators are not restricted in their timing of irrigations.
- Only one irrigated crop and one dry land crop are considered and it is assumed that they can be grown continuously on an area of land without ill effects when using the budgeted production practices.
- It is also assumed that prices and reservoir capacities are fixed.

Although restrictive, the assumption of a single decision-maker internalises the derivation and communication of supply and demand probabilities. This results in a higher level of economic efficiency and sets a standard against which to judge decentralised models.

The systematic relaxation of the above-mentioned assumptions serves as the basic motivation for the development of the concepts of volume-sharing of reservoir water and, later on, capacity-sharing of water reservoirs.

3.3 Volume-sharing of reservoir water

The concept of volume-sharing was the first attempt to examine alternative methods for allocating reservoir water within a catchment area when reservoir managers and farm managers are separate decision-makers (when the main assumption of the single decision-maker model is relaxed). A major problem in relaxing the assumption of a single decision-maker is communicating of stochastic nature of supply and demand between reservoir and farm managers.

It is important to note that water supply under the concept of volume-sharing is redefined to the quantity of reservoir water released for irrigation, which is a function of random inflows and release strategies. (Note that price is still not included in the definition.) Demand[55] remains the quantity of irrigation water required to maintain a given minimum soil water level over given areas of specific irrigated crops. The probabilities of supply to irrigators depend in part on the degree to which reservoir management considers stochastic demand. According to Dudley (1988b:641), reservoir managers can consider user demand when formulating reservoir release rules and associated supply probabilities of a reservoir in three ways:

- User demand may be taken into account by assuming deterministic demand, a target to be met in each inter-seasonal interval. Depending on targets set and the penalties for failure to meet them, reservoir-

[55] Demand is a function of the (1) random difference between evaporation and rainfall, plus the transfer and application efficiency losses, (2) soil water deficit at which irrigations take place and (3) areas of specific crops irrigated (Dudley, 1988b:641).

optimising models could be used and probability distributions of supply derived. This approach has the advantage of determining the probability clearly and simply, but has the disadvantage that if these probabilities are to be maintained in practice when demand is random, releases would have to be made even when not required (releases would actually be made irrespective of demand!).

- The reservoir management could apply irrigation water use data from a soil water-growth model (the "Narribri"-model, mentioned in section 3.2) as the basis of stochastic demand and derive reservoir release strategies that would minimise the squared differences between quantities supplied and demanded[56]. Another option is to take historical records and take some measure of the evaporation less effective rainfall per hectare, multiplied by the size of the irrigable area to obtain the total water demand, and calculate the probabilities of supplies matching demands when following specific release strategies. This approach has the advantage of providing users with clear information on the relationships between uncertain supplies and uncertain demands as long as these releases are actually made. Because actual farm management behaviour is not considered when determining reservoir releases, actual user demand may sometimes be less than releases made to satisfy potential evaporation minus rainfall over the whole irrigable area. Within this setting, three problems need to be addressed. *Firstly*, there is the problem of developing a decision model to determine reservoir release rules/strategies for the reservoir management. *Secondly*, there is the problem of developing a means of communicating the probabilistic nature of reservoir releases to users. *Thirdly*, there is the problem of modelling the water-using behaviour of users in response to the probability of releases. This should help users to make better use of the probabilities of releases, and provide a way of choosing between reservoir management and system design alternatives, as well as providing information necessary for public evaluation of the total project.

- The reservoir management may also consider actual user behaviour. Under actual system operation, both supply and demand probabilities would interact and evolve over time as the supplier reacts to perceived demand stochasticity and the demanders react to perceived supply stochasticity. At any point in time, each probability would be conditional on the other. Therefore, any form of modelling would only be approximate. Accurate modelling would be limited to real-time processes that would be of little use for planning purposes.

The volume-sharing model also consists of three sub-models. The *first* is a simulation sub-model deriving data for the *second* (a stochastic dynamic programming sub-model), which in turn provides data to a *third* model (a second simulation sub-model). Both of these simulation sub-models use data from the "Narribri" soil water plant-growth model mentioned in section 3.2. The purpose of the *first* simulation sub-model is to derive state variable transitions and expected values of squared deficits for each state and decision variable combination in each stage. The stochastic dynamic programming sub-model chooses the maximum releases, which will minimise the expected

[56] The statistical theory behind this method is grounded in the method of ordinary least squares as mentioned in Gujarati (1992:129-138).

square of deficits (for example demand release squared) for each state and stage combination. To do this, it requires the first simulation sub-model. The second simulation sub-model, provides a sequence of reservoir releases for each of the four decision-making stages per year[57] for the 84 years (therefore 336 values) of data available. This sub-model uses externally determined quantities to release in each decision interval as a function of reservoir capacity. Dudley (1988b:643) used two types of release rules:

- Release enough to satisfy demand if reservoir content is sufficient.
- Releases must not exceed the quantity specified as the optimal release by the stochastic dynamic programming sub-model.

Thus, the stochastic dynamic programming sub-model releases are considered as maximum releases. Releases actually made by the second simulation sub-model will be less than maximum release if demand during the specific decision interval is less than the maximum release.

Dudley (1988b:641) used an optimising model to develop release rules for reservoir management when all users share equally in releases, and computer simulation is used to generate an historical time sequence to announce releases. These announced releases became a state variable in a farm management model that optimises farm area-to-irrigate decisions over time. Such modelling uses climatic data to gauge water demand and the transfer of water supply data from reservoir managers to irrigation farmers.

The results of the volume-sharing model showed a lower mean aggregate farm income and lower variance of aggregate farm income than the single decision-making reservoir management model. This short-term efficiency loss coupled with likely long-term economic efficiency losses due to the attenuated nature of property rights, indicates the need for quite different ways of integrating reservoir and farm management decisions (Dudley, 1988b:641).

It appears impossible to equate the single decision-maker model (in terms of efficiency) with centrally controlled reservoir and farm management strategies. Therefore, a quite different property-right structure incorporating decentralised management and preserving economic efficiency (if a user is risk neutral), or allowing each user to choose his own level of income variability independently of others (if risk aversion is present) will be discussed in the next section.

[57] Dudley assumed that there are four irrigation decision-making stages within the growth season. The *first* is just before sowing/planting, the *second* is 60 days after sowing, the *third* is 90 days and the *fourth* is 120 days after sowing/planting (Dudley, 1988a:634).

3.4 The theoretical concept of capacity-sharing

The most common approach to the management of publicly owned resources for irrigation purposes is to allocate either the current reservoir contents or potential reservoir volume of regulated flow. Capacity-sharing is different in the sense that it is an **integrated, demand-oriented water management strategy that focuses on the interaction and communication between water users and managers of water reservoirs or storage capacities** (Dudley and Musgrave, 1988:649). Major questions to be answered include (1) how reservoir releases should be managed through time, (this question includes aspects like the way weather dependent fluctuations in irrigation water demand should be incorporated into release strategies), (2) how best the probabilities of such releases can be summarised and communicated to users and (3) how users could be assisted to make the best use of such information.

The basic procedure, (as with sections 3.1 and 3.2) develops computer models of a simplified river irrigation system and uses these models to answer the above-mentioned questions. This simplified system makes use of inflow, evaporation and capacity characteristics of the specified storage capacity and climatic data of the cultivation area, for the modelling. Tributary flows downstream of the storage capacity are assumed not to contribute to water supplies and the growing area of the water storage and distribution system is of such a nature that it does not limit the user's ability to apply water when desired. The only limitation to water supply is the quantity available for release from the storage capacity. Only one irrigated crop is used in the initial modelling, but later multiple crops are used.

The concept of capacity-sharing divides the single large reservoir into many "compartments" or "sub-reservoirs", each controlled by a single decision-maker who controls releases from the sub-reservoir and makes farm management decisions. The management of the whole reservoir is reduced to the monitoring of the individual releases by water-using decision-makers. Thus, the model is essentially an aggregation of the many small, single decision-maker models that are scaled-down versions of section 3.2.

Each user is allocated a percentage share of the reservoir's total capacity and a percentage of the net reservoir inflows (in the form of water use rights)[58]. These percentage shares would not need to be equal across users, nor would the percentage shares of inflow and capacity allocated to a specific user necessarily be equal. It is therefore possible for a specific user to have a 2% capacity share, but a 1 % inflow share, where another user could have a 1% capacity share, but a 2 % inflow share (Dudley and Musgrave, 1988:650). (For the sake of simplicity, it will be assumed that each user's capacity share is equal to his inflow share and that these are equal to all the other users shares).

Dudley and Musgrave (1988:650) illustrate the fundamentals of capacity-sharing as follows:

[58] Net inflow is defined as the inflow within a specific time-period minus the evaporation and seepage losses (Dudley and Musgrave, 1988:650). Note that the water use right (that was bought) on inflow shares reserves only the right to buy these shares, the shareholder must still pay for the volume of water he wishes to buy.

"To illustrate the fundamentals of reservoir capacity-sharing as envisaged in the paper, first assume that the single reservoir in question is cube shaped. Imagine that vertical water tight partitions are inserted in this cube, two parallel to the east-west sides and two parallel to the north-south sides, dividing the cube into nine equal-size cells. Thus the plan or birds-eye view of the reservoir would show nine equal-sized squares. Each of the users would be allocated exclusive use of the cell, able to withdraw water from it over time as wished, and each receiving an equal share (one ninth) of net inflows to the reservoir unless the relevant cell was too full to take the net inflow share. In the latter case the inflow in excess of that required to fill the cell would be lost to that use." (Note that there will be periodically adjustment of spilled inflows where the user will regain some of the lost inflow.)

"Refer to the contents of each user's cell as that user's inventory. It would be necessary to monitor each user's inventory through time in a real-world application of capacity-sharing because the imaginary partitions introduced above would not exist. Thus, the operations of the reservoir could be likened to those of a money bank where each depositors' money is not kept in a separate physical location to monitor accurately the amount, which that depositor has in the bank. Instead, the homogeneous money is intermixed and the monitoring performed by keeping tally of each depositors' withdrawals, deposits, interest charges, ect. Similarly, each users' inventory within the reservoir would be monitored by tallying withdrawals and net inflows."

It is useful to continue this analogy by noting that the reservoir capacity shareholder is like a bank depositor who cannot incur a negative balance, cannot accumulate deposits in excess of a maximum (which is a percentage of the maximum sum of deposits which the bank can hold) and cannot control the amount or timing of deposits. Instead, deposits (inflows) are made according to a stochastic process with a probability distribution, which is known to the capacity shareholder. However, beyond these stochastic deposits (inflows), which are made independently of the actions of other shareholders, there may be extra deposits made periodically to a depositor's (shareholder's) account (capacity share) because of the heterogeneous behaviour of all shareholders (periodic adjustments of spill over effects and trading). To illustrate this, let us use the cube example again. Identical withdrawals (and therefore identical management behaviour) by each of the capacity shareholders from their "accounts" would under the assumption of equal sharing of net inflows, result in all capacity shares (or inventories) being equal as they fluctuate over time. Such identical behaviour would eliminate the need for the periodic adjustments, since all would fill simultaneously. As one cell of the "cube" is filled, it would spill into the "neighbouring" cell and so on. However, these spill-over flows from one cell to another do not realise in reality (because they are not measurable, attitudes towards risk differ and therefore release patterns will differ) and are accumulated in a separate capacity share. This capacity share is allocated among capacity shareholders at the beginning of the next season - this allocation is the "periodic adjustment" mentioned earlier. The magnitude of the above-mentioned periodic adjustment depends on evaporation losses through the season. The assumption of a cube-shaped reservoir meant that the surface area of each capacity shareholder's share (cell) was independent of the volume (inventory or current level) of the capacity share. The assumption also implied that the sum of the "cells" equals the total surface area of the reservoir (cube). Since surface area and depth are important factors determining evaporation losses, the assumption implied that each shareholder's inventory level (or volume of the capacity share) could be ignored in calculating total reservoir evaporation losses. (This also implies that the evaporation component of each user is identical.) However, in reality, reservoirs are not cube-shaped, which implies that the tempo of evaporation losses changes as the volume of the reservoir changes. This means that the total reservoir evaporation is dependent on the withdrawal behaviour of all the shareholders. This raises questions on how best these evaporation losses could be divided between shareholders. Should they be divided equally or should those whose capacity shares contribute to more than a proportional share of evaporation loss be debited accordingly?

Given that capacity-sharing has the accumulation of these surpluses as a by-product, the management of these surpluses would be the main concern of the reservoir managers. Within the model of Dudley and Musgrave (1988:652), two ways are tested, but only at one time period (beginning of the season). The *first* way (also known as "efficiency sharing") allocates surpluses first to the risk preference users (the users who are prepared to take some risk) until their inventories are full and lastly to the risk averse (those who will avoid risk) users. The *second* way (also known as "equity sharing") allocates the surplus equally across all users until some inventories become full, then equally to the remainder etc., until exhausted. (Note that such allocations, or periodical adjustments, are not taken into account by decision-makers when formulating decision strategies.) A major concern is to gauge the net *social benefits* from the two allocation methods. (The surplus is allocated free of charge within the model, but in reality it could be auctioned under efficiency sharing or sold at a flat rate under equity sharing.)

It is likely at this stage that the reader will not have a clear picture of the different types of "sharing". Therefore, it seems appropriate to distinguish between the terms. Let *contents-sharing* be the allocation among users of the current actual contents of a reservoir at a given point in time and let *volume-sharing* refer to the allocation of water which will become available from the reservoir over time. If the reservoir could be assumed to be full at the beginning of each irrigation season with no further inflows during the season, there would be no point in distinguishing between contents and volume-sharing, because the contents at the beginning of the season would equal the total volume available for the whole season (which would be the relevant future, since the reservoir fills completely at the beginning of the next season and a user with a capacity share would allocated his total share for that season). However, if significant inflows during the irrigation season are the norm (stochastic water supply), the total volume available for that irrigation season could exceed the total storage capacity of the reservoir if all the water received through the irrigation season were to be stored at one moment in time. (Note that building a bigger reservoir is not an option since that would be a supply-oriented water management strategy and this study is concerned only with demand-oriented water management strategies.)

For illustrating the difference between *volume-* and *capacity-sharing*, given a stochastic water supply, assume that the term "volume" refers to the current reservoir contents plus the net inflow received through the season. The volume through the whole season is therefore dependent on demand early in the season. If releases are made early, reservoir space will become available to store the later flows. A capacity shareholder would be able to use the reservoir volume at the beginning of the season as well as the probabilities of stream flow and evaporation, to determine the probabilities of various quantities of water being available through the season, depending on his own water use pattern. (The user with a volume share would need the demand patterns of **all** the other users through the season in order to be able to determine the same information, namely probabilities on water availability for various use patterns for the user). Therefore, a user under a capacity share system has a greater sense of *security* via a more *clearly defined right* (the estimation of supply probabilities in response to different use patterns would be the responsibility of the individual user) and would require less information (reducing transaction costs) for decision-making. Secured capacity shares provide a better basis for the transfer of water between users than the probabilities of water becoming available conditional to early season use patterns as in the case of volume-sharing (Dudley and Musgrave, 1988:651). Users with capacity shares would therefore be able to predict their future supplies more accurately and therefore be able to determine with greater certainty the quantities of water they wished to buy or sell. This last point makes capacity-sharing an ideal point of departure for the introduction of water markets in the given catchment.

If there is no guarantee that the reservoir will be full at the start of the irrigation season (in other words assuming a stochastic supply), a user with a more secure title to a capacity share might behave risk-aversely by developing only a small area of land for irrigation purposes (one that can be irrigated across years with a high degree of reliability). Alternatively, a user might develop a large area, knowing that irrigated production from it will fluctuate from year to year. In this case, it seems that the greater degree of security of tenure offered by the capacity share, which includes the net inflow, would allow for more effective long-term investment decisions and short-term water transfers in comparison with volume-sharing.

What makes capacity-sharing appealing (according to Dudley and Musgrave, 1988:651) is because it allows the probability of water supply for a user to be defined to a large extent independent of intra- and inter-seasonal carryover policies of reservoir management as well as being independent of the quantities and timing of the usage demands of other users through time. Therefore, each user can, to a greater extent, achieve his desired reliability of water supply, independent from others. This also means that the adverse effects from other users and water supply authorities are minimised. This greater control over storage capacity in the long run should allow a user to consider the full opportunity cost of stored water in his capacity share. If market transfers of such capacity shares were possible or be allowed, the efficiency of water usage should further increase.

In summary then (Dudley, 1990a:401):

- Capacity-sharing would make water within a reservoir a private property rather than a common property resource. Therefore, users would have incentives to conserve water when it becomes relatively more scarce (the opportunity cost of water is considered). Note that common property regimes may be accommodated by making it a separate user who participates in the market with other users, but the share that was bought will be managed as common property (Dudley, 1992:776 and Backeberg, 2002).

- Capacity-sharing would have the consumption-reducing advantages of highly fluctuating water prices, without producing a destabilising effect on the user's finances.
- Capacity-sharing would stabilise the net revenue of supply authorities. The "user pays" principle would apply to water collection and distribution rather than water use as such.
- Capacity-sharing allows a high degree of separation between the allocative and revenue-raising roles of water pricing.
- Capacity-sharing virtually eliminates the problem of uncertainty regarding supply probabilities and water costs over time.
- The sound non-attenuated (that is, explicit, enforceable, exclusive and transferable) property rights nature of capacity-sharing provides an ideal basis for the development of water markets as such and for reservoir capacity and inflow shares.
- Existing water users and owners of capacity shares will not experience water supply and reliability reductions without compensation via the market.
- A market for capacity shares (separated from inflow shares) would provide a measure of the value of marginal units of current reservoir capacity, which could be used to indicate the best time to expand reservoir capacity.

Capacity-sharing is therefore designed to integrate and coordinate supply and demand management decisions, which is in line with the arguments of integrated and decentralised water resource management mentioned in the National Water Act of 1998.

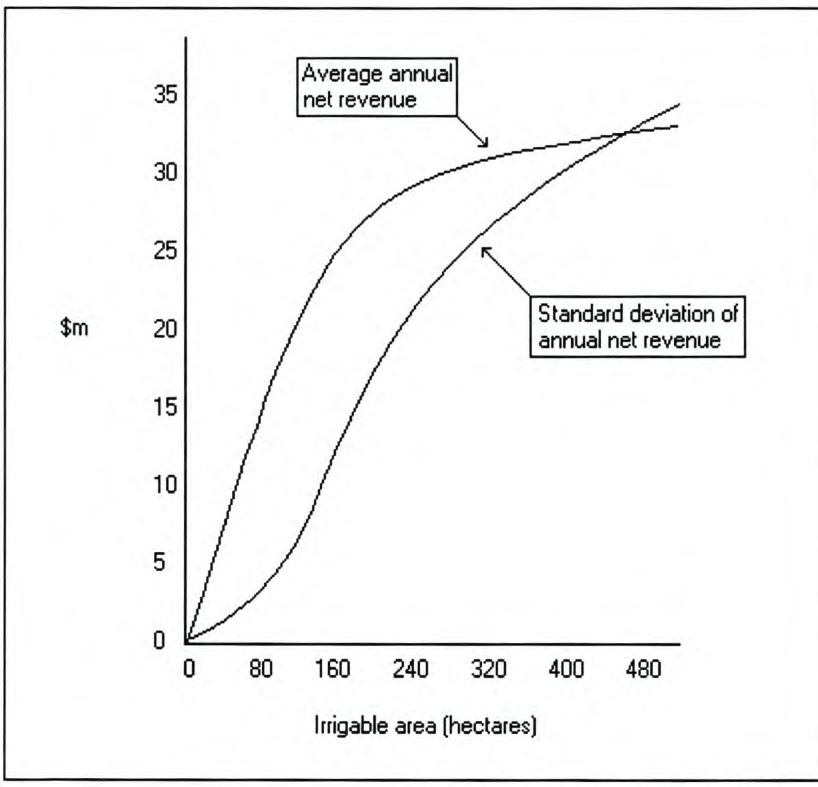
3.5 The modelling of capacity-sharing

The implementation of capacity-sharing could be modelled with the aid of a computer simulation model, using only one irrigated crop (this could be developed into a multi-crop simulation).

In section 3.2 a single decision-maker approach towards reservoir management[59] was briefly discussed. This model could be used to derive estimates of the annual net revenue obtainable from different sized irrigation areas, given a particular reservoir and a non-limiting distribution system. Where section 3.2 was applicable for a whole reservoir,

[59] The single decision-maker approach towards reservoir management showed average annual net revenue and the standard deviation of the annual average net revenue as a function of area developed for irrigation when the cost of expanding the area is $100/hectare (refer to figure 3.1), (Dudley and Musgrave, 1988:651). Figure 3.1 shows average annual net revenue increasing at a decreasing rate for larger areas while the standard deviation curve is slightly sigmoidal. For higher costs of expanding the irrigable area, the decreasing rate of increase in average annual net revenue is more pronounced, with a maximum value becoming evident and occurring at smaller and smaller areas developed as expansion costs are increased.

this same argument could be applied to the capacity-sharing model (and therefore to the individual decision-maker) by changing the scales of the answers obtained in section 3.2. For example, if a user has a 1% share in both reservoir capacity and net inflows, the answer obtained in section 3.2 and by Dudley (1988a) divided by 100 would be applicable to that specific user. Therefore, it is possible for a user to apply the model in section 3.2 to select the combination of mean annual net revenue and its standard deviation and consequently the area to develop for irrigation which best suits that user's risk preference (Dudley and Musgrave, 1988:652). In other words, the long-term investment decision problem faced by a single capacity shareholder would be a scaled-down version of the land-development-investment problem facing the single decision-maker of section 3.2.



Source: Dudley and Musgrave, 1988:651)

Firgure 3.1: Average and standard deviation of annual net revenue.

A potential participant in a capacity-sharing system is envisaged to have access to such a scaled-down single decision-making model with which computer experimentation could be conducted. The results of such experimentation would help the user decide whether or not to become a share user in the system at all, how large an area to develop and what short-term inventory release and farm management strategies to follow.

The model (Dudley and Musgrave, 1988) requires a historical sequence of reservoir inflow and cultivation area climatic data. Note that no assumptions would be required about the reservoir management's release policy, because there would be none. Each capacity shareholder will formulate his own release strategy in conjunction with farm management strategies used. Decision-makers could make their own decisions without being concerned that the water demands of others would influence their own water supply probabilities.

The results from the single decision-maker approach could be made applicable to the capacity-sharing model if two conditions are met (Dudley and Musgrave, 1988:652):

- All users must make identical releases (but not necessarily at the same time). If they did so, all inventories would move together (all would fill and spill together). This means that the sum of the spills would equal the actual reservoir spill. To the extent that users employ different release strategies, individual inventories would fill and spill at different times, causing the aggregate to be greater than the actual reservoir spill. This would result in the accumulation of a surplus in the actual reservoir that would need to be allocated across users periodically on some basis.

- The second condition is that reservoir evaporation and seepage loss must be a linear function of reservoir contents. If this were true, the sum of individual inventory losses would equal the actual reservoir loss. To the extent that this is not true, a discrepancy will arise, resulting in either a surplus or deficit allocation to shareholders.

From the above-mentioned a computer model could be developed to simulate the behaviour of all the capacity shareholders so that the importance of the difference between the sum of shareholder capacity shares and actual reservoir volume can be gauged. This type of model could also be used for aggregating the effects of each decision-maker's behaviour on the overall social, economic and environmental outcome. (This is important in following a true integrated water management approach.) The following is a model that makes use of crop-water-requirement data and was developed by Dudley and Musgrave (1988:561) for a single crop (cotton). This could also be done for multiple crops[60].

One of the major characteristics of capacity-sharing is the freedom it gives to shareholders for managing their share. Therefore, it would be impossible to forecast the exact behaviour of shareholders when running the model. Thus, to operate a model that simulates the decisions and outcomes of each shareholder and the effects of this behaviour on broader issues, we need assumptions about the nature of their short- and long-term behaviour. To simplify the presentation of the results of such a model, the shares have been assumed to fall into four classes, each with equal numbers. The assumed differences between the long-term objectives of those in each class can be shown with reference to figure 3.1. Assume that there are 100 users, 25 in each class. The users in the *first* class are assumed to be risk averse (operating in the first increment on the horizontal axis in figure 3.1) and would therefore develop only 80 hectare per user (or 2000 hectare for the class) for irrigation purposes. The *second* class is assumed to be

[60] This model fits perfectly into the Water Management Plan that has to be performed by each Water User Association, as proposed by DWAF (2000). See chapter 4 for a further application of capacity-sharing within the current South African context.

slightly less risk averse and would develop 160 hectares per user (or 4000 for the class). The *third* class is assumed to develop 240 hectare per user or 6000 for the class and the *last* class's users will develop 320 hectares per user or 8000 hectares for class four. The short-term decision strategies for each user class are taken from the results of the stochastic dynamic programming model of section 3.3. It is assumed further that the users operate in the short-term in such a way as to maximise expected net benefits. (In a real world situation, it is possible to have other short-term objectives.)

Dudley's model (1988:653) simulates the operation of each individual user for eighty-four years of stream flow and climatic data. The output of the capacity-sharing computer simulation model will not be displayed in full, but only in part to explain the functioning of the model. The sample which was chosen and which satisfies these criteria fell on years 56, 57 and 58 (See table 3.1 for details and Dudley and Musgrave, 1988:653).

The detailed results are shown in table 3.1: the *first column* shows the user class (recall that each class consists of 25 decision-makers or users where a type one user is the most risk averse and a class four user the least risk averse). The *second column* indicates the stage of the year (the year consists of four decision-making time intervals namely the pre-sow stage in the spring, 60 days after sowing, 90 days after sowing and 120 days after sowing). The *third column* shows the year number (recall that Dudley's model runs over a time span of 84 years but only the data of years 56, 57 and 58 are displayed). The *fourth column* shows the sum of the 25 inventories of that class (that is the water in 25% of the reservoir, given that the reservoir holds 425 GL and therefore 106.25 GL per class when the inventory is full). Thus, the table shows that all the classes had full inventories at the beginning of year 56. To simplify the discussion of table 3.1, each 25% of the reservoir capacity will be referred to as an inventory, whereas it is composed of 25 separate but similarly managed inventories. For the purpose of discussion of table 3.1, assume that these are four big users, rather than four classes each composed of 25 identical users. The *fifth column* shows the net inflows (stream flow less reservoir surface evaporation loss) into each inventory. (Note that the stream flow for the first stage is large, being more that 150% of reservoir capacity.) The *sixth column* shows the millimetres of irrigation water required to maintain a 50% soil-water deficit at that particular point in time[61]. The *seventh column* shows the translation of this requirement (column six) into the quantity of water that has to be released from the reservoir to satisfy the need of a specified irrigated area, which is shown in the *tenth column*. The *eighth column* shows the contributions of this stage to the overall annual gross margins of each user. It is composed of planting costs plus the gross margin from a dry land crop on the remainder of the 8000 hectares. For example, user one is assumed to plant 2000 hectare of irrigated crops (cotton) at a cost of \$402.50/ha and 6000 hectare of dry land crop which gives a gross margin of \$125.00/ha, making an aggregate negative value of \$55 x 10^3 (\$750 000-\$805 000 = \$55 000). Other users have larger negative values because of their larger plantings of irrigated crops. The *ninth column* shows the accumulated gross margin across stages per year. The *twelfth column* shows the yield per hectare after refraining from applying any further irrigation. Such refraining will be referred to as "abandonment" in

[61] DWAF, (2000) contains a detailed equation to estimate the irrigation water requirements of a Water User Association as a whole.

the following time interval. Thus, table 3.1 shows that abandonment at the start of the season, or in other words, applying no water at all, would result in a yield so low as to be unprofitable for harvest that year. The season was so severe that abandoning it at the start of stage two (applying no water after the pre-planting irrigation) would also result in a yield not worth harvesting, whereas abandonment at the start of stage three (i.e. 90 days) would give a yield of 254 kg/ha. Abandonment at the start of the last stage would yield 466 kg/ha, whereas irrigation throughout the whole season would result in a yield of 1007 kg/ha (shown in *eleventh column*).

Table 3.1: Detail results of the capacity-sharing model for years 56, 57 and 58.

User class	Decision stage	Year	Class inventory (GL)	Net inflow (GL)	Crop water demand (GL)	Release(GL)	Stage gross margin ($)	Accululated gross margin ($)	Area irrigated (1000ha)	Full yield (kg/ha)	Abandoned yield (kg/ha)	Sum of relaese (GL)	Sum of inventories (GL)	Surplus (GL)	Accumulated GM($)	Reservoir evap(GL)	Inventory evap(GL)
1	1	56	106.25	187.58	50	1.67	-0.06	-0.06	2	0	0						
2	1	56	106.25	187.58	50	3.33	-1.12	-1.12	4	0	0						
3	1	56	106.25	187.58	50	5.00	-2.18	-2.18	6	0	0						
4	1	56	106.25	187.58	50	6.67	-3.24	-3.24	8	0	0	16.67	425	0	-6.61	13.36	19.97
1	2	56	106.25	16.67	220	7.33	-0.12	-0.19	2	0	0						
2	2	56	106.25	16.67	220	14.67	-0.25	-1.37	4	0	0						
3	2	56	106.25	16.67	220	22.00	-0.37	-3.56	6	0	0						
4	2	56	106.25	16.67	220	29.34	-0.50	-3.74	8	0	0	73.35	406.99	15.3	-7.86	8.03	12
1	3	56	106.25	6.22	124	4.13	-0.01	-0.20	2	0	254						
2	3	56	106.25	6.22	124	8.27	-0.03	-1.40	4	0	254						
3	3	56	100.91	6.32	124	12.40	-0.04	-2.60	6	0	254						
4	3	56	93.58	6.47	124	16.54	-0.06	-3.80	8	0	254	41.34	388.79	20.65	-8	7.25	10.51
1	4	56	106.25	68.21	132	4.40	2.97	2.77	2	1007	466						
2	4	56	104.2	68.33	132	8.80	5.95	4.55	4	1007	466						
3	4	56	94.83	68.88	132	13.20	8.93	6.32	6	1007	466						
4	4	56	83.51	69.57	132	17.60	11.89	8.09	8	1007	466	44.01	425	0	21.73	20.39	29.1
1	1	57	106.25	2.25	214	7.13	-0.08	-0.08	2	0	0						
2	1	57	106.25	2.25	214	14.27	-1.16	-1.16	4	0	0						
3	1	57	106.25	2.25	214	21.40	-2.24	-2.24	6	0	0						
4	1	57	106.25	2.25	214	28.54	-3.32	-3.32	8	0	0	71.35	362.67	6.61	-6.8	13.36	19.97
1	2	57	101.37	-2.33	370	12.34	-0.14	-0.22	2	0	0						
2	2	57	94.23	-2.16	370	24.67	-0.28	-1.44	4	0	0						
3	2	57	87.1	-2.00	370	37.01	-0.43	-2.67	6	0	0						
4	2	57	79.97	-1.83	370	49.34	-0.57	-3.89	8	0	0	123.36	231	9.89	-8.22	7.3	10.57
1	3	57	86.71	-1.60	258	8.60	-0.03	-0.25	2	0	126						
2	3	57	67.4	-1.16	258	17.20	-0.06	-1.51	4	0	126						
3	3	57	48.1	-0.70	258	25.81	-0.09	-2.76	6	0	126						
4	3	57	28.8	-0.18	258	17.20	0.69	-3.20	8	0	126	68.81	158.54	11.47	-7.72	4.93	6.51
1	4	57	76.51	135.10	0	0.00	3.16	2.91	2	1066	1066						
2	4	57	49.03	136.98	0	0.00	6.33	4.82	4	1066	1066						
3	4	57	21.59	139.10	0	0.00	9.49	6.73	6	1066	1066						
4	4	57	11.41	139.96	0	0.00	6.33	3.13	8	1066	1066	0	425	0	17.59	11.09	13.3
1	1	58	106.25	48.87	199	6.63	-0.08	-0.08	2	0	0						
2	1	58	106.25	48.87	199	13.27	-1.16	-1.16	4	0	0						
3	1	58	106.25	48.87	199	19.90	-2.23	-2.23	6	0	0						
4	1	58	106.25	48.87	199	26.54	-3.31	-3.31	8	0	0	66.35	425	0	-6.78	13.36	19.97
1	2	58	106.25	-0.82	214	7.13	-0.12	-0.20	2	0	0						
2	2	58	106.25	-0.82	214	14.47	-0.25	-1.40	4	0	0						
3	2	58	106.25	-0.82	214	21.40	-0.37	-2.61	6	0	0						
4	2	58	106.25	-0.82	214	28.54	-0.50	-3.81	8	0	0	71.35	350.36	3.97	-8.02	8.03	12
1	3	58	98.29	-0.13	121	4.03	-0.01	-0.22	2	0	713						
2	3	58	91.16	0.02	121	8.07	-0.03	-1.43	4	0	713						
3	3	58	84.02	0.18	121	12.10	-0.04	-2.65	6	0	713						
4	3	58	76.89	0.33	121	16.14	-0.06	-3.87	8	0	713	40.34	310.42	6.87	-8.16	6.43	9.32
1	4	58	94.14	37.00	133	4.43	4.88	4.66	2	1648	1218						
2	4	58	83.11	37.67	133	8.87	9.75	8.32	4	1648	1218						
3	4	58	72.1	38.38	133	13.30	14.63	11.98	6	1648	1218						
4	4	58	61.08	39.12	133	17.74	19.50	15.64	8	1648	1218	44.34	392.14	32.86	40.59	17.11	24.22
1	1	59	106.25	7.02	187	6.23	-0.08	-0.08	2	0	0						
2	1	59	106.25	7.02	187	12.47	-1.15	-1.15	4	0	0						
3	1	59	106.25	7.02	187	18.70	-2.23	-2.23	6	0	0						
4	1	59	105.47	7.05	187	24.94	-3.31	-3.31	8	0	0						

Source: Dudley and Musgrave (1988:654-655)

Table 3.1 shows a large net inflow at stage one resulting in a full inventory at the start of stage two, therefore implying positive reservoir spills. In stage two net inflows are again sufficient to fill inventories 1 and 2 after their releases, but not inventories 3 and 4, as shown by the inventories at the start of stage three. At the start of stage four only the most risk averse user (class one) had a full inventory.

Columns 13 through 18 summarise the results across classes for each stage. *Column 13* shows the sum of releases from all inventories for the stage and *column 14,* the resulting sum of the inventories. *Column 15* shows the surplus of actual reservoir contents over the sum of the inventories at the end of the stage. (At the end of stage 1, it is zero because all inventories have filled and spilled. Note that this is in spite of the evaporation of the actual reservoir in *column 17* being less than the sum of the evaporations from the individual inventories in *column 18* (the high stream flow eliminated the difference.) The accumulation of gross margins across classes and stages within a year is shown in *column 16*. Note that a surplus of actual reservoir contents over the sum of inventories of 15.3 GL occurs in stage 2. This is made up of the excess of the sum of inventory evaporation (12.00) over the actual reservoir evaporation (8.03) of 3.97 plus the sum of the inventory spills exceeding actual reservoir spills. For example, the class 1 user began stage 2 with a full inventory (106.25 GL), received a net inflow of 16.67 GL but released only 7.33 GL, resulting in a contribution to the surplus of 9.34 GL. Similarly the class 2 contribution to the surplus is 16.67 – 14.67 = 2.00 GL. The remaining users had no spills, since their releases exceeded their net inflows. Thus, the total surplus equalled 3.97+ 9.34 + 2.00 = 15.31 GL.

The accumulated surplus of 20.65 GL at the end of stage 3 is obtained from adding the evaporation surplus (10.51 - 7.25 = 3.26) plus the class surplus (6.22 - 4.13 = 2.09) to the stage 2 surpluses, but this accumulated surplus is wiped out by the large stream flow in stage 4, which resulted in inventories having filled and spilled by the start of the following irrigation season.

Note that because of the full inventories at the beginning of year 56 and the high inflows during the season, all users had sufficient water to avoid abandoning any irrigated crop during the season. Year 57 is characterised by low inflows in stage 1 and negative inflows in stage 2 and 3 because of reservoir evaporation exceeding stream flows. Therefore, there are no inventory or reservoir spills in stages 1, 2 and 3. Surplus of inventory evaporation over reservoir evaporation is the only contributor to the surplus of reservoir contents over the sum of inventories. Note that reservoir evaporation being higher for large inventories causes net inflows to be lower for large inventories.

The combination of low inflows and high crop water demand during the first three stages resulted in relatively large releases until supplies became low. Then class 4 halved the area to keep irrigated at the start of stage 3 and almost halved it again at the start of stage 4. User three also abandoned some at the start of stage 4, but stage four proved to be extremely wet, both in the reservoir catchment (high inflows) and in the growing area (zero crop water demand) which meant equal yields on both areas abandoned and areas not abandoned at the start of stage 4. From the accumulated gross margins, it is evident that users 1 to 3 did better than in the previous year but user four did much worse. With hindsight, abandoning some area at the start of stage 3 proved wrong that year. Note that the accumulated surplus of 11.47 GL was wiped out in stage 4, because all inventories and the actual reservoir filled and spilled.

Year 58 had high inflows in stage 1, low in stage 2 and 3 and reasonably high in stage 4. These, coupled with high beginning season inventories, resulted in no abandonment in the season. The most interesting new point in year 58 is the large surplus at the end of the year to be allocated to the users at the start of year 59. The surplus grew rapidly in stage 4 because two inventories filled and spilled. Allocating the surplus equally across users whose inventories are less than full, resulted in the class 4 inventory only being a little less than full at the beginning of year

59. On the other hand, allocating the surplus first to the least risk averse users, resulted in class 3 having a slightly under-full inventory at the start of year 59.

Considering the allocation strategies of efficiency- and equity sharing, the model of Dudley and Musgrave (1988:658) showed that users in class 3 received a higher mean and lower standard deviation of gross margins under equity than under efficiency sharing. For users in class 4 the mean was higher and the standard deviation lower under efficiency sharing. The total gross margin across all users is somewhat higher under the efficiency sharing method (Dudley and Musgrave, 1988:658). The model also showed that the average annual surplus to be distributed among users is relatively small (about 3.5% of reservoir capacity) and average start-of-the-year contents 4.5%.

It should be clear to the reader, that this capacity-sharing model is a practical example, displaying "water accounting" and the analogy of water banking with ordinary commercial banking.

The above-mentioned model was based on one irrigated crop (cotton) only and the question could be asked what would happen when multiple crops are considered. There would be a greater hectare spread with some users with high-valued perennial crops (using fewer hectares than the risk averse cotton grower) and other users with crops on which small quantities of supplementary irrigation could result in large increases in yield in some years (such as wheat and maize) using more hectares than the least risk averse (class 4) users.

Modifying the model to cover multiple crops would not be too difficult if the necessary data were available. This, however, would imply substantial computer work for stochastic conditions and multiple crops. (Refer to the research recommendations at the end of chapter 5.)

3.6 Potential feasibility of capacity-sharing under multiple purposes

Criticism on the above-mentioned section could emphasise the fact that only agricultural uses were accommodated. The following section deals with possible alternative applications of capacity-sharing. Therefore, the following are possible applications of capacity-sharing other than for irrigation purposes:

- *Urban use* – the urban authority would obtain capacity shares by means of the market and make releases to urban users over time as desired (this form of capacity-sharing is also known as "urban capacity-sharing" and is discussed in more detail in Dudley, 1990a). The quantity of shares obtained relative to the quantity of urban demand would depend on such factors as the method of rationing water to consumers in times of shortage, the urban user's perception of the price of water in times of shortage and the political acceptability of fluctuating prices and/or quantities of water available to consumers (Dudley and Musgrave, 1988:657). The situation could range from urban use having a relatively large number of shares and selling water to other users when the urban inventories are high and buying water when inventories are low. Expansion of urban demand over time could be satisfied by buying shares from other users or by expanding the reservoir capacity (supply-oriented approach).

- *Environmental use* – the authority responsible for the management of the ecological functioning of the catchment would also obtain shares by auction and similar factors to those operating in the urban case would determine the quantity of shares desired relative to the perceived in-stream demand. If share allocation is obtained by auction with the purchase funds coming from beneficiaries, then needed shares for ecological functioning are likely to be undersupplied because of the "free-rider problem" among beneficiaries due to the impracticability of charging each beneficiary their marginal willingness to pay for ecological related benefits received. The question could be ask whether it is fundamentally fair for the environment to have to compete on equal terms in the market for the required share, or could a certain capacity be specified for environmental use? (Refer to chapter 5 for more detail.)

- *Flood control* – reservoirs used for flood control seem to be in conflict with the above-mentioned uses since reservoirs are required to be less than full during the flood-prone season. A common compromise is to specify some space (like the above-mentioned environmental case) therefore usable capacity for irrigation is less than the total capacity of the reservoir. Under capacity-sharing there may be no need to distinguish flood control from water supply use since the flood control authority could obtain shares just like other users and then sell water to downstream users at the best time to balance water price and value of flood control reservoir space. However, this flood control capacity share needs to be specified because of the potential uncertainty of supply it could cause to other users.

3.7 Capacity expansion under capacity-sharing

Suppose another reservoir or dam is proposed (like the proposed "Skuifraam dam" in the Berg River) upstream from the current reservoir. Since its operation would modify the existing reservoir's inflow probabilities, the problem becomes one of doing this in a manner acceptable to the existing downstream users. One way of overcoming this problem is to let the agency that is responsible for the construction of the upstream reservoir purchase the "upper tails" of the reservoir inflow distributions from the current users. That means that a current user sells his inflow rights above some level per time interval (say per month). As the "length of tail" being transacted increased, so would its value to both the seller and buyer. Unlikely high flows are less valuable per unit of water than more likely lesser flows.

The reservoir development agency would in turn sell shares in the capacity of, and net inflows into, the new reservoir. The difference between the social opportunity cost of "tails" purchased from the users of the existing reservoir and social benefits from sales of shares in the new reservoir would need to cover all social costs associated with the construction and operation of the new reservoir if the development is to be *pareto optimal*.

3.8 Comments on assumptions of the model

It was assumed that downstream tributary flows do not contribute to the supply of the reservoir system. However, in reality all sorts of tributaries are present and these could be accommodated as independent capacity-sharing structures when suitable.

Dudley and Musgrave (1988:658) assumed that no adaptation to new irrigation systems would be required. Rather, potential share users decide on their level of investment initially and do not change their plans over time. It is more likely that a user will start off rather conservatively and build up confidence and financial resources before developing larger areas for irrigation in relation to their reservoir capacity share. Detailed modelling of alternatives to capacity-sharing may be necessary here, but it seems that capacity-sharing at least gives users the flexibility to adapt over time. The uncertainty regarding the rate of adaptation makes the public evaluation of a water resource difficult. Capacity-sharing results in an increase in the value of capacity shares through time as the value of information gained through experience is capitalised into share prices. This would have an effect on income distributional effects of water resource development (Dudley and Musgrave, 1988:658).

Another assumption so far, is that water distribution capacity is non-limiting. (It is therefore theoretically possible for all users to withdraw their shares at the same moment in time.) In systems where users must share limiting distribution facilities (in terms of timing) the release patterns must be adjusted accordingly, resulting in a potential loss of flexibility and could possibly cause a loss of the attractiveness of the concept relative to other allocation methods.

Another assumption is that the reservoir management is responsible for only the monitoring of the individual inventories through time and periodically allocates the surpluses across users according to a predetermined system (efficiency- or equity sharing). It is true that some conservative users normally carry large stocks surplus to their needs for long periods. (As illustrated earlier and these stocks are wiped out occasionally when the reservoir fills and spills.) Reservoir management may begin a system of "advancing" some of this stocked water[62] to other uses in the belief that not all inventory holders will demand their water before the next spill. The feasibility of this idea of water banking (akin to that of normal commercial banks) seems worthy of further research (refer to section 5.2.).

Some concern may be present regarding to what extent private irrigation management decisions influence or determine reservoir management decision-making. If it is heavily depended, there is considerable scope for opportunistic decision-making behaviour by private decision-makers and therefore a problem of moral hazard /

[62] It is important to remember that apart from the fact that this water is "stocked" for future use for the particular user, the stocked water also has a variety of positive externalities which must be considered when the possibility of water banking is investigated. (Some of the most important positive externalities include the sustaining of aquatic ecosystems within the reservoir as well as downstream.)

adverse selection[63] presents itself. Therefore, the question arises what safety features do capacity-sharing present to confine possible opportunistic decision-making practices. An example of such opportunistic behaviour in capacity-sharing is the practice of buying (or renting) all additional unused storage capacity a private decision-maker could find. The rationale behind this behaviour is seated in the rule that any inflows exceeding the unfilled space of a shareholder's capacity share will be lost to that user and being shared among others whose share is not yet full. The opportunistic private decision-maker with ample unused storage capacity will therefore receive a windfall gain each time another user (who is likely to be considerable more risk averse) caused an internal spill. (The more unused storage capacity the decision-maker owns, the more windfall gains will be received). In this way, the opportunistic decision-maker could minimise his inflow shares and therefore save considerably on buying irrigation water (cost saving would therefore prove to be the underlined motive for this type of opportunistic behaviour). However, such opportunistic behaviour of gaining on internal spills, are unlikely to occur in practice since the individual shareholder would sell some inflow shares before the loss of an internal spill could realise. In the case of spilling of the whole reservoir, no trading would be necessary since all capacity shares are filled and spilled. The water "lost" in such an event will be of little value to anyone within the reservoir, because it cannot be stored and therefore the opportunity cost not preserved.

Another argument against the above-mentioned problem of opportunistic private decision-making could be based on the natural supply-characteristics of the area in which the reservoir is located. Recall that capacity-sharing is especially suitable for areas with stochastic water supply characteristics. A great degree of uncertainty regarding the inflow probabilities are associated with this type of supply and therefore creates an incentive to keep an adequate stock of water at all times. This will certainly not enhance opportunistic decision-making, but it will also not restrict such behaviour.

A last argument against the problem of opportunistic private decision-making focuses on the management hierarchy of the capacity-sharing system. Recall that the reservoir management do not deal directly with small private decision-makers, but with "bulk[64]" capacity shareholders unless the private decision-maker is of a similar size as the "bulk" shareholder. Opportunistic decision-making is based on incentives for private gain in order to enhance efficiency (cost saving or greater profits). Recall that the "bulk" capacity shareholders do not have the same high level of incentives for enhancing efficiency (and therefore opportunistic decision-making) and since the private decision-maker deals more with the "bulk" capacity shareholder, the reservoir management is not exposed to opportunistic decision-making to the same degree as the "bulk" capacity shareholder (refer to Dudley and Bryant, 1995:8).

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63 Adverse selection is defined by Lipsey and Courant, (1996:369) as the tendency of people who are most at risk to buy the most insurance. This problem is closely related to the problem of moral hazard where one party of a transaction has the ability and incentive to shift costs on the other party (Lipsey and Courant, 1996:368). Both the problems of adverse selection and moral hazard could arise when privately held information is bought and sold.

64 Scott and Coustalin (1995:968) refer to "trusts" and could be seen as similar to "bulk" capacity shares.

The capacity-sharing model therefore introduces an innovative type of property right structure for managing water. Its adoption would lead to a decentralised market-orientated approach towards water management allocation and use. (This is in line with the National Water Act of 1998.) The model also indicates that capacity-sharing has a number of attractive features (subject to certain assumptions) for promoting socially efficient water use in a highly variable environment.

3.9 Responses from irrigators

After its initial introduction in Australia in 1988, a number of changes were made to the model. Dudley and Bryant (1995) presented a discussion paper at the Cotton Research and Development Corporation and the Cooperative Research Centre for Sustainable Cotton Production on June 15, 1995. The aim of the paper was to focus on some key questions relevant to the implementation of the capacity-sharing model. These revisions seem relevant to this study, because it represents experience (in similar conditions) that could save both time and money in the implementation process in the South African context.

The following (Dudley and Bryant, 1995) explains the most frequently asked questions related to the concept when it was introduced for the first time and therefore seems relevant for this study.

"What are the main advantages and disadvantages of capacity-sharing?"

The main advantages include:

- Clearly specified water use rights to percentage shares of stream-flows and reservoir capacity. (Therefore creating a more transparent water right.)
- The shares can apply to all user groups including irrigators, urban residential, environmental and industrial uses. (This reflects on the flexibility of the concept.)
- The supply of water into the reservoir is known or determinable from historic stream flow data. It is not affected by policy and institutional rules and therefore enables the user to make use of modern production and financial aids provided by consultants.
- Computer simulation programmes are available to aid irrigators to integrate supply and demand decisions.
- Capacity-sharing promotes the decentralisation and integration of supply and demand management for both the short-term operational decisions and the long-term investment decisions. The integration of demand- and supply-management by shareholders enables irrigators to determine their reliability requirements and therefore save on transaction costs.
- Individual users may manage their shares with no interference from other users, unless they violate the operating rules of the system. They may or may not choose to interact with other users through

participation in water markets when it is advantageous to do so. (Physical constrains in the delivering system may sometimes limit the extent of involvement of other users.)

- Capacity-sharing allows water marketing to convey the current opportunity costs of water, eliminating the need for centralised pricing. However, the accommodation of opportunity costs will remain a function of private decision-making.
- Under capacity-sharing, a greater degree of certainty regarding the timing of capacity increases will be achieved. (The best time to increase the capacity of the reservoir or to build new reservoirs would be when the aggregate value of bids for the shares for the new storage capacity plus a government subsidy equals the construction costs.) The question could be asked whether this advantage could lead to rent-seeking behaviour[65]. There will always be incentives for rent-seeking behaviour within a democratic and capitalistic regime and it would be naïve to try to neutralise all incentives for rent-seeking behaviour. In this case, a more realistic argument could be based on the ability of capacity-sharing to withstand rent-seeking behaviour. (Note that rent-seeking behaviour within this context will be focused on the increase of water supply to the private decision-maker.) The concept of capacity-sharing hinders private rent-seeking behaviour because water management is more transparent under this strategy. All water users have lobbying power through Water User Associations and because of the water market mechanism and sometimes contradictive water use patterns, water users will monitor each other. If the state decides to give way to one particular rent-seeker, other rent seekers could make a strong argument against the viability of the decision based on measurement-related problems associated with the quantification and balancing (prioritising) of potential gains for the favourable group against the potential social and environmental costs of the decision. This implies the quantification of the opportunity cost of water that proves to be a controversial topic. The argument will end in a moral hazard because of the insufficient measurement of decision-making criteria and the decision will be made in the interest of the party with the biggest lobbying power. However, given the firm objectives for sustainable development and an efficient but equitable water allocation as mentioned in the National Water Act of 1998, it would be difficult to imagine that the state would be interested in private rent-seeking behaviour unless bureaucratic self-interest has the final decision-making authority.

A second argument against rent-seeking behaviour within a capacity-sharing regime, could be based on the definition of water use rights. Given that rent-seekers exercise their lobbing power for an increase in supply, it should by noted that private decision-makers are only allowed the volume as specified in their water use rights. If the user needs more water, the additional water use rights must first be obtained before the extra water could be bought. The definition of water use rights will therefore play an important role in the prevention of rent-seeking behaviour. Braden (1995:1205) notes that water property rights are multi-

[65] Rent-seeking behaviour could be defined as behaviour whereby private decision makers try to use the powers of the state to enhance their own economic well-being (Lipsey and Courant, 1996:377). Within the context of this study, rent-seeking behaviour could be found when private decision makers use the power of the state to either subsidise their water, keep their water prices at artificially low levels or promote the development of new water supplies by ignoring negative social and ecological externalities.

contextual and dynamic. This is an important point for the following discussion. Fundamentally, all animal and plant species on earth (including humans) must have access to water for the completion of their specific life-cycles. Any additional needs[66] (which are only relevant to humans) must be allocated via an organised allocation mechanism and within this study the market mechanism is promoted as a suitable allocation mechanism.

The inherent "common property" and variable nature of river flows complicates the definition of property rights to water. This variability in supply (stochastic supply) complicates water balances (by creating uncertainties regarding supply probabilities) within a catchment and it is therefore common practice to use dams or other forms of storage capacities to regulate and smooth out the supply of water from year to year. However, these storage capacities do come at a price and it is a complex task to determine the exact magnitude of such practices. Suitable storage management strategies and policies have to be developed to cope with this situation. The work of Dudley, 1988a, 1988b, 1990a, 1992 1994, 1999 and Dudley and Musgrave, 1988) deals extensively with this type of problem. The definition of tradable water use rights must therefore be compatible with the management of storage capacities. It is, however, important first to define the use right and then to develop the management strategy and not the other way around.

Recall that in defining water rights for the purpose of accommodation within a market, the emphasis should be on the use right of a specific unit of water and not on the property right of that unit of water. The reason is because the utility of water is derived from the use right and not the property right. Therefore, the characteristics of the water use right should play the dominant role in defining water rights for adoption in the market. The question could be asked whether water use rights will be satisfactory in terms of exclusiveness, enforceability and certainty, to develop a market mechanism.

A water use right should not refer to a fixed volumetric unit because in reality, the volume of the catchment is a variable and a situation could therefore develop where the volume represented by the water use rights and the actual volume of water within the catchment would never be the same. This could result in a situation where there would be trading in and transfer of volumes that do not exist. Capacity-sharing present a possible answer, because the water use rights within this system are defined in terms of a percentage of stream-flow and a percentage of storage capacity. If the precise volume of the water-use right is acquired for pumping volumes, computer technology and modern measurement techniques could be used to estimate the current volume of the right.

The "public characteristics" of some water uses imply that parties affected by water trades may not always be represented in the market. The benefits of improving water resources use through the market will

[66] Some controversy may be found here because the definition of the human life cycle is not that simple. Specialisation caused commercial agriculture to develop and the question therefore arises whether agricultural usage should be included in the natural life cycle of humans or not.

depend on how these issues are dealt with when tradable water use rights are defined. Capacity-sharing has the unique feature that the above-mentioned parties (mostly previously disadvantaged and minority groups) could be accommodated as a single shareholder[67] within the capacity-sharing regime.

One of the difficulties in defining property rights for irrigation water and water per se is that the net use of water by crops (consumptive use) is generally far less than the total volume diverted to irrigate those crops. On the other side of the spectrum is the urban use where consumptive use is an even smaller portion of the total diverted volume. The difference between the consumptive use and the total volume diverted from the main drainage system is known as the return flow[68]. These return flows could hold negative or positive externalities for downstream uses, depending on the current use pattern. If water price determination is based on the diverted use, private decision-makers will have an incentive to use as much of the diverted water as possible, because the return flow will be considered as a loss to that user. Therefore, upstream users have no incentive to accommodate downstream users. If the upstream user is paid for his return flow, there will be an incentive to divert only the needed volume of water (consumptive flow), therefore it should be argued that water price determination should be based on the consumptive use of water resources and not on the diverted volume. This could be done by making use of "use specific water consumption data[69]" to determine the precise amount of water needed for a given use within a certain set of assumptions. Only this needed volume of water together with a certain amount of water for transport, drainage and evaporation losses should be diverted for such use. The same type of argument could be followed for urban use patterns.

However, given that the consumptive use of urban uses is even smaller than that of agricultural-related uses, the non-consumptive urban use plays a far more important role in determining the needed volume of diverted water. In other words, relative to agricultural use patterns with "bigger" consumptive uses (the net amount of water that is removed from the drainage system) the return-flow related uses[70] for urban areas is bigger. It is clear that non-consumptive use is more important for urban use patterns relative to agricultural

[67] For example, 100 small farmers form one capacity share. It should be noted that these farmers would need to have similar water use patterns. This single share will then be managed as a common property.

[68] While the former could be sold without restriction, the non-consumptive element can be sold only if the distribution does not deprive other uses of water. Thus for transfers in the same basin owners would be free to sell all of their water rights, but if a user wants to sell his rights to a user whose return flow does not return to the same catchment, only the consumptive element within the new use could be sold. However, because of the technical difficulties in calculating the return flow component on a case-to-case basis, this approach may not be appropriate for a developing country like South Africa. It may be possible to calculate averages that specify the volume of water consumed by a certain crop or activity. In those cases where return flows are an issue, this average could become the limit on the amount that the current owner is allowed to sell. This procedure would work for both ground and surface water and even though this system has its shortcomings, it would be an improvement over prohibiting all transfers or having no control at all.

[69] The determining of such data could be achieved by making use of historical use patterns of specific uses. Within the irrigation sector for example, the water needs of a variety of irrigated crops (given a set of assumptions) is well researched and available. This data could be used to determine the exact volume needed to satisfy the current consumptive use for that specific crop (use).

[70] The urban sector has a small consumptive use demand for drinking, cooking and gardening-related needs, but the biggest amount of water diverted for urban use goes to return-flow related uses such as personal hygiene, general household and industrial cleaning purposes, cooling (depending on the technology used) and sewerage.

use patterns. It would therefore be naïve to base the definition and pricing of water use rights only on the consumptive use of water. Capacity-sharing defines water use rights in terms of percentage of the total storage capacity (no open access or common property on stored water exists) and percentage of the total inflows within the season. It is possible for a specific user to have only inflow shares and no capacity shares. Each shareholder (which includes consumptive and non-consumptive as well as in-stream and off-stream users) will have an incentive to save water (economic gains associated with savings) because each shareholder is responsible for the management of his own capacity and inflow share and the additional cost incurred in the determining of the exact needed amount of water to be diverted will be justified by water-saving incentives such as economic gains from water saving.

Capacity-sharing does have some obvious benefits associated with giving users more autonomy in managing inter-temporal reliability, but would need a detailed institutional arrangement in order to function effectively. In addition to the market for storage capacity, there would need to be an associated spot market for water and clearly defined rights to inflows. Moreover, while the aim of capacity-sharing is to make users independent from each other, the reality often proves to be the contrary[71].

The problems associated with capacity-sharing could be overcome by "better" definition of property rights. This requires a specification of rights to inflows and also a specification of rights to water held in the storage capacity (a market in spills and releases). One of the most important advantages of the capacity-sharing system is that risk associated with water use rights does not have to be specified. In contrast, the design of a priority-based system of release rights requires specification of volume and an associated level of reliability (which proves to be difficult).

Given the above-mentioned discussion on some of the complexities of water use rights, it should be clear that the rent-seekers would face difficulties exercising their lobbying power in order to enhance their individual preferences regarding water supply.

The main disadvantages include:

- Capacity-sharing does have the potential to separate the various roles of water pricing, whereas these become blurred and lose effectiveness under current centralised policy. This separation is certainly a

[71] As an example of the interdependency between capacity-sharing shareholders, the more conservative (risk averse) shareholder will have a higher frequency of "spills" from his inventory which would increase the volume of water flowing into the capacity shares of less conservative users. The management of this water (which yields a positive externality) has not been dealt with adequately in the literature on capacity-sharing. Dudley and Musgrave (1988) treat the distribution of this water as a positive externality that is not included in the decision-making process of shareholders. Unless the market is used to allocate this "internal spill", the water will not be allocated efficiently (unless all the other shareholders place the same value on the external benefit). Also, refer to the question *"How secure is a capacity share?"* in the current section.

disadvantage under a centralised policy regime, however it could be turned in an advantage under a decentralised water policy regime.

- The estimation of supply system losses must be accurate[72]. The difficulty in sharing transmission losses resulting from evaporation and seepage since transmission losses vary according to the distance water must travel and the volume of water accompanying it in the stream. This is particularly important for the South African context because of the substantial water transition distances associated with water management.
- Each user would need to share the delivering capacity of the distribution system. Maximum release rates must be synchronised in order to satisfy all needs. This is a potential problem for agriculture in particular, because of the synchronised nature of irrigation farming in dry seasons.
- Capacity-sharing requires a certain minimum level of education of water users. Capacity-sharing may pose some administrative difficulties regarding the literacy levels of shareholders (mostly small farmers) who will need to make their own management decisions, hence principal-agent problems are to be expected.

"How would a capacity-sharing system operate?"

Dudley and Bryant (1995) distinguishes between "bulk" and "retail" capacity shares (refer to figure 4.3). "Bulk" capacity-sharing (or wholesale capacity-sharing) allocates reservoir water to a few large water users. These users represent water user groups and may be geographical entities or political jurisdictions like nations, states and regions, or distinguished according to user class such as irrigation, environmental, urban or industrial users.

The principal objectives of implementing "bulk water entitlements" are (DWAF, 1996:68):

- To provide authorities with a clearly defined property right to water.
- To provide authorities with more flexible management options to manage their entitlements.
- To provide a basis for sharing limited water resources.
- To facilitate water trading between user groups.
- To allow specific entitlements for environmental purposes.

In order for the system to be successful, "bulk water entitlements" must be (DWAF, 1996:68):

- Explicit in defining where or from which source the water will be extracted.
- Exclusive to the authority to which the water has been granted.
- Tradable in part or in total to other authorities.

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[72] Capacity-sharing is an "real time" water accounting system and it is therefore important to ensure a continuous flow of information (regarding flow characteristics) for updating the management system and to assist in water management decisions.

- Enforceable by law through proper monitoring.

The transferring of shares under "bulk" capacity shareholders may occur by means of water auctions, organised by the catchment management agency. The market could, however, stay active whenever a buyer and seller agree to exchange shares under the supervision of the catchment management agency. Should someone, say a landowner, wish to engage in intensive water-use activities (like the construction of a dam) in the catchment of the reservoir which reduces the inflow of the reservoir, the shareholder would need to buy a quantity of inflow rights from a bulk user in order to offset the resulting effect on stream flows. However, if there are two reservoirs in the same river with no important tributary inflows between them, the capacity of the two reservoirs may be added if needed. Bulk shareholders would be recorded as having shares in the combined capacity.

To support the system of entitlements, a form of water accounting is necessary. Under the system of tradable entitlements, legal entitlements can be made to environmental users, and it is possible to buy back the entitlements from users of the state to reallocate them to the environment. In the case of new water supply developments, the entitlement of the environment would be allocated based on representations made by environmental managers. At this level, capacity-sharing is a precise, concise and transparent mechanism for allocating water through uncertain times. However, the incentives for efficient allocation under "bulk" capacity-sharing are limited because the individual decision maker does not feature and the "free rider" problem occurs.

"Retail" (refer to figure 4.3) capacity-sharing allocates water to the individual users (such as households, irrigation farmers and firms) each holding their own capacity share of reservoir capacity and reservoir inflows. Capacity-sharing at this level provides great incentives for efficient water use by the integration of demand and supply management decisions. Therefore, each user considers the likely value of the unit of water before using it. There is no "use it or lose it" pressure except for the known probability of large inflows causing the reservoir to fill and spill.

The operator of the system (say for example the "catchment management agency") would monitor all additions to and non-release subtractions from the main waterworks. (Additions include stream inflows and rainfall directly into the reservoir and non-release subtractions include evaporation, seepage and reservoir overflow spills. From these, plus the ordered releases by each of the bulk users, the contents of each bulk user's capacity share would be updated daily by computer.) Computer printouts of these records could be sent to the users and would be like "bank statements". Capacity shares are expressed in *megalitres* to represent a percentage of the total usable storage capacity. For example, percentage shares of a reservoir with a usable storage capacity of 200 megalitres would be two megalitres when the dam is first built. If the storage capacity declines because of siltation, the 1% share would fall below two megalitres. If the storage capacity were increased, however, the original two megalitres would not change. In this event, the extra storage capacity would result in additional capacity shares. It is however necessary to periodically "update" each bulk shareholder's share, in order to adjust the sum of all the shares to match the actual volume of the reservoir. It is recommended that the catchment management agency would be responsible for notifying the shareholders of the location of their ordered water within the distribution system. This could be expressed in terms of volume, the expected time of arrival at the receiving point, estimated travel time and expected constraints on the distribution system due to the need to limit releases to suit distributional requirements. The provision of such information would require sophisticated monitoring and system modelling, but would help users in planning the time of their next release in relation to their on-farm storage capacity.

"How would the transition from the current allocation system to capacity-sharing be accomplished?"

If capacity-sharing is to be introduced, the timing of the transitions is important. That is because various changes to the level of demand for water for irrigation and for other purposes have occurred over time, which affects the reliability of supply. The objective of calculating how many capacity and inflow shares each user would hold under capacity-sharing, is to determine what portfolio of shares would be needed to provide similar volumes of supplies at each user's receiving point. Having provided users with portfolios of capacity shares that reflect their previous volumetric allocations, users would be able to alter their own supply (from that point onwards) in several ways. No user's portfolio can be affected by other users other than compensation via the market at an agreed price. The only source of interdependency between users is the release capacity and timing capabilities of the storage facility and distribution system.

"Would there be any trade-offs in the amount or reliability of water?

Each user makes his own trade-off between volume and reliability of supply. The use of open, shared channels or rivers, rather than individual pipelines, causes interdependence between users. If a particular user wants an extremely high reliability of supply, and the others do not, that user might have to "spend" a great deal more reservoir water to transport the supply to his receiving point, because of transmission losses that must be covered by him alone. Users are therefore confronted with their own transmission losses and this is an efficiency-promoting feature of capacity-sharing but does not eliminates the "free rider" problem associated with transmission losses. (A capacity share could, however, be devoted to keeping a minimum flow in the river, but this would involve low-reliability users foregoing water for the benefit of high-reliability users and in effect subsidising the latter.)

"How secure is a capacity share?"

The original formulation of capacity-sharing specified that the water use right would be **held in perpetuity**, so that holders would make the correct long-term investment decisions. The only way a capacity share may be removed from a user, is by means of market compensation, unless the user breaks some law. If society or a new user should decide that water was needed for a new use, the needed shares must be bought in the market from a willing seller. Whereas the value of land depends on its location, a unit of water (measured in megalitres or cubic meters) **within a**

reservoir is indistinguishable from any other, and therefore it would be difficult to imagine a case where some particular share (unit of water) would be specifically needed. However, when a whole catchment drainage system is considered, there might be preference through the catchment (the upper reaches against the lower reaches) in terms of water **quality.**

However, there were suggestions that the water use rights should **not be held in perpetuity**, but be held as some form of long-term lease that would be re-negotiated after a number of years of notice. If leases can be devised in such a way as not to harm long-term investments and resource management, they could provide a return to society (social gain) in the form of leasing fees.

There is some interaction of reservoir users due to "internal spills". Recall that capacity-sharing contains the rule that any inflows exceeding the unfilled space of a shareholder's capacity share, are lost to that particular user and are shared among other users (through either efficiency or equity sharing) whose share is not yet full. The marketing of unused storage space could provide some flexibility. This could be done by buying or renting extra reservoir empty space or capacity from another shareholder. Therefore, a user could become accustomed to receiving internal spills from other users (probably from those users who need a high level of reliability and thus maintain a higher level of storage). If some of these high-reliability users were to be replaced with low-reliability users, the above-mentioned user would find that his spill-over gains disappeared. This phenomenon is rather unlikely in practice because the user will certainly sell his water before losing it by means of an internal spill. In the case of a total spill of the reservoir, the spilled water has little value, because it cannot be stored.

> ***"Who are the people and institutions most likely to be considered as capacity shareholders and what are the likely proportions of water held by each?"***

It is important that **all** water users be part of a capacity share scheme, at either a "bulk" or "retail" level. Uncertainty among users will not be overcome if some user group (say environmental in-stream flows) does not have a firm capacity share and can be allocated water by some authority on an "as needed" basis. This "as needed" basis will be appealing to some users but others will welcome the firm basis of the market mechanism. Environmental users do need flexible and adaptable access to water until more is known about the "minimum flow for sustaining the basic ecological functioning" of the catchment-area. The basic idea of capacity-sharing is that **all** water users be part of the capacity-sharing scheme, including the environment. If the initial water allocations prove to be unsatisfactory, the allocation could be changed at a later stage by means of market transfers. However, water that is currently "in transit" to the desired receiving point, within a natural transport system (the river and not a manmade channel) does play an ecological role and it is therefore necessary to keep this in mind when buying shares for the ecological functioning of the river. It is therefore of financial interest for the authority, which is responsible for the environmental shares to provide incentives for irrigators to alter their release times and their private storage capacities slightly, to maintain a sufficient in-stream flow for sustaining the ecological functioning of the river.

"How would water transfers take place under capacity-sharing?"

Initially, probably only two types of water transfers would occur. The *first* would be the transfer of shares within the main storage capacity of the reservoir. The catchment management agency would be responsible for checking whether the seller has sufficient shares in stock to sell and then whether the buyer has the capacity to "absorb" new stock. The agreed price would be a matter of balancing willingness to pay and willingness to accept between the two market participants[73]. The agreed transaction will be recorded and shown in the buyer's, seller's and catchment management authority's records. The *second* would probably be the transfer of long-term rights to percentages of reservoir inflows and storage capacities. The catchment management agency would first verify titles held by sellers and buyers to see that the proposed transfers are feasible (other factors which must be checked include the distribution system effects of possible under-utilising of the distribution system and rules of inter-basin transfers).

The essential point of transfers under capacity-sharing is clarity about exactly what is being traded, namely rights to water, with the specific probabilities of its availability in the quantities agreed upon (for water within the reservoir the probability is 1 (100% or certainty), but with rights to future water, probabilities vary with the streams involved. Probabilities do change, but these are long-term events and are applicable to any kind of distributional system and not just capacity-sharing.

3.10 Requirements of capacity-sharing

In matured water economies such as Australia, Chile, Spain, South Africa and the Western United States (note that a matured water economy does not necessarily imply a highly developed economy per se) demand outstrips the supply of water, with sites for further development considered to be few and un-economical. To avoid potential conflict between different water uses and users, a sophisticated but user-friendly management and allocation system is needed. Gakpo *et al* (2001:97) mentioned that the level of sophistication increases linearly with the scarcity (or competition level between uses) of water resources. It therefore does not make sense to have a highly complex and powerful water management system in an area with little or virtually no competition for water. With the current institutional changes shifting more towards allocation, decentralisation as well as privatisation, economic viability, physical sustainability and integrated management strategies, capacity-sharing as an alternative becomes appealing and the following are the main requirements for the adoption of the concept.

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[73] The functioning of this water market could also be seen as similar to a stock exchange where buyers and sellers place their bids and only the matched bids will realise in a successful transaction and the transferring of shares. This could be accomplished by making use of specialised brokers or regular and irregular (after heavy rains) auctions. After the system has been up and running for a while, it may be possible to introduce other forms of trading as well (such as futures and options).

3.10.1 Institutional requirements

Definition of property rights

The introduction of transferable water use rights needs proper definition of the right itself (Pigram, 1993:1316). This is important in South Africa, because the whole water market is based on a secured property-right structure.

Institutional arrangements

The structure and role of catchment authorities must be flexible, allowing for varying social structures and issues. The government's role in integrated catchment management should be limited to the co-ordination, transfer and provision of technical advice and support for local groups or individuals.

Long-term relationships

The successful implementation of integrated catchment management depends on sound long-term relationships between the parties involved. Long-term commitment and continuity from leading agencies for financial assistance will also be required.

Catchment and waterway management

Catchment and waterway management remains the responsibility of the environmental protection agency and the catchment management agencies.

Community involvement in water management

The involvement of the community is essential to decentralise the management of water resources to the lowest possible level and to attain the highest possible degree of efficiency and equity.

3.10.2 Infrastructure requirements

Separation of commercial and non-commercial water sectors

The functions of water supply and sanitation should be separated from the non-commercial function of catchment and waterway management, unless it is more practical not to do so on a local basis. Water authorities and supply boards must be regionalised (for greater efficiency and economy of scale) and commercialised. The supply agencies thus become **bulk users** of water and/or effluent discharges, and are subjected to the same licensing procedures as other catchment stakeholders. Metropolitan water supply agencies will be allocated a bulk water entitlement, which they in turn allocate to domestic and industrial users. Rural water boards should further partition their bulk entitlement to agricultural and rural domestic users.

Reliability and security of supply

Suitable water transport systems must be in place to deliver the water to the required point of need. (This is important with regard to the certainty-factor in a market regime.) Water market transactions are made with the assumption that the new user will receive the water. Therefore, the ability of the water distributional system to deliver the required volume of water at the specific site of use, will be a key factor determining the efficiency of this demand orientated management strategy.

3.10.3 Economic requirements

All the economic related requirements are similar to that of any market situation. *Firstly*, bureaucratic control over water must be deregulated and limited to some specific, defined functions. *Secondly*, because water use rights will become private property within a market regime, the "user pays approach" must be followed. Any individual who needs not use water must be paid a certain pre-agreed compensation (Pigram, 1993:1315). *Thirdly*, the functioning of the market relies on the fact that a commodity must be tradable or transferable between willing buyers and sellers. This requirement is closely related to the institutional requirements.

3.10.4 Physical-biological requirements

Regional water supply and demand characteristics must be taken into account when a market system is proposed for a specific region. In most cases, stochastic water supply and demand characteristics are responsible for most of the uncertainty regarding investment decision-making. The market mechanism is specifically well equipped (better relative to administrative control) to deal with uncertainties regarding supply and demand. (Note that capacity-sharing could also be applied to areas with deterministic water supply and demand characteristics.)

3.11 Possibilities for South Africa

Capacity-sharing is a possibility for the current water management problems experienced in South Africa, because the concept could easily be integrated and associated within the broad policy and institutional requirements laid down in the National Water Act of 1998. Capacity-sharing is suitable for integration with water markets because it provides water property rights that are explicit, exclusive to the shareholder and enforceable by law. Such property rights form an excellent basis for the development of water markets, for water already in the reservoirs and streams and for long-term rights for the future. There are incentives to move water between users according to its most valuable use and time of use and this promotes the integration of supply and demand water management across users through time.

For South Africa and most developing countries, capacity-sharing may not always be feasible for two reasons:

- Capacity-sharing does need a certain minimum level of education from water managers to make full use of the advantages offered by the concept in order to manage supply side- and demand-side water decisions.
- Capacity-sharing needs an effective water release system where a specific amount of water could be released to satisfy the independent needs of individual users.

Gakpo and Du Plessis (2001) suggested a path of development (in chronological order) for achieving an optimal water allocation in order to assure water security and flexibility and to guide investment decisions. (Refer to figure 3.2 below for a schematic representation of the development path.) Block 1 will start the development path by determining the true value[74] of water (by using a multi-disciplinary and integrated approach) and setting consumer prices right. (It is clear that the government is struggling to clear this first, but important hurdle.)

The reaction to this new price setting is still unknown, but full cost recovery prices are likely to force inefficient and low-value users out of the market. However, it is expected that most users will seek innovative new ways of remaining in business, as referred to in block 2. Production will be characterised by techniques like dynamic cropping patterns (depending on market conditions) and new water-saving technologies (however this may bring additional externalities to the fore) as reflected in blocks 3 and 4.

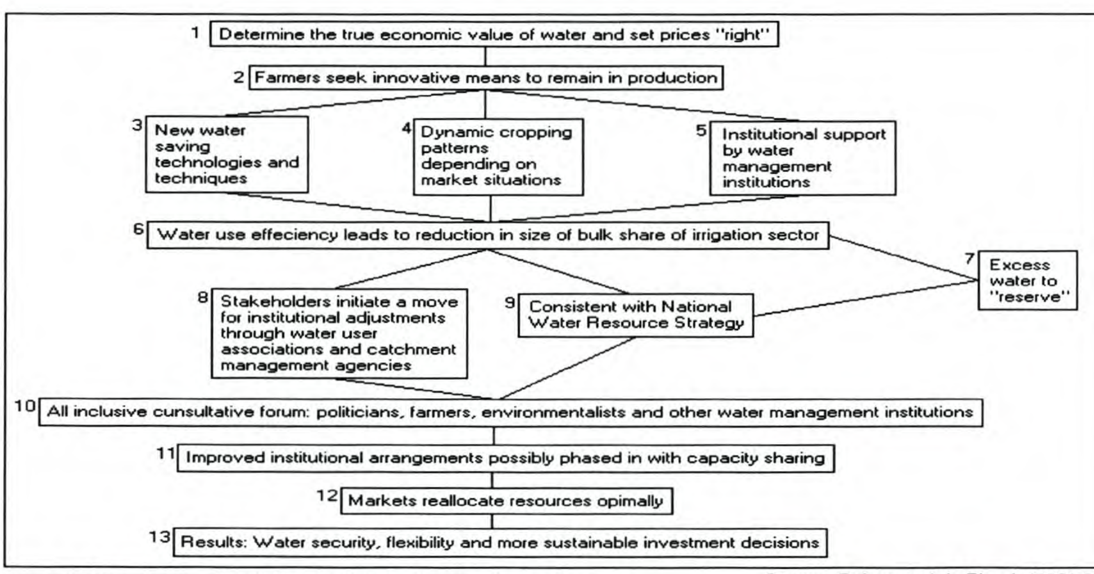

Figure 3.2: Developmental path for an optimal water allocation and security strategy

Source: Gakpo and du Plessis (2001:99)

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74 Viljoen *et al* (2000) researched the simultaneous comparison of marginal value products between linear programming and stochastic programming for estimating the value of water downstream of the Vanderkloof-dam. Their study did not accommodate the whole capacity-sharing model as developed by Dudley (1988a and 1988b) and Dudley and Musgrave (1988), but included two of the fundamentally important sub-models of the single decision-maker approach, namely the stochastic dynamic simulation model which was used for optimising the use of stored water within the dam and the linear programming model which was used to optimise water use on the farm during the immediate season. Johansson (2000) did a survey (as part of a World Bank project: "Guidelines for Pricing Irrigation Water Based on Efficiency, Implementation and Equity Concerns") on current and past views on water pricing in the irrigation sector that will be useful for water policy-makers as they address the growing demand for allocating scarce water resources efficiently.

Users may rely more on water management institutions (like Catchment Management Agencies and Water User Associations) for institutional support and information on appropriate methods of optimal water use (block 5). This may lead to a reduction in the bulk share of irrigation water as indicated by block 6, and a considerable amount of water will become available for alternative uses. It is important that these water savings should be used in a way beneficial to society as a whole (probably to be added to the "reserve" as defined within the National Water Act of 1998). It will therefore be appealing for the government to co-operate with the irrigation sector, should this goal of water saving be achieved. On the other hand, the irrigation sector (which now has some bargaining power in the form of water use rights) can exploit the situation by lobbying through the Water User Associations for some changes within the National Water Act of 1998 and therefore display rent-seeking behaviour.

The final stages of the development path will probably see decision-makers within the water sector considering other institutional arrangements (such as capacity-sharing) that thrive on well-defined water markets. Judging from the advantages mentioned above, the agricultural sector should be one of the main beneficiaries if capacity-sharing is adopted.

The next chapter will look in more detail at some of the problems experienced within the current South African water management context and what properties of capacity-sharing could be used in resolving some of these problems. The philosophy of an integrated approach will be followed throughout the chapter and, where possible, some recommendations will be made regarding potential institutional reforms for achieving a more equitable and efficient water allocation.

Chapter 4

WATER DEMAND MANAGEMENT: POLICY IMPLEMENTATION AND THE ROLE OF CAPACITY-SHARING

"If the misery of our poor be caused not by nature, but by our institutions, great is our sin."

- Charles Darwin

In his presidential address, Backeberg (1997) emphasised the importance of change in water institutions, markets and decentralised resource management within policy reform for the South African irrigation sector. He argued that the development of a suitable institutional framework to direct the needed policy changes for achieving the policy objectives as stated in the National Water Act of 1998, was necessary and relevant. Backeberg (1997:350) also noted that further research contributions are required for the design of un-attenuated water entitlements in order to achieve sustainable resource use. Vink (2000:439) also emphasised the necessity of further research in problems related to structural change within policy and institutional changes in the South African water sector.

This chapter will provide a suitable conceptual framework against which the identified institutional water-related issues should be seen and the role of demand-oriented management strategies in resource management will be emphasised. By using the insights of the detailed literature review and chapter 3, a few of the most important key problems currently experienced within the South African water management arena will be identified. These problems will then be conceptualised within the capacity-sharing paradigm and suggestions will be made on how to negotiate these problems with the aid of the possibilities and advantages of capacity-sharing. The suggestions made within this chapter could serve as a point of departure in the operationalisation of this concept in South Africa.

4.1 Perspectives on water demand management

Rather than pursuing a definition of water demand at this stage, it is more useful to look at water demand management[75] from three different perspectives. These range *firstly* from the mundane level of the individual firm or household, *secondly* through the more important level of society as a whole and *thirdly* to the radical level of questioning common notions of need and consumption.

[75] Recall that throughout the discussion on water demand management, it is not the demand for water per se to be accommodated but the *derived demand* for water (in other words not the physical substances of water, but rather the "usefulness" of the physical substance i.e. it is about use rights and not property rights). The differences in demand elasticity between water per se and the wide range of uses support this fact.

Firstly, the water utility, industrial firm, household or irrigation farmer can be discussed as one perspective because they are all individual economic units and, to one degree or another, all interested in savings. For many of them, water demand management (or demand side management) is simply a matter of cost-effectiveness: "Will investment (of time, money or effort) in saving water pay off in whatever terms are relevant to that economic unit?" Of course, many things may be in the way of achieving an accurate balance, particularly when water is low priced. In addition, incentives can be misplaced (from an economic perspective) as when is the case, for example, women carry water but men decide when to invest in water-related infrastructure, or when buildings are charged for water but those rates are not applied to individual offices or apartments. In sum, calculations for the individual user may be complex, but the principles are not.

Secondly, a much wider set of variables comes into play when water demand is viewed from the perspective of society as a whole. Concerns which are of particular relevance here include the renewable and partially non-renewable characteristics of water per se, the fact that water moves around, crosses boundary lines and has enormous absorptive capacity. However, when for example user/community "A" uses water, this use affects the ability of user/community "B" to use that water. Therefore social rules[76] are needed to define **who** can use water, **how much** and **when.** Because all human communities and livelihoods (all life-forms on earth) depend on water, principles of equity demand that there should be special rules to ensure that each water user and type of use is provided with its basic need for water. In the case of human-related uses, there is an environmental effect also to keep in mind. Calculations at the level of society are more complex and less definite than those involved for individual economic units. Concepts such as externalities, common property resources and public goods all come into play and a large literature has grown up to deal with them.

Thirdly, there is the radical perspective that asks the question: "What is the purpose of water use anyway?" Modelled on the approach to energy analysis dubbed "soft energy paths" (Capra, 1997), the theory of soft energy paths is still too nascent to discuss extensively at this time. However, some lessons can already be seen as analogous to those learned from energy (Capra, 1997):

- Beyond the few litres required to sustain life, there are many alternative ways to satisfy demand for water. Most relevant in areas with severe water shortages (like the Middle East), the importation of food is an alternative to using water for irrigation purposes (virtual water). If the objective is to feed a given population, then the use of water to irrigate or use of money to buy food are equivalent. Obviously, the two options are anything but equivalent in socio-economic and environmental effects.
- Look beyond the immediate end-use to ask about demand management in a larger sense. Drip-irrigation techniques might be extremely efficient, but the larger question is whether the water should be used for

[76] The government is responsible for these social rules and this implies the "first contact" between the state as a regulatory mechanism and the market mechanism.

irrigation at all. One could install low-flow toilets in isolated villages, but the larger question is whether water-based sanitation should be used at all.

- Water quality has a direct effect on the opportunity cost of water. High-quality water can be used for many purposes but low-quality water for only a few. On the other hand, the volume of use that requires high-quality water is rather small, whereas the volume of use that accepts low-quality water is large. (It is therefore possible to propound that the dominant use characteristic of water for human-related use is not quality-related, but "gravity or flow"-related whereas within environmental-related uses, no such distinction exists.)

The above-mentioned discussion could lead to questioning the rationale of water saving and the question could be asked: Why do we need to save water? To be able to answer this question, let us first define what would be understood as water saving. Assume that all human-related water use patterns degenerate water quality. Given that a certain use (with a specific level of utility) requires "x" cubic meters of a specific quality of water, but a new or different technology requires only "x-c" cubic meters for the same use and utility level[77], a water saving of "c" will be realised[78]. By assuming further that technological advances and accumulation of knowledge on efficient water uses will provide an absolute optimum level of water-use efficiency for all human-related uses, it could be argued that a substantial amount of water (represented by "c" times all possible uses) will be "freed up" out of current uses and will become available for alternative uses. The more water is "freed up" from human-related use, the more water is not exposed to the potential negative impacts of human-related uses and the more sustainable the complete hydrological cycle will become. The rationale for saving water is therefore directly linked to preserving the quality of present water resources and, in economic terms, preserving the opportunity cost of water[79].

4.2 Institutional arrangements to ensure optimal water allocation and security

The central question regarding regional water policy has always been: "What institutional arrangement will provide the most socially desirable allocation of water in a water-scarce environment?" This issue within the South African context will be the main topic of discussion for the remainder of this chapter. Before starting off, first consider precisely what is meant by a "socially desirable water allocation". Within the literature regarding equity-related issues, not one single description could be found of what precisely is meant by a "socially desirable (or optimal) water allocation". The researcher therefore makes the assumption that the above-mentioned socially optimal (or ideal)

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[77] Utility-theory is the basis for multi-actor decision-making under uncertainty (Beroggi, 1998:199).

[78] Note that under an open-access property regime, no incentives exist for water-saving practices. Therefore, if a given water resource is in danger, all the lawful owners will have an incentive to use the last possible amount of water before any other competing user. However, under the same circumstances, private and common property regimes will provide some incentives to conserve the water and to use it freely when plentiful. (The opportunity cost of water is also considered as being under a private property regime.) Capacity-sharing can accommodate both private and common property regimes within one catchment because the property rights are not on the physical substance of water, but on the use rights of the substance.

[79] If the opportunity cost of water is equal to zero, it means that given the current level of technological development, the current use of water produces its highest possible level of utility. It is highly unlikely that this point will ever be reached because perfect information would be needed in order to determine that the current use is indeed the highest level of utility. Together with this dilemma, a moral hazard presents itself, because it is impossible to compare different types of uses in terms of utility.

water allocation is something imaginary and that there will *never* be a point in time when an optimal or ideal water allocation will be reached. The best that current institutional arrangements can do is to try to develop a situation where social order (conflict levels kept at manageable levels) and justice are maintained.

According to Louw (2001), institutional factors often restrict transfers among users, limit incentives for efficient use and where uncertainty regarding water use rights occurs, a nation's development is likely to suffer. Besides the state of resource endowments, the origin of concerns for future water shortages lies in the laws, administrative practices and other institutions that create uncertainty over water use rights, pose obstacles to developing new water supplies or reallocating existing supplies to new uses, as well as providing few incentives for conservation. In order to sustain economic and social activity with regard to water resources, unquestionable institutional arrangements must be in place to guarantee efficient and equitable water use. In order to ensure the development of proper institutions, some principles must be followed.

4.2.1 Principles of water policy

According to Winnpenny (1997), the following national water policy principles must be kept in mind when policy development is underway:

- **Water is a holistic resource**. To obtain the maximum benefit for society, all sources and consumers of water should be taken into account when planning and operating water systems. The complexity and interdependency of different parts of the hydrological system should be considered.
- **Water is a scarce commodity**. A sense of the economic value of water is necessary in order to induce the needed shifts of consumption towards higher value uses, and the reduction of waste and losses.
- **Water is an environmental asset**. Supplying, using and disposing of water have a drastic effect on the environment. Conversely, water is a key feature of the natural environment, with an inherent value as such which should be recognized in the event of potentially competing uses.
- **Water has many stakeholders**. The interdependency of different parts of the hydrological system creates many stakeholders (e.g. upstream-downstream users and users of polluted water). Groups representing the environment are increasingly asserting their claim on the resource and potential users in neighbouring countries may have a legitimate stake. Future generations and "passive" users are also, in some eyes, stakeholders.
- **Water is a basic need**. Huge numbers of people in developing countries (according to DWAF (1999) more than 12 million people in South Africa) still lack access to safe drinking water and sanitation. The cost of under-provision is revealed in disease, and the human and financial costs of people making their own alternative arrangements. Many of these costs fall on women and children. Providing a basic water supply and safe sanitation to those currently lacking them should be the first priority of any country's water policy.

- **Participation, delegation and subsidies**. Whatever the theoretical advantages of centralised public provision, there are many situations where this is not, in practice, efficient. The notion that water should be managed at the lowest appropriate level is a sound general principle, often driven by imperatives of maintenance and cost recovery.
- **Financial self-sufficiency**. Shortages of funds because of poor cost recovery are problematic to all kinds of water systems, at every scale. This is commonly caused by timidity in fully charging for water, inefficiency in collecting what is due, sometimes corrupt collusion between users and collectors, and a relentless growth in the demand for services. Whatever institutional model is chosen, there is a need for better financial performance in future.

To merely take note of the above-mentioned policy principles, will not ensure effective policy development therefore, some guidelines will be necessary to guide policy-makers.

4.2.2 Policy guidelines

The following could be seen as important aspects (and therefore policy guidelines) in developing an appropriate water policy for the South African context (Bromley, 1990, 1995a, 1995b, World Bank, 2002 and Van Zyl, 2002):

- Avoid large capital projects, which tie up major portions of scarce capital.
- Focus on applicability through promoting research, the development of technology and products, institutional reforms, and innovatory systems that are potentially widely applicable.
- Use foreign aid as a catalyst to enable the involvement of other interested parties, (for example NGOs', the private sector and local communities).
- Be prepared to take risks by backing innovations (whether of products, systems, finance or institutions).
- Stress the diversity and specificity of solutions, and avoid imposing categorical blueprints (especially those with ideological overtones).
- Be flexible over aid criteria. Assistance to the water sector should not be tied down too narrowly to specific countries, regions, or target groups. It is important that managers are allowed freedom to intervene across a range of situations. It is in the interests of aid recipients that the supplier (of foreign aid) has access to as wide a range of relevant experience as possible.
- Monitor water developments in all countries, to gain some experience for application in the local context.

Effective water policy-making also needs a sound knowledge of social theory. The structuration theory of Anthony Giddens and the critical theory of Jurgen Habermas influenced developments in social theory in the second half of the twentieth century (refer to Capra, 2002:67-70). Both these social theorists integrate insights from the natural sciences, social sciences and cognitive philosophies while rejecting the limitations of positivism. This integration could be advanced by extending the systems understanding of life (as mentioned in chapter 2) to the social domain with the aid of the conceptual framework of four perspectives – form, matter, process and meaning (as mentioned in Capra, 2002:64). If this integration has taken place, the real systems understanding of social reality will come to the fore and it would then be possible to formulate effective water policy.

Given the above-mentioned guidelines and principles, the scene is set for the policy development process. However, before engaging in the process it is appropriate to mention some of the political risks associated with institutional reforms in the water sector.

4.2.3 Political risk of institutional reforms in the water sector

The conventional view of institutional change is that it is either in the interest of economic efficiency, or it merely redistributes income (Bromley, 1989). Interest groups form and attempt to influence the decision-making process so that the end result best serves their interests (rent-seeking behaviour). As correctly pointed out by Haggard *et al* (1995), interest-group analysis is not straightforward, and especially in developing countries where several limitations affect the ability of political scientists to analyse interest group impacts, which include (1) collective action problems (for example the ability of groups to organize and influence); (2) problems in identifying exogenous-endogenous reactions to the reform design (for example the design and the implementation sequence, affects the interest group reaction); and (3) problems in identifying mechanisms through which interests are translated into policy (for example strikes and bribes). The sustainability of any water related infrastructure investments are dependent on the performance of the institutions that manage them and it is therefore important to analyze the level of political risk associated with the implementation of the suggested institutional reforms (Cummings *et al,* 1996).

Eggertsson (1997) emphasises the need for approaches that allow interaction of economic, political, and social activities, in order to improve the design of economic policies and minimize the likelihood of policy failure. To be able to assess the political risks associated with institutional reforms, it is necessary to know how the stakeholders (also called interest groups or players) are affected by the reforms, what their interests are, and their ability to affect the reforms. A quantitative evaluation of risk can be estimated once the extent of the political effects on the institutional reforms is known, however, according to Dinar *et al* (1998:4) few studies exist that address the political economy of reforms in the water sector.

Dinar *et al* (1998) describe ways in which political impacts and political risks were handled in the literature dealing with various reforms and economic adjustment projects in countries like Pakistan, Morocco, Chile, Argentina and Brazil. From the studies surveyed, it can be generalized that reforms of any kind are likely to face the opposition or support of certain groups. The level of opposition or support is in turn determined by the change of power and benefits of each affected group compared with the status quo. Reforms may create new coalitions that were not in place, or predicted. The ability of a group to influence the implementation of a reform is a function of many factors, and is complicated to generalize. Establishing a quantitative framework to assess the likelihood of accomplishing institutional reforms associated with a specific project is therefore not a straightforward task and supporting data from which probabilities can be calculated, do not generally exist.

Dinar *et al* (1998) propose a procedure that can be used to calculate the political risks associated with implementation of institutional reforms in the water sector and also provide insights into the interrelationship of institutional arrangements, power structure and policy outcomes. The procedure is based on a combination of the work of Raiffa (1982), which assess the institutional feasibility of reform implementation and a Delphi process based on expert opinions.

The process used by Raiffa (1982) consists of: (1) an evaluation of the potential winners and losers from the reforms, (2) identification of the various reform performance levels, (3) identification of means by which the various parties may influence the level of achievement of various reforms, (4) identification of costs (for example effort required by each party) to influence the achievement levels. Thereafter, Raiffa (1982) applied the Delphi approach to estimate probabilities of risk associated with the implementation of the analysed reform.

The above-mentioned approach is a compromise between two options: the first is costly, time consuming, and often entails using pseudo-precise creation of indices and their analysis, while the second is based on an unstructured "expert opinion" way of assessing risk. It provides a manageable framework, which, after some testing, could be added to the feasibility analysis of projects undertaken in politically complicated environments. It would be worthwhile to investigate how the above-mentioned approach will perform in the South African water management context. The following section will discuss institutional arrangements made by policy-makers and theorists that are relevant for changes to be made in water policy.

4.3 Institutional arrangements to meet the changing South African conditions

In order to promote a situation where market transfers do produce net social benefits (by taking all the costs and benefits associated with a transfer into account) the marketing of water use rights must be conducted within a suitable institutional framework, which causes the buyers and sellers to take into account impacts on third parties without restricting water transferability (Bush *et al*, 1987:619-620). The reform of any sector is therefore primarily a political and not a technical process although high-level technical skills are a requirement for adequate and successful reform (Abrams, 2000).

Successful water institutions require co-operation between the public and the private sectors and the ideal institutional framework therefore needs an approach that will integrate the public and private sectors and give market forces the chance to facilitate the allocation of water use rights.

Gakpo and Du Plessis (2001) proposed a generic water institutional framework (refer to figure 4.1) to assist in the co-operation of public and private sectors and in shaping institutional arrangements for achieving economic efficiency as well as equity objectives and at the same time obtaining water security. This generic framework can be used to develop a policy for accommodating markets in water use rights within the current water legislation regime. The need for such a framework comes to the fore in a document of the Department of Water Affairs and Forestry that clearly mentions that a new institutional framework would be required to accommodate the full decentralisation of water management (DWAF, 1997).

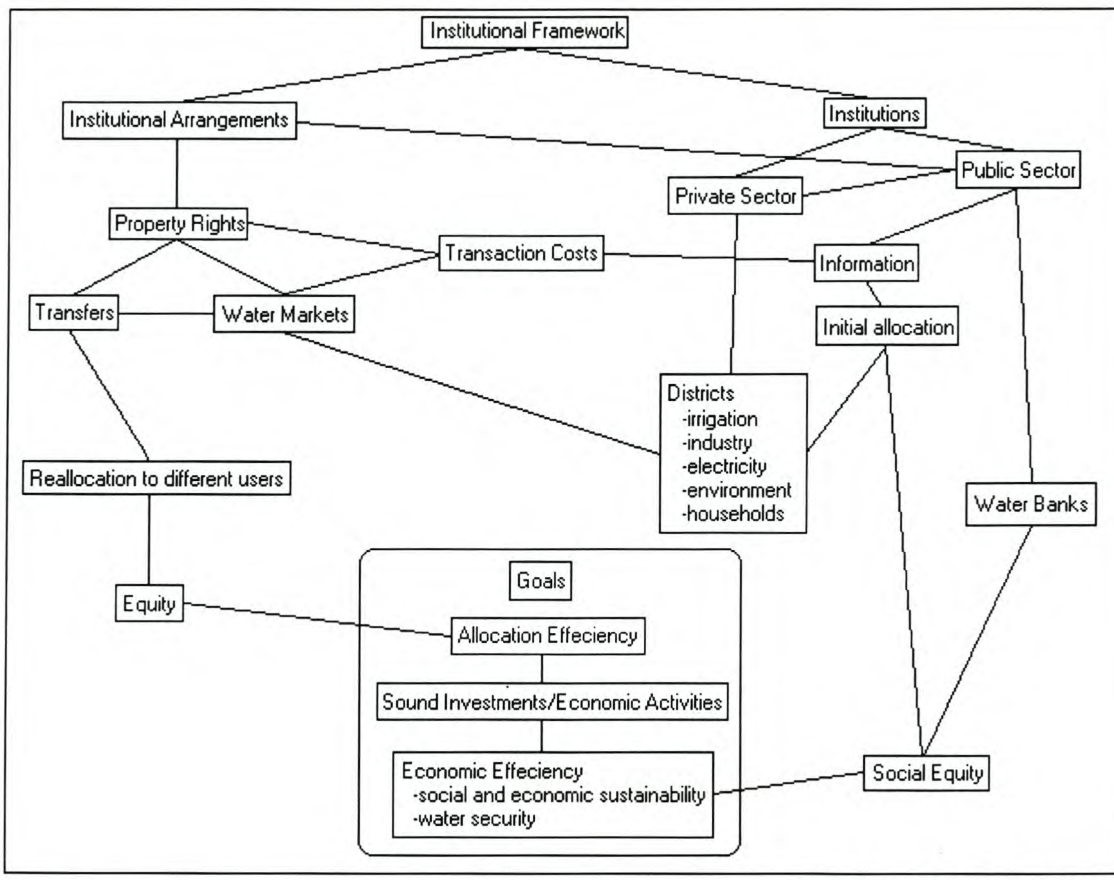


Figure 4.1: Proposed ideal institutional framework for achieving water security

Source: Gakpo and du Plessis (2001:4)

With regard to figure 4.1 the following: according to Gakpo and Du Plessis (2001) the *public sector* must ensure that the correct institutional arrangements are in place for the successful management of water resources. Such arrangements include:

- The establishment of water use rights.
- Setting the rules for trading in water use rights.
- The monitoring and enforcement of these rules.
- The mediation of conflicts.
- Making changes in the structure of water use rights and rules as time goes by and conditions change.

- Charging for water use – procedures and infrastructure maintenance.

The *public sector* also has to establish a national information system that covers virtually all aspects of water resources (like quantity, quality, demand, supply, floods, and droughts). This database can assist the central water agency to promote the fair and efficient allocation of water resources to districts through their respective regions. Due to the weakness of water markets in maintaining an equitable allocation of water, allocations to address equity have to be safeguarded by the public sector through regional allocation mechanisms (like Catchment Management Agencies[80]) supported by water banks[81]. This may be the best alternative to addressing efficiency and equity simultaneously (Gakpo and Du Plessis, 2001:9).

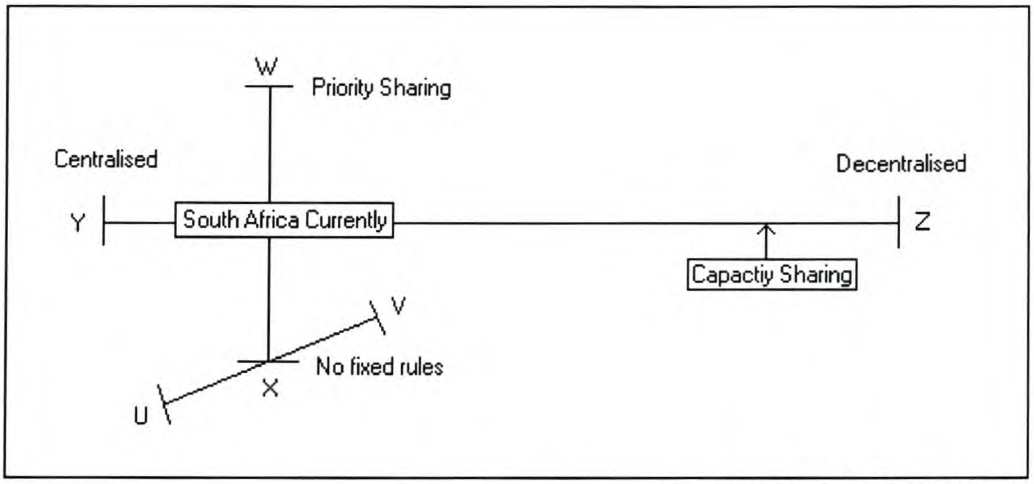
The *private sector* should be involved in water management at local level. Water management at local level has to be private to facilitate the development of water markets that would allow water to flow to the highest marginal product value. Other roles of the private sector include operation and maintenance, inducing technological innovations for the promotion of efficiency. With water use rights guaranteed institutionally, the Catchment Management Agency must rely on market forces and transfer mechanisms to reallocate water use rights to its most valued use. The opportunity costs of water between different uses will guide the market in terms of pricing and shadow prices can be used as estimates of opportunity costs in situations where it is difficult to determine these opportunity costs. The private sector should also be responsible for operation and maintenance, including technological innovations that would promote efficiency. They should also co-operate with the public sector for the achievement of equity objectives. If the public and private sector should perform in the above-mentioned way, South Africa could move towards a truly decentralised water management paradigm.

In Dudley (1990c), institutional arrangements for allocating water use rights among users were categorised dimensionally (refer to figure 4.2). Institutional arrangements generally oscillate between centralised bureaucratic management approaches to completely decentralised market-based systems. Line XZ (horizontal axis) illustrates a continuous spectrum of centralised bureaucratic administrative procedures to a completely decentralised system. Close to the "centralised" end of this spectrum (Y), is the line WX (vertical axis), representing a range of centralised types of water allocation. At W for example, water management is characterised by a pre-determined set of decision rules and no decisions are made without such rules, as in "priority sharing". At X, on the other hand, decisions are made over time in the absence of such rules. At point X lies another range, UV, illustrating decision-making by different combinations using administrative or political discretion and consensus among representatives of existing

[80] The main purpose of Catchment Management Agencies is to delegate water resource management to the regional (or catchment level) and to involve local communities in the management of water. The functions of these Agencies would therefore include: (1) investigating the protection, use, development, conservation, management and control of water resources in its management area, (2) co-ordinating activities of water users and water management institutions and (3) promoting community participation in water management issues (DWAF, 2001).

[81] A water bank is an institution that stands ready to buy and sell water under some set of rules regarding certain pre-agreed conditions. Water banking is a joint venture between the public and private sectors. The public sector makes the rules while the private sector runs and maintains the bank. In its operation, a full assessment of the target group (the poor) will have to be conducted periodically to establish shortages or surpluses existing in the current allocation (Gakpo and Du Plessis, 2001:8).

users. That means a group consisting of water-supply authority representatives makes allocation and reservoir carryover decisions periodically. The actual position on the axis is country specific and depends on the needs being addressed by the country's water sector. South Africa is still far from true decentralisation, especially if Catchment Management Agencies and Water User Associations do not enjoy autonomy.



Source: Gakpo and du Plessis (2001:8)

Figure 4.2: Spectra of Water Resource Management Decision Making

Internationally, a shift towards the Z – end of the horizontal axis has been reflected in global trends on institutional arrangements. This trend, together with the flaws and problems of the 1998 National Water Act, leads to the concept of capacity-sharing[82] as one of the options that can resolve some of the major water management issues for South Africa. Capacity-sharing as an institutional arrangement structures and guarantees water use rights that are exclusive, enforceable and transferable. Capacity-sharing is ideal for accommodating equity by also respecting the needs of small-scale irrigation farmers and the poor in general. The concept fits well in the proposed "ideal" institutional framework (refer to figure 4.1) discussed earlier and can also accommodate water banking for further addressing the equity issue. Therefore, it seems that further investigation on capacity-sharing is worthwhile.

4.4 Capacity-sharing within the context of South Africa

The concept of capacity-sharing is presented in figure 4.3. Essentially, the total capacity may consist of a single reservoir, multiple reservoirs or a whole catchment area. The shares within the capacity-sharing model could be sub-divided between "bulk" and "retail" where the bulk shareholders have few incentives for efficiency whereas the retail shareholders face incentives for efficient decision-making and management. According to Gakpo *et al* (2001:91 and also Dudley and Musgrave, 1988), capacity-sharing is feasible under multiple purposes, ranging from urban use where the relevant water authority would obtain shares by market or non-market means and make releases to users over time as desired, to in-stream or river valley environmental use, flood control, recreational use and hydro-power

[82] Refer to chapter 4 for a detail discussion on this concept.

generation. Dudley and Musgrave (1988) stipulated that, capacity-sharing coupled with market transferability of shares by auction would give all water users a greater security of tenure in water use compared with other water allocation alternatives. For example as urban- and environmental-related demand grows over time, irrigation users need not fear that their individual reliability of supply will change without them deciding to sell their shares at market value. Similarly, urban and environmental users are aware that their shares can always be expanded as demand increases by paying the market value for additional shares to willing sellers.

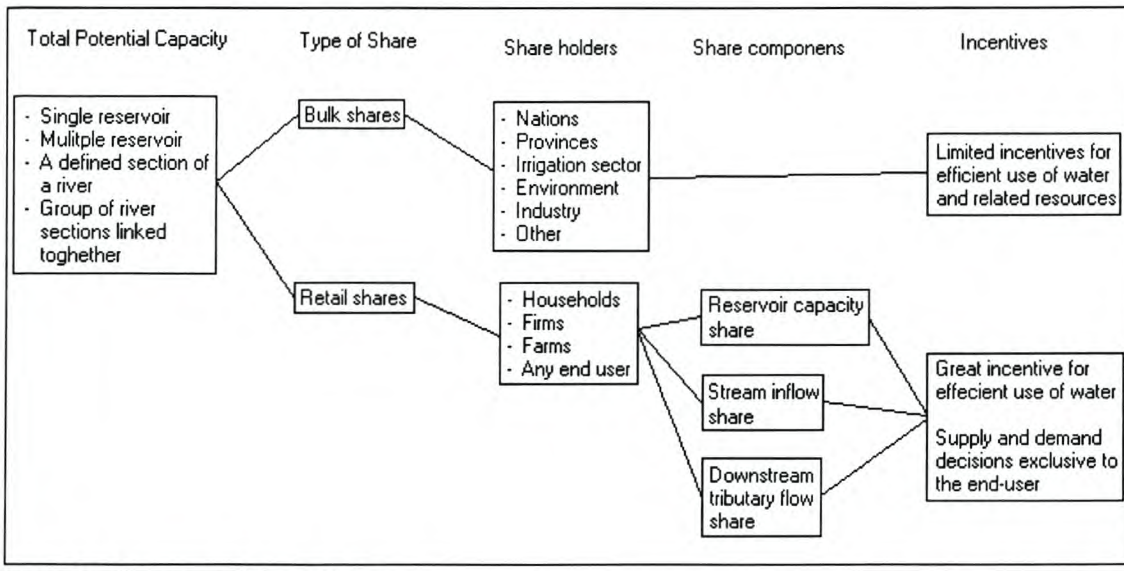


Figure 4.3: The concept of Capacity Sharing

Source: Gakpo et al (2001:92)

An integral part of capacity-sharing would therefore be the establishment of markets for tradable water use rights. These markets will operate on two levels within the capacity-sharing regime (Dudley and Bryant, 1995 and Gakpo *et al*, 2001:94):

- The transfer of water that is already in storage, streams or channels.
- The transfer of long-term use rights to parcels of shares in reservoir capacity and stream flows.

The water market ensures that water users cannot lose water use rights to other users or the state without market compensation. Thus, the water market provides two fundamentally important aspects for efficient and sustainable water use. These include security of tenure of supply rights with known reliabilities to users and the flexibility for water resources to be moved to alternative uses as conditions change (Dudley, 1994). The security of entitlement to water currently in the reservoir coupled with the estimates of the probability of future inflows, enables the user to decide when and how many water use rights to buy (or to sell) at any point in time. A spot price for water would also reflect current supply and demand conditions (water balance) while possible futures markets (where the user could hedge against risk) would also allow users to further reduce risk. This idea however, will be more suitable in areas with a *stochastic nature of water supply*. Note that a unit of water within a reservoir is indistinguishable and therefore under no circumstances will a situation develop where a specific share of water will be at risk of being needed specifically. This provision under capacity-sharing guarantees impartiality and protects the beneficiary's shares.

Capacity-sharing holds the added advantage of determining the value in use of different dimensions of irrigation water and other water uses. Since capacity shares consist of inflow shares and shares in storage space, the shareholder enjoys the leverage of managing his supply and demand effectively. Also the fact that inflow shares take into account inflow probabilities which are derived from long periods of historical hydrological inflow data means that water supply reliabilities can be near to perfect and hence the water user's decision to buy or sell water can hardly be impaired.

The above-mentioned discussion concludes the theoretical side of decentralised water management. The next section will discuss the current developments within central government in South Africa regarding decentralising water management.

4.5 Current developments with regard to decentralisation

The Department of Water Affairs and Forestry (1998 and 2000) launched a strategic plan and institutional framework for the facilitation of the implementation of catchment management agencies in South Africa (i.e. the implementation of a decentralised water management strategy). It should be noted that this document was not designed to be a guideline on future catchment management practice in South Africa, nor a manual for catchment management implementation in any specific catchment. This document forms part of the planning and preparation by the Department of Water Affairs and Forestry and proposes a catchment management implementation strategy and programme for the short- to medium-term, and clarifies budgetary and human resource requirements. It also sets out the policy context and elements of the underlying debate on the issues surrounding the department's role in facilitating catchment management implementation in South Africa.

The Department of Water Affairs and Forestry is in the process of developing Water Conservation and Water Demand Management strategies for each water use sector, namely, Agriculture, Municipal, Industry, Forestry and Environment. Each National Water Conservation and Demand Strategy will be incorporated into the National Water Resources Strategy, which is a legal requirement of the new National Water Act (Act 36 of 1998). The Catchment Management Strategies of each of the 19 Water Management Areas, the National Pricing Strategy and other strategies (currently being developed by the Department) will also contribute to the National Water Resource Strategy. The process outlined above is illustrated in figure 4.4 below.

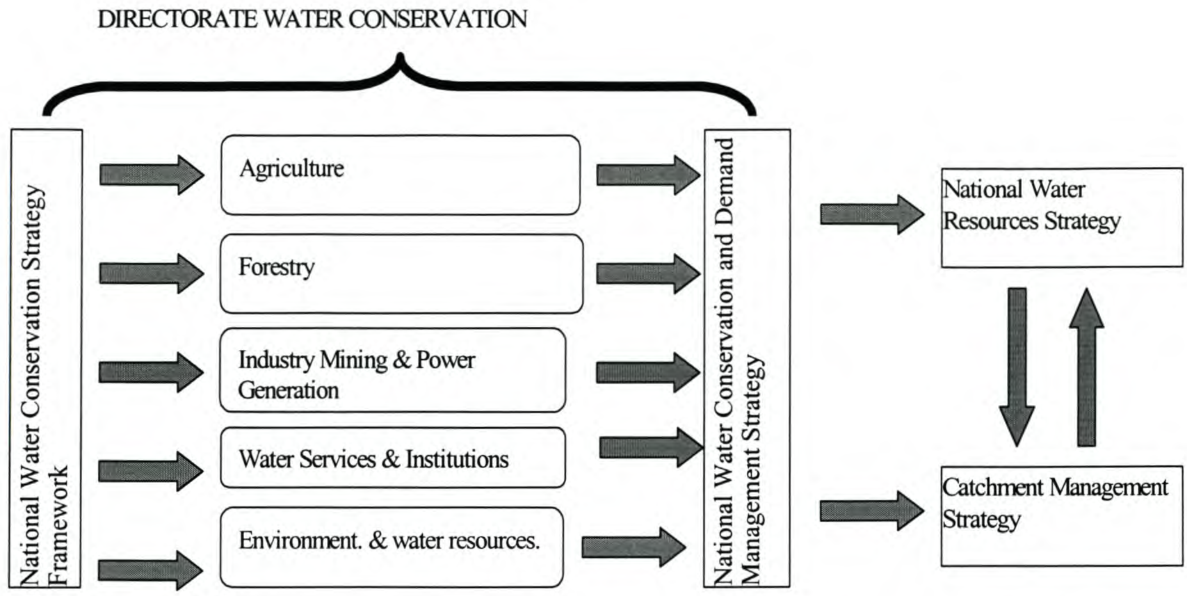


Figure 4.4: Overview of water conservation and demand management development processes in South Africa

Source: DWAF (2000)

The Agricultural Water Conservation and Water Demand Management Strategy has been circulated for comment and was discussed in consultation workshops. Water User Associations will implement the strategy through the drawing up and submission of Water Management Plans[83]. These Water Management Plans will be similar to the Water Services Development Plans currently being developed by Municipalities. The objective of the Water Management Plans is to improve agricultural water management by stimulating self-analysis and planning on the part of farmers, their water suppliers, catchment management agencies, officials, consultants and advisors. Water User Associations will develop and implement their plans in a progressive manner. The Water Management Plan may be superficial to start with and may be lacking in certain areas, but it will be improved annually when the Water User Associations reviews its plans. Water User Associations are now required in terms of the law to submit Water Management Plans to their Catchment Management Agency and/or the Department of Water Affairs and Forestry. **Essentially, the process aims to conserve water, to improve water supply services to irrigation farmers and to enable them to use irrigation water more efficiently.**

4.6 Specific problems and the role of capacity-sharing

Given the discussion thus far, it should be clear that a suitable water policy framework is already in place for the institutional accommodation of demand-oriented water management in South Africa. Therefore, the main focus shifts towards the practical implementation of the proposed policy, however, this point proves to be problematic. The remainder of this chapter will proceed by identifying some basic problems regarding the implementation of demand-

[83] In a Water Management Plan, a Water User Association describes its current irrigation water use and conservation measures and sets out how it plans to implement the best management practices to improve its irrigation water supply services and to achieve water conservation and water demand management (Van Zyl, 2002).

oriented strategies in South Africa. An institutional economic approach (supplemented by the field of new-institutional economics[84]) will be followed within the reasoning of each problem. The relevance of capacity-sharing will be discussed in each of the identified issues and possible remedies for the problems will be proposed. Due to the complexity of the problems mentioned within this chapter and the limitations of modern measuring[85] techniques, the quantification of the problems is not the focus of this study. Each problem will be described, defined and placed in context relative to capacity-sharing. Rational and systematic reasoning is therefore important within this discussion.

Due to limited time, resources and the complexity of presenting the capacity-sharing model as developed by Dudley (Dudley, 1988a and 1988b and Dudley and Musgrave, 1988), the actual modelling of all three sub-modules cannot be accommodated within this study[86].

4.6.1 Contradiction within the 1998 National Water Act

On evaluating the current South African Water Law, it becomes clear that present government policy takes on a dualistic nature. The National Water Act of 1998 clearly empowers the minister to regulate the use and flow as well as exercise absolute control over all water, which is inconsistent with a decentralised policy objective. If the National Water Act of 1998 (Act 36 of 1998) is studied closely, it becomes clear that there is a basic contradiction (or vagueness) regarding the management strategy, which is to be followed in order to achieve sustainable water resource utilisation. The following is a quote directly from the Act:

> "*Acknowledging the National Government's overall responsibility for and authority over the nation's water resources and their use, including the equitable allocation of water for beneficial use, the redistribution of water and international water do matter* (National Water Act, 1998:A-1)*; As this Act is founded on the principle that National Government has overall responsibility for and authority over water resource management, including the equitable allocation and beneficial use of water in the public interest, a person can only be entitled to use water if the use is permissible under the Act.*" (National Water Act, 1998:A-41).

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[84] New institutional economics is a dynamic multi-disciplinary field that includes the disciplines of economics, history, sociology, political science, business organisation and law within the reasoning process. Kherallah and Kirsten do not mention the viability of this paradigm for water policy research, but the researcher is of the opinion that new institutional economics would be an appropriate paradigm for reasoning the problems as mentioned in this study because of the strong emphasis on context dependency, holistic approaches and transaction cost economics. (Refer to Kherallah and Kirsten, 2002:111-134; Kirsten, 2002 and Karaan, 2002 for further detail.)

[85] Recall that the demand for most of the basic water needs of water is inelastic. Standard economic analysis instruments rely on a responsive demand relative to supply changes and therefore seems not to function satisfactorily within the water demand management context.

[86] Refer to section 5.2.

"Recognising the need for the integrated management of all aspects of water resources and where appropriate, the delegation of management functions to a regional or catchment level so as to enable everyone to participate" (National Water Act, 1998:A-1).

The first quoted paragraph emphasises the urgency of the state to achieve of an *equitable* water distribution throughout South Africa, while the second place the emphasis on an *efficient* allocation (via decentralisation), which must be accompanied by the equitable allocation[87]. The state's aim, therefore, is an equitable and efficient water allocation for South African water resources. This seems to be justifiable, but to achieve this in practice is indeed difficult and complex[88]. The achievement of these two basic ideologies leads to contradictions within the practical implementing thereof. Much of the current literature suggests the implementation of water markets as the answer to the above-mentioned dilemma and the concept of capacity-sharing also forms part of the argument for implementing a water market.

The following objectives are therefore of equal importance in formulating the new water management strategy (DWAF, 1999):

- social equity
- ecological sustainability
- financial sustainability
- economic efficiency

Social equity

Past water policies distorted the provision of water supply services, so that in 1994 an estimated 12 million people in South Africa did not have adequate supplies of potable water. These past policies also generated a biased approach to water resource management, and allocation was never merely an economic matter, but a socio-political one. Government water policy, and in particular the provision of subsidies (including those associated with the provision of irrigation water), resulted in considerable advantages to large, mainly white commercial farmers at the expense of emerging black farmers and smallholders.

It is therefore important to take into account the past social inequalities within the re-formulating and re-structuring of water policy for South Africa.

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[87] This contradiction is also observable in the 1998 National Water Act, A-21.

[88] The basic reason for this complexity can be found in the nature of the "product" (water) as well as the historical context behind water allocation and management in South Africa. The demand for water is a derived demand and there are no (depending on the use, but within the context it refers to basic needs) substitutes for water. This property is a potential source of conflict whenever there is an increase in competition over the resource. Inevitably, the supply capacity of water provision will run out and then the state will have to consider demand-oriented water resource management strategies.

Ecological sustainability

South Africa is committed to follow a path of development that is environmentally sustainable. In the case of water, this requires that the availability and quality of water resources inherited by future generations should be adequate to ensure human well-being and the maintenance of ecosystems. As part of overall water resource management, this means that we need to ensure that levels of water consumption, use, and pollution, as well as the associated infrastructure to impound, supply, treatment and dispose the water, do not cause either unacceptable or irreversible impacts on the population or ecosystems.

The following principles underlie ecological sustainability in water pricing strategy:

- In terms of chapter 3 of the National Water Act, 1998, the water needed for the effective functioning of all ecosystems must be protected. The water required for this purpose refers to both the quantity and quality of water in the resource and is called the ecological reserve. It must be safeguarded and not used for other purposes.
- There is a cost associated with the ecological management of the catchment, and all the users of the resource should be responsible for it.
- In order to preserve water quality, point and diffuse sources of pollution should be discouraged through the identification of control methods that are more effective than those presently in use. This requires the adoption of instruments such as a "polluter pays" approach towards the generation of pollution. (The underlying philosophy of the 'polluter pays' principle is to convince the polluter to internalise the environmental cost of pollution.)

Financial sustainability

The methods that have been used by the Department of Water Affairs and Forestry to finance major bulk raw water schemes in the past are not financially sustainable for a number of reasons. *First*, inflation was not taken into account, resulting in a decline in the value of tariffs over time in real terms. *Second*, no provision was made for refurbishment. *Thirdly*, no provision was made for asset replacement.

A new financial framework is required to accommodate the water sector's increased need to be financially autonomous, to attract greater contributions to its development from the private sector, and to be financially accountable and sustainable. In the new approach to water pricing, it is proposed that the **full** financial cost of supplying water should be recovered from water users, including the cost of capital. The new approach would however, be phased in by taking into account the constraints within various user sectors to be able to adapt quickly to price increases. It is therefore important to incorporate the market system within the new approach of decentralisation of water management. The question could be asked what incentives do the state have to not rise water prices to inefficient and inequitable high levels.

Economic efficiency

Economics is concerned with the optimum allocation of scarce resources between competing uses. In theory, meeting the goal of optimum resource allocation requires that goods be priced at their opportunity cost or scarcity value. Section 56 (2) (c) of the National Water Act of 1998 provides for setting a water-use charge for achieving the equitable and efficient allocation of water. This applies equally to the capital resources used in the development of water infrastructure (i.e. dams, reservoirs, pipelines, etc.), and to natural resources such as water. Failing to price water at its scarcity value can result in two kinds of misallocation of water:

- An inadequate incentive to conserve water. The resultant over-use necessitates the expansion of infrastructure and the premature tying up the country's limited capital resources when they could be better utilised for other purposes.
- Some water being used for low-value purposes. This imposes an opportunity cost in that this same water cannot be used for alternative, high-value purposes. Without an economic charge, there is no basis for competition for water supplies between low- and high-value uses, and thus no incentive to shift available supplies from the former to the latter.

Regarding the argument for the implementation of water markets, the state has made some of the necessary statutory provisions for the development of "Water User Organisations" in order to delegate water management to the lowest possible level (for the achievement of a greater degree of efficiency), but does not provide the necessary incentives and security of property to realise this in practice. The reason for this lack of incentives is because (given the sensitive nature of water) the state is uncertain regarding the balance of power (distributional related power) and fears social externalities that will be imposed on the rest of the economy after a market mechanism is introduced. The state therefore wishes for an efficient allocation without a loss of allocation-related power. This is problematic, because given the historical context of water allocation in South Africa, a complete reallocation by the state alone would not be considered as fair and efficient by at least some participants.

This problem is one of the strongest arguments for the implementation of water markets, because at first it may seem to the state that a market in tradable water use rights may lead to a loss of allocation-related power, but if the state also actively participates in the market, that power could be regained by buying an equivalent amount of water use rights for allocating purposes. This however, emphasises the urgency of defining property rights over water (water use rights) that must be exclusive, enforceable and explicit. The definition of water use rights relates to the water management strategy that is in place to manage this water and it is at this point that capacity-sharing features as a method of allocating water use rights in a fair and equitable manner.

There is an abundant literature available regarding efficiency within water markets and it will not be discussed further here. Therefore, the focus will be on equity-related issues within the water market (this proves to be more complex than efficiency-related problems because of the nature of the "product" as well as the historical context of water allocation management in South Africa). The equity-related issues that will be discussed here include the following:

- The basic need argument (efficiency vs. equity).
- The allocation of water use rights, suitable for conversion into a water market (refer to section 4.6.2).
- Equitable functioning of the market (refer to section 4.6.3).

Water as a basic need

In order to determine what is to be considered as a basic need, all the current water uses must be identified in order to construct a user hierarchy. Such a hierarchy may look like the following:

- Ecological needs for the basic functioning of the catchment.
- Basic human use like drinking, food preparation and personal hygiene (in urban and rural areas).
- Agricultural use for commercial food production.
- Industrial and mining-related uses.
- Sport and recreational uses[89].

The question could be asked which water needs are to be considered as "basic needs" and which are not. It is important to realise that the term "basic need" is not only applicable for human-related needs, but also for other needs as identified in the National Water Act of 1998:

> *"Sustainability and equity are identified as central guiding principles in the protection, use, development, conservation, management and control of water resources. These guidelines recognise the basic human needs of present and future generations; the need to protect water resources; the need to share some water resources with other countries; the need to promote social and economic development through the use of water and the need to establish suitable institutions in order to achieve the purpose of the Act. National Government, acting through the Minister, is responsible for the achievement of these fundamental principles in accordance with the Constitutional mandate for water reform. Being empowered to act on behalf of the nation, the Minister has the ultimate responsibility to fulfil certain obligations relating to the use, allocation and protection of and access to water resources"* (National Water Act 36 of 1998:A-15).

[89] Most of these activities do not consume or degenerate water quality and may be included in the ecological functioning.

According to the National Water Act of 1998 (Act 36 of 1998:A-177), a person has a basic right to use water:

- For the need to take water from any water resource to which the person has lawful access for reasonable domestic household use (this reasonable use includes water used for drinking, food preparation and basic personal hygiene).
- For small gardening purposes and watering of animals that graze on that land within the grazing capacity of the land.
- When stored from runoff from a roof.
- In an emergency situation for human consumption or fire-fighting.
- For indirect recreational purposes like boating.
- For discharging waste or water containing waste and run-off water into a canal, sea outfall or other conduct controlled by another person authorised to undertake the purification, treatment or disposal of waste or water containing waste.

According to Gleick (2000:11), evidence from international law, declarations of governments and international organizations, and state practices, concludes that access to a basic water requirement must be considered a fundamental human right. A formulation appropriate to the existing human rights declarations might be: *"All human beings have an inherent right to have access to water in quantities and of a quality necessary to meet their basic needs. This right shall be protected by law."*

Capacity-sharing accommodates "equity" within the market system by assuming that the functioning of the market for current market participants is fair. Capacity-sharing does, however, also accommodate this fundamentally unfair assumption by using the state as a market participant to care for non-market participants (refer to sections 4.6.2 and 4.6.3 for detail).

4.6.2 An initial allocation for implementing tradable water use rights[90]

After the proper definition of water use rights for adoption within a market regime, but prior to the activation of the market, it is important to have a proper initial allocation of water use rights. This allocation should not be based on market-related powers and characteristics, but rather on alternative[91] allocation criteria, depending on the context of use. How the initial property rights to water are allocated is crucial to the acceptance and success of a water market and the approach will vary according to the country under consideration. In cases where a well-functioning registry of water use rights is in place, it is sufficient to simply register the rights in a newly created property rights register. In cases where the existing property rights registry contains many overlapping property rights (the sum of the water

[90] Recall that this whole section refers to the market of water use rights and not water per se.
[91] These criteria could be past water use patterns, historical context, national socio-economic objectives and ecological objectives.

rights exceeds the available water) it would be better to base the initial allocation on historical use patterns. In cases where there are gross abuses of water use rights, it would be preferable to assign rights based on need or with a reasonable upper limit on irrigation water per hectare. In all cases, it is important to recognise the rights of the poor.

It is, however, important to assess the allocation method used for each current water allocation because it would be fundamentally unfair if owners of current water use rights (who bought the right directly or indirectly via capitalised land prices) were not compensated accordingly for their use rights. In order to avoid potential conflict, a fair and justifiable allocation of water use rights (which is defined in terms of capacity and inflow shares) must be in place before the activation of the water market. It is therefore necessary to obtain a record of all water user patterns and volumes within the catchment area and the water registration effort that was conducted up to January 2001 was the first step in the direction of establishing such an allocation.

The essence of equity concerns lies in the tension between individual and collective interests. Trade-offs exist between the autonomy of individual right holders to lease or sell water to the highest bidder, and collective preferences for predictability and stability in water allocation. Individual farmers negotiate satisfactory prices for their water use rights on their own behalf, but have few incentives to consider third party and community impacts (such as a declining tax base, and multiplier effects on communities). The equity concerns of those who have something to bargain with (money, water use rights, political power or legal power to impose transaction costs) can be reflected in market decisions. However, those with no bargaining power can have little influence on market outcomes.

Within this study, it was assumed that there was an unequal distribution of water use rights in South Africa due to history and past political inequalities. Based on principles of fairness, equity and justice, privileged holders of water use rights must be prepared to sell some of these rights in favour of disadvantaged (mostly small farmers[92]) individuals or groups. These adjustments cannot be made randomly by government, but must be negotiated with the lawful owners. The distribution must recognise both historical uses and the needs of the disadvantaged. Social harmony in rural communities would certainly be promoted by such measures. There needs to be a general acceptance of the fairness of this redistribution of initial water use rights before the water use rights could be quantified and registered and only then can a market for the rights be established (Backeberg, 1997:357).

This study proposes an alternative for accommodating the previous disadvantaged (as well as the "reserve" component) in order to obtain a suitable allocation of water use rights prior to the activation of the market for water use rights[93]. It is the opinion of this study that the water use rights of the "reserve" component as defined in the National Water Act of 1998 should not be managed external to the market in water use rights as current policy-

92 Dudley (1999:559) mentioned that large tradeoffs between small and large irrigation farmers could be the result of irrigation development costs, opportunity costs and price elasticity of demand for irrigation inputs and outputs. However, the size of the potential gains from "spreading the water more thinly" indicate that examination of the potential advantages and disadvantages could well be worthwhile in South Africa. This should be kept in mind when small farmers are empowered from the state.

93 In reality, this initial allocation of water use rights implies the first transactions in the market and the activation of the market.

makers propose (Van Zyl, 2002), because the water use right does not belong to the state and given the sensitivity of water use rights, command and control measures on these rights could lead to conflict. Therefore, the needed water use rights must be obtained in the market from the legal owners of those rights[94]. Given that the state possess water use rights equal to the volume of the "reserve" as specified by the National Water Act, it would not be necessary for the state to buy the water (in the market for water as a physical substance) because all water resources already belongs to the state. In reality, the state must make sure that the water usage of the "reserve component" equals the volume as specified in his water use rights. If this is true, the state could allocate the volume, represented by the water use rights, as the state pleases. It is important to note that no component of the "reserve" will own water use rights since it is the responsibility of the state to provide the needs of the "reserve". However, if an individual small irrigation farmer who received his part of the "reserve" wishes to enter commercial agricultural production, he needs to obtain the additional water use rights in the market for water use rights to be able to buy the additional water for irrigation purposes since commercial agriculture is no longer part of the "reserve". At this stage, capacity-sharing would play an important role in accommodating this individual small irrigation farmer who needs additional water use rights[95]. This argument would hold for all components of the "reserve". The question could be asked whether rent-seeking behaviour will be found at some components of the "reserve" (refer to section 3.9 for a discussion on rent-seeking behaviour).

If the "reserve" component could be accommodated in the market for water use rights, the responsibility of the state should end with the allocation of water to the different components of the "reserve" (according to the allocation of water use rights for each "reserve" component) before the activation of the market for water use rights. (Certainly some water users and uses who failed to apply for water use rights prior to the activation of the market, should still be accommodated by the state, but only if the applied use qualify as part of the "reserve".) Therefore, the state will remain an active market participant for as long as applicants[96] apply for water use rights[97]. The monitoring cost for the state will then be limited to the registration of all applications and approvals of water use rights. Note that the only way for the state to obtain additional water use rights is to participate in the market and buy the use right from the current lawful owner. The state would therefore have no incentive to buy more rights as needed and therefore no "principal agent problem" or "free riding" would exist.

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[94] The identification of the legal owners of water use rights prior to the state intervention, should be based on historical water usage and use patterns.

[95] Small farmers need a certain minimum level of education to actively take part in the workings of capacity-sharing and market activities of water use rights. Therefore, these farmers operating under common property regimes, will need representation by agents or specialists and hence face agency problems. The question therefore arises what incentives or safety features are in place (such as monitoring mechanisms) to ensure that the agent act in the best interest of the principle. This agent related problem could partially be engaged by making use of transparent and participative management processes.

[96] This point actually reflects on the ability of the state to define and identify the "reserve" and the needed amount (volume) of water use rights as accurately as possible.

[97] Note that the state will only be responsible for providing the water which are part of the "reserve" and which comply with the definition as mentioned in the National Water Act of 1998. It would therefore not be possible for a specific person (who qualified as part of the reserve prior to the market activation and who received water from the state) to sell his water use rights in the market for water use rights, because no component of the "reserve" will be in the possession of such rights.

Capacity-sharing accommodates the problem of an initial water allocation by facilitating this transfer from the previous property right structure (under the 1956 National Water Act) to the market for water use rights by making use of "bulk" and "retail" capacity shares. The first task is to determine how large the various "bulk" allocations to the main user groups would need to be, in order to give each approximately the same sequence of flows over an historical period to what they would received before the transition date. These main user groups would include irrigation boards, environmental, stock and domestic, urban and industrial users. After the determination of the transition sizes of bulk capacity shares, a suitable "transition speed" should be considered in moving towards retail capacity-sharing (water markets). The precise speed will be determined by various factors including the social- and political acceptance of capacity-sharing. A feature of capacity is that some irrigators could operate as "retail" shareholders from the start, while others remain sharing in a "bulk" capacity share.

4.6.3 Equitable functioning of the market

People's perspectives regarding fairness within water markets are influenced by the economic conditions and social characteristics of the local area (the local context) (Keenan *et al*, 1999:290). Syme and Nancarrow (1997) studied the determinants of perceptions of fairness in the allocation of water to multiple uses. The focus of their study was to determine whether social-psychological theories of procedural and distributive justice could serve as a basis for evaluating the "equity" or "fairness" of water allocation systems. The study showed that people (individual decision-makers) could make confident judgements on fairness in a wide variety of case studies varying in complexity. They are able to make these judgements *after being presented with detailed information*[98] pertaining to both procedural and distributive aspects of the system under consideration. These fairness judgements seem to relate to group identity especially in the case of environmental users (Syme and Nancarrow, 1997:2151). It was also found that the four measures of fairness[99] were influential in governing the overall fairness of heuristic judgement.

Equity and efficiency are inextricably tied together since the prices used in efficiency analyses depend on the distribution of wealth. Beyond that, many equity considerations have efficiency implications. In some situations, there are genuine efficiency tradeoffs, but in many, building equity into policy design also will enhance efficiency. Therefore, appropriate governing institutions that more closely correspond with the resource systems being governed, help assure appropriate consideration of both efficiency and equity (Howe, 1996:37).

Equity considerations regarding different market participants could be addressed as follows: a market for tradable water use rights consists of two types of participants (buyers and sellers) who represent the demand and supply forces of the market. The relative balance between these two powers will have a dominant influence on the market

[98] The quantification of the effects of asymmetrical information and transaction costs on water price determination will have an indirect effect on the efficient and equitable functioning of the market. Policy measurements that focus on the improvement of the above-mentioned, would therefore also enhance the efficient and equitable functioning of the market.

[99] Being (a) generalised attitudes and philosophies, (b) the importance ratings of philosophical principles, (c) localised attitudes and (d) ratings of importance of allocation to different uses of water.

or "spot" price (not necessarily the "real" value of water) of water use rights. However, any market for a tradable commodity consists of a set of "rules" or "requirements" which all participants within this market must comply with in order to be able to participate actively in the market. These "rules" or "requirements" ensure the fair and equitable functioning of the market. However, some potential participants do not comply with these rules and requirements because of externalities or historical context and the question could be asked whether they should be excluded from the market or not. Given that water qualifies as a basic resource (which implies that it is essential for the sustainment of all life forms), the above-mentioned situation could be regarded as a sensitive and emotional problem. As mentioned in section 4.6.2, the state could become a market participant in the process of providing the "reserve" with the needed amount (volume) of water use rights.

Capacity-sharing has an advantage over administratively planned strategies because each user knows the value of water to other users to a greater extent *before* deciding whether to use a unit of water now or later[100] (Dudley, 1999:97). The capacity-sharing model determines the optimal quantity of water to trade in response to various water prices for given levels of other stated variables and times of the year. This allows a demand curve, conditional to the specific time of the year and state of the system, to be formed. (This demand is only for water already in the reservoir.) With such trading water does not leave the reservoir. Only the title to it is exchanged. The volume one can buy is limited to the empty capacity space available (the difference between the contents and the total capacity of the share) whereas the volume one can sell is limited by the contents of the capacity share. The market price of stored water, relative to its perceived value over the planning horizon, determines quantities traded. (Assuming that the water trader is risk neutral, the perceived value will be the present value over the planning horizon.[101]) From these water sales and purchase decisions, supply and demand curves can be derived for the individual, and the aggregate supply and demand for each specific time and condition in a catchment area. These demand and supply curves could then be used to determine a justifiable measure of the opportunity cost of removing marginal units of water from that specific catchment (given a specific set of conditions) at a specific time.

Therefore, the opportunity cost of water is much more transparent under the capacity-sharing regime, because of the workings of the market mechanism[102]. The market price of water use rights (minus the transaction costs and externalities[103]) serve as an indication of the opportunity cost of water given a specific use. In addition to this argument, Syme and Nancarrow (1997:2151) showed that people could distinguish what is fundamentally fair if presented with suitable information. Capacity-sharing presents suitable decision-making information and should therefore enhance the efficient and equitable functioning of the market.

[100] This characteristic of capacity-sharing engages the problem of asymmetrical information.

[101] However, the problem of discounting and choice of a suitable discount rate still remain. The choice of suitable discount rates remains problematic because different uses have different time spans and different discount rates which complicates the comparison of present values.

[102] There are less uncertainty regarding the supply of water under a capacity-sharing regime.

[103] Not disregarding the difficulties in quantifying these costs.

The accumulation of surpluses while the capacity-sharing system is running seems to be an unavoidable by-product of capacity-sharing (given a stochastic supply). The timing and method of allocation of these surpluses is the responsibility of the reservoir management and needs to be efficient and equitable in order to avoid conflict between users (refer to chapter 3 for a discussion on efficiency sharing and equity sharing within reservoirs).

The above-mentioned discussion focussed on the functioning of the market, but the question could be asked why do agricultural water markets, as observed by Louw and Van Schalkwyk (2000), not release water for use to other sectors in South Africa. This is a relevant question since these releases implies the comparison of opportunity costs between sectors and are currently viewed as an enhancement of equity in water allocation. The *first* possible reason is that the water trades that have taken place are between non-users of water (sleeper rights) and intensive users (Armitage and Nieuwoudt, 1999). The equity objective of releasing water for urban use is therefore at present not being promoted in South Africa and it may take some time before all sleeper rights are activated. The market mechanism will need some time before equity-related objects are promoted. The *second* reason is that the transfer of diverted use (consumptive use plus non-consumptive use) of water in agriculture neglects to attach an opportunity cost to the non-consumptive use of water. Agricultural water is therefore not released for urban use despite the higher opportunity costs involved. The transfer of diverted use provides irrigators with the incentive to irrigate larger areas by adopting technologies that reduce application rates. The result is that consumptive use of water increases and higher water prices thus do not promote water conservation. The only way to overcome this problem is to transfer water at consumptive use-related prices[104]. Capacity-sharing promotes the decentralisation of water management and therefore the pricing of consumptive water use (the individual water user has an incentive to divert only the needed volume of water) and the concept therefore seems viable.

4.7 Summary and the viability of capacity-sharing

Chapter four conceptualised the concept of capacity-sharing within the current transition in South Africa from a supply-oriented water management strategy to a demand-oriented management strategy. An important point of notice should that considerable scope for further research still exists for the integration of supply and demand management by decentralised, individual managers as well as the analysis on this integration. The role of capacity-sharing within this integration should be researched.

The chapter gave three perspectives on demand-oriented water management strategies, form where institutional arrangements to ensure optimal water allocation and security, was discussed. The discussion focussed on some principles, guidelines and potential risks within water policy making. After the theoretical discussion in general, the emphasis shifted to the South African context and some institutional arrangements to meet the changing conditions in South Africa. Thereafter, the concept of capacity-sharing was broad on the scene of decentralised demand-oriented water management where the relevance and possibilities of capacity-sharing within this transition were

[104]Not disregarding the fact that non-consumptive uses may have positive externalities.

identified. The last section mentioned three of the most important problems (a contradiction within the National Water Act of 1998, the problem of an initial allocation of water use rights prior the activation of the market and the problem of an equitable market) experienced within the current South African water policy context and also suggests possible answers derived from the concept of capacity-sharing. In terms of these problems, it seems that capacity-sharing holds some relevant and viable possibilities for South Africa. However, each possibility must be evaluated in its own terms and additional research (as mentioned in chapter 5) will be necessary before any policy-related decisions regarding these possibilities could be made.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study has offered critical and detailed insights into the current water resource management problems faced by South African policy-makers. It should be clear that these problems are complex in nature and that the only way to address them is by making use of multi- disciplinary approaches[105]. The problem of institutional choice was posed as follows: for a particular allocation decision (or class of allocation decisions) what is the "best" institutional arrangement that establishes the processes for the decisions to be made and the mechanisms for the decisions to be implemented? Transaction costs matter, since the structure determines the transaction costs and thereby determines how closely the ultimate resource allocation will approach the hypothetical "efficient and equitable" allocation. Under an assumption that the distribution of transaction costs is important, the policy problem in choosing an institutional structure becomes one of selecting the structure (including property-right regimes, entitlement systems and mechanisms of allocation and reallocation) that minimise transaction costs. However, this study showed that different types or classes of transactions costs have different effects on institutional choice and therefore, the choice of policy becomes a problem of optimising an objective function with components of static transaction costs. There has been a reasonable amount of research regarding this problem, but what is lacking is methodology and experience in *ex ante* estimation of transaction costs of alternative institutional structures.

Water policy could be either supply- or demand-oriented. This study has emphasised that supply-oriented water management strategies perform unsatisfactorily in addressing current efficiency- and equity-driven objectives as described in the 1998 National Water Act. It was assumed that the future water demand will increase between different types of uses and therefore not be dominated by one overwhelming use (irrigation). The result will be that water management will become too complex for public policy and authorities will have to adapt their water institutions by calling on to the water right system for settling conflicts between different water users. However, the combination of water use rights and water rights need a market system to fully develop the advantages of a private property regime. The question of how to make private right-holding users able to contribute to multiple purpose flexibilities (as a result of the diversified demand for water), transferability and versatility was considered. A strong argument is made for demand-oriented approaches where the market mechanism is used in order to accommodate private decision-making in water allocation. This is certainly not a new idea, but what this study has accomplished is to provide the reader with a problem-driven, structured and organised description of the current situation with detailed discussions of the most important problems. This was necessary because the current literature on water management is diverse and bounded by different contexts.

[105] However, when multi-disciplinary approaches are used, measurement and comparison related problems come to the fore.

Some of the criteria for the adoption of a market mechanism have proved to be problematic. Most of these problems originate from the commodity itself (water) as well as past water management regimes. This study has emphasised the measurement-related problems when valuing water in different applications for adoption within the market. A water market could only be developed around water use rights and not water property rights. (This study therefore supports the fact that all water resources inherently belong to the state, while the water use rights do not.)

It is the conclusion of this study that if the state is serious about its current water legislation, urgent consideration should be given to the definition of water use rights as well as the other three problems (namely: a contradiction within the 1998 National Water Act, an initial allocation for implementing tradable water use rights and the equitable functioning of the market) mentioned in chapter 4. Capacity-sharing could be particular helpful in facilitating the initial allocation of water use rights prior to the activation of a market for water use rights. The concept also has several safety features to realise a more equitable functioning market.

The concept of capacity-sharing was identified to assist in the transition from a supply- to demand-oriented water management strategy by keeping potential conflicts between water users at manageable levels. Capacity-sharing accommodates the private decision-maker and seemed a viable option to assist in the definition of water use rights and the development of a market for water use rights. Judging the concept from its developmental stages in 1988 through to its current successes in Australia, it seems worthwhile for further investigation within the South African context. The running of the three sub-models (by means of pilot studies) within the capacity-sharing model should provide sufficient information on which to base decisions regarding the viability of the concept for South African conditions.

If the concept proves to be viable (on the grounds of various case studies), the state could incorporate the concept in the process of decentralisation of water resource management for each catchment. This study therefore suggests that a study should be conducted on the customisation of the capacity-sharing model for South African conditions, but this will only be effective after clarity is received on the three issues (namely: a contradiction within the 1998 National Water Act, an initial allocation for implementing tradable water use rights and the equitable functioning of the market) mentioned in chapter 4.

5.2 Recommended studies

The recommended studies within this section are not necessarily exclusive from one another, because most of them could be grouped into studies addressing broader-defined problems. It is therefore important to conceptualise and delimit the study in order to determine the correct context for the proposed study.

The *first* study suggested by this thesis would engage the problem mentioned in section 4.6.1.[106]. It seems that efficiency and equity related issues are inherently contradictive and bounded to a specific context (situation). This contradiction is complicated further by the inability of measuring techniques to quantify efficiency and equity in comparable units of measurement. It would therefore be impossible to propose a suitable water policy for all contexts of use. The best current research can do is to identify and define a specific context (therefore taking care of the problem of generalisation and too many assumptions) from which to work. The problem of measuring efficiency and equity could then be engaged within the identified context[107] by making use of existing mathematical models. Within the study, particular attention must be paid to transaction cost considerations as one of the major parameters in institutional choice, by looking at both the static[108] and dynamic[109] dimensions of these costs. If some common ground could be identified from where to compare efficiency with equity objectives (within the context of water management) it would be much easier for water policy-makers to prioritise their objectives and adjust water policies accordingly.

Another study (an alternative to the above-mentioned but on the same issue) could focus on the comparison of different contexts of water uses in terms of efficiency, equity and sustainable development by estimating the political risk associated with each context. The study should try to develop broad comparison techniques that could be used to prioritise different contexts of water use. Subsequently, suitable measuring techniques (for comparing efficiency and equity within the specific context) should be developed. It would be irrational to develop a specific measuring technique (like marginal-benefit analysis or cost-benefit analysis) and then try to use the technique within different contexts of water use, because different contexts are not comparable at a specific point in time. The context should therefore determine the measuring technique used and not the other way around. The procedure suggested by Raiffa (1982) and Dinar *et al* (1998) could be used to act as a guideline within this regard.

The *second* study recommended by this thesis should focus on the proper definition of water use rights in order to engage the potential problems of rent-seeking behaviour and adverse selection. The objective of such a study should be the measurement of the viability of water use rights in terms of enforceability, certainty and exclusiveness for adoption within a market for water use rights market. The most important aspect should be the testing of the legitimacy of water use rights for adoption within the market regime.

Another study that could be mentioned under the definition of water use rights is an investigation on what effect the adoption of water use rights will have on the land reform process. The availability of water on a given patch of land had a definite effect on the market value of that piece of land and has therefore been a consideration in the

[106] Recall that this section focused on a basic contradiction between efficiency and equity within the stated objectives of the National Water Act of 1998.
[107] Suggested contexts include commercial agriculture, non-commercial agriculture, urban and industrial use and ecological use.
[108] The static dimension is the conventional application of transaction-cost theory to institutional analysis: selecting an institutional structure to minimise transaction costs of decision-making to achieve particular objectives in resource allocation.
[109] The dynamic dimension relates to the transaction costs incurred in institutional change per se. These costs are manifest as transaction costs and create path-dependencies in institutional developments.

settlement of land disputes. It is still uncertain what effect unbounded water use rights will have on land reform and land prices.

The *third* study recommended by this thesis should focus on the initial allocation of water use rights prior to the activation of a market mechanism. Such a study should answer questions regarding a "fair" distribution of water use rights. (In other words, what exactly is meant by a "fair" distribution?) This thesis proposes a few ways of dealing with this transition phase, but is insufficient to make policy recommendations. Within such a study, equity related measurements must be developed to deal with fairness within the market.

The *fourth* study recommended by this thesis should focus on the detailed modelling of the three sub-modules (as mentioned in chapter 3) of the capacity-sharing model within the context of an equitable functioning market. This could only be done by means of a case study within a selected area and care should be taken not to generalise from that area (context) to the whole of South Africa. The study should answer questions regarding the viability of capacity-sharing within a specific context. Such a study could also be seen as a "pilot study" for each target area where water policy-makers are planning to implement elements of capacity-sharing.

The *fifth* study proposed by this thesis should focus on the ability of capacity-sharing to withstand rent-seeking behaviour as mentioned in section 3.9. This study mentioned two arguments against rent-seeking behaviour in a capacity-sharing regime, but a detailed study is necessary to clarify potential problems that could result from rent-seeking behaviour. The focus should be on the transparency of the market mechanism, the identification, categorisation and quantification of opportunity costs and externalities regarding water markets, and the definition of water use rights (the second recommended study as mentioned above, should compliment this study) in order to neutralise all forms of windfall gains such as mentioned in section 3.9. Rent-seeking behaviour is of particular importance, because if opportunistic individual decision-making should have a substantial effect on the management of a capacity-sharing system, a principal agent problem would be the result where there would be a great number of principals and only one agent (the state).

The *sixth* study proposed by this thesis should focus on potential principal-agent problems. Specific problems foreseen by this thesis includes agency related problems regarding the minimum level of education needed by capacity share holders to fully make use of the advantages offered by capacity-sharing. Agency related problems would be likely in cases where a "bulk" capacity share is managed under a common property regime. Another aspect of capacity-sharing that is prone to principal agent problems is the price of water per se. The question could be asked what incentives does the state have for not rising water prices to inefficient and inequitable high levels. Therefore, the proposed study should focus on the role of capacity-sharing within the context of a market for water per se (and not for the water use rights) for supplying incentives for not rising water prices.

A *seventh* study could be added to these proposed studies, and the emphasis should be on the role of water banking within a capacity-sharing regime addressing rent-seeking behaviour and principal-agent problems as identified in the study. Such a study will focus on the administration and management of the reservoir and should be done with reference to principles of equity. The state would find such a study particularly helpful in managing water reservoirs.

"Nobody makes a greater mistake than he who did nothing because he could do only a little."

- Edmund Burke

REFERENCES

Abrams, L. (2000) *Water Resources Management Reform Process.* The African Water Page, *http://www.thewaterpage.com/policy_development.com*

Armitage, R.M. (1999) *An economic analysis of surface irrigation water rights transfers in selected areas of South Africa.* Report to the WRC, Report No 870/1/99, University of Natal, Pietermaritzburg.

Armitage, R.M and Nieuwoudt, W.L. (1999) *Discriminant analysis of water trade among irrigation farmers in the lower Orange River of South Africa.* Agrekon, 38(1):18-45.

Arriaza, M., Gomez-Limon, J.A. and Upton, M. (2002) *Local water markets for irrigation in southern Spain: A multi-criteria approach.* Australian Journal of Agricultural and Resource economics, 46(1):21-43.

Backeberg, G.R. (1994a) *Die politieke ekonomie van besproeiingsbeleid in Suid Afrika.* Unpublished PhD thesis, University of Pretoria, Pretoria.

Backeberg, G.R. (1994b) *'n Polities-Ekonoiese benadering tot aanpassing van waterinstitusies in besproeiingslandbou.* Agrekon, 33(4):225-241.

Backeberg, G.R. (1997) *Water institutions, markets and decentralised resource management: Prospects for innovative policy reforms in irrigated agriculture.* Presidential Address, 35th annual Conference of the Agricultural Economics Association of South Africa, Osner Conference Centre, East London.

Backeberg, G.R. (2002) *Personal communication.* Water Research Commission, Pretoria.

Bardhan, P. (1989) *The economic theory of agrarian institutions.* Oxford University Press, New York.

Bauer, C.J. (1997) *Bringing water markets down to earth: The political economy of water rights in Chile, 1976-1995.* World Development, 25(4):639-656.

Beroggi, G.E.G. (1998) *Decision-making in policy management: An introduction to the analytic concepts.* Kluwer Academic Publisers, London, UK.

Braden, J.B. (1995) *Changing agricultural property rights for the twenty first century: Discussion.* American Journal of Agricultural Economics, 77:1204-1206.

Brennan, D. and Scoccimarro, M. (1999) *Issues in defining property rights to improve Australian water markets.* The Australian Journal of Agricultural and Resource Economics, 43(1):69-89.

Bromley, D.W. (1982a) *Land and water problems: An institutional perspective.* American Journal of Agricultural Economics, 64:834-844.

Bromley, D.W. (1982b) *Improving irrigated agriculture.* World Bank Staff Working Paper No 532, The World Bank.

Bromley, D.W. (1989) *Institutional Change and Economic Efficiency.* Journal of Economic Issues, 23(3):735-759.

Bromley, D.W. (1990) *The ideology of efficiency: Searching for a theory of policy analysis.* Journal of Environmental Eonomics and Management, 19:86-107.

Bromley, D.W. (1995a) *Natural resource issues in environmental policy in South Africa.* Land and Agricultural Policy Centre, Wits University.

Bromley, D.W. (1995b) *Property rights and environmental conflicts in South Africa.* Working Paper 14, Land and Agriculture Policy Centre, Johannesburg.

Buchanan, L.M. (1989) *Liberty, market and the state: Political economy in the 1980's.* Wheatsheaf Books, Brighton.

Bush, D.B., Martin, W.E. and Brown, T.C. (1987) *Do water market prices appropriately measure water values?* Natural Resource Journal, 27(3):617-651.

Capra, F. (1997) *The web of life.* Harper-Collins Publishers, London, UK.

Capra, F. (2002) *The hidden connections.* Harper-Collins Publishers, London, UK.

Challen, R. (2000) *Institutions, transaction costs and environmental policy : Institutional reform for water resources.* Edward Elgar Publishers, Cheltenham, UK.

Cilliers, F.P. (1994) *Modelling Complexity.* Unpublished PhD thesis, University of Stellenbosch, Stellenbosch.

Colby, B.G. (1987) *Do water markets work? – Market transfers and trade-offs in the South western states.* Water Resource Research, 23(7):1113-1122.

Colby, B.G. (1990) *Transaction costs and efficiency in Western water allocation.* American Journal of Agricultural Economics, 72(5):1184-1192.

Colby, B.G., Crandall, K. and Bush, D.B. (1993) *Water right transactions: Market values and price dispersion.* Water Resource Research, 29(6):1565-1572.

Connor, J.D. and Perry, M. (1999) *Analysing the potential for water quality externalities as the result of market water transfers.* Water Resource Research, 35(9):2833-2839.

Cummings, R., Dinar, A. and D. Olson, (1996) *New Evaluation Procedures for a New Generation of Water-Related Projects*. World Bank Technical Paper No 349, The World Bank, http://www.worldbank.org

Denzin, N.K. and Lincoln, Y.S. (1994) *Handbook of qualitative research*. SAGE publications, London, UK.

Dinar,A. and Latey, J. (1991) *Agricultural water marketing: Allocative, efficiency and drainage reduction*. Journal of Environmental Economics and Management, 20:210-223.

Dinar, A. and Lee, D.J. (1995) *Review of integrated approaches to river basin planning, development and management*. Policy Research Working Paper No 1446, The World Bank, http://www.worldbank.org

Dinar, A. and Saleth, R.M. (1999) *Water challenge and institutional response: A cross country perspective*. Policy Research Working Paper No 2045, The World Bank, http://www.worldbank.org

Dinar, A., Balakrishnan, T.K. and Wambia, J. (1998) *Politiacl economy and political risks of institutional reforms in the water sector*. The World Bank, http://www.worldbank.org

Dudley, N.J. (1988a) *A Single decision-maker approach to irrigation reservoir and farm management decision-making*. Water Resources Research, 24(5):633-640.

Dudley, N.J. (1988b) *Volume-sharing of reservoir water*. Water Resources Research, 24(5):641-648.

Dudley, N.J. (1990a) *Urban capacity-sharing-An innovative property right for maturing water economies*. Natural Resources Journal, 30(3):381-402.

Dudley, N.J. (1990b) *Economics of irrigation water allocation under uncertain conditions*. Centre for Ecological Economics and Water Policy, University of New England, Armidale, NSW, Australia.

Dudley, N.J. (1990c) *Alternative institutional arrangements for water supply probabilities and transfers*. Centre for Ecological Economics and Water Policy, University of New England, Armidale, NSW, Australia.

Dudley, N.J. (1992) *Water allocation by markets, Common property and capacity-sharing: Companions or Competitors?* Natural Resources Journal, 32(4):757-778.

Dudley, N.J. (1994) *An innovative arrangement with the potential of improving the management of international water resources*. Centre for Ecological Economics and Water Policy, University of New England, Armidale, NSW, Australia.

Dudley, N.J. (1999) *Integrating environmental and irrigation management in large-scale water resource systems. In: Modelling change in integrated economic and environmental systems. Ed.: Mahendrarajah, S., Jakeman, A.J. and McAleer, M.* John Wiley & Sons Publishers.

Dudley, N.J. (2002) *Personal communication* Centre for Ecological Economics and Water Policy, Armidale, NSW, Australia.

Dudley, N.J. and Bryant, M.J. (1995) *The concept of capacity-sharing and responses to questions posed on implication for irrigators.*Centre for Ecological Economics and Water Policy, University of New England, Armidale, NSW, Australia.

Dudley, N.J. and Musgrave, W.F. (1988) *Capacity-sharing of water reservoirs.* Water Resources Research, 24(5):649-658.

DWAF (1996) *The philosophy and practice of integrated catchment management: Implications for water resource management in South Africa.* WRC Report No TT 81/96, Pretoria.

DWAF (1997) *White Paper on Water Policy.* Pretoria.

DWAF (1998) *A Strategic plan for the Department of Water Affairs and Forestry to Facilitate the Implementation of Catchment Management in South Africa.* WRC Report No KV 107/98, Pretoria.

DWAF (1999) *Establishment of pricing strategy for water use charges in terms of section 56(1)of the National Water Act of 1998.* Government Gazette 20615, Pretoria.

DWAF (2000) *Implementation guidelines for water conservation and water demand management in Agriculture.* Directorate of Water Conservation and Demand Management, Pretoria.

DWAF (2001) *A major water plan for the Cape Metro.* http://www.dwaf.gov.za/Projects/Capewaterplan.htm

Easter, K.W.; Dinar, A. and Rosegrant, M. (1998) *Markets for water: Potential and performance.* Kluwer Academic Press, Massachusetts.

Eggertsson, T. (1997) *The Old Theory of Economic Policy and the New Institutionalism.* World Development, 25(8):1187-1203.

Feichtinger, G. (2001) *Environmental policy design and the economics of crime: Some analogies in intertemporal optimisation. In: Models, methods and decision support for management. Ed.: Kischka, P., Leopold-Wildburger, U., Möhring, R.H. and Radermacher,* F.J. Springer-Verlag Publishers, Deutschland.

Gakpo, E.F.Y. and Du Plessis, L.A. (2001) *Alternative water institutional framework to meet the changing agricultural environment in South Africa.* Paper delivered at the 39th annual conference of the Agricultural Economic Association of South Africa, Champagne Sports Resort, Natal.

Gakpo, E.F.Y., Du Plessis, L.A. and Viljoen, M.F. (2001) *Towards institutional arrangements to ensure optimal allocation and security of South Africa's water resources.* Agrekon, 40(1):87-103.

Gleick, P. (2000) *The Human Right to Water.* Water Policy, 1(5):487-503.

Goodstein, E.S. (1999) *Economics and the environment.* Prentice Hall, New Jersey.

Groenewald, J. (1998) *Irrigation policy. In: Agricultural Policy Reform in South Africa. Ed.: van Rooyen, J.* Francolin Publishers, Cape Town.

Gujarati, D. (1992) *Essentials of econometrics.* McGraw-Hill Publishers, New York.

Haggard, S., Lafay, J.D. and Morrisson, C. (1995) *The political feasibility of adjustment in developing countries. In: Political Feasibility of Adjustment, Ed.: Christian Morrisson,* Development Centre of the Organization for Economic Co-operation and Development, Paris, France.

Hanley, N. (1995) *Controlling water pollution using market mechanisms: Results from empirical studies. In: Turner, R.K. Sustainable environmental economics and management.* Belhaven Press, London.

Hawken, P. (1993) *The ecology of commerce.* Harper-Collins Publishers, New York.

Hearne, R.R. and Easter, K.W. (1997) *The economic and financial gains from water markets in Chile.* Agricultural Economics, 15:187-199.

Hosking, S.G. (2002) *The pricing of water for conservation projects in South Africa.* Unpublished paper, Forum for Economics and Environment Annual Conference at the Waterfront, Cape Town

Howe, C.W. (1996) *Water resource planning in a federation of states: Equity v/s Efficiency.* Natural Resources Journal, 36:30-57.

Howe, C., Schurmeier, D. and Shaw, W.D. (1986) *Innovative approaches to water allocation: The potential of water markets.* Water Resources Research, 22:439-445.

James, D. (1993) *The application of economic techniques in environmental impact assessment.* Kluwer Academic Publishers, Netherlands.

Jennings, D and Wattam, S (1998) *Decision-making: An integrated approach.* Financial Times, Pitman, London, UK.

Johansson, R.C. (2000) *Pricing irrigation water: A literature survey.* World Bank Report No WPS 2449, http://www.worldbank.org.

Karaan, M. (2002) *The new institutional economics in agribusiness development and empowerment: Theoretical approaches to key development challenges.* Invited paper delivered at the 40th annual conference of the Agricultural Economic Association of South Africa, President Hotel, Bloemfontein.

Keenan, S.P., Krannich, R.S. and Walker, M.S. (1999) *Public perceptions of water transfers and markets: Describing differences in water use communities.* Society and Natural Resources, 12:279-292.

Kherallah, M. and Kirsten, J.F. (2002) *The new institutional economics: Applications for agricultural policy research in developing countries.* Agrekon, 41(2):111-134.

Kirsten, J.F. (2002) *Presidential address.* delivered at the 40th annual conference of the Agricultural Economic Association of South Africa, President Hotel, Bloemfontein.

Lipsey, R.G. and Courant, P.N. (1996) *Economics.* Harper-Collins Publishers, New-York.

Livingston, M.L. (1993) *Normative and positive aspects of institutional economics: The implications for water policy.* Water Resources Research, 29(4):815-821.

Livingston, M.L. (1995) *Designing water institutions: Market failures and institutional response.* Water Resources Management, 9:203-220.

Louw, D.B. (2001) *Modelling the potential impact of a water market in the Berg river basin.* Unpublished PhD thesis, University of the Orange Free State, Bloemfontein.

Louw, D.B. and Van Schalkwyk, L.A. (2000) *Water markets an alternative for central water allocation?* Unpublished paper delivered at the 38th annual conference of the Agricultural Economic Association of South Africa, Sun City.

Louw, D.B. and Van Schalkwyk, L.A. (2001) *The impact of transaction costs on water trade in a water market allocation regime.* Unpublished paper delivered at the 39th annual conference of the Agricultural Economic Association of South Africa, Champagne Sports Resort, Natal.

Lund, J.R. (1993) *Transaction risk versus transaction costs in water transfers.* Water Resource Research, 29(9):3103-3107.

McCormick, Z. (1994) *Institutional barriers to water markets in the West.* Water Resources Bulletin, 30(6):953-961.

Moilanen, M. and Schultz, C. (2002) *Water pricing reform, economic welfare and inequality.* Unpublished paper, Forum for Economics and the Environment Annual Conference held at the Waterfront, Cape Town.

National Water Act (1998) *National Water Act No. 36 of 1998.* Statutes of the Republic of South Africa-Water, Pretoria.

Nieuwoudt, W.L. (2000) *Water market institutions: Lessons from Colorado.* Agrekon, 39(1):58-67.

Pigram, J.J. (1993) *Property rights and water markets in Australia: An evolutionary process toward institutional reform.* Water Resource Research, 29 (4):1313-1319.

Raiffa, H. (1982) *The Art and Science of Negotiation*. Harvard University Press, Cambridge.

Randall, A. (1983) *The problem of market failure.* Natural Resource Journal, 23:131-148.

Rosegrant, M.W. and Binswanger, H.P. (1994) *Markets in tradable water rights: Potential for efficiency gains in developing country water resource allocation.* World development, 22(1):1613-1625.

Saleth, R.M. (1996) *Water institutions in India: Economics, Law and Policy.* Commonwealth Publishers, New Delhi.

Sampath, R.K. (1992) *Issues in irrigation pricing in developing countries.* World Development, 20(7):967-977.

Scott, A. and Coustalin, G. (1995) *The evolotion of water rights.* Natural Resources Journal, 35(4):821-978.

Syme, G. and Nancarrow, B.E. (1997) *The determinants of perceptions of fairness in the allocation of water to multiple uses.* Water resource research, 33(9):2143-2152.

Tietenberg, T. (1994) *Environmental economics and policy.* Harper-Collins College Publishers, New York

Thobani, M. (1997) *Formal water markets: Why, When, and How to introduce tradable water rights.* The Word Bank Observer, 12(2):161-179.

Tisdell, J. (1996) *The price of irrigation water.* Economic Analysis and Policy, 26(1):95-103.

Tisdell, C. and Roy, K. (1997) *Good governance, property rights and sustainable resource use.* The South African Journal of Economics, 65(1):28-41.

Van Zyl, G. (2002) *Personal communication*. Department of Water Affairs and Forestry, Bellville.

Van Zyl, J. and Vink, N. (1997) *The effect of water policies on the farm sector in the Western Cape.* Agrekon, 36(4):573-581.

Van Zyl, J., Kirsten, J. and Binswanger, H.P. (1996) *Agricultural land reform in South Africa – Policies, Markets and Mechanisms.* Oxford University Press, U.K.

Vaux, H.J. (1986) *Economic factors shaping Western water allocation.* American Journal of Agricultural Economics, 68:1136-1142.

Vaux, H.J. and Howitt, R. (1984) *Managing water scarcity: An evaluation of inter-regional transfers,* Water Resources Research, 20:785-792.

Viljoen, M.F., Dudley, N.J. and Gakpo, E.F.Y. (2000) *A methodological perspective on valuing water: A comparison between* *linear programming and stochastic dynamic programming*. Paper delivered at the 38th annual conference of the Agricultural Economic Association of South Africa, Sun City.

Vink, N. (2000) *Agricultural policy research in South Africa: Challenges for the future.* Agrekon, 39(4):432-471.

Winnpenny, J. (1997) *Water policy issues.* Water Resource Occasional Papers, Occasional Paper No 2, Department for International Development, UK, http://www.difid.gov.uk

World Bank (2002) *World development report.* http://worldbank.org