THE ECONOMICS OF GROUNDWATER USAGE:

The importance of intrinsic value as a basis for sustainable management

Report to the
WATER RESEARCH COMMISSION
by
ECONOMIC PROJECT EVALUATION (PTY) LTD

WRC Report No 639/1/96

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THE IMPORTANCE OF INTRINSIC VALUE AS A BASIS FOR SUSTAINABLE MANAGEMENT

FINAL REPORT

Prepared for the

WATER RESEARCH COMMISSION

by

Economic Project Evaluation (Pty) Ltd

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THE STEERING COMMITTEE

The research in this report emanated from a project funded by the Water Research Commission entitled:

The Economics of Groundwater Usage: The Importance of Intrinsic Value as a Basis for Sustainable Management

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The Steering Committee responsible for this project consisted of the following persons:

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The financing of the project by the Water Research Commission and the contributions of of the members of the Steering Committee and their representatives are gratefully acknowledged.

THE PROJECT TEAM

In view of the diverse nature of the inputs required to put this project report together, use was made of a tightly-knit team of specialists drawn from many disciplines. Each team member was able to use unique skills to bring an added insight to this report. Thanks are due to all team members, without whose dedication and expertise this research report could not have been produced.

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EXECUTIVE SUMMARY

The specific aims of the project as outlined in the brief are as follows:

(1) To undertake a survey of ground water valuation approaches adopted in other countries, with particular reference to their acceptability, practicality and contribution to improved aquifer management.

(2) To estimate the economic value of ground water, to selected user sectors, and to estimate the likely economic impact of a sub-optimal water supply resulting from poor aquifer management.

(3) To develop standard methodologies for determining the value of ground water.

(4) To investigate the potential of economic-based incentives to promote a more self-regulatory, localised approach to ground water management.

The first aim produced two deliverables, a literature review and a comparative review of the supporting legislation under which selected ground water systems are managed. The second aim provided sample data for the development and testing of economic evaluation methodologies. The data was derived by the examination of five case studies. These were:

- **Indaleni**

  Indaleni is a sprawling peri-urban settlement in the Natal Midlands near the small town of Richmond. The population is about 14 000, and residents have access to three sources of water:
  - springs;
  - small streams and the Illovo River; and
  - boreholes.

- **Verwoerdburg**

  In the district served by Verwoerdburg Town Council three areas receive a mixture of groundwater and surface water provided by the Rand Water Board. No limits to groundwater extraction exist in the area, except where there is a possibility of sinkholes occurring.

- **Dendron**

  Dendron is an area some 60 km north of Pietersburg, in the Northern Province, and in the centre of the Doringlaagte drainage basin. The climate is semi-arid.

  Water supply in the area comes from both surface and ground water usage. Surface water is, however, variable, made available by a small dam construction mainly for agricultural use of stored water. Agriculture is the main economic activity of the area.

- **De Aar**

  Is a town situated in the Northern Cape Province - again in a semi-arid location. This is a particularly interesting case in so far as a market exists for water, the only one known in South Africa. Essentially the de Aar municipality purchases groundwater from farmers to augment the town's domestic supply.

- **Atlantis**

  Atlantis lies some 45 km north of Cape Town, close to the West Coast and falls within the economic fringe of Greater Cape Town. It is supplied with water from two groundwater aquifers located between the existing town and the coast.

The report is composed of eight parts. The introduction comprises Part one. Part Two contains an international literature survey regarding ground water management experiences in numerous countries around the world.

Integral to an economic analysis of ground water management regimes is an insight into its legal status and the rights attached to its use. The legal overview in Part Three examines these issues within the context of the interim constitution and presents recommendations for policy and legislative reform of ground water law.

Part Four provides an overview of the economics of ground water valuation in South Africa. It presents a framework for the use of economic methodologies in assigning values to ground water resources that will potentially lead to their management on a prudent and sustainable basis. Four methodologies for economically valuing groundwater, based on classical economic theory are developed for use in the case studies, and are discussed in this section. Unfortunately data availability did not allow them to be implemented in all case studies. It was therefore necessary to develop a further approach which is able to use readily available data, and this is discussed in Part Five.

The five case studies undertaken in various parts of the country, and mentioned above, are summarised in Part Five. These serve to support the broad situation and policy analysis with actual examples, as well as providing sample data for the development and testing of economic valuation methodologies. Groundwater values for the five case studies are also determined in this section.

Economic incentives for ground water management are presented in Part Six.

Part Seven contains the conclusions of the report and Part Eight presents recommendations for further research.

Six appendices are included at the end of the report.

Appendix One contains the original project brief and the proposal submitted by Economic Project Evaluation (Pty) Ltd.

Appendices two to six contain the complete case studies which are summarised in Part Five.

The objective of the international literature survey is to review the more recent publications on ground water economics and its application in different regions of the world. The majority of the literature surveyed considers the North American situation and hence the examples and applications are discussed in that context.

One of the most crucial aspects arising from the survey is that it is very difficult to divorce ground water from surface water, and indeed other water sources. This is because ground water supply is highly dependent on recharge from other sources.

Ground water can however, play a stabilising role in the situation where surface water supplies are uncertain. Where pumped ground water is used in conjunction with surface water for irrigation, it serves two main purposes: to increase the quantity of supply (and therefore the area of land being irrigated) and to mitigate fluctuations in the water supply. The latter is referred to as the stabilisation factor (Tsur (1990)). There are, of course, disadvantages to developing groundwater resources. In the case of urban and industrial water supply, over-pumping (especially where the aquifer recharge rate is low) may lead to land subsidence, intrusion of salt water and consequently ground water deterioration (Neher (1990)).

With respect to the recharge rate the literature made clear that although groundwater is rechargeable, it must not be considered limitless. The literature contains numerous discussions of groundwater-related issues pertaining to the joint use of aquifers with a limited recharge rate, i.e., the common pool problem. A particularly good review of this topic is to be found in Neher (1990).

So far as economically valuing groundwater is concerned, the literature survey had limited success. Rather, it was found that when this value was addressed, it was done so in qualitative terms. The literature emphasises, however, that the price of water should reflect its true economic value in order to guarantee conservation and efficient use. It is normally recommended that water be priced at its marginal cost in accordance with the rules applied to economic efficiency criteria.

The literature also suggests that there are a number of economic issues related to ground water development which have to be considered by policy makers and technical specialists in developing countries. Such issues include factors affecting the costs of ground water, the economics of conjunctive use and conservation, and public vs. private development of the resource. In this respect the literature emphasises that users of water, whether industrial, agricultural or municipal, must be made aware of the fact that neither groundwater nor surface water is a free public good, but that the supply entails costs which must be borne by someone (i.e., other individuals, the environment or future generations).

Fano and Brewster (1989) point out that the challenge facing water managers for dealing with the problem of sustainable groundwater use is that of finding a reasonably stable combination of regulation and pricing which will lead to efficient water use, capital recovery as well as equitable distribution of benefits.

The literature indicates that there are two main measures that a government can employ to promote sustainable development of ground water resources. These are of an institutional and fiscal nature. Institutional measures may take the form of regulations and rationing, i.e. the non-market allocation of water. Institutions have a major role to play in controlling the development of regional water resources system. The historical trend has been towards a dichotomy of water resource development where ground water was managed and developed by individuals on a small scale, and where public investment targeted large-scale surface water projects. Buras and Nunn (1987) emphasise the need to overcome this dichotomy in order to utilise and develop regional water resources more effectively. They call for combined and co-ordinated management of surface and ground water resources.

It is suggested in the literature that water marketing is a method that may be utilised to secure efficient and equitable allocation of water resources from an aquifer. Water marketing is essentially the creation of markets for water resources, where buyers and sellers can trade water quotas. An important consideration in South Africa, however, is the community value of ground water in relation to water marketing. In South Africa many communities, particularly rural communities, have depended on ground water supply for many years. Should ground water marketing be introduced as one means of assuring a more efficient allocation of ground water resources in South Africa, the implications for rural communities, if not considered carefully may be profound.

So far as the economics of groundwater conservation is concerned, private development of ground water resources usually gives the immediate advantage of high operating efficiencies, coupled with the incentive to conserve ground water. However, uncontrolled private development can lead to very high investment per unit of area. This may be especially crucial in a situation where more than one private developer draws water from a common aquifer (c.f., Neher, 1990).

The economic impact of deteriorating groundwater quality was debated in the literature and salinisation was found to be important, in particular with respect to agriculture.

The project reviewed current water law in South Africa with respect to groundwater and found that South African water law is currently in transition. A process to redraft the Water Act has recently been initiated by the Department of Water Affairs and Forestry. In this regard, the Water Laws Rationalisation and Amendment Act 32 of 1994, has been passed as has a white paper on water supply and sanitation policy.

The historical development of South African water law is characterised by a fluctuating focus. It originally had a public law orientation (concerned with public ownership and public rights), which later changed to a private law orientation (concerned with private rights to water) and eventually, with the passing of the Water Act in 1956, it once again assumed a public law focus.

It is a commonly held perception in South Africa that all ground water is private and thus capable of individual ownership. This section of the report challenges the perception that all ground water is private and capable of individual ownership. It further challenges the notion that an individual's right to the use of ground water is a right in property protected by the constitution. By questioning these assumptions, the section concludes that the reform of ground water law, which would involve increased state control over the resource would in fact not be a dramatic departure from the current legal position and would furthermore not subject the state to increased liability for compensation or fall foul of the constitutional protection of rights in property.

The study also developed a framework for valuing groundwater. It was shown that groundwater economic value (usually signalled by its price) is a necessary, although not the only, indication of its importance to society.

It was pointed out that the economic value of groundwater is a derived value and depends upon its utility to human beings. As the South African economy grows with increased industrial development and a burgeoning population, new demands will be created for ground water and conflict between end-users can be expected to increase.

The report points out that the economic value of a commodity (including ground water) is underpinned by two assertions. These are that economic value depends on the preferences held by individuals, and that such value can be influenced by an individual's limited means and the resource's scarcity.

The report mentions that market prices reflect economic values by and large. Here a buyer exchanges the prospective gain from one good or service against the purchasing power represented by the price of the good or service. If a purchaser's willingness-to-pay is greater than the seller's willingness to accept compensation, a transaction can normally follow.

It was emphasised that markets however, only operate smoothly when suitable institutional conditions are in place, e.g., property rights to goods and services must be secure. Further, water usually violates the conditions for smoothly operating markets and is often considered to be a "special" good due, no doubt, to its life giving properties. The analytical framework for economically valuing groundwater developed in the study was based upon the trade-offs made by different consumers as represented by the demand curve and the concept of consumer surplus. Four methods of valuing groundwater were discussed. These are:

1. Utilising a price elasticity of demand for groundwater,
2. Residual imputation,
3. Alternative cost techniques, and
4. Value added.

It was pointed out in the report that each of these techniques for estimating the value of groundwater has problems attached to it which make the application sometimes difficult and signals that caution must be used when choosing a technique for a particular application.

The authors of the report believe that the Residual Imputation method of valuing groundwater has the most to commend it as a long-run public or private valuation technique. Because of the data-gathering problems the methods of valuing groundwater mentioned above could not generally be implemented in the case studies. An alternative method of valuing groundwater based upon the premise that water can be valued by measuring the value of total output of a particular region was therefore used. Adopting this approach the value of the groundwater in the different case studies was calculated. These values are shown in the table below.

Case Study	Value of Groundwater	Methodology	Comments
Atlantis	R624 million	imputed valuation	Value of total groundwater used per annum
Dendron	R13,587 million	imputed valuation	Value of total groundwater used per annum
De Aar	R25.46 million	imputed valuation	Value of total groundwater used per annum
Indaleni	R0,25 / 25litres ≡ R10,00 / m^3	Survey of willingness-to-pay	
Verwoerdburg	R1,00 / m^3	Proxy price elasticity of demand	

The use of economic instruments for improved groundwater management was also addressed in this study. It is suggested that the most promising of these instruments are:

- levies, taxes and charges,
- pricing policies,
- groundwater markets, and
- tradable permits.

The practical application and likely benefits of using these instruments was also commented upon.

The report also made recommendations for further research. These recommendations were, with one exception, concerned with economic analysis *per se*, and ranged from data-gathering exercises for clarifying certain issues concerning groundwater management to those in which the data would be used for forecasting the future demand for groundwater.

The exception was the identification of the need to initiate an educational campaign to make the general public aware of the value and characteristics of groundwater and its place in the water economy of South Africa.

PART ONE

INTRODUCTION

1. INTRODUCTION

1.1 PROJECT BACKGROUND

The decision to improve water management systems is invariably prompted by the reduced utility value of the water supply. This is often a result of either a reduction in the assurance of supply or a decline in water quality. Although the utility value of water is seldom calculated with any degree of preciseness, the response from consumers claiming to be disadvantaged by its decline, is usually sufficient to convince water managers of the need to allocate money and manpower to improve its management.

Unfortunately, reductions in the utility value of South Africa's ground water are unlikely to lead to increased aquifer management. There are three primary reasons for this:

Firstly, ground water in South Africa is essentially Private Water, and is therefore the property of the owner of the land under which it occurs. The limited involvement of the State in the management and utilisation of ground water has tended to discourage users from seeking State assistance when aquifer management problems have arisen. Where the State has adopted a more assertive approach to ground water management (i.e. the declaration of Ground Water Control Areas) regulatory measures have been found to be expensive and impractical to enforce effectively. Where ground water users have sought the support of the courts to improve aquifer management, this has also proved to be expensive, and often fruitless, due to the inconclusive nature of ground water dynamics, especially in South Africa's secondary fractured rock aquifers. Thus, the current legal status of ground water encourages ad hoc, fragmented approaches to its management, and the prevalence of self-interest in its utilisation.

Secondly, the State's past emphasis on surface water-based solutions to water supply problems, has tended to undermine the potential role and value of ground water in meeting the nation's needs. Although the recent decline in cost-effective and affordable surface water supply options has, to some extent, re-affirmed the importance of ground water, many municipalities and irrigators still view their ground water as a temporary and inferior supply requiring replacement by a surface water supply the moment problems are experienced. Lobbying to this effect continues unabated.

Thirdly, the shortage of holistic ground water management plans which function across individual property boundaries, and which are capable of demonstrating the full potential of properly managed aquifers, has meant that users lack confidence in the ability of ground water to meet their long term needs. Such scepticism is common throughout both First and Third World communities in South Africa.

Apart from the obvious legal problems, the central issue which emerges from the above reasoning is that there is insufficient value placed on ground water by those people who use it and depend on it. If an aquifer were to be correctly valued, users and water managers alike, may review their perception of its role as a water supply, and may even be prompted to address the legal constraints which hamper its efficient management. Economists have shown that the level of management accorded a resource is related to the value society attaches to it. Thus, the more realistic valuation of ground water will establish a justifiable basis for its appropriate utilisation and management.

1.2 AIMS AND OBJECTIVES OF THE PROJECT

The full project brief is incorporated in Appendix A. The primary goal of the project is to develop methodologies for placing a value on groundwater which is proportional to the importance of the use to which it is put.

This goal can be broken down as follows:

Aim 1. Survey of overseas groundwater valuation approaches and related management systems.

Aim 2. Determination of the economic value of groundwater through case studies

Aim 3. Development of groundwater valuation methodologies.

Aim 4. Assessment of the potential of economic instruments to contribute to groundwater management.

The project is largely exploratory in nature and consequently, with the exception of the data capture work, it is structured to take the form of a desk study. A series of case studies is undertaken in order to reflect several different examples of groundwater development and usage in South Africa.

1.3 REPORT STRUCTURE

The report is composed of eight parts. This introduction comprises Part one. Part Two contains an international literature survey regarding ground water management experiences in numerous countries around the world.

Integral to an economic analysis of ground water management regimes is an insight into its legal status and the rights attached to its use. The legal overview in Part Three examines these issues within the context of the interim constitution and presents recommendations for policy and legislative reform of ground water law.

Part Four provides an overview of the economics of ground water valuation in South Africa. It presents a framework for the use of economic methodologies in assigning values to ground water resources that will potentially lead to their management on a prudent and sustainable basis. Four methodologies based on classical economic theory are developed for use in the case studies, and are discussed in this section. Unfortunately data availability did not allow them to be fully implemented in all case studies. It was therefore necessary to develop a further approach which is able to use readily available data, and this is discussed in Part Five.

Five case studies undertaken in various parts of the country are summarised in Part Five. These serve to support the broad situation and policy analysis with actual examples, as well as providing sample data for the development and testing of economic valuation methodologies. Groundwater values for the five case studies are also determined in this section.

Economic incentives for ground water management are presented in Part Six.

Part Seven contains the conclusions of the report and Part Eight presents recommendations for further research.

Seven appendices are included at the end of the report.

Appendix One contains the original project brief and the proposal submitted by Economic Project Evaluation (Pty) Ltd

Appendix Two contains the proceedings and analysis of the workshop held in at the Development Bank of Southern Africa in August, 1994.

Appendices three to seven contain the complete case studies which are summarised in Part Five.

PART TWO

INTERNATIONAL LITERATURE SURVEY AND INTERNATIONAL EXPERIENCE OF THE USE OF ECONOMICS IN GROUND WATER MANAGEMENT

2. INTERNATIONAL LITERATURE SURVEY AND INTERNATIONAL EXPERIENCE OF THE USE OF ECONOMICS IN GROUND WATER MANAGEMENT

2.1 INTRODUCTION

2.1.1 Objective

The objective of this survey is to review the more recent publications on ground water economics and its application in different regions of the world. The majority of the literature surveyed considers the North American situation and hence the examples and applications are discussed in that context. The prevailing situation in South African makes any comparison with these examples difficult due to the significant political, legal, institutional and socio-economic differences.

2.1.1.1 Approach

One of the most crucial aspects arising from the survey is that it is very difficult to divorce ground water from surface water, and indeed other water sources. This is because ground water supply is highly dependent on recharge from other sources. Therefore tackling the issue of ground water in isolation from other water sources becomes a difficult task. It is for this reason that this report also touches on the economics of other water supplies in relation to ground water.

2.1.2 Structure

Part Two is structured along the following lines:

- The allocation, pricing and abstraction control of ground water in a multi-user system, a situation which is very common in South Africa;
- Determining the value of ground water according to its use by different abstractors and users;

- Alternatives to ground water mining;
- The economic impact of deteriorating ground water quality.

2.2 ALLOCATION, PRICING AND ABSTRACTION CONTROL OF GROUND WATER IN A MULTI-USER SYSTEM

2.2.1 Background

In many regions of the world water has been regarded as a free commodity. This has led in many instances to over-exploitation of the available resources as well as uncontrolled releasing of pollutants into water resources by households, industry and agriculture. As previous WRC studies on economics and water supply have already discussed, pricing plays a major role in facilitating a more sustainable use of available water resources. This section discusses the role of pricing in ground water exploitation.

2.2.2 The common pool problem

Although ground water is rechargeable, it must not be considered limitless. Availability is largely dependent on the prevailing recharge rate. The literature contains numerous discussion of ground water related issues pertaining to the joint use aquifers with a limited recharge rate, i.e. the common pool problem.[1]

The analysis of the common pool problem is based on the idea that any efficient intertemporal allocation of resources demands that the current rate of use takes into account future supplies, an issue that is related to the notion of sustainable yield. Tenure difficulties arise when more than one owner, who would naturally utilise the resource to their best interest, is present. Each user/owner knows in a common-pool situation, that the benefit they derive from using the resource is vulnerable to extraction by others.

1 See for instance: Philip A. Neher, Natural Resource Economics - Conservation and Exploitation, chapter 14, Cambridge University Press, Cambridge, 1990.

Ground water can function as an excellent example in the discussion of the common pool problem, since aquifers can be large (in geographic terms), and tend to have many users. An unregulated extraction rate will therefore be "too high" as the water table is drawn down to "too low" resulting in the extraction costs being "too high". One interesting example for a multi-user ground water system is the Ogallala aquifer, which serves about half of the irrigated land of the Great Plains of the United States. It has therefore many users and additionally falls under the jurisdiction of six USA States. The aquifer receives little recharge and as such represents a finite, non-renewable resource stock.

2.2.3 The Value of an Aquifer

Neher (1990) has postulated that the dynamic constraint (where the natural recharge rate is modelled) of an aquifer can be written as follows:

$$\dot{b} = G - x$$

where $\dot{b}$ is the dynamic constraint, i.e., the depletion of an aquifer G is the exogenous recharge rate (megalitres per unit of time) and x is the flow rate of extraction. The aquifer loses volume and the water table falls if x> G thus reducing b.

The depletion of an aquifer has three dominant economic effects:

I. An aquifer can be lost through overuse if its geology is such that the structure of the aquifer is supported by the hydraulic pressure of the water. If the water is extracted, the structure may collapse causing surface subsidence and aquifer compaction.
II. Ground water is important as a supplementary source for use in times of shortage, i.e. to increase the assurance of supply.
III. Extraction costs rise as the water table falls. Even if the social benefits of the water exceed the extraction costs, these latter costs will become economically excessive if extraction is uncontrolled.

The objective of an aquifer management scheme should be to maximise the present value of net social benefits. Net benefits are the gross benefits (B) minus costs (C). Benefits increase with extraction (x) but at a decreasing rate.

It can be shown c.f., Neher , (1990) that the value of an aquifer can be written as:

$$MAX\ V = \int_0^T \left(B(x) - C(b)x\right)e^{-rt}dt$$

where

e = base of natural logarithm and r is the chosen discount rate.

The technical aspects of ground water abstraction costs are comprised of fixed and recurrent costs.[2] The fixed costs include exploration, data collection and analysis, drilling and installation, which is amortised over time. Recurring costs include energy, labour, operation and maintenance and interest charges.

Drilling and exploration costs depend on the depth of the aquifer, type of drilling equipment required, diameter of the well, well-screen length, design of the discharge level and available drawdown.

Other related factors when calculating the fixed costs are the location of the well, the surrounding geology and the cost and availability of different types of energy.

Given equal equipment costs, overall exploration costs will be lower in areas with favourable hydrogeological conditions, shallow water tables, and where materials and skills are available locally. In arid areas underlain by hard rock, with dispersed population settlements and little supporting infrastructure, the costs may be extremely high.

2.2.4 Promoting sustainable ground water development

2.2.4.1 Background

In order to facilitate sustainable ground water use, it may be necessary to impose charges on ground water use for a variety of objectives which are dependent on the

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[2] See for instance: E. Fano and M.M. Brewster, Issues in Ground water Economics, in: E. Custodio and A. Gurgui (eds.), Ground water Economics, Developments in Water Science, No. 39, Elsevier Publishers, Amsterdam 1989, pp. 485-507.

given situation[3]. Such objectives include the recovery of costs incurred and the promotion of distributional equity. The latter is often found to be in conflict with efficiency objectives, a issue which is discussed later in this report. The challenge facing water managers is that of finding a reasonably stable combination of regulation and pricing which will lead to efficient water use, capital recovery as well as equitable distribution of benefits.

The use of optimal pricing for ground water may also find application in achieving a conservation objective. By levying charges on industry and farmers for excessive use and contamination of ground water resources, wastage and pollution beyond a certain level may be avoided and conservation induced. The pricing mechanisms for ground water, although different in their application, are very similar to those that are used for surface water as will be shown in Part Five of this report.

The literature indicates that there are two main measures that a government can employ to promote sustainable development of ground water resources. These are of institutional and fiscal nature.

2.2.4.2 *Institutional measures*

Institutional measures may take the form of regulations and rationing, i.e. the non-market allocation of water. The regulation of ground water pumping is related to the individual's legal right. Through the issuing of permits which allow private developers to drill wells, some control over ground water use may be achieved (c.f., Part Six). However, although the number of wells in a given area can be optimised, abstraction control is only achieved if discharge rates are relatively homogenous or maximum pump capacities set.

One model that attempts to balance ground water budgets in an arid region of the United States is Arizona's Ground Water Management Act of 1980. The Act requires conservation taxes to be levied on ground water withdrawals and provides the state with the right to retire or buy farmland if necessary. Another attempt to optimise ground water

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3 Fano and Brewster, op cit.

utilisation has been made in Israel: by setting efficiency standards for various uses of ground water. Water consumption above the standard level of water use efficiency may result in financial penalties.

In the case of extreme water scarcity, governments may resort to rationing of some or all types of water using activities. Such a scenario is, however, only possible in a situation where the government has good control over the water distribution system. It may be difficult if not impossible in a situation where a number of users are drawing directly and independently from an aquifer. This is problematic for those situations where a water management plan has to be devised.

A further institutional measure that the public sector can employ to ensure efficient use and allocation of ground water resources are technical improvements to the water distribution system, which may for instance involve leak detection or telemetry controlled valves.

The control of ground water allocation and use can be aided by computer models, which can provide an important management support tool. Some models are able to link aquifer (and surface water) characteristics, farmers' responses and management decisions. There are two main types of models: hydraulic management models, and policy evaluation and allocation models[4]. These, however, lie outside the scope of this report, and will receive no further discussion.

2.2.4.3 *Pricing Policies*

A further set of measures that can be employed by a government to facilitate sustainable ground water use and allocation is found in pricing policies.

The price of water should reflect its true value in order to guarantee conservation and efficient use. It is normally recommended that water be priced at its marginal cost in accordance with the rules applied to economic efficiency criteria. This however, is rarely

4 See for instance: O'Mara, Gerald T., Issues in the Efficient Use of Surface and Ground water in Irrigation. Wold Bank Staff Working Paper No. 707, The World Bank, Washington DC, 1984.

implemented. Economically efficient pricing becomes even more crucial when considering the fact that accessible supply water not only increases a user's output and income, but can also disproportionately increases the value of the land, especially in the case of agriculture. At issue here is the need for hedonic pricing. This topic will be touched upon further, later in this report.

With increasing scarcity, water becomes more valuable, and hence metering and monitoring become cost-effective. This is especially the case in urban areas with an established delivery and metering system. The use of tariffs is a further measure that may be employed. High marginal tariffs could be charged for water withdrawn in excess of basic ground water allotments. These tariffs should however reflect the social cost of excessive use

The literature to do with studies of irrigation projects in developed and less developed countries often shows that benefits of irrigation are lower than projected. The evidence suggests that this is due to poor on-farm water use efficiencies and rent-seeking activities. One reason for this is low water charges, which are often unrelated to consumption levels[5]. Low water charges and loosely enforced water rationing guidelines can lead to environmental damage, and excessive mining of ground water resources.

A number of conflicting objectives are often reflected in irrigation water pricing policies:

- efficient water use;
- income distribution towards agriculture;
- capital cost recovery;
- small farmer incentive provision; and
- the minimisation of administrative costs.

One measure that can be undertaken to combine the goals of subsidy provision and water use efficiency is to make use of two or more prices combined in a system of permits or quotas and coupled with progressive penalties for exceeding permit

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5 Chakravorty, Ujjayant, Roumasset, James, Efficient Spatial Allocation of Irrigation Water, in: American Journal of Agricultural Economics, Vol. 73, No. 1, February 1991, pp. 165-173.

conditions. The subject of permits will be raised again Part Six of this report. Such a system would provide a primary low cost water quota, covering basic needs for a given use. Any quotas obtained beyond the basic allotment would be priced at a high marginal cost, whilst rebates could be offered for utilising less than the allotted quota. Such a system would be particularly beneficial where the conjunctive use of ground and surface water is exercised. The system would in particular increase economic efficiency, if quotas are tradable or if the state could buy back unused quotas (c.f., Part Six).

Another system is to use 'progressive' block rates which have been widely discussed in the policy arena in South Africa, not only with regard to pricing of water, but also other publicly provided goods, such as electricity[6].

Municipal and industrial water suppliers have not traditionally been heavily subsidised. Pricing in these sectors should rather fall in the category of "users pay for the cost of services" which would provide a greater possibility of economic efficiency. For household and industrial users, the use of metering coupled with an effective pricing structure would provide incentives to conserve water and improve efficient use.

2.2.4.4 Means to secure efficient allocation of water resources from an aquifer

When ground water users are scattered over a large geographic area the use of taxes to guarantee the efficient allocation of water resources from an aquifer should be avoided.[7] Rather, water quotas should be introduced, for the following reasons:

- Whereas tax evasion is generally viewed as being targeted at the government, the overuse of quotas would be viewed as an infringement upon the other users rights. Quotas are more efficiently and more effectively controlled and are more transparent and accessible to the public.
- Alternatively, in a case where the extraction of water from aquifers is the responsibility of a public agency, or a large private utility, marketable quotas could be assigned. The authority could in turn charge appropriate water rates to the end users.

6 pers. comm. with Johann Basson, DMEA and NELF, November 1993.

7 Neher, Philip A., op cit.

It is generally regarded that no matter which system is chosen, the water authority should have jurisdiction over the entire geographic area occupied by the aquifer. Administration for aquifers which extend over large geographic areas can be very costly and difficult to implement, especially in a situation where the aquifer is transnational. It is nonetheless held that, in view of a rising resource cost on water in a depleting aquifer, more costly procedures to guarantee efficient water allocation should be given priority.

Water marketing is a further method that may be utilised to secure a more efficient and equitable allocation of water resources. Water marketing is essentially the creation of markets for water resources, where buyers and sellers can trade water quotas. For water marketing to work perfectly, a number of conditions must prevail:

I. Property rights must be well defined
   Property rights are the most commonly and, historically, the most often used means of ensuring the management of scarce resources. "By implication, water stored in an aquifer has no value, is not priced, and is sometimes made available free of charge."[8] This is a classic example of a public good that can easily be subjected to misuse and abuse. There is only scope for effective quantitative and qualitative management of the ground water resource once property rights are well defined.
II. There must be many buyers and sellers
III. Resources must be mobile
IV. Good information systems are required

Water marketing for surface water has been found in several instances to be economically flawed and not always able to fulfil equity requirements. However, the method has found wide-spread application for use with ground water. Most attempts to examine and compare the efficiency of water rights markets have been qualitative. Some attempts have been made, however, to quantitatively consider the

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8 N. Buras and S.C. Nunn, Central issues in the combined management of surface and ground waters.

efficiency of regional water rights markets . Rosen (1974) has applied hedonic pricing techniques to this problem.[9]

A 'Rosen Commodity' can be a farm parcel which consists of land and water which cannot be traded separately because of legal and institutional constraints. Where legal and institutional constraints are placed on water rights transfers, the emergence of a competitive price structure for water rights is restricted.

In a given fixed market of land and water we have potential buyers bidding for these fixed supplies, with different production functions determining their bidding function. In this market each piece of land goes to the highest bidder. These comments are also relevant to discussions pursued in Part Six of this report.

It is important of course to look at ways to separate land and water in the market. If we assume separate markets for land and water, the implicit land and water markets must reflect this, and the hedonic price function will be additively separable in land and water.

Experiences from the United States with hedonic land prices have shown that progressive depletion of aquifers is causing many farmers to return to dryland production methods. This entails an important economic impact for landowners since land values are falling. A court decision from 1965[10] found that taxpayers, i.e. the landowners affected, are entitled to a cost depletion allowance for the exhaustion of their capital investment in the ground water resource.

Crouter (1987)[11], however, points out that even where laws and institutions allow separate and piecemeal water transfer, non-separable and non-linear hedonic price functions for water can be found in the presence of transaction costs (although these costs may themselves be affected by laws and regulations) which can be very high in thin markets. The identification of attributes of a water right is costly, since as a 'good',

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9 Rosen, Sherwin, Hedonic Prices and Implicit Markets: Product Differentiation in Pure Perfect Competition, in: Journal of Political Economy, No. 82, January/February 1974, pp 34-55.

10 United States v. Marvin Shurbet et ux., 347 Fed. (2D) 103 (1965)

11 Crouter, Jan P., Hedonic Estimation Applied to a Water Rights Market, in: Land Economics, Vol. 63. No. 3, August 1987.

water is characterised by location, delivery rate, period of delivery, quality, abstraction points etc.

One must assume that transaction costs (i.e. search, identification, negotiation, legal costs) decrease when more transactions are made by a respective buyer and seller.

If transaction costs are high only one (or few) transactions are carried out and the buyer and seller create a bilateral monopoly trade relationship. At this stage other agents' bids or offers do not matter since high transaction costs do not permit further transactions. In this case the hedonic price function cannot be separated and no competitive water market can be created.

If transaction costs are zero each agent may make multiple transactions. Land and water are sold in separate markets at competitive prices and hence the hedonic price function must be separable and linear for water.

This shows that high transaction costs may be detrimental to the creation of a competitive market for water, even in cases where legal and institutional restrictions on water right transfers are absent.

Torell et al.[12] compute the water value as the price differential between irrigated and dryland farm sales. The value of water is a significant part of irrigated farmland transaction prices. It is found that the price differential between dryland and irrigated farms (which is considered to be the value of the water including irrigation equipment), has fallen over time. Depending on the locality, the water value component of irrigated farm sale transactions ranged from 30 to 60% of the farm sale price.

Chan[13] argues that relying on markets for allocation of interstate ground water has some serious defects, including impacts on equity, freedom and community cohesion between

12 Torell, L. Allen, Janes D. Libbin, and Michael D. Miller, The Market Value of Water in the Ogallala Aquifer, in: Land Economics, Vol. 66, No. 2, May 1990, pp. 163-175

13 Chan, Arthur H., To Market or Not to Market: Allocation of Interstate Waters, in: Natural Resources Journal, Vol. 29, Spring 1989, No. 2, pp 529-547.

the states. He proposes a regulatory approach on the basis of the doctrine of equitable apportionment.

Another method of ensuring the efficient allocation of water resources is through regulation, an issue that relates to all types of water supply. Regulation can be directed at reducing the demand of one user group in order to fulfil the development goals of a particular region. The introduction of water duties may be one possible means of regulating and reducing water demand by one user group. In Arizona (Arizona Revised Statutes, 1980) a water duty was introduced for irrigation and was calculated as follows:

$$\text{Irrigation water duty} = \frac{(\text{total irrigation requirement/total cultivated area})}{(\text{assigned irrigation efficiency})}$$

2.2.4.5 *Water Farming*

The 1980 Ground water Management Act in Arizona triggered a land acquisition boom on the grounds of associated water rights. Such a phenomenon is known as water farming and has occurred in many parts of the United States. However, there is little or no unappropriated surface water in Arizona, and the Safe Yield provision of the Act severely limits future ground water extraction from aquifers underlying urban areas. Plans were therefore developed to transfer water to urban areas, thereby eliminating much of the irrigated agriculture in the areas of origin. Water transfer markets are operating in other parts of the United States, but the Arizona case differs in the following ways:

I. acquisitions are driven by the legal requirement to secure 'paper' water rights, rather than being based on actual need.
II. the transactions are very few in number but concern large transactions in acres, acre feet and dollars.
III. the focus lies on unquantified ground water rights, rather than quantified surface water rights.

Water farms are characterised by a number of features one of them being access to a large and high-quality source of surface or ground water. The purchase of large, continuous parcels of land when acquiring unquantified ground water rights is a further element. The existence of reliable and low-cost means of transporting water from the area of origin to the area of use is crucial for a successful water farm.

Water farming in Arizona is mainly concentrated in one area, La Paz County, which is 95% public land and lacks a diverse economic base. The economic impacts that water farming and transfers have on this region have been analysed for a hypothetical case where 1000 acres of farmland are retired to provide ground water to the urban area. The study highlights the potential as well as the shortcomings of water farming and water transfer in an arid environment. It is particularly interesting since it deals with both economic and institutional problems.

There are a number of impacts associated with the farming and transfer of ground water from the area of origin to the area of use. Direct economic impacts of transferring water include the employment and income aspects which are often linked with agriculture. Indirect impacts consist of forward and backward inter-industry linkages. Induced impacts occur due to changes in local flows of income and population changes. Charney and Woodard[14] show that the economic impacts on the region itself may be considerable, with employment losses in the agricultural and non-agricultural sector, plus a loss of revenue and taxes, factors which have detrimental effects on the growth scenario of a region.

Overall the impacts of rural-to-urban water transfers, resulting in a loss of irrigated agriculture, do not yield a significant effect on the national economy. However, when viewed from a regional and especially local perspective, the impacts may be substantial, particularly where economic impacts tend to be concentrated in a few areas and where land is transferred for its high water value. Hence, although overall economic benefits to the country as a whole can be achieved, the costs incurred on a local level may justify consideration of compensation and mitigation for the areas most negatively effected.

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14 Charney, Alberta H. and Gary C. Woodard, Socioeconomic Impacts of Water Farming on Rural Areas of Origin in Arizona, in: American Journal of Agricultural Economics, Vol. 72, December 1990, pp 1193-9.

2.2.5 THE VALUE OF GROUND WATER

2.2.5.1 Background

The value of ground water to the respective user differs from user to user. A distinction must be drawn between value and price. Although the use of pricing can be a good indicator for deriving the value of ground water to a given user, if no market exists, it becomes very difficult to derive a value in terms of price. This literature survey did not encounter much research that has been undertaken into methods of valuing of ground water. Rather, it was found that when this value was addressed, it was done so in qualitative terms and will not be discussed further.

An important consideration in South Africa, however, is the community value of ground water in relation to water marketing. In South Africa many communities, particularly rural communities, have depended on ground water supply for many years. Should ground water marketing be introduced as one means of assuring a more efficient allocation of ground water resources in South Africa, the implications for rural communities, if not considered carefully may be profound. The Indaleni case study highlights some of the issues concerned with valuing rural groundwater.

2.2.5.2 Community values of ground water in relation to water marketing

Groundwater marketing, more than surface water marketing, has been found to be one reasonably efficient way of ensuring equitable allocation of ground water resources among competing users. Part Six of this report expands upon the use of Tradable Permits in this regard. However, one of the issues that has not received much attention is the effects such marketing has on historic uses by different users (c.f., some interesting comments by farmers in the De Aar case study in this regard). The literature indicates that the re-allocation of water from rural to urban areas which is practised extensively in the United States is seen as a possible solution to a major problem, especially in arid areas with water shortages. Water marketing transactions are, however, often hampered by institutional and legal constraints. On economic grounds, ground water transfer is justified by the argument that economic efficiency can be achieved by leaving such transfers to market forces.

However, the rationale that underlies ground water transfers does not acknowledge or take into account community values placed on ground water[15]. Such consideration is especially crucial, when taking into account the close relationship between water and social organisations, a factor that is even stronger in the developing regions of South Africa.

The trend to transfer water from low-value (in monetary terms) agricultural areas to high-value urban and industrial areas is fairly well established in the United States. Although some studies suggest that the impacts of such transfers are modest in a nation's overall economic context, the impacts are substantial on the community from whence the water flows. Hence, equity issues with regards to the areas-of-origin must be taken into account and assessed when water export is considered.

2.2.6 ECONOMIC ISSUES IN GROUND WATER DEVELOPMENT

2.2.6.1 Background

The literature suggests that there are a number of economic issues related to ground water development which have to be considered by policy makers and technical specialists in developing countries. Such issues include factors affecting the costs of ground water, the economics of conjunctive use and conservation, and public vs. private development of the resource.

In order for ground water development to take place it is not sufficient for an excellent ground water source to be present. Economic issues that have to be taken into account by policy makers when making decisions about ground water development include the availability of infrastructure, demographic features, and natural conditions and markets, in order to place the investment in an acceptable economic context. Costs and benefits of different options of ground water development should be weighed up against each other to ensure an optimal resource utilisation/exploitation within a given economic and social context.

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[15] Arthur H. Chan, Rural Community Values in Ground water Marketing, in: Journal of Economic Issues, Vol. 24, No. 2, June 1990, pp 463-472.

When considering the exploitation of ground water resources as an alternative to surface water use, which is of particular importance in an arid country like South Africa, the danger of over-exploitation as well as long-term depletion of ground water resources has to be borne in mind (c.f., the Dendron Case Study). The literature suggests in this regard that an appropriate public management system of ground water exploration has to heed to the following considerations:

- minimum well spacing,
- taxes and tariffs for water use,
- rationing and permits, as well as
- setting standards for efficient use and penalties in the case of withdrawal beyond the set standard.

Within such a public sector framework, the private sector displays some comparative advantage as to the efficient utilisation of ground water on an individual basis. The private sector may not, however, adhere to optimal social utilisation of ground water.

At the community level, it is found that rather than providing and maintaining services publicly, community-based associations and committees are more suited to carry out such tasks, since the issue of ownership and responsibility plays a major role in the success of community-based development projects. The same holds for ground water development.

The literature emphasises that users of water, whether industrial, agricultural or municipal, must be made aware of the fact that neither ground water nor surface water is a free public good, but that the supply entails costs which must be borne by someone (i.e. other individuals, the environment or future generations.).

2.2.6.2 Advantages of ground water development

The exploitation of ground water may be particularly beneficial in order to supplement the supply from surface water in times of shortage. This is particularly so for agriculture: - if wells are sited adjacent to the areas to be irrigated, costly new distribution systems can be avoided. Furthermore, ground water supply can be phased in with demand, thus avoiding excess capacity in the early stages of development.

Providing low-cost ground water pumping technologies and energy sources to rural areas may help to decrease vulnerability to drought. Ground water can be pumped by hand and is thus a relatively inexpensive way of providing some form of guarantee of water supply. Providing a ground water supply in rural areas may also help rural women, by freeing them from having to carry water for long distances.

A similar scenario to that for agriculture also holds for industry in developing countries. Rather than relying on a public water provision system, ground water supply, obtained through wells adjacent to industrial installations, may be more reliable.

Furthermore, ground water can play a stabilising role in the situation where surface water supplies are uncertain. Where pumped ground water is used in conjunction with surface water for irrigation, it serves two main purposes: to increase the quantity of supply (and therefore the area of land being irrigated) and to mitigate fluctuations in the water supply. The latter is referred to as the stabilisation factor[16]. It is found that the investment in ground water development should increase with the variability in the supply of surface water. Hence, depending on ground water pumping technology, a pumping capacity sufficient to irrigate an entire region, may indeed be advisable, if the supply of surface water is likely to fail completely.

The crop yield response to water does not only depend on the available quantity of water but also on how the quantity is allocated and applied during peak-demand seasons. Using ground water to improve the timing of water application in such seasons would increase the stabilisation role of ground water.

2.2.6.3 *Disadvantages of ground water development*

In many instances, agricultural demand for ground water outstrips the actual supply rate. For an example of this phenomenon in South Africa refer to the Dendron Case Study. Furthermore, ground water quality is in many cases poor. In addition, ground water irrigation tends to be expensive and only economically viable for high-value, low-water

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16 See: Yacov Tsur, The Stabilization Role of Ground water When Surface Water Supplies Are Uncertain: The Implications for Ground water Development, in: Water Resources Research, Vol. 26, No. 5, May 1990, pp. 811-818

using crops. When high returns on investment in ground water development are not forthcoming from agricultural productivity and produce prices, users may not be able to sustain the high recurrent costs of ground water development.

In the case of urban and industrial water supply, over-pumping may lead to land subsidence, intrusion of salt water and consequently ground water deterioration (c.f., Neher , (1990)).

At the community level, the main constraint to ground water utilisation is cost. In many areas, especially rural, water supply has been satisfied by surface and precipitation water, often supplied at little or no cost. The introduction of ground water supply has led to costs that are difficult to meet by many communities. Water, in many cases, has rather been seen as a free commodity, a view that involves its own particular problems in terms of willingness-to-pay for alternative water supplies.

2.2.6.4 Conjunctive use and management of ground and surface water

Physical, social and economic dimensions enter the decision making process with regard to the conjunctive use of ground and surface water. In a situation where both surface and ground water are used extensively, the economic impact on surface water may be considerable. Conjunctive use of surface and ground water is especially important for consideration in a maturing water economy.

There are a number of aspects which characterise a maturing water economy. Scarcity values of water are high and rising, and the long-term supply of impounded water is inelastic. Furthermore, the demand for delivered water is high and growing, the physical condition of impoundment and the delivery system is often decaying and there is intense competition for water between agricultural, industrial, urban and instream users. Finally, there are pressing externality problems and the social cost of subsidising increasing water use is high and rising.

It is clear from foregoing discussions that the South African water economy is entering its mature stage, and in a maturing water economy there tends to be a shift towards demand management and co-ordination of the use of available supplies, or conjunctive management of demand with ground, surface, atmospheric and low quality water. A further shift is experienced among water management institutions: traditional supply agencies are replaced by demand management orientated structures which use regulations, zoning, moral persuasion and price.

The increasing competition among users creates pressures to replace public water development policies with market-like allocation institutions in order to satisfy high-valued uses. Market-based re-allocation requires property concepts that account for the relations among hydrologically interrelated sources or conjunctive management.

In a maturing water economy, the management of regional water resources is based on trade-offs between competing demands c.f., Part Four of this report in this regard. It requires the management of the utilisation and development, of surface streams and ground water aquifers. Effective management of regional water resources must recognise the dynamic character of natural hydrologic systems, and formulate appropriate policies.

Naturally, the reliance on ground water resources is greater in arid zones. In Arizona, for instance, the maturing economy led to the depletion of ground water resources, as the use of ground water aquifers outstripped the rate of natural replenishment. This led to the occurrence of a regional water crisis and demanded the importation of surface water into the region. The Arizona Ground water Act (June 1980, Arizona Revised Statutes, 1980) is very closely linked with the federally funded Central Arizona Project, transporting substantial amounts of water from the Colorado River to Arizona.

2.2.6.5 The role of institutions

Institutions have a major role to play in controlling the development of regional water resources system.. The historical trend has been towards a dichotomy of water resource development where ground water was managed and developed by individuals on a small scale, and where public investment targeted large-scale surface water projects.

Buras and Nunn[17] emphasise the need to cancel this dichotomy in order to utilise and develop regional water resources more effectively. They call for combined and co-ordinated management of surface and ground water resources.

2.2.6.6 *The dynamics of complex hydrological systems*

Surface water and aquifers interact in that fluctuations of streamflow may have a direct or even immediate effect on the adjacent water table. The interconnections are of the following nature:

(a) quantitative, where

- an increase in the river stage causes water to move from surface streams into the aquifer
- a decrease of the river stage can causes the discharge of an aquifer into the river
- intensive exploitation of an aquifer next to river banks leads to a decrease in the stream discharge

(b) qualitative, where

- water quality may be affected by the movement from an aquifer into surface streams and vice-versa

(c) measurements, where

- the flow in open channels (including streams and rivers) is measured in metres per second
- the water movement in aquifers is measured in velocity, which is several orders of magnitude smaller
- the complexity of the interactions can often only be reflected in mathematical models.

The quantification of the interaction between surface water and aquifers determines the relationship between controllable decision variables and known existing conditions, and

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17 N. Buras and S.C. Nunn, Central issues in the combined management of surface and ground waters.

ensures the state of combined stream-aquifer systems, which can be expressed by a set of coefficients termed the 'influence coefficients'[18]

2.2.6.7 Economics of conservation

The literature suggests that world-wide, extensive ground water mining has led to saline intrusion in coastal areas (c.f., Atlantis Case Study in this report), increased pumping costs and, in some cases, the total depletion of ground water resources. the literature points out that due to the short-term nature of ground water exploitation, conservation and demand management control should be the main factor in sustainable ground water resource utilisation. In order to avoid unsustainable resource utilisation, a conscious effort has to be made to manage aquifer systems on a national as well as local level. Such management may even extend beyond national boundaries, due to the nature of large transnational aquifers, although clearly this is not a problem in South Africa.

The economics of ground water development is dependent on the type of ownership and investment, i.e. public, private and mixed systems.

Public sector investment may be appropriate in underdeveloped areas where ground water development is not affordable by the local communities. The most important involvement of the public sector, however, lies in the integrated management of the national water resources. The public sector should facilitate institutions and regulations to control and monitor sustainable ground water utilisation.

Private development of ground water resources usually gives the immediate advantage of high operating efficiencies, coupled with the incentive to conserve ground water. However, uncontrolled private development can lead to very high investment per unit of area. This may be especially crucial in a situation where more than one private developer draws water from a common aquifer (c.f., Neher, 1990). Such utilisation may quickly lead to over-exploitation and unsustainable yield, i.e. every man for himself.

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18 See: Illangasekare and Morel-Seytoux, 1982

In a mixed system ground water development becomes a public sector initiative with subsequent utilisation and maintenance by private entrepreneurs. Such a system should be especially beneficial in rural areas where the management of an aquifer is handled by the public sector, whilst efficient operation of wells is left to the private entrepreneur - in this sense, both actors display a comparative advantage. Nevertheless, such mixed systems demand a well-developed management plan, which may entail licences for wells and restrictions on abstraction.

2.3 ALTERNATIVES TO GROUND WATER MINING

2.3.1 Background

Ground water mining demands a low capital input to deliver a unit of flow with a very high probability. It is very attractive in the short term, since the immediate investment is low and the cost consequences of excessive pumping will be borne by future users.

A number of alternatives to ground water mining may be considered, the most important being artificial recharge, reclamation and re-use of waste water and desalination. These alternatives will be considered in the following three sections.

2.3.2 Artificial recharge

The artificial recharge of aquifers is practised in parts of Israel, Southern California, and other parts of the world. Sources of water for the artificial recharge of aquifers include imported waters from other hydrological units, enhancement of infiltration of flood waters in ephemeral streams, and treated effluent from waste-water treatment plants.

2.3.3 Reclamation and re-use of waste water

Reclaimed and re-used waste water can be used for irrigation. However, as waste water production rates and irrigation water demand rates are not coincidental, low cost, nuisance free storage is necessary. Environmental considerations are paramount with such use, and the quality and suitability of waste-water treatment must be assessed, before such an alternative is considered.

Waste water use was analysed for a region in Israel[19] The objectives of the proposed scheme were to maximise:

- the regional income;
- public health standards;
- the capability of the agricultural production systems that were to use the effluent, given the availability of land and other inputs;
- the prevailing pricing system;
- the existing technology.

Further constraints on the use of waste water were environmental quality and the need to decrease ground water mining. If successful, this scheme would result in fresh water savings and may attract government subsidies for the treated effluent.

The analysis showed that in the absence of government subsidies, there was no incentive to use the treated effluent. It was found that the threshold was a 15% government subsidy on the overall treatment and investment in the effluent conveyance system. A 50% government subsidy gave an incentive to all farmers to use the treated effluent and led to a full regional co-operation.

2.3.4 Desalination

Desalination constitutes a further alternative to ground water mining. Since, a substantial amount of energy is required for the desalination of sea water, such an option is generally considered to be too costly in all but the most water scarce areas. The desalination of brackish water is found to cause serious economic damage to farmers and municipalities. Cost estimates were made in Colorado and Southern California but it was found that the costs were too high to justify desalination.

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19 See: N. Buras and S.C. Nunn, Central issues in the combined management of surface and ground waters.

2.4 THE ECONOMIC IMPACT OF DETERIORATING GROUND WATER QUALITY

2.4.1 Salinisation

The costs of ground water salinisation on agriculture include:

- farm level costs
- actions to be undertaken to mitigate the impact on the farm
- the time evolution of the costs associated with ground water quality degradation
- timing of remedial action

Howitt and Mean[20] argue that farmers can take actions to offset much of the cost of expected salinity increases and that the reactions of farmers to physical and economic changes must be taken into account when deciding on the timing as well as the specific salinity reduction projects.

Farm managers are under constant pressure to maintain or increase their profit margin. To achieve this goal they use the best agricultural practices available to offset the mitigating effects of ground water salinisation in a given aquifer. Possible changes in crop production technology may include the following:

1. changes in cropping pattern
2. increased leaching fraction
3. changes of irrigation technology
4. blending of water of different quality to suit different crops

In order to undertake any analysis it is essential to understand the salinity tolerance of different crops. Furthermore, crop rotation is determined by a combination of crop profitability, agronomic constraints, risk in yield or price, and local custom. Any changes in salinity can drastically alter the crop rotation pattern.

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20 Howitt, Richard E. and Phillippe Mean, An Economic Approach to Ground Water Quality Management.

The choice of the method of irrigation in the presence of increasing aquifer salinity is dependent on three main characteristics:

1. the depth of the unconfined aquifer
2. the existence of perched ground water levels
3. the availability of relatively low cost supplies of additional water

The intertemporal nature of salinity increases in ground water implies that the physical effects, and the consequent costs, are cumulative. In an optimal intertemporal plan the long-term cumulative cost is reflected back to the incremental salinity build-up and presents the planner with the incentive to achieve "steady-state-salinity" rather than lose the total productivity of the area. An important consideration that has to be taken into account is the time lag of the salts percolating into the aquifer. This means that a control policy for remedial action will have to be formulated well in advance.

The optimal economic management of an aquifer requires that both short and long term costs of salinity build-up are equated to remedial costs at any given time. However, since the salinity level in an aquifer has all the characteristics of a common property resource, the non-excludability of access to the resource would demand a compulsory ground water quality management programme.

2.4.2 Control of diffuse-source pollution of ground water

Harris and Skinner[21] discuss UK legislation with regards to controlling ground water pollution from diffuse sources. The problems associated with non-point source pollution of ground water are, in many cases, very similar to those to pollution of surface water[22].

A slow build-up of nitrate in ground water can be compared with a seasonal peak runoff component in surface watercourses, leading to only occasional excedance of drinking water standards. Hence, different means of controlling nitrate leaching from agricultural

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21 Harris, R.C. and A.C. Skinner, Controlling Diffuse Pollution of Ground water from Agriculture and Industry, in: Journal of the Institution of Water and Environmental Management, Vol. 6, No. 5, October 1992, pp. 569-575.

22 refer to WRC2 for a detailed discussion of point and non-point source pollution and potential control mechanisms.

lands may be applicable. When a policy for protecting ground water is formulated, it must state clearly the manner in which available legislation will be applied by the regulatory agency and how control over polluting activities will be sought by the involvement of other regulatory bodies. Furthermore, such a policy must also explain the rationale behind the concept of protection and devise ways in which control can be induced outside the legislative framework. Such a rationale is best presented in an economic context in order to establish broadly applicable and relevant incentive structures.

Raucher[23] assessed the costs of ground water contamination policies in relation to the benefits yielded from such policies. It was found that substantial costs are incurred in reducing the risk of ground water contamination. With increasing economic implications of aquifer contamination it becomes highly important to gauge the value of the resources to be protected. Based on three empirical studies it was found that preventing contamination should not necessarily be preferred over post- contamination corrective action. Since resources may be mis-allocated if efficient prevention and clean-up options are not pursued. It is of crucial importance to assess preventive and remedial measures on the grounds of their economic efficiency in the long term.

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23 Robert L. Raucher, The Benefits and Costs of Policies Related to Ground water Contamination. in: Land Economics, Vo. 62, No. 1, February 1986, pp. 33-45.

PART THREE

THE NEED TO REFORM GROUND WATER LAW IN SOUTH AFRICA: POSSIBLE CONSTITUTIONAL IMPLICATIONS

3. THE NEED TO REFORM GROUND WATER LAW IN SOUTH AFRICA: POSSIBLE CONSTITUTIONAL IMPLICATIONS

3.1 INTRODUCTION

South African water law is currently in transition. A process to redraft the Water Act has recently been initiated by the Department of Water Affairs and Forestry. In this regard, the Water Laws Rationalisation and Amendment Act 32 of 1994, has been passed as has a white paper on water supply and sanitation policy. Whilst the Act does not directly address the question of water rights, their timeous review is considered crucial by the Department. The discussion below, whilst taking cognisance of some of the policy developments that have been initiated thus far, is however, still rooted in the common law and the Water Act 54 of 1956.

The historical development of South African water law is characterised by a fluctuating focus. It originally had a public law orientation (concerned with public ownership and public rights), which later changed to a private law orientation (concerned with private rights to water) and eventually, with the passing of the Water Act in 1956, it once again assumed a public law focus. These changing priorities were in response to changing development patterns within South Africa.

Until the beginning of this century agriculture, in the form of irrigation, was the only significant user of water. Although water was always known to be a scarce resource, the riparian rights principle, in terms of which the owner of land bordering a public river has extensive rights to the use and enjoyment of the water flowing in it, was, for agricultural users, a fairly equitable way of distributing water. With the rise of the mining industry between 1900 and 1950, however, South Africa underwent a change from an agriculturally based economy to a mining based economy and the demand for water increased, both in terms of increased consumption levels and in terms of the fact that available water was becoming increasingly polluted. The increased demand for water for the mining industry, who were not generally riparian land owners, meant that the State had to become increasingly involved in the allocation of water.' Through this process, water law once again assumed a public law orientation.

One of the main aims of the 1956 Water Act was thus the regaining of control over water by the State from private individuals. Certain private rights to water, were nonetheless retained in the Water Act and have in fact proved to be a major obstacle to effective water management. This is particularly evident in the case of the distinction, which still exists in our law, between public and private water which is central to the topic under discussion.

It is a commonly held perception in South Africa that all ground water is private and thus capable of individual ownership. This perception has created enormous problems for authorities charged with controlling the abstraction and pollution of scarce ground water resources. As stated above, a process to reform South African water law is currently underway. Fundamental to this reform will be a consideration of the appropriateness of the category of private water and private rights to water in the South African context where it is estimated that 12 million people do not have access to an adequate supply of potable water. Given the perception of the status of and rights to ground water, the alteration or reform of these rights necessitates consideration of the constitutionality of such water law reform, which may be perceived to fall foul of the property clause of the interim constitution.

This section intends challenging the perception that all ground water is private and capable of individual ownership. It further challenges the notion that an individual's right to the use of ground water is a right in property protected by the constitution. By questioning these assumptions, it is concluded that the reform of ground water law, which would involve increased state control over the resource would in fact not be a dramatic departure from the current legal position and would furthermore not subject the state to increased liability for compensation or fall foul of the constitutional protection of rights in property.

Upon a survey of international trends a framework for future legislation will be offered, and the constitutional implications of a reallocation of rights to ground water will be analysed. To do this, it will first be necessary to define the precise nature of the common law and statutory right to ground water. Common law ground water doctrines, developed by courts in other jurisdictions, will also be discussed as these inform the policy considerations that justify legislative responses. Recent legislation enacted in Germany, Spain, New Zealand, Alberta, British Columbia and Arizona will be referred to to indicate a world-wide trend away from the vesting of water rights in private hands. A survey of case law in the United States, Australia, and New Zealand, which interprets the constitutionality and effect of such legislation, will conclude the analysis.

3.2 THE LEGAL STATUS OF GROUND WATER

The allocation mechanism contained in the Water Act of 1956 and the process in terms of which rights to use water have been granted by the courts, is based upon the status of the water in question. Whether water is public or private thus determines the rights of use accorded to it. It is beyond the scope of this paper to trace the history of this distinction. Suffice it to say that from early in our case law a distinction was drawn firstly between surface and underground (subterranean) water[24] and secondly between private and public underground water.[25] In Ohlsson's Cape Breweries Ltd v Artesian Well Boring Co Ltd[26] the court held that underground water could still qualify as public water provided it complied with the definition of a public stream, i.e. the water flowed in a known and defined channel. This criterion was regarded to be satisfied if the position of the stream was known within narrow practical limits without it being necessary to excavate to determine its position.[27]Underground water was thus only private if it flowed in unknown and undefined channels.

The Irrigation Act of 1912[28] by omission drew a distinction between subterranean water and underground water. Subterranean water was defined as water which was derived from dolomitic formations and which was declared to be subterranean water by notice in

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24 Vermaak v Palmer 1876 6 Buch 25, quoted in Uys "The legal status of water", Report No.II Chapter IV,124

25 Ohlsson's Cape Breweries Ltd v Artesian Well-Boring Co Ltd 1919 CPD 125

26 Ibid

27 Uys op cit, 140

28 Act 8 of 1912

the Gazette. This category of water was not defined as public or private in the Act. Underground water that was not declared subterranean water as well as non-dolomitic underground water thus fell outside the definition contained in the Act and was presumably to be regulated by common law rules.[29]

The category of subterranean water was retained in the Water Act 54 of 1956. As in the 1912 Act, the Minister is empowered to declare a subterranean Government water control area. He may only do so however, when he is of the opinion that it is in the public interest that the abstraction, use, supply or distribution of subterranean water in the area should be controlled.[30]Subterranean water is defined in the act to include;

> "water naturally occurring underground or obtained from underground in an area declared in terms of s28 as a subterranean Government water control area or deemed to have been so declared".

Once again however, the status of subterranean water is not defined as either public or private water in the Act. It is thus a separate category of water, distinct from underground water and subject to different allocation rules.

The common law distinction between public and private underground water has been retained by the Water Act of 1956. Section 6(2) of the Act states that;

> "Whenever an owner of land obtains, by artificial means on his own land, a supply of water which is not derived from a public stream, such water shall be deemed to be private water".

This section essentially refers to water that is pumped from underground such as the water from boreholes. The Act defines private water as;

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29 Uys op cit, 148

30 s28

"all water which rises or falls naturally on any land or naturally drains or is lead on to one or more pieces of land which are the subject of separate original grants, but is not capable of common use for irrigation purposes"[31]

Statutory private water thus includes rain water, the water from springs, wells, certain dams and wetlands. It does not include underground water as this water does not rise or fall naturally on any land.

Ground water can however, also fall within the statutory definition of public water which is "water flowing or found in or derived from the bed of a public stream, whether visible or not."[32] A public stream is essentially a natural stream of water which flows in a known and defined channel and is capable of common irrigation use on two or more pieces of original riparian land.[33] Thus provided the underground water complied with this definition it would qualify as a public stream containing public water. In practice such water would only exist in a connected system of fairly large aquifers. The allocation of water from public streams depends upon a further categorisation of the water within public streams as either normal flow or surplus water. Underground water cannot qualify as normal flow since this must visibly flow in a public stream.[34]Surplus water is any public water other than normal flow.

On this analysis it would therefore appear that underground water can be subterranean water if it is found in a subterranean Government water control area, deemed private water or public surplus water.

That underground water is not always private water is supported by the 1994 Appellate Division case of De Witt v Knierim[35] which held that:

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31 s1

32 s1

33 s1

34 s1

35 1994 (1) SA 350 (A) at 353J - 354A.

> 'Volgens ons gemenereg kan die eienaar van 'n grondstuk al die ondergrondse privaatwater gebruik wat nie die bron van a publieke rivier is nie tensy hy deur 'n serwituut die reg ontneem is om dit te doen.'

Although this dictum may be regarded as obiter it seems clear that the court was aware that not all underground water is private and thus it was necessary to limit the statement only to "ondergrondse privaatwater" and not all underground water.

3.3 THE CRITERIA FOR A RATIONAL COMMON LAW GROUND WATER DOCTRINE

Lukas,[36] upon an extensive survey of ground water law literature,[37] identifies five criteria most commonly used to analyse ground water rights. She claims that a rational ground water doctrine should:

> '(1) protect the right to use a resource which is held in common
> (2) correspond to hydrological knowledge of ground water movement
> (3) encourage the maximum beneficial use of ground water
> (4) promote public interests by providing water supply for all and protecting the environmental and recreational values of water resources, and
> (5) provide courts with tools for making fair allocations of a finite resource.'

Most commentators, referred to by Lukas, believe that ground water rights should be classified as usufructuary rather than proprietary rights. Since ground water is a resource which is held in common, it seems illogical to assign proprietary rights in a fugitive resource which cannot be contained within boundaries. Possessory rights can only attach once the water has been withdrawn from an aquifer, and cannot be divided into discrete portions while in its natural state. Moreover, if ground water rights are regarded as usufructuary, then constitutional problems of 'taking' might be avoided when regulatory legislation limits a landowner's rights to withdraw water.

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36 Lukas at 460-461.

37 ibid at 460 note 115.

As stated above, a legal regime ought to reflect the scientific reality. Courts and policy makers should recognise the hydrologic cycle and the effects of ground water withdrawals on the water table and other water users.

Secure water rights should be provided by a ground water doctrine, which provides mechanisms for penalising a user who causes well interference. Legal protection should not, however, freeze the pattern of water use, but be sufficiently flexible to promote beneficial utilisation.

In an arid country like South Africa it is obvious that the public has an interest in ground water. The determination of fair allocation depends on social and political values. There must be an equitable balancing of interest between individual users, communities, municipal water suppliers, industrial abstractors, and other large-scale ground water consumers.

3.4 DOES 'ABSOLUTE OWNERSHIP' OF GROUND WATER RESULT IN A RATIONAL GROUNDWATER DOCTRINE?

The so called 'absolute ownership' doctrine recognised in South African law fails to protect rights to water as the landowner is powerless to prevent interference by another user.[38] It leads to economic insecurity as, with over-pumping, external costs are imposed on other abstractors who must drill more deeply. It also imposes social costs by failing to protect the resource itself. Thus economic efficiency, maximum beneficial use of water and the public interest are not encouraged. In addition, the doctrine is not based on current hydrological knowledge.

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38 For a discussion of the inadequacies of the absolute ownership doctrine, see Karen H Norris 'The Stagnation of Texas Ground Water Law: A Political v Environmental Stalemate' (1990) 22 St Mary's Law Journal 493 at 507-509; Lukas at 467-500; Leshy and Belanger 701-706; Note 'Continued Preference for Domestic Ground Water Users in Idaho: Parker v Wallentine' (1983) 19 Williamette Law Review 789 at 791-792; and J David Aiken 'Ground Water Law and Policy' (1982) 53 University of Colorado Law Review 505 at 510-512.

The beneficial use doctrine, reflected in Union Government v Marais and others has been labelled a misnomer.[39] Apart from prohibiting wasteful and off-site use, it incorporates the absolute ownership rule. The result is that the problem of over-competition for the common pool between local users is not resolved, and the dichotomy between surface and ground water is perpetuated. Since waste is prohibited, the public interest in the resource is better protected than under the absolute ownership doctrine, although aquifers are still at risk from over pumping.

Some US courts, in response to the inadequacy of the 'absolute ownership doctrine' have developed alternative doctrines. The doctrine of correlative rights, for example, was developed in California to deal with ground water scarcity. Under this doctrine, the owners of the overlying land have a usufructuary right to the use of the water in the aquifer. Each pumper is restricted to a rate of withdrawal which does not unreasonably interfere with reasonable water use by his neighbours. It allows for judicial allocation of finite supplies and allows courts to consider the relative needs of landowners. It requires that competing overlying landowners receive an amount of water proportionate to their ownership of the overlying land. Non-overlying landowners will only have a claim to surplus water. In California, a 'just and fair proportion' has been allocated according to previous pumping rates.

The correlative rights doctrine grants a usufructuary right and is firmly grounded in modern hydrological principles. The doctrine provides greater economic security, as the protection is based on the comparative reasonableness of competing uses by other landowners. In times of drought, each user's right to the resource will be reduced proportionately. Thus well races and waste are excluded. Moreover, since future water supplies can be preserved, the public interest is better protected. Fairness is promoted as a balance is struck between competing uses. Equities which have been considered include, the economic and social value of the use, the extent of the withdrawals, the measure of harm, and alternatives for satisfying needs. The doctrine does not, however, resolve conflicts between competing transporters. It has been argued that the distinction

39 Lukas at 484.

between local users and transporters is unnecessary, and that the rule of correlative rights should apply to all ground water users.

3.4.1 The need for legislative intervention

It is possible that the South African common law could be developed to ensure equitable access to ground water.[40] It is likely, however, that such development will be overtaken by legislative intervention. The State has an interest in managing ground water to achieve the greatest sustained economic benefit from ground water use, while conserving the resource, and implementing its water policy. The vesting of ground water rights in persons other than overlying landowners, will require a fundamental reform of our ground water law. Legislative innovations in other jurisdictions are instructive in this regard.

3.4.2 Ground water legislation in the United States, Australia, New Zealand, Canada, Germany and Spain - a comparative analysis

Having undertaken a comprehensive study of groundwater law in Eastern European countries, the United States, Africa, Great Britain and some European countries, Hayton[41] states that deliberations regarding appropriate legal and administrative water

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40 Where necessity dictates, the judiciary is competent to engage in judicial lawmaking to develop the common law. Hahlo and Kahn hold that 'a judge may have to construct a rule out of consideration of one or more of several desiderata, some of which may compete with others : justice, equity, social utility and trends, public and individual interests, moral standards of the time, convenience (both commercial and communal), common sense, equality, freedom of the person, the safety of the State and the upholding of international good relations.' See Hahlo and Kahn The South African Legal System and its Background at 311.

It is, of course, a moot point whether the courts could develop an effective doctrine free of the potential restrictions placed on its activities by s 28 of the Interim Constitution. The application clause states that the Chapter binds all legislative and executive organs of the state at all levels of government, and applies to all law in force. Are courts part of 'government' and does 'all law' include the common law? See Gardener v Whitaker 1994 (5) BCLR 19 (E) at 32C, where Froneman J was of the view that 'all aspects of the common law ... should, in cases that now come before the courts, be scrutinised to decide whether they accord with the demands of the Constitution.'

41 Robert D Hayton 'The Ground Water Legal Regime as Instrument of Policy Objectives and Management Requirements' (1982) 22 Natural Resources Journal 119 at 131.

regimes tend to include the following issues: title to ground water; the appropriate jurisdiction to be vested in the national government, and the role of provinces, municipalities etc.; the amount of 'override' to be given the concept of the 'common good' at any level of government as opposed to preserving the right of the individual user of ground water; the costs of due process machinery; participation by water users and other interest groups in the formulation of policy and in conflict resolution;[42] and the question of compensation to holders of valid water rights when these are diminished or taken away altogether.

It is with these and Lukas' submissions in mind that a comparative analysis of recent ground water legislation will be attempted.

3.5 RECOGNITION OF THE HYDROLOGICAL REALITY AND THE VESTING OF PROPERTY AND RIGHT TO USE AND FLOW OF WATER IN THE STATE

No distinction is drawn between surface and ground water in the jurisdictions under discussion. In addition, title to water is vested in the State. The German Federal Water Amendment Act 1986, for example, applies to surface water, coastal waters and ground water, thereby recognising the hydrological cycle. Ownership of land does not bestow an entitlement to any use of water.

Similarly, in the British Columbia Water Act 1979 a 'stream' is defined as a natural watercourse or source of water supply, ground water, a lake, river, creek, spring, ravine, swamp and gulch. The property in and right to the use and flow of water is vested in the Crown.

42 For an interesting analysis of interest group participation in the formulation of groundwater legislation see Jon L Kyl 'The 1980 Arizona Groundwater Management Act: From Inception to Current Constitutional Challenge' (1982) 53 University of Colorado Law Review 471 at 474 - 481, where the author describes the intense negotiations between the mining industry, cities and private water users (agriculture) prior to the passage of the Act.

In the 1979 Alberta Water Resources Act, amended in 1981, 'water' is defined as all water on or under the surface of the ground. The Act vests the property in and the right to the diversion and use of all water in Her Majesty in right of Alberta.

The Spanish Water Law of 1985 defines groundwater resources as public property. The general principles of the Law are the following: respect for the unity of the river basins, of the water resources systems and of the hydrological cycle.

In terms of the New Zealand Resource Management Act 69 of 1991[43] 'water' is defined as 'water in all its physical forms whether flowing or not and whether over or under the ground'. It includes fresh, coastal and geothermal water, but does not include any water in any form while in any pipe, tank or cistern.

It is clear that any bifurcation between ground water and surface water is untenable. Legislative recognition, in South Africa, of the hydrological cycle would follow strong international precedent, and be in keeping with Lukas' definition of a rational ground water doctrine.

3.6 LICENSING

In all jurisdictions, the use of water requires an official permit or licence which does not confer a title to a supply of water in any specific quantity or of any specific quality. The use of water includes the withdrawal, conveyance to the surface or the diversion of ground water. A permit or licence may be granted subject to the imposition of conditions, which may also be imposed in order to prevent or make good any effects which are detrimental to other persons. Permits and licences may also be granted subject to the reservation that at a later date measures may be prescribed for monitoring water use and its consequences, and to ensure an economical use of water in the interests of natural water resources.

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[43] The Act is unique in that it provides for the integrated management of all the country's natural resources. It treats the environment as an holistic entity to be managed according to national, regional and district plans and policies. The purpose of the Act is to promote sustainable management of natural and physical resources. This entails, inter alia, safeguarding the life-supporting capacity of air, water, soil, and ecosystems.

A permit or licence may be refused, or revoked, in cases where the proposed use is likely to harm the common weal, and in particular where it would endanger the public water supply, and where the harm or danger cannot be prevented by the imposition of conditions.

The Canadian legislation entrenches a prior appropriation doctrine which holds that licences, authorising diversion of water from the same stream, have precedence in law according to the respective priorities of the dates from which the licences take precedence. Where authorities have been issued on the same date, preference is ranked according to the respective purposes for which the water is authorised to be used.[44]

The prohibition against use without a licence does not apply in the case of water required for an individual's reasonable domestic needs or the reasonable needs of an individual's animals for drinking water, provided that the taking does not have an adverse effect on the environment.

3.7 MANAGING CONFLICT IN THE LICENSING PROCESS

It seems that some form of public participation in the licensing system is crucial. All the statutes allow either for objections to be lodged, or for more expansive notice and comment procedures. In Germany and British Columbia, before granting a licence, the relevant authority must hear objections from affected persons. In British Columbia the authority may decide that a hearing is warranted, whereas the German legislation provides that licences will be granted only if the detrimental effects are prevented or made good by the imposition of conditions. Where this is not possible, the licence may nevertheless be granted, subject to the affected person being granted compensation. An affected person, who was unable to foresee any detrimental effects before the grant of a licence, may request that conditions be imposed ex post facto.

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[44] The rankings are from highest to lowest rank: domestic, waterworks, mineral trading, irrigation, mining , industrial, power, hydraulicking, storage, conservation, fluing conveying and land improvement purposes. Licences issued authorizing the diversion of water from the same stream, for the same purpose and on the same date, have equal precedence.

In Alberta, meanwhile, extensive provisions for public notification of applications, and objections thereto, are incorporated in the Act. Similarly, the New Zealand legislation provides that notice of the application must be served on persons who are likely to be directly affected by the application, including adjacent owners and occupiers of land. Decisions must be taken in accordance with plans and policies. Affected individuals may appeal to the Planning Tribunal.

3.8 SAVING OF EXISTING RIGHTS

Some of the legislation in point saves pre-existing rights thus only abolishing the right to previously unappropriated water. In Germany, existing rights of use and authorities are saved.[45] Where considerable harm is likely to result from the continued use of the existing rights and authorities, however, these may be revoked against payment of compensation. Existing rights and authorities had to be registered in the Water Register within 3 years of a public notice requesting the holders to do so. Failure to register results in extinction of the right 10 years after the publication of the notice.

In terms of the Alberta legislation, holders of rights of diversion or use, acquired pursuant to the Irrigation Act (Canada), the Dominion Lands Act or the Dominion Water Power Act, may continue to exercise the rights, subject to the Water Resources Act and the regulations, so long as they are not inconsistent with the terms on which the right was granted. Every person who had acquired a legal right to divert or utilise water in accordance with the above-mentioned Act, and who would have been entitled to a further permit, is entitled to receive such permit.[46]

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45 The rights may have been conferred by the water laws of the Lander, or by licences conferred in terms of a 1945 Ordinance, or by virtue of a licence issued under the Industrial Code, and in terms of which installations existed on 12 August 1957.

46 The Arizona Groundwater Management Act of 1980 sets up a system of determining grandfathered right to use groundwater, defining certain usages of groundwater previously being made and allowing these usages to continue. Thus, landowners who irrigated at any time during the five-year period preceding the Act have a right to pump ground water for continued irrigation. The water available to such users is limited to the amount necessary to irrigate effectively the number of acres previously cultivated by the landowner. If a farmer withdraws less than allowed, he can credit the unused water for future use. Farmers are also entitled to pump as much as fifty percent more than the allotted amount and pay back the excess used in subsequent years. The purpose of the Act is to establish of Active Managment Areas, which are

3.9 CONSERVATION OF THE RESOURCE

The German legislation provides for the establishment of water protection areas where it is necessary to protect certain waters against detrimental practices, in the interests of the existing or any future public water supply and to recharge ground water. Within these areas certain activities may be prohibited or permitted only to a limited extent. If an order amounts to expropriation, compensation will be paid. Where an order limits agricultural or silvicultural use of land, reasonable compensation will be paid to make up for the economic disadvantage. This section specifically allows recourse to the courts in matters of dispute.

In New Zealand, meanwhile, where water is outstanding as a habitat for terrestrial or aquatic organisms, as a fishery, for its wild, scenic, scientific and ecological values, or for recreation, historical, spiritual, or cultural purposes, a water conservation order may provide for the preservation of that water in its natural state.

3.10 REGULATORY AUTHORITY

The holistic management of water resources is, in all countries, placed in the hands of a centralised regulatory authority. In Germany, the Lander are required, for the purpose of managing water, to draw up specific water management schemes which take into account the need to protect waters as an integral part of the ecosystem and the rational use of ground water resources. The goals of regional planning and planning at Lander level must be taken into consideration. Water registers must be kept for all water under the Act. The register must reflect permits, licences, existing rights and authorities, water protection areas and flood plains.

In Spain, Basin Authorities and the National Water Council act on behalf of the State. The latter is the supreme consultative body on the matter in which the State, the Autonomous Communities (municipal authorities), the Basin Authorities, professional

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geographical areas where gorundwater supplies are imperiled. However, the distinction between groundwater and surface water is maintained. See Canaille 'A History of the Arizona Groundwater Management Act' (1982) Arizona State Law Jomal 313 at 333.

and economic organisations are represented. The National Water Council is obliged to draft a National Hydrological Plan and hydrological plans for each different basin for submission to Parliament; measures of a general nature to be applied to the whole of Spain with respect to the planning of the water resources; plans and projects of a general nature concerning agricultural, urban and industrial planning, exploitation of energy resources or land use planning, in so far as they have a substantial effect on water resources planning or water use; and matters common to two or more Basin authorities in relation to the exploitation of water resource and other public property.

Each Basin Authority has the responsibility to prepare, follow up and revise the hydrological plan for the particular basin; to administer and control the water resources public domain; and to design, construct and operate works financed by the Authority's own funds. The Authority has the power to grant permits and concessions in relation to the water resources of the public domain, except those referring to works and action of general State interest which are the responsibility of the Minister of Public Works; to inspect and monitor operations to ensure the fulfilment of the conditions laid down in the concessions and permits; to carry out gauging and hydrological studies, and to collect information about floods and to control water quality; to study and design, construct, maintain, operate and improve the works included in their own plans; and to define the aims of quality programmes in accordance with water resources planning.

Hydrological plans must include, inter alia, the inventory of the water resources; the present and predictable uses and demands; the criteria for priority and compatibility of use, and the order of preference of different uses and exploitations; the allocation of water resources for current and future uses and demands, taking into account the conservation and restoration of the natural environment; and guidelines for groundwater recharge and protection.

The New Zealand legislation charges local authorities with a duty to monitor the resource consents in their districts and to take appropriate action where necessary. A local authority may authorise any of its officers to carry out all or any of the functions and powers as an enforcement officer under the Act.

3.11 OFFENCES AND PENALTIES

To be effective, legislation must impose sufficiently stringent penalties. The German Act provides for offences and penalties, stating that a fine of up to one hundred thousand deutschmarks may be imposed for statutory offences. Provisions for the prevention of water pollution are also contained in the Act.

In British Columbia, the Act creates offences and stipulates penalties. A person who commits an offence under this section is liable on conviction to a fine of not more than 2,000 dollars or to 6 months imprisonment of both and where the offence is a continuing one to a fine of not more than five hundred dollars a day for each day the offence is continued.

The Arizona legislation was amended in 1987 to incorporate substantial penalties for ground water usage abuse. Any violation directly related to illegal withdrawal, use or transportation of groundwater may attract a penalty of ten thousand dollars per day. In addition to civil penalties, the code categorises some violations as criminal misdemeanours. Since the regulations are uniform throughout the state and controlled by one entity, enforcement of compliance is more likely to be even handed.

3.12 FEATURES OF MODERN GROUNDWATER LEGISLATION

Having analysed ground water regimes in numerous countries the following similarities emerge. It is clear that the legislation is informed by the necessity to conserve, and distribute, the resource in the public interest. With the exception of the Arizona legislation, the hydrological cycle is recognised in the statutory definitions of 'water'. No distinction is made between surface and ground water. Property in the national water resources vests in the State and is allocated according to a licensing system. The New Zealand, German and Canadian statutes provide for public participation in the licensing procedure, while the German legislation advocates the use of alternative dispute resolution mechanisms to resolve conflict. In some cases where licences are revoked, the licensee is statutorily entitled to compensation. The licences pass with the land to the successor in title.

In spite of the vesting of title in the State, certain rights to use water are saved by the legislation. Landowners rights to use as much water as they used prior to the enactment of the legislation is saved. The effect of this is that only unappropriated water is available for redistribution by the State. The right to use water for domestic purposes, without requiring a licence is protected.

Administrative agencies are vested with the power to manage water resources on a sustainable basis, and penalties are provided for infringements of the legislation.

Returning to Hayton's analysis, it would seem that the discrete pieces of legislation satisfy most of the criteria which he raises for consideration, namely, title, jurisdiction, recognition that the 'common good' overrides private interests in water, public participation and conflict resolution, and the question of compensation, where licences are revoked.

Hayton claims that, even with the increased attention to ground water in modern legislation, non-management, rather than mismanagement, of the resource still occurs. He claims that the first principle of rational management requires national water policies which are tailored to the development situation and water resource potential of the particular country. Hayton asserts that:

> '[I]nstitutional arrangements should actively conduce the political levels of government to foster the essential prior studies and bring about the decisions that result in a set of coherent policy statements, co-ordinated with the overall national or regional development and environmental protection planning. Ground water aspects, as integral parts of the country's water resources potential, should be assured constant consideration during this policy formulation process.'[47]

It is clear, however, that the Spanish and New Zealand legislation are particularly concerned with such co-ordination. This legislation provides a useful precedent for countries, like South Africa, that are embarking on the reform of ground water law.

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[47] Hayton at 31.

It seems that the legislation establishes a rational legal framework for the use of ground water. The legislation satisfies Lukas' criteria for a rational ground water doctrine. It may be recalled that these include the need to protect the right to use a resource which is held in common, to correspond to hydrological knowledge of ground water movement, to encourage the maximum beneficial use of ground water, and to promote public interests, by providing water supply for all and protecting the environmental values of water resources.

If South Africa were to follow the international trend towards vesting title in water resources in the State, which it is argued it should, would the legislation be challenged as an unconstitutional taking of property?

3.13 THE NATURE OF THE RIGHT TO GROUND WATER IN SOUTH AFRICAN LAW.

It was stated previously that water rights in South Africa are determined by the legal status of the water concerned. The status of ground water has been shown to be capable of qualifying as public "surplus" water, "deemed" private water or subterranean water which is neither public nor private.

In terms of the Water Act, including the 1987 Amendment Act (Act 68 of 1987), as soon as a subterranean government water control area is declared, the right to the use and control of the subterranean water, vests in the Minister.[48] From that point on, no rights of use vest in the owners of the land within the control area unless allocated by the Minister.[49] The use of this water is thus subject to statutory allocation rules and the right granted is clearly a restricted right of use in prescribed quantities and for prescribed purposes and is not a right of ownership.

The application of this section is limited by the provisions of section 30(1) of the Act. This section states, inter alia, that

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48 S29

49 S29, 31, 32A and 32B.

> "Any person, who during the qualifying period,[50] abstracted subterranean water on a piece of land in a subterranean government water control area and used it for any purpose on that land ...shall ...
>
> be entitled to continue, by means of an existing water work, with the abstraction and use",

of the quantity of subterranean water they were actually using during the qualifying period.

This section implies a distinction between water that was allocated and used immediately prior to the declaration of a subterranean government water control area and water that was not so allocated and used. The right to the use and control of subterranean water that was allocated and used immediately prior to the declaration of the control area vests in the owners to which the right was allocated. The right to the use and control of subterranean water only vests in the Minister if the water was unallocated or unused immediately prior to the declaration of the area as a subterranean government water control area. The fact that the section expressly reserves only the right to use the water, once again indicates that this right is a statutory right of use and not of ownership. It is also limited in terms of quantity and the purpose for which it may be used.

The right to use ground water that qualifies as surplus water is governed by the rights applicable to the use of public water. It is thus available for beneficial use for domestic purposes, stock watering, agricultural and urban purposes and it may be impounded

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50 The period determined by the Minister immediately preceding the declaration of a control area.

and stored for those purposes by the owners riparian[51] to the public stream where the surplus water is found.[52]

That the nature of the right to public water is not ownership is clear from the wording of section 6(1) of the Act, which reads;

> 'There shall be no right of property in public water and the control and use thereof shall be regulated as provided in this Act'.

It is the categorisation of ground water as 'deemed private water' in terms of section 6(2) of the Act that has created the greatest obstacles to water managers concerned with managing all water resources in the national interest.

The use of private water is governed principally by section 5 of the Act which provides that the sole and exclusive use and enjoyment of private water vests in the owner of the land on which it is found. This right of exclusive use is subject to sections 5(2), 12 21-24, 'rights lawfully acquired and existing at the commencement of the Act' and the rights of lower owners to a reasonable share of water flowing to their land which they have used beneficially for thirty years.[53]

The question that arises is what is the content and nature of the statutory right of sole and exclusive use? Findlay has argued[54] that this phrase is nothing else than 'poetic language' for ownership. It is submitted however, that if cognisance is taken of the restrictions that are placed on this right, it emerges as no more than a statutory right of use, not dissimilar to the right of use granted in respect of public water.[55]

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51 A riparian owner is defined in section 1 of the Act as an owner of land 'whereon or along any portion of any boundary whereof a public stream exists ... .' It is a moot point whether riparian ownership of an underground stream is possible in terms of this definition. The use of the word 'along' in the definition, which is defined in the Oxford Dictionary as 'through part or whole of things' length', seems to indicate that riparian ownership of underground streams is possible. This limitation is however merely technical and is rectifiable with a simple amendment.

52 S10(1)

53 S5(1)

54 'The Water Act and Private Water' 1973 THRHR, 140

55 See generally Uys, Report NoII, Ch1

Private water may not be conveyed, negotiated or disposed of without ministerial permission, except for domestic use and stock watering, beyond the boundaries of the land on which it is found.[56]The use of private water is quantitatively restricted in that in the absence of a permit from the Minister, it may not be used in quantities of more than 150m^3 per day for industrial purposes.[57] Where it is so used, it must be purified to certain prescribed standards.[58]The pollution control provisions of the Act as well as those sections preventing wastage of water apply equally to public and private water[59]. In terms of section 24(2), the Minister may reduce or suspend the use of (private) water if the pollution control provisions of the Act are not satisfied. Another restriction, expressly mentioned in the proviso to section 5(1) is a right of reasonable use, acquired by a 'lower owner' of land who has used the water beneficially for thirty years.

The Water Act imposes further restrictions on the right to use private water which are not mentioned in section 5(1). When an owner has rights to use 'deemed' private water and public water and the use of both is wasteful, rights to the public water may be negated.[60] Thus "although the wording of section 5(1) could create the impression that private water is uncontrolled water, being a bonus for an owner on whose land it occurs, the occurrence of this water could materially influence or even replace his rights in respect of public water".[61]

Further control is exercised over the use of private water by provisions regulating its impoundment in certain circumstances.[62]Restrictions are also placed on an owner's right to use 'deemed' private water found in a mine.[63] Section 26(b) expressly authorises the Minister to make regulations relating to;

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56 S5(2)

57 S12

58 S21

59 S22-24, 26

60 S6(3)

61 Uys, op cit p21

62 S9C

63 S12B

"the prevention of wastage or pollution of public water and private water, including underground water...".

Rights to private water are also restricted in areas which are declared dam basin control areas. Owners of land in such areas, who suffer damage or are likely to suffer damage as a result of the declaration are entitled to compensation.[64]

Section 56(1) provides that the Minister may construct a government water work for conserving, utilising, storing, preventing waste or pollution of, controlling or abstracting any water "derived from an underground source". Express mention is made of the fact that the rights and privileges of <u>ownership</u> in respect of a government water work vest in the state.[65]This is in fact the only place in the Act where mention is expressly made of "ownership".

In light of the restrictions discussed above it is clear that the right of sole and exclusive use applicable to private water is a right severely restricted by statutory control measures. It is restricted as far as qualitative and quantitative use is concerned and by constraints on the purposes for which it may be used. It has been suggested that "the right of exclusive use is therefore a statutory preferential right of beneficial use for particular purposes and in particular qualities and quantities, as far as the public interest or the control of government water works are not injured thereby".[66]

The fact that the legislature expressly abolished the reference to ownership contained in earlier legislation and replaced it with rights of sole and exclusive use indicates that the right to private water is, in essence, a statutory right of use and not a right of ownership.

Section 5(2) however, also subjects the right to the use of private water to "rights lawfully acquired and existing at the commencement of the Act". Before one can conclude that the right to use underground private water is not ownership, it is necessary to examine the nature of the rights that were expressly reserved by this section.

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64 S59(4)(b) and (c).

65 S56(4)

66 Uys Report II ch1 p30

Although many courts have upheld the right of a land owner to use ground water, none of the cases have actually defined the nature of the right to the water.

In Snijman v Boshoff[67] Maasdorp CJ alluded to the difficulty that arises with a classification of the right. The court had to decide whether, where land had been subdivided, the defendant was entitled to sink a well and appropriate water so that it ceased to run. Equating the private fountain with water from the basin, Maasdorp CJ held that:

> '[He] was practically owner of the water, though as a matter of law it may not be so. This is as far as we can go. He had the right to the water coming out of the fountain, but he had no right to it before it came out, i.e., he could not prevent anyone from interfering with the underground streams feeding the fountain.'[68]

Most of the cases dealing with the rights to use ground water have been concerned with identifying the circumstances where the owner of land is not entitled to the exclusive use of the water which flows beneath their land. Rarely have the courts referred to the right to use underground water as anything but an exclusive right of use.

The 1876 case of Vermaak v Palmer[69] was the first case to refer specifically to underground water. The court drew a clear distinction between surface water and underground water. In respect of the underground water, the court held obiter, that for underground water to be available for exclusive use it had to flow in undefined channels in a way unknown to the land owner and it could not have been the subject of beneficial use by another owner for a period of thirty years.[70]

Struben V Cape Town District Water Works Co[71] was the first case to refer to the right to ground water as one of ownership. The court held that that underground water belongs

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67 1905 ORC 3.

68 ibid at 5-6.

69 1876 6 Buch 25

70 Uys Report No II, ch IV

71 1892 9 SC 68 referred to in Uys op cit p 128

to the owner of the land below which it is found provided that the water did not flow in a defined channel and that the owner did not know of its existence when he excavated. This knowledge, the court held, deprives the owner of ownership of the water. Despite the fact that this dictum was obiter as the water in dispute did not flow in a known and defined channel, it is submitted that this is peculiar exception to the exercise of a real right.

The Snijman v Boshof case referred to above is further evidence that the 'ad coelum' doctrine (which implies that an owner of land is also owner of everything above and beneath the surface of his land, including the ground water) was not accepted as part of our law. By stating obiter, that private subterranean water was "practically" the property of the land owner "though as a matter of law it may not be so" implied that the doctrine was not accepted as part of the subterranean water law.

As stated previously, in terms of the Irrigation Act of 1912, subterranean water was statutorily defined and a distinction between subterranean water and other ground water was drawn. The cases that followed this Act dealt mostly with ground water that did not qualify as subterranean water.

In Ohlsson's Cape Breweries Ltd v Artesian Well-Boring Co. Ltd[72] the court held that a landowner has a right to search for and appropriate underground even if by doing so the spring or well of another is intercepted. The court conceded that three exceptions to this right exist, namely; an existing servitude, a known and defined channel and malice. Regarding the latter exception, the court decided obiter that it was not a valid exception because it could not co-exist with the exception of a known and defined channel. The court also reiterated the distinction drawn by earlier courts between private and public underground water, private underground water being water that flows in unknown and undefined channels. By drawing a distinction between visible and invisible ground water that flows in known and defined channels the court further indicated that the ad coelum doctrine was not the basis of our ground water law. The court held that water in invisible channels could qualify as public ground water, as long as the channels were known and

72 1919 CPD 125

defined. If the ad coelum doctrine was part of our law, known and defined yet invisible underground water would not qualify as public underground water, but would fall within the proprietary rights of landowners.[73]

The right to use ground water was further developed in Union Government v Marais and others[74]. Concerning the nature of the right to ground water, Innes CJ held that;

> "The principle is fundamental that the owner of land is owner not only of the surface but of everything legally adherent thereto, and also of everything contained in the soil below the surface. And this operation with regard to water on or in the land, though subject to important modifications, is not excluded."

The chief justice qualified the application of this principle by holding that the existence of a servitude or malice are exceptions to the general principle. As far as the legal status of underground water is concerned the court claimed that;

> "subterranean water not flowing in a known and defined channel, but percolating through private property, may be there intercepted and appropriated by the owner in spite of the fact that if not intercepted it would reach the well or the spring of a neighbour or would find its way into a public stream"

This conclusion is not compatible with the courts acceptance of the ad coelum doctrine. In terms of the decision, if the flow of water between two wells or springs is known and defined the upper owner is not entitled to appropriate all the water derived from his well or spring. The fact that the flow of water is known and defined excludes ownership. In terms of the ad coelum doctrine, the upper owner is entitled to everything beneath his land.[75] Once again it is submitted, that to deprive land owners of their right of ownership of ground water on the basis of the existence of a known and defined channel, an

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73 Uys op cit p141

74 1920 AD 240

75 Uys op cit p143

existing servitude and the existence of malice are rather peculiar exceptions to the exercise of a real right.

It is significant that the court relied heavily on foreign law and referred only cursorily to three South African cases on underground water. The fact that the courts have not provided any relief to an aggrieved landowner militates further against classification of the right as one of ownership.[76]

The only case to deal with rights to the use of ground water after the promulgation of the 1956 Water Act and 1987 amendment, is De Witt v Knierim.[77]In this case the court did not refer to the right of an owner to ground water as a right of ownership but refereed instead to a right of use. The court held that an owner of land is entitled to use the water beneath his land unless it is the source of a public stream or he is prohibited from such use by virtue of an existing servitude. The dictum may however, be regarded as obiter as the principle issue to be decided was an alleged infringement of an actio confessoria in rem, in terms of which the appellant had the sole right to the use of the water of certain dams on the respondent's farm.

From the discussion above, it is clear that the right to use ground water is dependent upon the status of the ground water in question. The right to the use of ground water which exists in a declared subterranean government water control area vests in the Minister if the water was unallocated or unused immediately prior to the declaration of the area as a control area. If it was allocated and used immediately prior to the declaration of the control area the right of use vests in the owners to which the right was allocated.

If ground water qualifies as "public" surplus water it is subject to rights of beneficial use for domestic purposes, stock watering, agricultural and urban purposes by the riparian owner. Thus if an owner of land can prove that an upper owner draws underground

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76 Indeed in Gien v Gien 1979 (2) SA 1113 (T) Spoelstra AJ stated that, '[i]t may be difficult to define dominium comprehensively ... but there can be little doubt ... that one of its incidents is the right of exclusive possession of the res, with the necessary corollary that the owner may claim his property whenever found, from whomsoever holding it.'

77 1994 (1) SA 350 (A)

water that qualifies as a public stream, he is only entitled to the remainder of the water that the upper owner could not beneficially use.

Ground water that qualifies as deemed private water is available for the sole and exclusive right of use of the owner who exploits it. It has been argued that this right of use is not ownership but an exclusive right of beneficial use for specified purposes. In this instance, if the owner cannot prove the existence of a known and defined channel connecting his well to that of the upper owner, the upper owner is entitled to a sole and exclusive right of use in respect of the water. This right is however, restricted to beneficial use by quantitative and qualitative limitations. This right of use may also be restricted by the common law restrictions of whether the underground water flows in a known and defined channel, whether a servitude exists which prevents the use of the ground water and whether there was malice involved in the use of the water.

3.14 IS THE RIGHT TO GROUND WATER A RIGHT IN PROPERTY PROTECTED BY THE CONSTITUTION?

Having shown that the right to ground water is not a right of ownership, it now remains to be seen whether the right is a 'right in property' for the purposes of s 28 of the Constitution?

Since the courts have been unable to recognise an overlying landowner's rights of ownership in respect of ground water, is it an 'unpropertised resource which remains in the commons, available for use and exploitation by all.' Gray[78] notes that:

> 'The primordial principle which emerges from the majority judgements[79] ... is that a resource can be propertised only if it is - to use another ugly but

[78] Kevin Gray 'Property in Thin Air' (1991) Cambridge Law Journal 252.

[79] Gray is referring to the Australian High Court case Victoria Park Racing and Recreation Grounds Company Ltd v Taylor and others (1937) 58 CLR 479. In that case the courts had to decide whether the plaintiff company, which carried on the business of racing, could prevent the defendant from describing and commenting on the racing spectacle which he observed from an elevated platform on his land. His commentary was broadcasted by the Commonwealth Broadcasting Corporation resulting in decreased attendance at the racecourse. Dixon J stated (at 507), 'English law is, rightly or wrongly, clear that the natural rights of an occupier do not include

> effective word [the first being propertised'] - "excludable". A resource is "excludable" only if it is feasible for a legal person to exercise regulatory control over the access of strangers to the various benefits inherent in the resource.'[80]

According to Gray resources may be physically[81], legally or morally[82] non-excludable. Lewis[83] believes that this approach minimises problems of interpretation. She supports Gray's thesis particularly because it allows considerations of morality, often absent under the South African legal system, to prevail.[84]

It would seem that groundwater is non-excludable in all three senses. Being a fugitive resource it cannot be physically controlled. Only when it has been drawn will the landowner control it. The common law, by denying a landowner an action against excessive pumping by a neighbour has failed to promote legal excludability. The right to ground water is excludable only in the sense that the water must be used on the overlying land and cannot be transported off the property. This doctrine effectively protects landowners against transporters of water such as municipalities. Off-site use is excluded even where water flows in a known and defined channel. The immorality of vesting exclusive ownership in a public resource like groundwater to any one group in society is self evident.

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freedom from the view and inspection of neighbouring occupiers and of other persons who enable themselves to overlook the premises. An occupier of land is at liberty to exclude his neighbour's view by any physical means he can adopt.'

80 ibid at 268.

81 Physical non-excludability arises 'where it is not possible or reasonably practicable to exclude strangers from access to the benefits of a particular resource in its existing form'; see Gray at 267.

82 Gray (at 280-1) claims that '[t]he notion of moral non-excludability derives from the fact that there are certain resources which are simply perceived to be so central or intrinsic to constructive human coexistence that it would be severely anti-social that these resources should be removed from the commons ... In setting the moral limits of "property", the courts effectively recognise that there is some serial ranking of legally protected values and interests: claims of "property may sometimes be overridden by the need to attain or further more highly rated social goals.'

83 Carole Lewis 'The Right to Private Property in a New Political Dispensation in South Africa' (1992) <u>SAJHR</u> 389 at 430.

84 ibid at 408.

It is instructive, and congruent with the interpretation clause in the interim Constitution, to refer to US case law which decided the constitutionality of amending ground water legislation.

3.14.1 United States of America

The United States Supreme Court, as well as state Supreme Courts, have had frequent occasion to decide whether legislation which restricts the overlying landowner's right to water is unconstitutional.[85]

In Town of Chino Valley v City of Prestcott[86] the Supreme Court of Arizona, seeming to adopt the excludability theory, found that there is no right of ownership in groundwater prior to its capture and withdrawal from the common supply and the right of the owner of overlying land is simply to a usufruct of water. The court compared underground water with wild animals which are free to roam as they please, and 'are the property of no one.'[87] In an insightful statement of the nature of the right Struckmeyer CJ stated:

> 'The common-law concept of absolute ownership of percolating water while it is in one's land gave him the right to abstract from his land all the water he could find there. On the other hand, it afforded him no protection against the acts of his neighbours who, by pumping on their own land, managed to draw out of his land all the water it contained. Thus the term "ownership" as applied to percolating water never meant that the overlying owner had a property or proprietary interest in the corpus of the water itself. The right of the owner to ground water underlying his land is to the usufruct of the water and not to the water itself.'

Acknowledging that, previously, Arizona courts had held otherwise on three occasions, his lordship went on to say that 'dictum thrice repeated is still dictum.'[88]

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85 Kline's case at 212.

86 See note ....

87 ibid at 1328.

88 ibid at 1327.

In Village of Tequesta v Jupiter Inlet Corp[89] the Supreme Court of Texas held that '[t]here can be no ownership in seeping and percolating waters in the absolute sense, because of their wandering and migratory character, unless and until they are reduced to the actual possession and control of the person claiming them.' Further, since the common law 'afforded him no protection against the acts of his neighbours who, by pumping on their own land, managed to draw out of his land all the water it contained ... the term ownership as applied to percolating water never meant that the overlying owner had a property or proprietary interest in the corpus of the water itself.' Adkins J concluded that:

> 'The right of the owner to ground water underlying his land is to the usufruct of the water and not to the water itself. The ownership of the land does not carry with it any ownership of vested rights to underlying ground water not actually diverted and applied to beneficial use.'

On the above analysis, it is questionable whether landowners' rights to groundwater can be defined as 'rights in property'. However, if this argument is not accepted could legislation, which vests the ownership of all water resources in the State, survive constitutional challenge?

3.15 Constitutional Challenge

The enactment of legislation which interferes with rights of ownership is not unknown in South African law.[90] It is possible, however, that legislation which seeks to alter existing rights in ground water will be challenged as an infringement of a constitutionally protected right in property. The Constitutional Court will have to decide whether the legislation amounts to a 'deprivation in accordance with a law', or whether it in fact expropriates rights which are compensable.[91]

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90 Carole Lewis "The Modem Concept of Ownership of Land" (1985) Acta Juridica 241;

91 For a discussion of the US distinction between the valid exercise of the police power in restricting proprietary rights, and acquiring property by eminent domain, in which case compensation must be paid, see Rosemary Lyster "Protected Natural Environments": Difficulties with environmental land use regulations and some

3.16 THE RIGHT TO WATER AND THE PROPERTY CLAUSE

Should the Constitutional Court decide that legislation, which reflects a world-wide trend towards vesting property in all water resources in the State, is an unconstitutional 'taking of property'? Murphy calls for an acceptance of the mediating function of property rights and a move away from the representation of property as a 'factually and interpretatively discoverable truth.' He states that the crucial issue is whether the government action is efficient and should be encouraged rather than whether property is taken or given.[92]

The limitation clause has been touted as the mediator between these competing theories. Woolman states that the limitation clause, 'establish[es] a test which determines the extent to which the people's elected representatives may modify or determine the limits of constitutionally protected rights and the extent to which an unelected few may determine the law of the land.'[93]

How should the limitation clause be applied in the present case? It is trite that legislation divesting ground water rights from overlying landowners would fall into the sphere of activity protected by the property clause, and probably amount to an infringement of that right. Accepting this, the onus shifts to the government to prove that the legislation is 'reasonable' and 'justifiable in an open and democratic society based upon freedom and equality.' In addition, the government must show that the legislation does not negate the 'essential content of the right'. Adopting the interpretative approach described earlier, it seems that the equitable allocation of a national resource is eminently reasonable and justifiable in an open and democratic society. Indeed, it may be regarded as essential for the establishment of such a society. Would such legislation negate the essential content of the right?

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thoughts on the property clause' (1994) 2 De Jure 136 and Matthew Chaskalson 'The Problem With Property: Thoughts on the Constitutional Protection of Property in the United States and the Commonwealth' (1993) SAJHR 389. See also J Murphy 'Property Rights in the new constitution: an analytical framework for constitutional review' (1993) THRHR 608; Richard W Bauman 'Property Rights in the Canadian Constitutional Context' (1992) SAJHR 344; Carole Lewis 'The Right to Private Property in a New Political Dispensation' (1992) SAJHR 389; and Matthew Chaskalson 'The Property Clause: Section 28 of the Constitution' (1994) SAJHR 131.

92 Murphy at 397.

93 Woolman at 78.

US cases are helpful for comparative purposes. In Kline v State, Ex Rel. Water Resources Board[94] the Oklahoma Supreme Court had to decide whether the Oklahoma Water Resources Board had acted unconstitutionally in establishing maximum annual yields of fresh ground water from alluvium and terrace deposits in five counties in north-western Oklahoma. The court found that Oklahoma ground water law (the Oklahoma Groundwater Law 1972) did not infringe constitutional inhibitions against taking of property without due process, of law, denial of equal protection of law, or taking property without just compensation. Indeed, in the opinion of the Court the Board's decision was supported by substantial evidence compiled by the United Geological Survey. In giving judgement, the court referred to its earlier decision Anderson-Prichard Oil Corporation v. Corporation Commission, that the Legislature may regulate and restrict the use and enjoyment of landowners of the natural resources of the state such as subterranean waters, so as to protect them from waste and to prevent the infringement of the rights of others. In that case, the court held that such legislation does not infringe the constitutional inhibition against the taking of property without due process of law, denial of equal protection of the laws, or taking property without just compensation. Although this case is not concerned with the divesting of water rights, the policy considerations, relating to the need to allocate water equitably and to conserve the resource, inform the present discussion.

In Town of Chino Valley v City of Prestcott the court found that the Arizona Groundwater Management Act of 1980 neither took property without due process and or without just compensation. Struckmeyer CJ declared that overdraft of groundwater was a serious problem in Arizona, and that it was necessary for comprehensive legislation to both limit groundwater use and allocate its use among competing interests. As to the question of compensation, the court found that legislation which denies or restricts rights to use property necessarily results in diminution of that property's value. However, it referred to numerous occasions where the United States Supreme Court has upheld under the state's police power, regulation of land use which has virtually destroyed private

[94] 205 Okl. 672, 241 P.2d 363, appeal dismissed, 342 U.S. 938, 72 S.Ct. 562, 96 L.Ed. 696 (1952).

interests. The court added that many state courts[95] had rejected the idea that groundwater percolating through the soil may not be limited and regulated but must be acquired by eminent domain.[96]

In both these cases the right to use ground water was limited but not expropriated. In Oklahoma the Act established a maximum annual quota, while the Arizona saved existing water rights. In order to escape claims for compensation it is submitted that the legislation should follow the precedents of the Arizona, German and Alberta legislation whereby existing water rights are saved and only unexercised rights are appropriated for off-site distribution. In this way the legislation would satisfy the final test laid down in the limitation clause, that the essential content of the right should not be negated.

3.16.1 Australia and New Zealand

Although the constitutional question does not arise in Australian and New Zealand case law, as neither country has enacted a Bill of rights, there are numerous cases which have held that the abolition of water rights is effective. They are mentioned only with reference to the public policy considerations behind a reform of water law.

In Grant Pastoral Co Pty Ltd v Thorpe's Ltd[97] the court found that the Water Act 1912 (NSW)[98] altered the common law, and transferred rights to the use of water to the Water

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95 Village of Tequesta v. Jupiter Inlet Corp. 371 So.2d 663 (Fla), cert denied, 444 U.S. 965, 100 S.Crt. 43, 62 L.ED.2d. 377 (1979); Williams v. Wichita 190 Kan. 317, 340-41, 374 P.2d 78, 9-96 (1962), cert. denied, 37 U.S. 7, 84 S.CT. 46, 11 L.Ed.2d 38 (1963); Crookson Cattle Co. v. Minnesota Department of Natural Resources 300 N.W.2d. 769, 774 (Minn.1980); Baeth v. Hoisveen 17 N.W.2d 728, 733 (N.D.1968); Knight v. Grimes 80 S.D. 17, 23-27, 127 N.W.2d 708, 711-14 (1964).

96 Town of Chino Valley at 1329; see also Matthew Chaskalson "The Problem with Property: Thoughts on the Constitutional Protection of Property in the United States and the Commonwealth" (1993) SAJHR 388 at 398. It is arguable on the factors set out in Pennsylvania Central Transportation Co v New York City 438 US 104 (1978) that Struckmeyer CJ's approach is correct, since the Groundwater Act specifically protects rights which existed at the time of enactment.

97 (1953) 71 W.N. (N.S.W) 101.

98 This Act has subsequently been replaced by the Water Administration Act of 1986, which has as its object to ensure that the water and related resources of the State are allocated and used in ways which are consistent with environmental requirements and provide the maximum long-term benefit for the state and for Australia; and to provide water and related resources to meet the needs of water users in a commercial manner consistent with the overall water management policies of the

Conservation and Irrigation Commission for the benefit of the Crown. The court found that one of the purposes of the enactment was for the conservation and supply of water, its more equal distribution and its beneficial use.

In Glenmark Homestead Ltd v North Canterbury Catchment Board[99] the Supreme Court of New Zealand held that the Water and Soil Conservation Act of 1967 was intended to codify the legislation relating to the use of natural water and also soil conservation. It was intended to promote a national policy in respect of natural water and, inter alia, 'to make better provision for the conservation, allocation, use and quality of natural water.'[100] The court went on to hold that 'when the Act came into force, therefore, private rights in relation to those matters could no longer be acquired in accordance with the common law.'[101] On appeal, the Court held that sec 21 of the Act, may be regarded as 'a sort of conduit leading from the old to the new. It effects what may properly be regarded as a transformation in the law. Common law rights are extinguished and statutory rights where appropriate take their place.' The Court recognised that in spite of such extinction, s 21 of the Act preserved 'existing uses' which existed prior to a date specified in the Act.[102]

3.17 Conclusion

It has been argued that the common law 'absolute ownership' ground water doctrine fails to recognise the hydrological reality and that legislation is needed to promote the equitable distribution and conservation of a scarce resource. It seems that the right to ground water is not a 'right in property' for the purposes of s 28 of the Constitution. However, if this is not accepted by the Court, it is argued that the individual right to property should in this instance give way to the dire need of 12 million people for access to water.

Government. The right to the use and flow of water vests in the Water Administration Ministerial Corporation.

99 [1975] 2 NZLR 71.

100 ibid at 87.

101 idem.

102 [1978] 1 N.Z.L.R. 407 (C.A.)

PART FOUR

AN ECONOMIC FRAMEWORK FOR VALUING GROUNDWATER

4. AN ECONOMIC FRAMEWORK FOR VALUING GROUND WATER

4.1 INTRODUCTION

Access to ground water is dependent on various rights and obligations defined by economic circumstances and the law. Ground water economic value (usually signalled by its price) is a necessary, although not the only, indication of its importance to society.

To understand the trade-offs (these will be discussed later) which are important in ground water management and policy formulation it is helpful to approach the problem from a systems context. Such a system includes a wide range of physical, economic, management and biological inputs. Fig 4.1 below suggests an appropriate system configuration for ground water analysis.

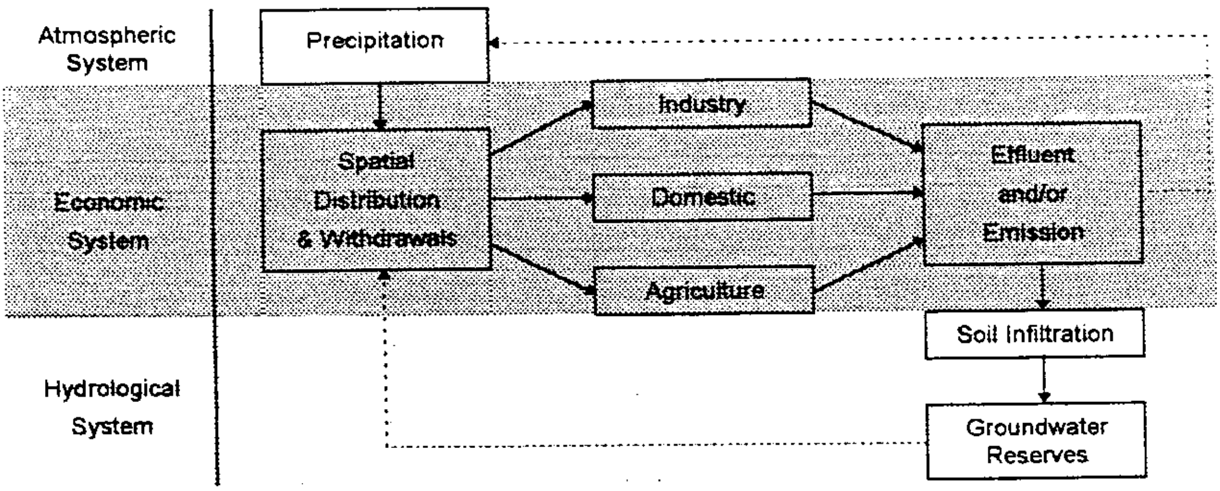

FIG 4.1 SYSTEMS IN GROUND WATER MANAGEMENT

The complete system can conveniently be broken down into three subsystems; these are:

- The Atmospheric System
- The Economic System

- The Hydrological System.

Precipitation is the primary input source whilst industry, agriculture and domestic users are the primary consumers. Competition between these three types of consumers dictate the allocation and pricing process in economic terms. A complex institutional structure establishes the rights and liabilities of these end-users.

The primary objective of this section is to determine the essential dimensions of the economic sub-system. To do this it is necessary to:

- Develop an analytical framework for valuing ground water in its different uses so that policy makers will be provided with guidelines concerning the welfare gains or losses attached to increases or decreases in the price of ground water, and changes in the quality of ground water.
- Improve the quality of information on ground water usage available to researchers in South Africa.
- Establish what future research thrusts should be adopted.

4.2 AN ECONOMIC FRAMEWORK FOR ECONOMICALLY VALUING GROUNDWATER IN SOUTH AFRICA

4.2.1 Introduction

The economic value of ground water is a derived value and depends upon its utility to human beings. Conflicts may arise as users attempt to access more and more ground water and competition for the resource increases.

As the South African economy grows with increased industrial development and a burgeoning population, new demands will be created for ground water and conflict between end-users can be expected to increase. Public policy and the management of ground water must anticipate such conflicts and be able to respond to them by means of economically defensible trade-offs. This section outlines a framework for measuring the economic value of such trade-offs.

4.2.2 The measurement of economic values

4.2.2.1 Overview of the problem

The economic value of a commodity (including ground water) is underpinned by two assertions.

Economic value depends on the preferences held by individuals.

Economic value can be influenced by an individual's limited means and the resource's scarcity.

Limited means imposes the discipline of trading-off desires by individuals. For example, an individual has to sacrifice one thing for another if his budget does not allow him to purchase both items. Economic value is therefore a combination of preferences and limited resources, and measures the trade-offs individuals are prepared to make between goods and services.

Market prices reflect economic values by and large. Here a buyer exchanges the prospective gain from one good or service against the purchasing power represented by the price of the good or service. If a purchaser's willingness-to-pay is greater than the seller's willingness to accept compensation, a transaction can normally follow. Trade will clearly continue until the willingness-to-pay equals the willingness-to-accept.

Markets however, only operate smoothly when suitable institutional conditions are in place, e.g., property rights to goods and services must be secure. If ownership is attenuated the exchange price will reflect the uncertainty of ownership.

Water usually violates the conditions for smoothly operating markets and is often considered to be a "special" good due, no doubt, to its life giving properties. There is debate concerning the economic classification of ground water which may complicate the introduction of a market mechanism into the water economy, e.g., is ground water a public or private good?

With price signals which are unclear ground water may not be allocated optimally i.e., to its highest economic value. In South Africa it may be that legal, legislative or regulatory policy options will have to be put in place when determining the benefits of allocating ground water to different users.

4.2.2.2 An analytic framework for valuation

A policy change that purports to maximise the benefits from a particular allocation and pricing regimen has to ensure that the individual households and industrial enterprises making up the economy of South Africa are made better off by such a change. To ensure that this aim is achieved it is essential that the trade-offs that individuals and firms are willing to make are known. Such trade-offs are summarised by demand schedules.

A demand schedule can be written in mathematical notation follows:

$$Q = f(p_q, p, q, h, k, c, i) \quad \text{.......(1)}$$

where:
Q = quantity of water demanded
p_q = price of water
p = price of substitutes for water and conservation devices etc.
q = quality characteristic of water
h = household characteristics, size, pool area, age, etc.
k = water use customs and legal constraints to water usage, etc.
c = climatic variables, arid area, summer precipitation only, etc.
i = income of household

Individual household demand schedules may be summed to provide analysts with composite domestic demand schedules for water usage. This demand schedule summarises the domestic trade-offs with regard to the variables listed above. In addition it is important to note that these trade-offs take cognisance of other adjunct variables such as substitutes, etc., as listed above. Agricultural and industrial demand schedules can similarly be considered.

A demand schedule is useful in formulating economic policy. In this regard two types of information can be gleaned using equation (I) above. The first is obtained by examining the variables on the right hand side of equation (I). If these variables can be estimated from secondary sources e.g., a census, climatic handbook of different areas in the Republic and municipal demand figures for water, householder's demand may be able to be estimated without recourse to expensive field studies. Furthermore, if forecasts of future water price increases are known and increases in income are also known for the same temporal vector then future demand may be forecast for ground water usage. These pieces of information should help policy makers and water resource investment decision-makers anticipate future scarcities and conflict amongst end-users so that policies to deal with the problem can be put in place.

Now, demand schedules can measure economic trade-offs in the following manner: Referring first to Figure 4.2 below:

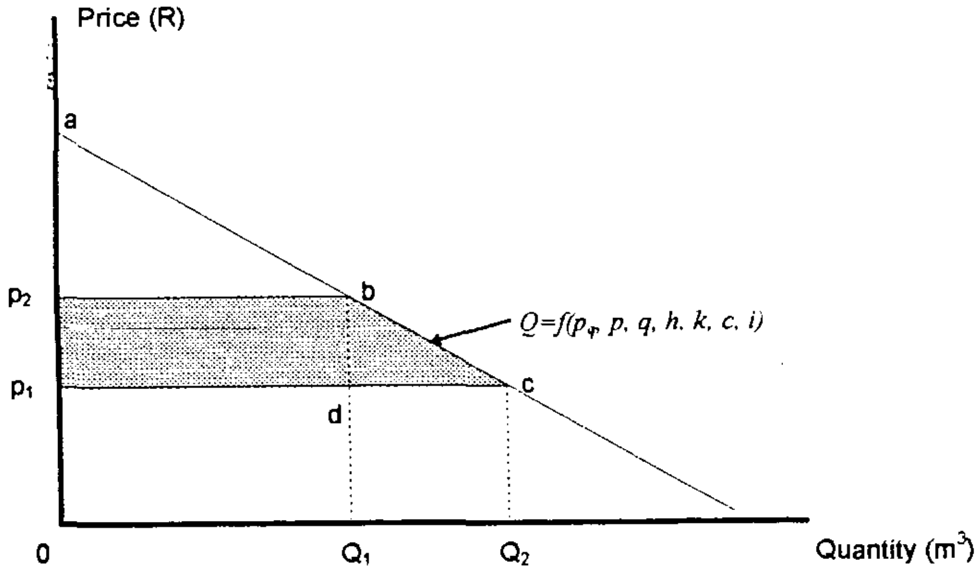

FIG 4.2 ECONOMIC TRADE-OFF - CHANGE IN WATER PRICE

The figure shows the relationship between the price of water and the quantity demanded. At price p_2 the amount of water demanded is Q_1 and at price p_1 the quantity demanded is Q_2. For a decrease in the price of water of (p_2-p_1) the change in water demand is (Q_2-Q_1).

The demand schedule slopes downward, reflecting that larger and larger quantities of water are less and less valuable at the margin. For example, the small amount of water required to sustain life is of infinite value and a consumer is probably willing to pay a high price for this small amount. For other uses such as lawn watering, car washing, etc., a consumer will only be prepared to pay a lower price.

The benefits or disbenefits of a change of price for water as shown in Fig 4.2 can be measured in the following manner. In the first instance a consumer buys Q_2 m^3 of water and pays p_1cQ_20. The consumer does, however, gain a surplus of benefits, usually termed "consumer surplus", equal to the area shown in Fig 4.2 as acp_1. This is because the consumer would have been quite willing to pay a price up to the amount dictated by the demand schedule for each successive unit of water. The consumer only pays, of course, the price p_1 (a constant price), hence a benefit is registered.

If the price of water rises for any reason the consumer losses a portion of his "surplus" equal to p_2bcp_1 if the price rises from p_1 to p_2. With this rise in price the consumer has lost two forms of surplus, however. In the first instance he no longer consumes Q_2 units of water but Q_1 instead and secondly he pays a higher price for a smaller quantity.

In mathematical terms the net loss in "value" of the ground water can be written as:

$$\Delta CS = \int_{P_1}^{P_2} f\left(p_q, p, q, h, k, c, i\right) \qquad (2)$$

where ΔCS = change in consumer surplus.

If there is a change in water quality the same approach can be used to attack the problem. In this case reference is made to Figure 4.3 below.

If the quality of water declines consumers are likely to demand less water. An example would be a change in taste or smell for the worse. In this case even where the water supplied meets public health standards it may be offensive to the user and consumers may reduce their demands for drinking water, substituting municipally supplied water with bottled mineral water. In such cases the consumer demand curve shifts to the left and less municipal water is demanded at a given price.

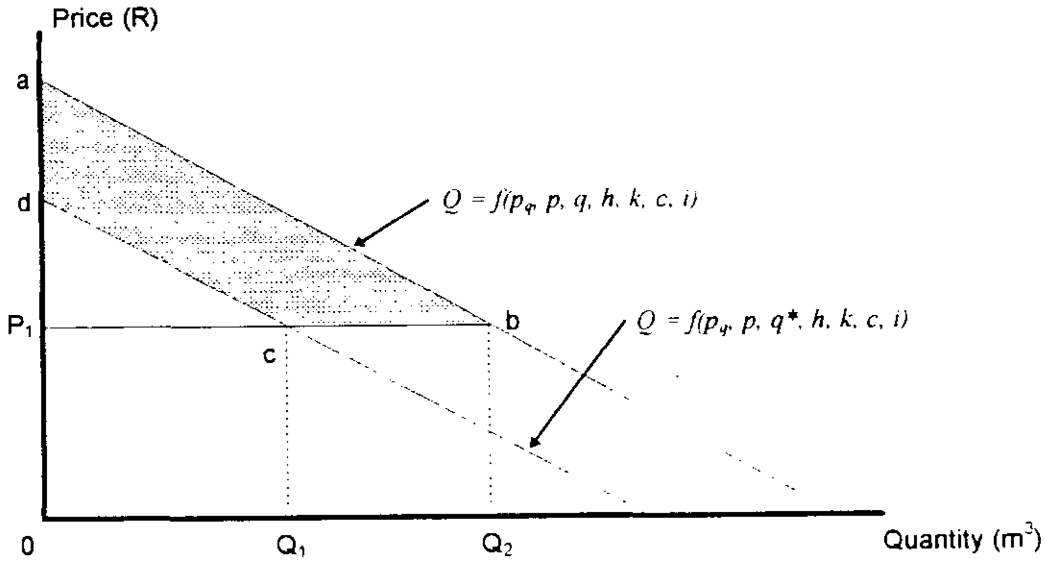

FIG 4.3: ECONOMIC TRADE-OFF - CHANGE IN WATER QUALITY

The net loss in welfare is shown by the area abcd in Fig 4.3. Mathematically the net loss can be written as:

$$\Delta CS = \int_{P_1}^{a} f(p_q, p, q, h, k, c, i) - \int_{P_1}^{d} f(p_q, p, q^*, h, k, c, i) \quad \text{.................. (3)}$$

The foregoing discussion provides water managers and policy makers with a simple yet powerful method of assessing the economic gains or losses to consumers from changes in the price or quality of ground water.[103] Demand schedules are required, however, and this means extensive data gathering. A side benefit of obtaining such data is that price elasticities of demand may be calculated providing analysts with

103 For example if ground water prices were increased in one area to provide money for infrastructural development providing ground water in another area, the losses in the first area could be calculated and equated with the welfare gains in the second area.

the means for forecasting future demands for ground water and the concomitant scarcities.

The approach the authors would have liked to implement in valuing groundwater in South Africa was as follows:

1. By means of surveys determine consumers' willingness-to-pay for groundwater, develop demand schedules and determine price elasticities of demand.

2. Check the value of groundwater found from 1. above, by means of other valuation approaches, these being:

   I. Utilising a price elasticity of demand for groundwater
   II. Residual imputation
   III. Alternative cost techniques, and
   IV. Value added.

The problem in South Africa with this approach is that demand information i.e., the relationship between water price, income levels, quality and demand is simply not available at present. This study did make an attempt to gather such information in each of the case study areas. Problems were encountered, however, which rendered these attempts a failure. The main problems were as follows:

(I) Consumer Ignorance.
Generally urban white consumers were ignorant of some very basic facts concerning where their supply of water came from and what its price was. Generally water costs were seen as being a very insignificant part of the household budget and did not constitute a major item of expenditure. As a consequence it was not possible from the brief survey conducted during this study to develop demand schedules for municipal water. It must be pointed out that black rural dwellers have a much greater perception of the value of domestic water than white urban dwellers.

(ii) Industrialists (power generation excluded) also do not generally take the costs of water into account when setting up an enterprise or locating production facilities.

As a consequence it was also not possible to generate meaningful demand schedules for industrial water.

(iii) Agricultural (irrigation) water has been heavily subsidised in South Africa for many years. This has meant that a culture has developed whereby the true value of ground water used for irrigation is difficult to assess from simple surveys like the one undertaken for this study. As a consequence it has also been impossible to generate demand schedules for irrigation water.

Because of the problems inherent in deriving demand schedules it was considered necessary therefore to concentrate in this study on describing in some detail the valuation methods listed above, these being independent of such schedules.

It is also appropriate to mention here that the approach utilising the price elasticity of demand for valuing groundwater has to make use of a proxy value for this parameter since such elasticities are largely unknown in South Africa at present. The proxy value used in estimating the value of groundwater usage in Verwoerdburg will be taken from a major study conducted by Howe and Linaweaver in the USA. The value chosen will be that calculated for an area in America that resembles Pretoria so far as climate, economic and social profiles are concerned.

Because of the importance of demand schedules in general valuation processes (they represent the willingness-to-pay of consumers for a commodity) however, it is thought necessary to comment on the derivation of value estimates using demand functions prior to discussing the other four valuation processes mentioned above.

4.3 DERIVING VALUE ESTIMATES FROM DEMAND FUNCTIONS

The classical method of estimating the value of any unmarketed commodity, including groundwater, is to estimate the demand for that commodity Where groundwater is a final consumption good, the demand curve can be derived from price-quantity observations. In all sectoral uses (except municipal use) water is an intermediate good, however.

Theoretically in the case of an intermediate good the derived demand can be found from the first derivative of the production function. For example in studying the response of crops to irrigation water application and other inputs the schedule representing the short-term value of the marginal product is derived from the conditions under which the study was conducted and depends on climate, fertiliser applications and many other factors. Difficulties arise, however, in utilising this approach as an estimate of value if public sector intervention occurs in the pricing process by way of subsidies or other market distorting mechanisms. Such a price manipulation is of course very common in many agricultural products and since irrigation is the largest water use in South Africa, this fact is important.

With subsidies in place the willingness-to-pay will overstate the social value of the marginal unit of production. Generally direct estimates of the demand for water as an intermediate good has little application then because often there is a lack of data for demand and production costs in non-agricultural uses. This is particularly the case for South Africa.

So far as can be determined there has been no instance of research in South Africa where water has been included as a variable in the production function of non-agricultural production.

A method closely allied to valuing groundwater from demand functions is that of utilising a proxy price elasticity of demand. This approach is discussed in the next section.

4.4 UTILISING THE PRICE ELASTICITY OF DEMAND IN VALUING GROUNDWATER

The procedure developed below allows a value for ground water to be estimated. For a given change in water supply the value of this water is equal to the area under the demand schedule. Consider Figure 4.4 below:

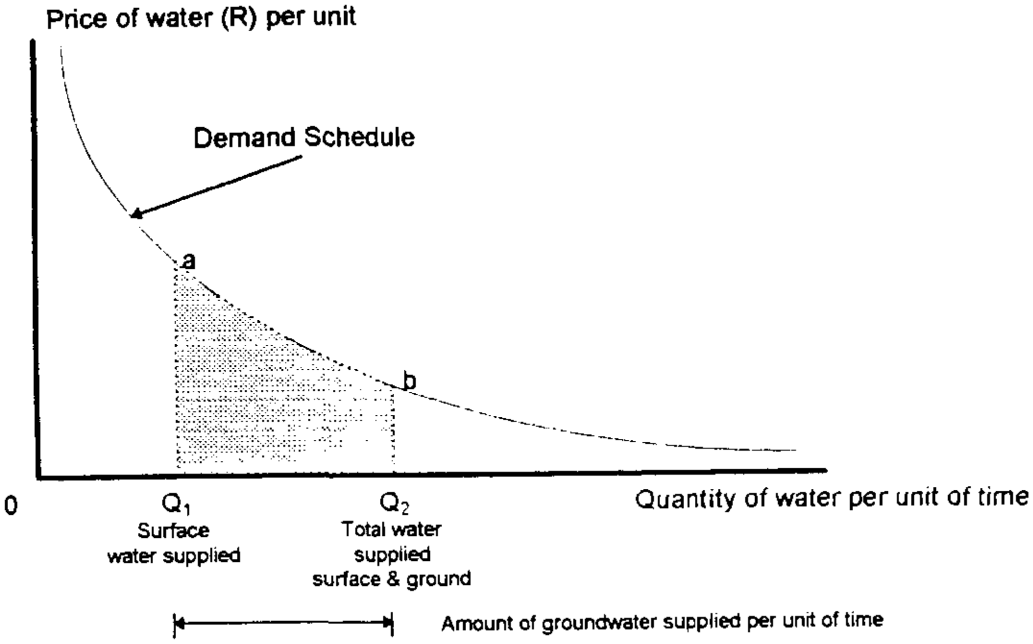

FIG 4.4 DEMAND SCHEDULE FOR WATER

For the given change in water supply i.e., from Q1 to Q2, the total value of this water can be written as:

$$Value\ (V) = \int_{Q_1}^{Q_2} \text{Price}\ dQ \quad \ldots\ldots (4)$$

Now, if the price elasticity of demand e is known and does not vary between points a and b and it is not equal to 1,0 and further a point on the demand schedule can be specified i.e., a price P* for a certain quantity of water Q* then it can be shown that equation (4) can be rewritten in the following form:

$$V = \frac{P_* Q_*^{e^{-1}}}{1 - e^{-1}} \left[\frac{Q_2}{Q_2^{e^{-1}}} - \frac{Q_1}{Q_1^{e^{-1}}} \right] \quad \ldots\ldots (5)$$

This equation represents the area abQ_2Q_1, and therefore represents the total willingness-to-pay for the increment Q_2Q_1 which is in fact the ground water component of the supply system.

It is of course of interest to know the net value of raw water at its source, for purposes of comparison with values in alternative uses. This value can be found using equation (5) above and making some further simplifying assumptions. Consider Figure 4.5 below in this respect.

If it is assumed that water is supplied at a price that covers the average cost of supply P* (a relatively typical practice) then imputing a value for raw water under these circumstances means that the total cost equals total revenue and the residual value of water is zero. There is, however, a consumer's surplus accruing to the water user, this is represented by the area abc in Fig 4.5. To calculate this consumer's surplus is an easy matter since using equation (2) to value v (a price) for a quantity of water per unit of time is found and the consumer surplus is found by subtracting price P* from this result. The method is demonstrated when a value of the groundwater for Verwoerdburg is estimated.

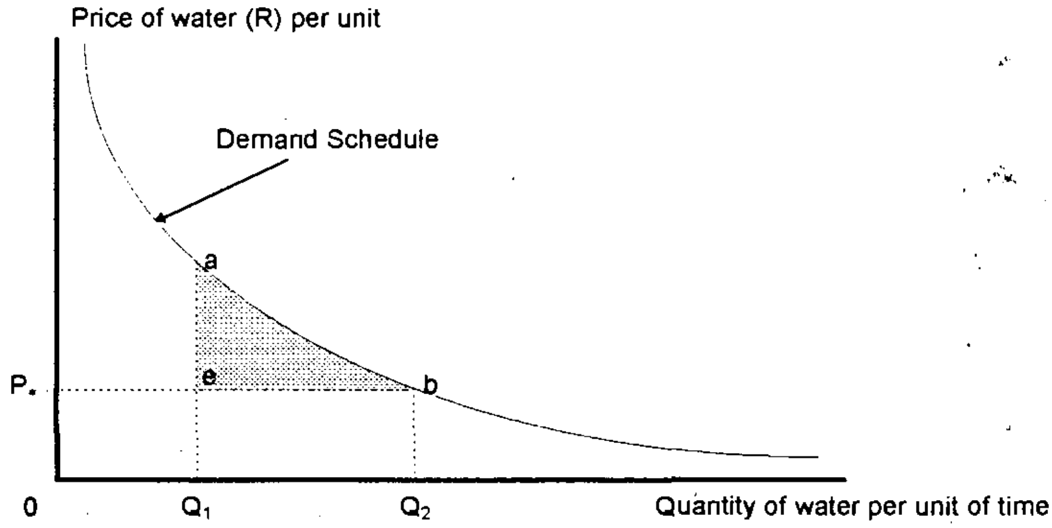

FIG 4.5: DEMAND SCHEDULE FOR WATER (SHOWING CONSUMER SURPLUS)

4.5 RESIDUAL IMPUTATION AS A METHOD OF VALUING GROUNDWATER

Residual imputation is a technique which assigns a price to a resource by allocating the total value of output to each of the resources used in the production process. Conceptually the method is quite simple and involves assigning appropriate prices to all the inputs into the production process except one; the price to be imputed.

The technique is based upon achieving economic efficiency in the production process. For an efficient allocation of resources marginal cost pricing is considered essential. Three postulates are important in residual imputation as a consequence; these are as follows:

From the input side of the production process all resources in that process are assumed to be priced equal to their returns at the margin.

From the output side of the production process the total value of the output can be divided into shares such that each resource is paid according to its marginal productivity.

The total value of output is completely exhausted.

The question of whether resources are, or are not exhausted can be answered with reference to Euler's Theorem. In this respect national output is distributed among the three basic factors of production: land, labour and capital. No arithmetical reason could be thought of as to how the different factors of income, derived from marginal productivity's could necessarily add up to the same total output. Euler's Theorem solved this problem by showing that resources paid according to marginal productivity will result in the complete exhaustion of total product.

The residual imputation method can be illustrated by considering the following example, involving three factors of production: capital, labour and water. It is required to impute the value of water. From the three postulates given above, the following expression can be developed.

$$TV = VMP_L \times L + VMP_K \times K + VMP_W \times W \ldots\ldots\ldots\ldots (6)$$

where:

TV = Total value of output.

VMP_i = Value of marginal product of any resource i, $i = K, L, W$.

If the values of the marginal productivity of labour and capital have been accurately computed the value of water can be found from (6) as follows:

$$TV - VMP_L \times L - VMP_K \times K = VMP_W \times W \quad (7)$$

and from postulate (I)

$$TV - P_L \times L - P_K \times K = VMP_W \times W \quad (8)$$

Residual imputation appears then to be a simple technique for estimating the shadow price of a resource. It is, however, subject to several limitations. These can be categorised under the following broad headings:

- The question of the price equalising the value of the marginal product of all resources except the one being sought.
- The problem of omitting variables.
- Problems of estimation when price supports or subsidies or other exogenous influences are exerted in the production process.

Firstly there is considerable operational difficulty encountered through the use of prices as indicators of value marginal products for all resources save one. If resources are not allocated so that all factor inputs are employed at the level where prices are not equal to the value marginal products the imputation process may result in an over or under-estimation of the resources being imputed.

Secondly there may be resources which have been omitted from the analysis, e.g., the management function. If such resources are not taken account of the returns properly attributed to them will be imputed to the residual resource resulting in an overstatement of the resource's value.

Thirdly where price support exists for certain inputs into the production process it is recommended that appropriate shadow prices are used instead of market prices. This is of particular relevance for agricultural inputs such as fertiliser, seeds and farm diesel fuel etc., in South Africa.

For practical purposes, but bearing in mind the limitation discussed above, when using residual imputation for assigning a value to ground water it is recommended being that market prices of factor inputs accurately reflect the contribution they would have made if employed in alternative productive activities.

4.6 ALTERNATIVE COSTS

This technique is deceptively simple and requires alternatives to be priced which, by substantially different means, accomplish the identical end product. For example groundwater use in an area can be replaced by a scheme bringing surface water to the area.

There are usually many alternatives to be considered e.g., there could be private alternatives to a public water supply or two public projects that compete with each other. The willingness-to-pay, and hence the value of the project, depends therefore on several parameters, e.g., the quality of service provided by the different alternative, and where water is concerned, the quality of the water itself.

The alternative costs technique is like the two other techniques discussed above, powerful in that it allows the analyst to estimate the maximum willingness-to-pay without actually estimating demand curves. The technique does, however, require considerable data to be compiled and analysed: more than is usually required for the other approaches to valuing ground water mentioned above.

Alternative costs as a measure of value has been extensively discussed by Prof. Steiner[104].

Consider a private alternative to a public development, e.g., a private groundwater supply to irrigate an agricultural schemes as opposed to a government schemes. Figure 4.6 below aids in the explanation

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[104] Steiner P.O. The Role of Alternative cost in Project Design and Selection, Quarterly Journal of Economics, Vol 79, No 3, August 1965.

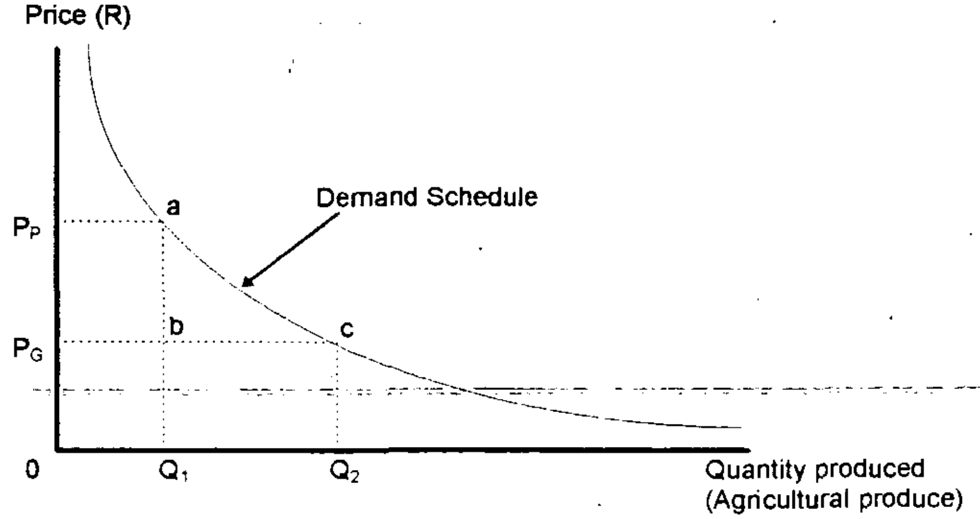

FIG 4.6: ALTERNATIVE GROUNDWATER SCHEMES

Let P_P be the cost of the private alternative

Let P_G be the cost of the government alternative.

Q_1 is the output from the irrigation scheme achieved by either the government or the private groundwater irrigation scheme, this is tantamount to assuming on inelastic demand at output Q_1 i.e. fixed scale of irrigation plant (pumps, channels etc). Since Q_1 is the output produced by either alternative the concern is the provision of agricultural produce at the cheapest cost.

The gross benefits or gross willingness-to-pay is reflected in the areas OQ_1aP_P while the net benefits or net willingness-to-pay is reflected by the area P_PabP_G. Now P_P represent the maximum willingness-to-pay for Q_1 units of agricultural output with the net benefit estimated by the reduction in cost associated with the public alternative.

The choice criterion is clearly one of comparative costs. Another case is were the higher cost private alternative would have been implemented on the absence of a public alternative irrigation schemes. Assuming that neither alternative need be built to a fixed scale and allowing for a demand schedule which is not inelastic. The optimal level of output from the government provision would be Q_2. In this case the

Benefits from government provision of output Q_1 are limited by private costs oP_PaQ_1. Because of the greater qualities demanded at lower cost, benefits must also include the area abc. Thus OP_p, the cost of the private alternative represent the upper bound of willingness to-pay for the government alternative.

A third case is one where both projects can be supplied by the government. In this case the two alternatives represent outputs provided by two different branches of government e.g., the DWAF and DBSA if one does not provide the service the other will. The same alternative cost technique can be applied and once again the criterion is one of comparative costs in which the demand schedule need not be estimated.

It is important to note here that when dealing with groundwater the alternative cost technique is somewhat complicated since ground water stocks may be finite in supply due to very slow recharge rates for the aquifer, or low rainfall conditions which do not allow for complete recharge. In this case withdrawal may impose additional social costs in the form of withdrawal today limiting future development.

Here the private value of groundwater represents at best the lower bound estimate of its social value in the alternative cost sense. Caution must therefore be shown in using this valuation technique because of the complexities introduced into the analysis by social costs associated with falling water tables over time for example.

4.7 VALUE ADDED[105]

This approach involves the estimation of the ratio of some measure of value added such as income additions for each unit of ground water used in a production process. Value added in manufacturing is used as a measure of production. Using data on value added in production processes (both manufacturing and agricultural) an average value of groundwater can be computed. Using input-output tables (I-O) it

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105 For a complete description of this method, refer to "Input-Output Tables and Linear Programming techniques as applied to Constrained Water Supply Conditions", Williams, CJ et al, NPI Conference on research in Economics, Business Economics and Manpower, 26-27 November, 199? University of Pretoria.

is possible to calculate both the direct and indirect value of groundwater in various uses. If an I-O linear programming (IOLP) approach to the problem of valuing groundwater is adopted, shadow prices representing opportunity costs can be calculated which represent an upper bound value for the groundwater used.

The basic mathematical approach is thus to use I-O tables to generate a system of constraint equations relating final demand in each sector to output of all sectors, thus taking full account of inter-industry linkages. The value-added section of the I-O table is used to generate a profit function, which sets out the value of the output of each sector to the economy. Given a final constraint equation stating the maximum draw-off of water available to each sector, we are now able to approach a linear programme.

Thus the equations finally submitted to the LP, expressed in matrix notation, are as follows:

Maximise $R = Va.X$ ....(9)

subject to

$Wi.X <= Wo$ ....(10)

$Y' >= (I - A).X >= Y$ ....(11)

$X >= O$ ....(12)

where

R = Regional value added

Va = Vector of value-added coefficients

X = Vector of gross outputs

Wi = Vector of sectoral water intakes

Wo = Total Water available

Y' = Vector of sectoral final demands, lower level

Y = Vector of sectoral final demands, upper levels

I = Identity matrix

A = Technical coefficient matrix of the I-O table.

For the linear programme to be able to find an optimum, it is necessary that the constraint equations should enclose a feasible region. In order to achieve this, the constraints submitted to the linear programme comprise an upper and a lower production constraint (embodied in equation 11) and a water availability constraint (equation 10). The lower production constraint represents a production level below which the sector will not be permitted to descend. This constraint exists in order to prevent the linear programme from driving any sector out of the basis (and thereby causing it to cease production altogether). This is done for the purpose of this exercise to keep all players in the game, as it is assumed that a scenario which completely eradicates any sector of the economy would not be viable. The upper production constraint would be determined by the sector's ability to expand, according to its own production functions and existing free-market forces. The water availability constraint is the key to the model formulation, and actually drives the model. The constraint states that the total water usage by all sectors does not exceed the total water available to the region (Wo). As Wo is increased or decreased, thus changing the total amount of water available to the region, water availability becomes an over-riding restraint to production in the various sectors in turn.

The essence of the linear programme is its objective function, which is the function which is optimised. In this formulation, the objective function (given in equation 9) is taken to be the regional value added, and is derived from the value-added section (quadrant III) of the I-O table. In our quest for shadow prices, the actual value of this regional value added is not of relevance, and is not recorded as the model is exercised.

The value added approach like all the other approaches for estimating the value of groundwater should be used with caution on the following grounds.

Firstly the concept of value added in manufacturing processes dues not reflect the productivity of water in the process e.g., industries which have a high value added but use small quantities of water will show a large value added per unit of water and

If value added is interpreted as the imputed price of water the opportunity cost (value) of other factors in the production process has been ignored. This value added may yield a large overestimation of the value of water.

4.8 CONCLUSIONS

Each of the techniques for estimating the value of groundwater has problems attached to it which make the application sometimes difficult and signals that caution must be used when choosing a technique for a particular application.

The authors believe that the Residual Imputation method of valuing groundwater has the most to commend it as a long-run public or private valuation technique. The method, whilst tedious, does represent factual output and input parameters that can be measured. Additionally, the method does not require complex mathematical analysis to be undertaken. Hence with careful data-collection, and bearing in mind the comments made concerning the problems attached to the process, a value of groundwater using this technique may be calculated which has a bearing on reality and has practical significance and furthermore can be defended.

It is important to recall that an important requirement of the research project is that the valuation techniques take into account the **sustainable** management of water. To ensure this the valuation methods must take cognisance of the **trade-offs** inherent in using water for different purpose i.e., **the opportunity costs** of the application. As discussed above the costs of these trade-offs are reflected in the demand schedule. As has been pointed out, deriving demand schedules for groundwater is, however, difficult. It is important therefore that the preferred valuation method does not sacrifice too much accuracy by the omission of such a schedule in the valuation process. The Residual Imputation approach uses market prices and these prices are assumed to have been derived from an equilibrium condition in the economy, i.e., where supply equals demand. Hence *a priori* the trade-offs spoken of above are inherently taken into account in valuing groundwater by this method.

It is to be further noted that accounting costs only allow for cash outlays which only approximate opportunity costs where competition ensures that the prices of all factors of production are equal to those for their best alternative use. In the case of imputed costs the competition is provided by the prices of factors of production all being determined in a market environment e.g., a farmer will make his own decision on how much water and how much fertiliser to use to grow a crop. Further, market prices reflect economic scarcity and are therefore economically efficient.

It can be expected therefore that whilst the method has the drawbacks listed it does provide a proxy for the value of groundwater that can practically be arrived at and which can be used for policy formulation in ensuring sustainable management of groundwater.

As already mentioned, during the tenure of this research project, every effort was made to collect sufficient data which would allow the methods for valuing groundwater developed in this study to be tested in the different case studies. However, just as attempting to gather data so that demand schedules could be constructed was a failure, gathering the required data for methods that did not require demand schedules also turned out to be fraught with such difficulties that sufficient data to undertake this task was not forthcoming.

As a consequence, and to provide some approximations of the economic value of groundwater in the different locations, recourse was made to an alternative practical approach to water valuation. This is described in the Atlantis, de Aar and Dendron case studies. At Verwoerdburg, however, the proxy price elasticity of demand was used to value the groundwater. At Indaleni none of the theoretical approaches described here could be remotely used to value the groundwater. Recourse was made therefore to some statistics gathered on willingness-to-pay for groundwater by the residents of the area. However, even this approach presented problems and these are described in the text covering the case study.

Future research thrusts so far as the groundwater valuation methods discussed in this section are concerned, are detailed in section 8 of this report.

PART FIVE

CASE STUDIES

5. CASE STUDIES

5.1 DISCUSSION ON THE SELECTION OF CASE STUDIES

5.1.1 Selection criteria

At a meeting between the researchers, the Water Research Commission and the Department of Water Affairs and Forestry held on .. April 1994, the need for a case study approach to this project was re-affirmed. The reasoning behind this was that the circumstances under which ground water is used in South Africa are highly variable and very localised. Therefore any attempt to place a value on ground water according to the use to which it was put must take cognisance of this variability. Consequently, an approach which involved the selection of a number of affordable case studies, each one reflecting a very different and specific aspect of ground water use, was adopted.

The relevant circumstances under which ground water is used in South Africa include:

- the nature of the aquifer from which the water is drawn, e.g. primary dolomitic and coastal sand aquifers, and secondary fractured aquifers;
- small scale abstraction for basic human needs;
- large scale abstractions for commercial agriculture; and
- large scale abstractions for municipal and industrial use.

In addition, it was decided that the problems, issues and controversies surrounding the use of ground water should influence the case study selection process. The reason for doing this was to see if certain economic approaches to ground water management could contribute to the resolution of these issues. The type of issues that were considered important were many, however the following ones were identified as having some priority :

- the unsustainable use of ground water, i.e. where the abstraction rate exceeds the recharge rate of the aquifer;
- the preferences of poor rural communities regarding the use and value of a ground water supply as opposed to a surface water supply;
- the preferences of affluent urban communities regarding the use and value of a ground water supply as opposed to a surface water supply;
- the competition between agriculture and municipalities for the use of a common ground water resource; and
- water quality problems in aquifers used for supplying quality sensitive users.

On the basis of these criteria a list of potential ground water systems was drawn-up. These were investigated to determine the availability of information that could be used in the case studies as there were insufficient funds for the collection of both geohydrological and economic data. From this cursory investigation and taking due cognisance of the budgetary constraints, five ground water systems were eventually chosen as case studies. These are described below :

5.1.2 De Aar

De Aar is probably one of the earliest examples of water farming in South Africa. The Municipality of De Aar purchased surrounding farms earlier this century in order to secure a reliable ground water supply for the town. However, as the years progressed, these sources were not sufficient to meet the town's demand and options for new supplies were drawn-up. These options included (i) linking De Aar by a pipeline to the Orange River and (ii) the further development of ground water. The pipeline option proved unattractive (not to mention expensive) to the South African government who proceeded to search for and locate ground water further afield on privately owned farm land. There are two problems with the ground water around De Aar. Firstly, it is hard water and prone to depositing excessive scale when heated, and secondly, it may deprive farmers of the water they need to run viable farms in a semi-arid environment. One of the questions posed by the De Aar ground water system was therefore - could the additional cost of an external surface water supply be offset by the benefits to local farmers of having more ground water at their disposal? Alternatively, assuming that De Aar exists primarily to meet the needs of the local farming community, either directly or indirectly, to what degree should the town be allowed to grow at the expense of the local farming economy?

5.1.3 Dendron

The seriousness of the problems surrounding the ground water resources at Dendron were first exposed during the Sand River Basin Study commissioned by the Department of Water Affairs and Forestry in 1987-91. Whilst the area is considered a successful farming area, with potatoes being one of the more profitable crops, this success has been achieved at the expense of the ground water levels which have reportedly fallen from 30-40m to over 120m in the last decade. Whilst attempts by the Department to introduce monitoring boreholes and raise interest among the local farming community in the information these holes produce, there remains little actual evidence of strict abstraction regulation intended to restore original ground water levels.

This situation raises two issues. Firstly, what is the best estimate of the time when the ground water table becomes so deep that abstraction for irrigation purposes is no longer viable? Secondly, as it is realised that ground water use at Dendron is not a sustainable use of natural resources, should the authorities not act in order to prevent further resource degradation and preserve the remaining water for future generations?

5.1.4 Indaleni

Indaleni is a medium sized rural settlement situated not far from Richmond in KwaZulu-Natal. The stability of the population has been greatly affected by the political violence in the area, particularly since the community contains both IFP and ANC supporters. With the recent reduction in violence levels, Indaleni has started to grow and give consideration to the provision of basic services such as water supply and sanitation. The community is currently supplied with water from a number of springs and contaminated streams. There are deeper ground water resources in the area however, these have not been extensively tapped by the locals. Different teams of engineers have studied the future water supply problems of the town. Some believe that the only safe answer is to install large pipelines linking the town with the bulk water supply system. Others believe that the local ground water has the resources to meet the community's needs for some time into the future.

The objective of this case study was to determine if the community held any preferences for either surface water or ground water as a means of supply, and whether they able to articulate that preference in monetary terms. This preference was captured by means of a very limited willingness-to-pay survey.

5.1.5 Verwoerdburg

Verwoerdburg is, to some extent, a sociological mirror image of Indaleni. The relatively affluent White community derive their water from two sources : the low cost dolomitic ground water which underlies the town in large quantities but which is also scale forming, and the Rand Water Board which is not a scale forming water but is a very expensive supply. Given the ease with which Verwoerdburg's residents obtain their water, relative to the problems experienced by Indaleni's residents, the first issue to be resolved is do the towns people know where their water comes from and how much it costs? The second, and more important issue from an economic stand point, is how much would they be willing to pay before they would consciously and regularly start to conserve water, and would they pay more for a better quality water or not?

Whilst these are quite straight forward issues from a market economics position, it is probably the first time most residents will have ever seriously considered their water supply and placed it in the context of a marketable commodity.

5.1.6 Atlantis

The small, but growing community of Atlantis on the West Coast has been at the centre of a number of ground water studies over the last decade or so. However, the economics of the town's somewhat precarious water supply have never really of recent deposits. The more water the town abstracts, the more likely it is to allow sea water to infiltrate the aquifer. Similarly, because of the urban and industrial land use activities in the area and the sandy nature of the substrate, the risk of aquifer contamination from surface waste water treatment and other polluting activities is quite high.

The situation at Atlantis is further complicated by the fact that certain of the industrial water users, most notably the textile industry, is sensitive to variations in the quality of the water supply, in particular the pH and the salinity. The issue that is raised is how long can Atlantis increase its 'careful' abstraction from the coastal aquifer without threatening the quality of the water supply and risk discouraging further industrial development in the area?

5.1.7 General

The above synopsis presents some of the problems that the economic valuation of ground water is going to attempt to unravel. The issues are varied, and although they are fairly representative of ground water issues in South Africa, they do not pretend to cover all the problems. The primary objective of this exercise is to test the application and usefulness of economics in understanding and perhaps resolving some of the more pressing issues.

Of course the success of this depends to some extent upon the availability of information concerning the case studies. In general, although a wealth of technical data often exists in situations where ground water is abstracted and managed by professional people charged with the task of community water supply, the corresponding economic data is often non-existent. This research study is not intended to embark on a widespread data collection campaign. To do so would greatly reduce the number of case studies that could be undertaken. Rather, the intention was to collect whatever information does exist, infer missing data from this and fill in the rest from either the literature or through sample surveys. It is the methodology that is considered important at this stage and not so much the accuracy of the findings.

5.2 SUMMARIES OF THE CASE STUDIES

5.2.1 Indaleni

Indaleni is an impoverished peri-urban settlement of roughly 14000 people, situated 4 kms south-west of Richmond in the Natal Midlands, roughly 40 kms south of Pietermaritzburg.

Residents rely exclusively on local springs, boreholes and streams, which are grossly inadequate and, in some parts, severely contaminated. Natural population increases as well as the return of people who fled the area during bouts of politically motivated violence are compounding the existing pressure on limited water resources. Improving the settlement's water supply is *the* local development priority.

Two augmentation options are currently being explored:

- additional boreholes in Indaleni
- connecting Indaleni to Richmond's water supply scheme. This will, in turn, necessitate large-scale augmentation of Richmond's water supply.

Umgeni Water has commissioned several studies which explore remedies to Indaleni's water shortage. One group of engineers maintains that Indaleni is well provided with ground water, and that provided new boreholes are drilled, there will be ample water to supply Indaleni's needs in the short and medium term. Opposing this view is another firm of engineers, which argues that local ground water resources are diminishing rapidly, are contaminated and require a degree of resource management that local residents are unable to provide.

The capital cost of upgrading and reticulating local ground water sources is significantly cheaper than connecting Indaleni to external surface water supplies and constructing a local reticulation network. It is difficult to compare prices directly, because the cost of the different supply options is modelled on different basic assumptions about demand and delivery requirements.

The debate over an appropriate solution to Indaleni's water demands is likely to become politicised. Following the progress of a peace initiative between local ANC and IFP leaders, Indaleni has been designated a test site for implementing the Reconstruction and Development Programme in KwaZulu-Natal. This means Indaleni residents can expect a major injection of funding for infrastructural development - but this funding will probably be finite, and `once-off'.

Given that Indaleni is unlikely to get more than `one bite of the cherry', local leaders will probably lobby for what they perceive to be the most dependable long-term remedy to Indaleni's water problems. These they perceive as a pipeline linking Indaleni to Richmond's water supply, which will in turn require a major upgrade of the district's bulk water supplies.

If they pursue this line of argument, they will almost certainly be supported by local farmers and business interests, who are keen to augment bulk water provision in the Greater Richmond area.

A random survey of 53 Indaleni residents suggests that the majority of local residents would be happy to continue using ground water, provided the supply was reliable, adequate, accessible and clean.

The majority said they were willing to pay for ground water, provided it was reliable, adequate, accessible and clean - even if they still had to fetch it themselves from a borehole outlet or spring reservoir.

If water was piped directly to their homes, the majority of residents said they would be prepared to pay for this water, regardless of whether it was ground or surface water.

Indaleni's water supply is extremely inadequate. On the basis of a limited survey of residents' perceptions, the priority is to provide residents with a reliable supply of clean water. The source of that water is a secondary consideration, and, provided the water is clean and the supply reliable, most residents are indifferent to whether they use ground water or surface water.

5.2.2 De Aar

De Aar is situated in the semi-arid Karoo and was initially established as a railway junction. The area is now used mainly for livestock grazing purposes, primarily through sheep for the production of mutton, wool and pelts. The largest industrial activity exists in the form of reinforced concrete product manufacture. De Aar also houses the region's abattoir and is a service centre for local farmers.

As the town has limited access to surface water supplies, ground water resources are relied on to fulfil the town's requirements. Ground water is purchased from local farmers and, as well as this, the municipality has purchased land from which it is able to extract ground water. The potential ground water supplies that have been identified by various geohydrological reports should be more than adequate to meet the demands of the towns growing population, at least until 2010 and possibly beyond. It is vital, however, that these resources are efficiently and scientifically managed in order to ensure the sustainability of the supply.

Farmers supplying the municipality need to be consulted and their grievances addressed. These relate primarily to the terms of the contracts and the lack of uniformity in them as well as the long-term effects of ground water exploitation on primary productivity and environmental degradation. Until the present time, no change in agricultural productivity as a result of the water supply scheme has been experienced. Water quality issues need to be more comprehensively addressed, especially in relation to the proposed development of the town. A sound basis for water valuation in the region needs to be developed and the municipal pricing structure needs to be re-evaluated, both in terms of the unit cost of water paid to the farmers and that charged to the public.

Observing the vast difference in prices paid for water it seems that the manner in which contracts are concluded between the municipality and farmers influence prices to an extent (and may even constitute some form of market failure). The price paid ranges from 3,05 c/kl to as much as 14,64 c/kl (in the data sample collected during our survey in De Aar).

It is nonetheless an extremely difficult task to disentangle the market related portion of the price from other considerations, imposed by the fact that there is, in effect, only one buyer in the market. Hence, we must rely on the existing prices in the market. Considering the nature of the supply of and demand for water in the area it is not surprising that there are such differences in price. Many contracts between farmers and the local authority stipulate minimum supply figures in kl/month, (while some also have maximum figures stipulated) which means that, by and large, farmers do not have a large degree of freedom in regulating supply (downwards, that is to influence the price upwards).

5.2.3 Verwoerdburg

Verwoerdburg is a rapidly expanding town with a current population of 90 000. During the mid 1980s, the drought in the area necessitated the drilling of boreholes to augment the existing supply from the Rand Water Board (RWB). This emergency water supply was commissioned by the Department of Water Affairs and Forestry (DWAF). The Verwoerdburg Town Council (VTC) acquired the use of three boreholes from the DWAF and developed the current ground water scheme.

In the area serviced by the VTC, there are eleven "reservoir areas" or separate reticulation systems. Of these, three receive mixed water (ground water mixed with RWB water in the ratio 1:1) whilst the rest receive RWB water only.

No assessment has been undertaken by the VTC with regard to scaling problems experienced by users. The water supplied meets the standards for drinking water in all respects, including hardness. The mixing ratio of RWB to ground water is monitored weekly. Although a 1:1 mix is aimed for, the proportion of ground water may reach 80% depending on consumption and rainfall.

As regards the industrial areas, three receive mixed water. However, these industries are not "water-quality sensitive". They include Centurion Centre, Technopark and Lyttelton Manor Extensions.

As regards the future use of ground water in Verwoerdburg: RWB policy will ultimately determine this, depending on the price of their water and the regulations which accompany provision of connection points. Borehole equipment is scheduled for renewal in 1997.

Against this background, a survey was conducted in two suburbs of Verwoerdburg: one in the West, which receives RWB water and one in the South, supplied with a ground water/RWB mix.

The pilot study aimed to compare the subjects' knowledge of water source and price, perceptions regarding quality and the willingness to pay for, conserve and use sources other than the Municipal supply.

One hundred respondents were sought from each area in a telephonically conducted survey.

In general, the results revealed a poor awareness of water supply. Trends would need to be validated in a much larger sample.

5.2.4 Dendron

Dendron lies some 60 km north of Pietersburg in the Northern Transvaal Bushveld. Relief maps show that the area is relatively flat (sloping around 0,004 to the North).

The area of Dendron has two catchment areas, namely the Brak River in the west and the Hout River in the east. A sub-catchment Doringlaagte is to be found within the Hout River catchment. The two rivers mentioned here are tributaries of the Sand River. The Doringlaagte Catchment with an area of $509km^2$ drains to the north-east with a length of 35km and an average width of some 15km.

Agriculture (mostly the production of potatoes) is the main economic activity in the area. This industry was originally established due to the high availability of water (fountains) and an ideal climate. Under irrigation this industry is expanding, but other crops, namely mealies, onions and pumpkins are now also being planted (Bertram, 1993).

Mechanised farming began after the Second World War. This period saw the utilisation of groundwater for irrigation. Higher returns from crop cultivation relative to stock farming (particularly during the 1950's) resulted in the present extensive irrigation projects along the Sand River around Dendron (and Pietersburg, Kalkbank and Vivo) (De Wet Shand Inc., 1992).

The catchment is highly dependent on groundwater.

The following irrigation equipment is generally used:

(a) Centre pivots
(b) Movable sprinklers
(c) Microdip
(d) Flood

In summer the entire irrigated area is cultivated for maize. During winter the main crops cultivated are as follows:

Potatoes	50%	
Wheat	10%	
Tomatoes	40%	(De Wet Shand Inc., 1992)

Throughout the area, however, the amount of land suitable for irrigation far exceeds the area for which water is available. And, although the geology is suited to groundwater storage, the low rainfall experienced in the area has meant that recharge has been limited. Over-abstraction of ground water has also led to boreholes drying-up.

Clearly agriculture and community services (including government) and to a lesser extent finance and manufacturing employ the greater part of the formal labour force. This is in line with the analysis on economic activity presented. However, employment in formal sector non-agricultural activity has stagnated somewhat, and even declined during the past decade. This is also true of the Catchment itself. No doubt drought conditions (which have adversely impacted ground-water reserves) have played a key role in determining this trend.

All the major water users (agriculture and rural and urban settlements) in the Sand River Basin (including the Doringlaagte Catchment) depend mostly on groundwater as a water source. Some 88 per cent of the total amount of water consumed is groundwater. Around 2 per cent of consumption is met by locally developed surface water sources.

Groundwater has been used in the area since the beginning of the century. Groundwater development for domestic purposes has been low. Demand for irrigation water, on the other hand, has been high. Large quantities of groundwater have been abstracted to meet this demand. In some instances, the rate of extraction has exceeded the recharge rate.

5.2.5 Atlantis

Atlantis lies some 45km north of Cape Town, close to the West Coast. Atlantis residents have suffered high unemployment levels, poverty, increasing social problems and a lack of adequate services. From 1989 to 1991 21 factories closed and 2 000 industrial jobs were lost. Health workers reported an increased incidence of poverty related health problems.

Atlantis falls within the economic fringe of Greater Cape Town. It is located in the southern part of the 03 Planning Region and is adjacent to Greater Cape Town Planning Region. It is joined by a group of several medium sized fringe towns. The group includes Paarl, Stellenbosch, Strand, Somerset West, Wellington and Kuils River. [2)]

In Atlantis the manufacturing sector is particularly strong, producing some 66% of the geographical product. Commercial and community service sectors are underdeveloped.

The single largest sector is the automotive and engineering sector which is represented by some 17 firms employing 3 117 people (25% of the total labour force). The two other largest sectors are clothing and textiles. Other sectors are food, electrical and light engineering, plastics, furniture, paper and packaging, drugs and chemicals and building materials.

Of the total number of people employed in Atlantis, 60% of people are employed in the manufacturing sector, 1.4% in agriculture and mining, 16.3% in electricity, transport and construction, 13.5% in community services and 9.3% in commerce and finance.

Atlantis is supplied with water from two groundwater aquifers located between the existing town and the coast. One of these is located at Silwerstroom and the other to the south at Witzand. There is potential to develop a new aquifer at Yzerfontein. The total capacity of the Silwerstroom and Witzands aquifers is 9.8 million m^3/year. The new aquifer at Yzerfontein has a potential capacity of 17 million m^3/year.

The peak annual demand to date has been 5,1 million m^3/year. Well fields have adequate capacity for the medium term.

Demand for water grew steadily in the period 1980 to 1987 when the demand stabilised and subsequently decreased in 1991 and 1992. Residential demand makes up approximately two thirds (66%) of total water demand in Atlantis with industry accounting for the remaining one third.

The bulk water supply is the responsibility of the Waterworks Branch of the WCRSC.

A graded tariffing system is in place, which depends upon the amount of water used. This is supplemented by a monthly service charge and an annual availability charge.

The wastewater reticulation system for the residential area of Wesfleur is separate from that which serves the industrial area. Both systems flow by gravity to the treatment works to the south-east of the area.

5.3 COLLECTIVE APPLICATIONS OF VALUATION TECHNIQUES FOR GROUNDWATER

All factors of production have relative scarcities. Some such as water, however, cannot be substituted or for that matter be easily transported from one region to the next without considerable additional capital outlay. This lends to water a rather unique quality. Specifically, one may even venture as far as to say that in many, if not most, forms of production the manufacture of goods is impossible without the presence of the liquid. Water acts as a coolant, a cleansing agent, an ingredient and a catalyst (e.g. agriculture) in the production process. This leads us to argue that the value of water can actually be measured as the value of total output in each industry, and especially so in agriculture.

It has already been mentioned that because of data-gathering problems the methods of valuing groundwater described in the previous section could not generally be implemented in the case studies. We must therefore find alternative methods of valuing groundwater based on arguments such as the one presented immediately above. We, therefore continue along the line of argument presented above that the actual value of (good quality) water is indeed equal to practically the entire production capability of the different areas under investigation (or at least equal to the value of the output of those industries that rely heavily on either the availability of a large volume of water or on a particular water quality). This is especially true of areas such as Dendron where the entire production capability of the area is dependent on agriculture, or Atlantis where textile industries, for example, are particularly reliant on good water quality.

5.3.1 Groundwater valuation for Atlantis

Current water prices

To provide some perspective on the calculations that follow it is useful to first consider the prices that are being paid at present for water in Atlantis - even though, or perhaps even especially though, they are not market related in any way. They must, for all intents and purposes, shed some light on the perceived value of water in the area. In analysing this perceived value one should remember that:

- the prices are largely set by the Regional Services Council, i.e. the supplier and hence there is no record of willingness to pay on the part of the consumer

- it is expected that sufficient groundwater (from the two existing sources mentioned and perhaps from the potential development of one further source) will exist even in the face of industrial expansion for at least the medium term (and perhaps even in the long term depending on one's favourite definition of such terms)

- the present water quality is considered adequate, despite some hardening of the resource. The building of a softening plant has assisted considerably in alleviating the problem. It should be remembered, however, that due to the close proximity of Atlantis to the sea and the fact that the groundwater sources lie between the sea and Atlantis, seawater is likely in time to encroach on the town's water supply. The local authority must at some point in the future be expecting a reasonably significant capital outlay in order to deal with such difficulties.

Given the tariffs for 1992/93 and consumption figures for May '92 to Jan '93 (see attached schedules) we are in a position to make an observation as to the value of groundwater in Atlantis. We have argued that the price has been set by the local authority. However, this does not mean that the demand side has been totally irrelevant. We must believe that consumers of water are in a position to cut back on at least some water consumption should they consider the price set by the local authority as being too high. And, in the absence of any significant protests over the price of water charged in Atlantis, by industrialists, we must conclude that the demand side (although perhaps not entirely due to the fact that some industrialists may indeed not be in a position to reduce/restrict their consumption) concurred in some sort of fashion with the price. Should this assumption hold we conclude that the collective value placed by industrialists of Atlantis on water is simply equivalent (by and large) to the sum of the product of the price paid by each for groundwater supplied by the Regional Services Council and their actual individual consumption.

Tariffs per kl for 1994/95 in Atlantis have been set as follows:

First 12 kl per month	R 1,25
Next 23 kl per month	R 1,65
More than 35 kl per month	R 1,75

Service charge per month	R 2,50
Availability charge per annum	R 30,00
Standpipes	Normal charge

Considering that consumption figures are not available as yet for the period above, however, we consider the water tariffs for 1992/1993:

Tariffs per kl for 1992/93 in Atlantis

First 15 kl per month.............................. R 0,86
Next 30 kl per month .... R 1,13
More than 45 kl per month...................... R 1,20

Service charge per month .... R 2,50
Availability charge per annum .... R 30,00
Standpipes .... R 1,13

Few, if any, industrialists in Atlantis utilise less than 45 kl of groundwater per month. Indeed, average water consumption is 35 kl per day. This means that in, say, 1992 the total collective consumption of industrialists of kl was bought at a cost of R1,20 per kl, so that the total value of groundwater for this sector amounted to R 2.24m (1992 prices) for the year, that is some 0,35 per cent of manufacturing GDP. In addition, each of the 108 factories paid R60,00 per month in service and availability charges - amounting to R6480,00.

A similar argument as above can be forwarded for residential consumption of groundwater in Atlantis which amounted to some 375 200 kl in 1992. **Average** consumption per household (i.e. per water account) amounts to 30 kl per month. The reader need only have a most basic understanding of statistics to realise that we cannot assume for households that each household consumes 30kl per month. What we can say is that, **on average**, consumers will pay (R0,86*15) + (R1,13*15) per month for groundwater. Excluding service and availability charges this amounts to some R375 000 per annum.

Collectively, therefore, if we were to assume that the prices charged by the Regional Services Council for water resembled a market price (influenced by both supply and demand) then the total value placed on this resource by the industrialists and residential consumers in Atlantis together amounted to around R 2,615 m in 1992. However, should we relax our assumptions above we cannot accept that the true value of groundwater is equal to that calculated immediately above. Of particular importance is whether or not the future availability/scarcity of groundwater along with changes in the quality thereof is reflected in the long run marginal costing of the local authority. We believe that this is not the case. Also, simply because industrialists are paying their water accounts, the price that they are currently paying is not necessarily an indication of their willingness to pay. Considering that water is such a key ingredient of most production processes industrialists may be willing to pay considerably higher prices in order to secure a reliable supply of quality groundwater in future.

What Price an Entire Town?

We argued in our opening comments that water is an unique product in the production process. Theoretically, without water many industries will not be in a position to continue production. This means that should the resource be removed / unavailable / of insufficient quality the entire manufacturing industry in Atlantis would cease to produce. Hence, the very reason for the existence of the town would no longer exist. An entire town would disappear and the manufacturing and agricultural jobs would disappear. Jobs in support industries (mainly services and local government) would follow. What price a town as the value of groundwater?

Of course our analysis is not entirely correct since we know that capital and labour is highly mobile and can simply move to a new location where there is sufficient water. Should we, however, argue that this is undesirable from the point of view that there must be some limit as to the extent which capital and labour can pursue water as a resource, before similar stresses are experienced in areas to which capital and labour moves.

Should we, therefore, accept the hypothesis that the true value of water in Atlantis is indeed the entire output of this industrial area we can argue that the value of groundwater equates the output of the manufacturing sector, the agricultural sector and support industries. From sources listed we know that the contribution of manufacturing and services type industries amounts to R624m. However, we also argue that the services industries are dependent on the manufacturing industries and the private consumption that follows from the employment of people by these industries. This means that the true value of groundwater is not only equal to the manufacturing output, but also the value of the output of the services and like industries. In 1992 these industries employed 2500 workers.

Knowing that industries employ 11064 workers and that additional service type industries employ around 2500 workers we can utilise the typical employment multipliers for those industries present and calculate the total GGP that they represent. Utilising the 1988 National Input Output Tables we calculate that total GDP in Atlantis amounts to R487,4m for manufacturing (with an average employment multiplier of 22,7 per million rand of output in 1994) and R136,6m for the rest of the services type industries (with an average employment multiplier of 18,3 per million rand of output in 1994). This leaves the total true value of groundwater at R624m. This is not to say that the total water bill in Atlantis should add up to this figure. Rather, it indicates that considering the currently insignificant expenditure on water as a factor of production relative to the total value of output, groundwater is not valued as highly as it should be in Atlantis. It is so that the quantity of water will be sufficient for industrial and residential use (with residential use closely related to growth in employment in the industrial sectors), even in the long term. However, deteriorating water quality through seawater intrusion could become a severe problem.

Industries Relying on Water Quality

There are some industries that rely to a far greater extent on water quality than others, particularly the textile manufacturers. From the table below it can be seen that in Atlantis there are 14 textile manufacturers that employ 2083 workers. This multiplier of around 23,5 per million rand of output in 1994). Further, one could perhaps include the clothing manufacturers here. These companies employ 1434 workers in 12 factories, contributing some R34,89m to GGP (with an employment multiplier of 41,1 per million rand of output in 1994). Hence, should the reader be sceptical of our conclusion that water is essential for the survival of virtually all industries, perhaps he will accept that at least these industries are highly reliant on water quality, so that the true value of the groundwater in Atlantis must at least be equal to some R88,6m or even around R123,49m. One could, of course, continue to add industries to our shortlist here depending on the extent to which industries other than textiles and clothing rely on water quality.

In the table below we have indicated which industries other than the more obvious ones mentioned above may also rely fairly heavily on water quality in order to sustain their production processes (and we also show which industries are likely to be less concerned with water quality).

INDUSTRIES IN ATLANTIS AND DEPENDENCE ON WATER QUALITY

Industry type	% of total factories	Total factories	% of total employees	Total employees	Depends on water quality	Does not depend on water quality
Automotive and engineering	16	17	25	3117		*
Food	6	6	6	749	*	
Electrical engineering	3	3	9	1067		*
Light engineering	7	7	3	335		*
Plastics	5	5	3	420	?	
Furniture	5	5	3	419		*
Paper & packaging	5	5	7	880	*	
Drugs & chemicals	7	7	2	277	*	
Building materials	9	10	4	518	*	
Household goods	4	4	2	265		*
Clothing	11	12	12	1434	*	
Textiles	13	14	17	2083	*	
Transport	1	1	1	100		*
Printing	1	1	1	125	?	
Miscellaneous	8	9	5	612	?	?
Total	100	106	100	12401		

Source: Atlantis Profile Base Document, Atlantis Development Forum, November 1992.

Note to table: Judgements as to reliance on water quality are our own.

Presently water quality in Atlantis are as follows. First, should an industrialist decide to sink a borehole in the area the following groundwater quality will typically be found:

**ATLANTIS WATER QUALITY
BOREHOLE G29749**

Sample	Quality
Ammonia	0,3 mg/l
Nitrate	0,2 mg/l
Dissolved solids	799 mg/l
Chloride	340 mg/l
Sulphate	10 mg/l
Sodium	160 mg/l
Potassium	1,0 mg/l
Calcium	34 mg/l
Magnesium	20 mg/l
Iron	2,0 mg/l
Hardness	167 mg/l
pH	6,6
Alkalinity	90 mg/l
Turbidity	1,2
Conductivity	128 mS/m

Source: Water Control Branch, Western Cape Regional Services Council, Jan 1995.

This water is not recommended for industrial use.

Treated water from the groundwater aquifer outside the town, presently used for industrial purposes, have the following water quality features:

**ATLANTIS WATER QUALITY
TREATED WATER FROM GROUNDWATER AQUIFER**

Sample	Water quality features
Ammonia	< 0,1 mg/l
Nitrate	0,5 mg/l
Dissolved solids	459 mg/l
Chloride	130 mg/l
Sulphate	59 mg/l
Sodium	71 mg/l
Potassium	2,0 mg/l
Calcium	62 mg/l
Magnesium	6,8 mg/l
Iron	< 0,1 mg/l
Hardness	183 mg/l
pH	7,9
Alkalinity	138 mg/l
Turbidity	0,35
Conductivity	78 mS/m

Source: Water Pollution Control Branch, Western Cape Regional Services Council, Jan 1995

This water, as can be deduced, is preferable for industrial use.

Supply Not the Problem

Peak annual demand for water to date has been around 5,1million m^3/year and therefore there is definitely adequate supply for at least the medium term with current capacity of the two groundwater sources at around 7,7 million m^3/year and potential future development increasing this to as much as 17,0 million m^3/year. Industrial demand has even declined slowly since 1988, with peak average consumption per factory at around 40 kl per day. Also, residential consumption has declined slowly during the same period.

5.3.2 Groundwater valuation for Dendron

Relative to Atlantis, water is a scarce commodity in Dendron. This is reflected in the "slip-scale" used for water pricing by the local authority in 1994 (see table below). Clearly, the charge for groundwater as consumption increases is much higher for Dendron than Atlantis. The existing "market" has responded to the present water crisis / shortage by attempting to temper demand through higher prices. The relatively higher tariff has been in place for a number of years, but has not been successful. Water use in the area has not been restricted. Further, the tariff does not apply to the bulk of the farming community (it is more applicable to local residents of the town), which extracts its own groundwater. The recent response from the local authority pertaining to residents of the town has been to place quantitative restrictions on the use of water in the town. First, gardens may not be watered. Second, the water flow is only turned on at specific times as follows:

06H00 - 09H00
12H00 - 14H00
16H00 - 21H00

There are no restrictions though on the use of one's own groundwater. As mentioned farmers have there own boreholes and no restrictions are placed on the use of this water.

DENDRON WATER TARIFFS

Consumption in kl	Tariff
0-25	R25,88
26-50	R1,02/kl
51-70	R1,12/kl
71-90	R1,54/kl
91 +	R1,85/kl

Source: Local Authority, 1994

The important point here is that the "market" for water such as it exists in Dendron, with the local authority being the major seller of the little water that is sold, has failed to contain / reduce the use of water by manipulating the price. This suggests that, currently, despite the severe water shortages in the area that water is undervalued. Further, the "market" for water is only applicable to a limited amount of consumption in the area. Pricing policy will not impact the bulk users, namely farmers who supply their own water.

Seemingly, the only way in which water can be restricted is to introduce quantitative controls (a non-market solution as it were), or possibly to introduce some form of a water market between farmers in the area. The latter solution has two difficulties. First, current legislation does not allow for the creation of such a market. Second, it is doubtful whether the market would actually function as a true market. If the severity of the current water shortage is insufficient to reduce water consumption then it is unlikely that a market of this nature will do so. Further, it is so that given the current severe water shortage in the catchment area it is unlikely that there will be many sellers in the market which should send the price of water upwards to a level that more accurately reflects its relative scarcity. Unfortunately, many farmers will simply continue to extract their own ground water at no cost other than there original capital outlay. Indeed, the creation of a market would actually discourage the optimum allocation of resources in this case. Whereas the market should encourage the use of boreholes with a greater supply than others, the overall price increase in the market (with the introduction of boreholes with relatively poor flows) will simply encourage farmers to stick to their own boreholes as they have done in the past.

Utilising the Same Analysis

In order to value groundwater in Dendron we apply the same line of argument as for Atlantis. The calculation is somewhat simpler for Dendron though given the one-sided composition of economic activity in the area.

Dendron is entirely different from Atlantis in that there are no industries other than agriculture and, obviously, some service industries for surrounding farmers. Indeed, agriculture is for all intents and purposes the only real contributor to economic activity, with all the support industries relying on this sector for their existence.

Agriculture simply cannot survive without water - the catalyst for output in this sector. Here, as opposed to Atlantis, the quantity of water supply is the critical issue rather than quality. We have indicated that groundwater is being utilised at a greater rate than it is being replenished. The value is in fact the total value of agricultural output and the concomitant employment opportunities that go along with economic activity in this sector.

Projections supplied by the Agricultural Co-op in Dendron place the expected value of agricultural output in the catchment area around Dendron at some R 13,891m for the financial year March '94 to February '95. The figure for the financial year March '93 to February '94 was R13,587m. This represents some 496 jobs (with an employment multiplier for agriculture of around 36,8 per million rand of output).

5.3.3 Groundwater Valuation for De Aar

Local authority tariffs for De Aar are by and large similar to those for Atlantis, with the surprising exception that the tariff for water consumption in excess of 40kl is lower than for consumption ranging between 20-40kl (see below).

DE AAR WATER TARIFFS

Basic charge	R11,17
5kl	-
5-20kl	R1,35 + VAT
20-40kl	R1,25 + VAT
40+kl	R1,08 + VAT

Source: Local Authority, 1994

Again we propose to utilise the line of reasoning introduced for Atlantis and suggest that the value of groundwater for De Aar is equal to the value of production. As is the case for Atlantis (and as described in the main text for De Aar) there is sufficient groundwater for De Aar, at least in the medium term and probably for the long term considering that economic growth projections for the area are somewhat subdued. Perhaps a more urgent consideration is the quality of groundwater. Here, the firms Grinacker and Rocla (two firms that produce reinforced concrete products) are experiencing water quality difficulties that will in all likelihood impact negatively on future growth in output. However, manufacturing (including the two aforementioned firms) and agriculture only make minor contributions to GGP in the area (2,63 per cent and 5,99 per cent respectively as calculated from mid 1980's data) and in the context of total production in these sectors the value of groundwater is low. Indeed, the drought in recent years has already reduced the value of output in agriculture - dominated by sheep farming.

The greatest contribution to GGP is made by transport and communications (some 2/3 of total production). This sector has minimal reliance on water. As for the total economy the status quo as it were has been maintained in economic activity since the mid - 1980's, which given known values of output for the mid-1980's, leaves the total GGP for the area at R299,5m. However, at best only some 8,5% of this figure is heavily reliant on water, leaving us with a "value" of R25,46m.

5.3.4 Groundwater Valuation for Indaleni

The various methods of valuing groundwater postulated in this report cannot readily be used for valuing groundwater in Indaleni. For example, no values of the price elasticity of demand for water can be even vaguely estimated for the Indaleni area, and therefore unlike Verwoerdburg a proxy elasticity cannot be postulated. Similarly, Residual Imputation is quite an inappropriate approach for domestic water usage since the method is structured to be more suitable for use in deciding on the value of water in production processes. The value-added method is also clearly not suitable to value groundwater in Indaleni since this approach is designed to calculate shadow, or accounting prices, for water (or of course, any other commodity). The alternative cost approach could possible be used at Indaleni to value groundwater. For example, the time taken for residents to walk to the nearest water point could be used in a production process if that journey became unnecessary due to running water being more immediately available. Most of the people in Indaleni are, however, unfortunately unemployed, hence even this approach is fraught with difficulties and clearly would not yield a defensible value for the groundwater used.

The economic consequences of changes in the quality of groundwater at Indaleni could be measured by studying statistics of water-related sickness such as gastro-enteritis etc., and the subsequent costs of treating the sickness and the loss of production capacity in the workplace. Taking account of the last comment relating to unemployment in the area, however, this becomes complicated. Further, sickness statistics are generally unavailable in the area.

In summary, then, at Indaleni the researchers were dealing with a sprawling peri-urban settlement with high unemployment and poor social facilities where little or no economic statistical gathering had taken place that could help with this study. The outcome is that none of the more classical economic methodologies for valuing groundwater described in this report could be readily used.

Some relief to the impasse was, however, garnered from the fact that the residents of the area know very well what they would be prepared to pay for water, bearing in mind their low income base.

The researchers were only able to interview a statistically small sample of people and of this sample the majority were women. The reasons for this are explained in the case study in the appendices attached hereto. From the questions posed to those interviewed definite values for groundwater were solicited. These values are shown in the table below (taken from the Indaleni case study, page C.29). The table is reproduced below for convenience.

It can be seen that the spread of values is very wide and because of the sample size and gender bias it would be incorrect to consider a mean or average value as representing the Indaleni residents' willingness-to-pay for groundwater. From the experience gained by the researcher, however, a value can be estimated, this being R0.25/25 litre.

WILLINGNESS-TO-PAY FOR GROUNDWATER IN INDALENI

No.	Fair price for ground water
3	a R10 a month flat rate
6	5 c or less
11	10c per 25 l
2	15 c
7	20c per 25 l
1	30c per 25 l
9	50c per 25 l
2	R1 per 25 l
1	a once-off payment of R50
1	currently had a fetcher R2 per 25 l and felt cheated; anything less than that would be acceptable.
1	whatever the community agreed was reasonable

5.3.5 Groundwater Valuation for Verwoerdburg

The municipality's main abstraction boreholes in Verwoerdburg yield between 50 to 70 litres per second. These three boreholes are relatively small (200 - 250mm diameter). The boreholes will ultimately be installed with pressure sensors. Since monitoring began six years ago, there has been virtually no drop in water level.

At present , ground water meets 21% of the town's demand of 14.5 million m3 per annum. There is sufficient yield to increase this amount.

The use of ground water saves the town approximately 1 million rand per annum. Annual operation and maintenance costs of ground water abstraction are 5% of the capital costs. The cost of RWB water rises at a higher rate than that of ground water due to the depreciation over ten years of the original loan for the ground water scheme.

The only limitation to ground water abstraction set by the DWAF is that abstraction must cease if the level falls more than 5 metres in any period. However, recharge in the system seems to be immediate.

For Verwoerdburg we propose to use the proxy price elasticity of demand approach for valuing the groundwater. Our aim was to find a city in the USA which most clearly models Pretoria's climate and socio-economic profiles to use as a proxy, so that an appropriate price elasticity of demand for domestic water usage determined in the Howe and Linaweaver study could be used. The closest city turned out to be Oklahoma. Climatically it has the same annual precipitation as Pretoria, it has a summer rainfall greater that its winter rainfall and its peak temperature is close to that of Pretoria in summer. Oklahoma is central, but east of the Rockies, so the appropriate price elasticity of demand (e) in the Howe and Linaweaver study is found to be -0.25. Using equation (5) from Part Five, section 4.4 together with data gathered from the Verwoerdburg case study, we have:

Q_1 = 11 460 000 m^3 / annum

Q_2 = 14 500 000 m^3 / annum

P_b = R1,5 / m^3

E = -0.25

hence:

V_T = R3,0057 / m^3

& V_I = R1,5057 / m^3

To all intents and purposes, therefore, the willingness-to-pay for groundwater is the same as the present price being paid for all water.

5.3.6 A Summary of Groundwater Values

For the sake of convenience, the different valuations for groundwater which were arrived at in the case studies are here brought together.

Case Study	Value of Groundwater	Methodology	Comments
Atlantis	R624 million	imputed valuation	Value of total groundwater used per annum
Dendron	R13,587 million	imputed valuation	Value of total groundwater used per annum
De Aar	R25.46 million	imputed valuation	Value of total groundwater used per annum
Indaleni	R0,25 / 25litres ≡ R10,00 / m^3	Survey of willingness-to-pay	
Verwoerdburg	R1,00 / m^3	Proxy price elasticity of demand	

PART SIX

USE OF ECONOMIC INCENTIVES FOR IMPROVED GROUNDWATER MANAGEMENT

6. USE OF ECONOMIC INSTRUMENTS FOR IMPROVED GROUND WATER MANAGEMENT

6.1 INTRODUCTION

6.1.1 Criteria for choosing Management Strategies

In choosing management strategies, the following objectives need to be kept in mind:

- Primary Objectives
    1. Economic Efficiency
    2. Equity
    3. Control of Economic Externalities
- Secondary Objectives
    4. Local Control
    5. Public Participation
    6. Easy Enforcement of Management Policies

In short, the aim is to manage both water and people.

6.1.2 Sustainable Management of Groundwater

Certain management policies have a once-off impact: for example when an immediate response to a drought situation is necessary a certain policy may be appropriate. Where, however, a management policy has to ensure the long-term economically efficient use of water it has to provide incentives which enhance the positive human reactions to the problem so that a basis for the sustainable use of water is assured. The sustainable management of water resources involves policies which use economic instruments in their application. The potential of economic instruments has to be assessed to do this.

A failure to treat water like other commodities is probably responsible for many of the problems attached to water management. Identifying the appropriate unit for analysing these problems and the appropriate unit for implementing them is of vital importance. For some problems the unit may be the same whilst for others it may be different. For example, the collection of data and the analysis of problems is often best done centrally whilst implementing solutions to the problem is sometimes best done at a local level subject to the legal and institutional constraints in force. It is important then to construct a policy mix that allows for all the exigencies of the situation. Assuming that the Government is legally empowered to impose taxes, levies and charges on private land-owners concerning the use of ground water, and create water markets, then there are a number of options that could be considered depending upon the circumstances and objectives. The most promising of these are:

1. Levies, taxes and charges
2. Pricing policies
3. Groundwater markets
4. Tradable permits.

These options are described in the following sections together with comments on their practical application and likely benefits.

6.2 *REGULATORY APPROACHES*

6.2.1 Include boreholes in local authority rateable valuations

Local authority rateable valuations are essentially based upon the market value of the land (or a part thereof) and the market value of any improvements. These improvements are generally taken to mean any structures on the property such as buildings and walls. Seldom does it include the value of a borehole and any related equipment, although in theory there is nothing stopping a local authority from including these as fixed improvements. As the value of a fully equipped borehole can range from R8 000 to R12 000, this could result in a 7% increase in monthly rates on a R150 000 property.

This option probably has few limited ground water management benefits. It may discourage those people that have not got boreholes from sinking them, thereby reducing the likelihood of excessive abstractions when municipal water restrictions are imposed. In cases where a local authority felt the need to monitor ground water levels, this approach could provide the necessary funding. However, where there are numerous existing boreholes and a local authority wants to control abstractions, then this type of levy is unlikely to be of much value. (Verwoerdburg Case Study)

6.2.2 One time levy when sinking a borehole

A single levy paid by the land owner to the State or a local authority on sinking a successful borehole is another way of discouraging the proliferation of boreholes. The cost of such a levy could be area and time specific and related to the availability and degree of utilisation of ground water. Thus sinking a borehole in a ground water sensitive area could prove very expensive.

Again this approach has few ground water management benefits other than the generation of revenue to fund monitoring and control activities and the limiting of the collective abstraction potential of boreholes. It would have no affect on existing boreholes and abstraction rates. Even the revenue characteristics would be variable depending on the demand at any one time for boreholes.

On the more positive side however, if the levy was collected automatically through the day-to-day activities of registered drillers, and forwarded together with the geohydrological information that drillers are supposed to provide to the Department of Water Affairs and Forestry but seldom do, then collection costs would be minimal and the geohydrological data may be more forthcoming.

6.2.3 Annual levy on boreholes

An annual levy on a working borehole could be a way of achieving a more continuous and reliable revenue stream to the authorities tasked with managing ground water. However, the collection of the levy would pose a problem as there are few annual levy payment systems in operation other than corporate tax. Thus it may be suited to farming operations which often pay annual irrigation water accounts and submit annual tax returns.

There is however an additional benefit of this approach. By raising an annual levy, the levy can be adjusted according to the capacity of the pump fitted to the borehole. This would discourage the practice of equipping boreholes with large pumps which are capable of significantly lowering the ground water level in an area and impacting negatively on other ground water users. It would also tend to favour small abstractors such as rural communities and emerging farmers.

The problem with this option is that it would require land-owners to correctly declare the size of pumps (something which may be difficult for the authorities to verify) and it would penalise those users situated in areas where the ground water may be plentiful but a long way down, thereby requiring the services of a more powerful pump. Clearly this approach is best suited to situations where there is good, but localised, control of ground water abstraction.

6.2.4 Levy on the quantity of water abstracted

A levy on the quantity of water abstracted from a borehole is the ideal instrument with which to manage ground water. However, its practical application throughout rural and urban areas, and between large and small abstractors, is extremely problematic. The majority of ground water pumps have no metering facility, and where meters do exist they are often very inaccurate and easily interfered with. Experience with irrigators abstracting water from rivers has shown that even tested and sealed meters which are subjected to regular inspections by water bailiffs, can be manipulated or bypassed. Moreover, the cost of such inspections would probably erode actual revenue levels considerably.

However, by virtue of the potential strength of this approach for accurately regulating abstractions, particularly through the incorporation of variations such as sliding-scale charges (i.e. the more you abstract, the more you pay), consideration should be given to using this option in those localised situations where the ground water resource is under extreme pressure from a limited number of known large abstractors. (Dendron Case Study)

6.2.5 Levy on the Eskom power consumed by borehole pumps

As levy collection costs and policing is a major stumbling block in abstracted volume charges, it may be worthwhile considering an alternative mechanism based not on the volume of water but on the amount of electricity used to abstract it. Of course, as the 'water abstracted to electricity used' ratio is not constant for every borehole, it will be necessary to introduce area specific adjustment factors to cater for the varying depth to water table level. As such factors would be set according to normal regional ground water levels, they could, in themselves be effective in discouraging localised excessive pumping of ground water. In other words, it may become an expensive exercise to pump a borehole down to 50m when the Eskom levy adjustment factor is set for 20m.

As many of the larger ground water pumps installed around the country use Eskom power, and as Eskom are aware of what the electricity is being used for (to the extent that they often encourage farmers to pump water at off-peak times by offering a reduced tariff), the introduction of this charge system could be easily achieved at both at a national and provincial level with the minimum of collection and policing costs. Of course this approach may tempt some large users to replace their electrical pumps with diesel driven ones. However, the capital cost of this replacement and the fact that Eskom's off-peak tariffs is far cheaper than diesel, means that the ground water management levy would have to be set very high before users would be tempted by this course of action. (Dendron Case Study)

6.2.6 Over-abstraction penalties

In situations where the ground water resources are plentiful, but because of potentially high levels of abstraction, there is the risk of lowering the ground water table to the point at which the quality deteriorates significantly, other users are unable to abstract, or where abstraction costs of other users become excessive, then it may be more meaningful to disregard volume-based charges and instead use water level-based charges. This would permit high levels of abstraction during periods of high recharge without any penalty being imposed. In other words, the penalty system responds continuously to the level of impact associated with resource exploitation and degradation, and not simply the volume of water pumped. In instances where the ground water is under considerable threat of over-exploitation, this approach offers a fair and simple control mechanism, with the added benefit that it protects the interests of the small abstractor.

The main drawbacks of this approach are to be found in the cost of monitoring and the design of the penalty system. Depending on the area affected by this system and the nature of the ground water in that area, a number of independent monitoring boreholes equipped with accurate instrumentation will be required. Following this, agreement must be reached on how long the water table has to remain below a certain level for the charges to be effected. Some sort of probabilistic approach will be required for this.

One of the advantages of this option is that it can be tailored specifically to the ground water circumstances in the area. For example, if there exists a well-defined water quality interface which must not be breached, then sliding-scale penalties can be introduced which exponentially increase in cost as the interface is approached. The revenue raised from the imposition of penalties can be used to compensate those ground water users who incur additional costs due to falling levels or deteriorating quality.

Because this type of control option applies to a large area, one alternative implementation approach would be to impose it on a community or several communities rather than individuals, thereby creating the opportunity for self-policing and implementation cost reduction. (Atlantis, De Aar and Indaleni Case Studies).

6.3 MARKET-RELATED APPROACHES

6.3.1 Pricing Policies

For economic efficiency water users should pay a price for water equal to the marginal cost of supply. In this situation the economic benefits acquired from the last unit (the marginal unit) equals the costs to the economy for its provision. It is essential that metering is involved in such measurements. It is generally accepted that the long-run marginal cost (LRMC) can be accurately arrived at. Clearly the associated costs of environmental impact involved with this supply should be taken into account.

Tariffs in South Africa have been traditionally considered to recover the costs of providing the infrastructure for water supply over time. These costs are then clearly not a method of managing water efficiently. Such costs are usually average costs and are therefore typically lower than the LRMC.

Clearly for reasons of equity, public health and social well-being there is every reason for supplying a certain amount of water at a low price. For consumption above the minimum to sustain life, however, water should attract higher prices.

In this respect there is empirical evidence that water users respond to higher prices by consuming less, but still keeping consumption above desirable levels for the maintenance of health etc. Industrial users have the potential to respond positively from price increases in water particularly so far as effluent restrictions and pollution charges are concerned. It has been estimated that in many OECD countries industrial water use by the year 2000 will be reduced by 50 per cent (Bhatia et al, 1993).

Water in agricultural use is likely to respond less dramatically to rises in prices since these prices are so low at present. Where water markets exist, however, the situation may be different since evidence suggests that farmers' price elasticity of demand for fertilisers, etc., is affected by water price increases. It can therefore be expected that their reactions to water price increases will be the same, (c.f., Gibbons, 1986), where price rises for water, including groundwater, have helped manage demand. It is appropriate to mention that in connection with the Tucson experience a high degree of public participation was obtained in conservation practices through price rises. The experience gained from this research is that information on water management policies should be made available to the public otherwise their general ignorance (as found in this study) will stifle attempts to effectively manage groundwater resources in South Africa.

Evidence of the effect of price rises on water consumption is widespread, e.g., in India and China industry has demonstrated active responses to price increases. In Egypt low water prices have been responsible for the limited application of recycling water in electricity generation.

Price increases for water will also encourage the re-use of waste water thus separating toxic and non-toxic waste for treatment and disposal. Such measures have a rewarding environmental aspect since they reduce water pollution levels.

Price increases will probably have a favourable impact on outside domestic use e.g., lawn watering, car washing, etc.

It must be noted, however, that price rises for water will only contribute to conservation if the unit price of supply exceeds its marginal value to the user.

Price rises can adversely affect the very poor of course. Clearly the very poor are vulnerable since a certain price has to be charged to amortise the investment in supply systems. From an equity viewpoint therefore it will be necessary in South Africa to establish water tariffs that will be applied to the very poor for the first 25 litres/person/day thus discouraging curtailing a basic supply on the grounds of social justice.

6.3.2 Groundwater Markets

Groundwater markets have existed in parts of Asia, Bangladesh and India for nearly a century (c.f., Shah, 1989). The question of property rights is important in this context and where these groundwater markets flourish wells are privately owned and the groundwater can be sold. Often such sales take the form of water surplus to the requirements of agriculture and domestic use. There is in addition to localised private sales of groundwater the sale, and transfer via pipelines, of large quantities of water on a regular basis.

Market forces can be used for an efficient and equitable solution to some water pricing and allocation problems, particularly as the resource gets scarcer. This has been an underlying theme in discussing the valuation techniques for future groundwater management in this report.

Promoting the efficient use of water is rather meaningless unless water prices are high enough to provide the incentive for the correct management of water. Establishing markets for water may, of course, mean higher prices being charged for water, and this would have a disciplining effect on users.

Markets can only develop, however, where users have an indisputable right to the resource, hence there are legal problems to overcome, especially if groundwater is classified as a public good in future as has been mentioned in this report.

The market can be used in two ways in promoting the efficient use of groundwater, these being:

- Raising its price, or auctioning it to the highest bidder, or
- Allocating water to higher-valued uses.

Effectively a market clearing price would encapsulate the opportunity cost of using water, and the trade-offs spoken of in Chapter 4 are thereby taken into account thus encouraging consumers to use the resource more effectively in the economic sense.

The impact of price rises for water in poorer sections of the community can be mitigated by judicious tariff structures. "Lifeline" rates for water can be established which should not seriously disrupt the formulation of a market for water.

So far as the farming community is concerned the existence of a groundwater market would encourage water to find its way into the hands of those who use it most efficiently. Also the fact that water can be bought and sold via a market enables some farmers to avoid sinking expensive boreholes on their property to meet their water requirements./

The distributive effects of groundwater markets are not readily discernible in many instances, for example larger farmers would probably be dominant as sellers of water whilst smaller farmers would have to be content with the role of buyers. This does allow the smaller farmer to avoid making expensive investments in pumps, canals, etc., however, as mentioned above.

Transaction costs, i.e., the cost of putting buyers and sellers in touch with each other, will have to be considered where markets for groundwater are established. As a market grows of course, contacts between buyers and sellers will develop spontaneously, but initially a management structure should be established to do this if the market is to work efficiently.

There is little doubt that water markets work well in the Western United States in allocating water to high-value uses between urban users, agricultural users and industrial users. The process has been shown to be economically efficient and equitable. In this respect sellers are paid market prices for water which satisfies them.

One of the most successful and long established water markets is the Colorado-Big Thompson market (cf., Howe et al, 1986). This market includes water from the western slopes of the Rocky Mountains in Colorado. Water is marketed principally for agricultural uses but urban and other users have increasingly entered this market over time. The organisation of this particular marketing effort could be used as a basis for establishing a water market in South Africa.

So far as the development of groundwater markets for industrial users is concerned, this will depend upon several economic factors, such as *inter alia*:

- The importance of water in the production process so far as quantity, therefore costs, is concerned; e.g., the wet cooling of power stations.
- The problem attached to the physical transfer of water to an industrial process, e.g., canals or pipelines, etc.

- The ability for sellers of water to enforce long-term contracts for marketing water with industrial enterprises.

The equity aspect of private groundwater markets is unclear and problems can arise as a result of:

1. The depletion of an aquifer by mining the water. This is complicated further when the aquifer is of a large size and covers an area owned by several people.
2. The environmental effects of mining aquifers where the re-charge rate is slower than the depletion rate.
3. In water-scarce areas prices for groundwater can be driven downwards, leading to mining of the water and to the problems associated with 1. and 2. above.

These problems raise legal questions, the central question being whether groundwater is a public or private good. If it is indeed a private good then certain public sector involvement in its management might be required to internalise the externalities cited in 1., 2. and 3. If, however, groundwater can be classed as a public good where the problems outlined in I., 2., and 3. above occur the problem of market failure also exists due to the excessive use of a common property resource.

6.3.3 Tradable Permits

In terms of water management a permit is essentially a consent issued by a competent authority which entitles its owner to abstract or discharge water in accordance with the rules governing the issue of the permit. Thus a permit could be used to mange discharge of pollution or allocation of water (which could be ground or surface water). Both taxes and permits have essentially the same outcome in practice, and share many characteristics. They are both easily administered and they are economically equitable. When permits are made marketable instruments (i.e., they can be openly traded in an appropriate market) then several of their inherent shortcomings fall away. For example, as marketable instruments, tradable permits are less vulnerable to inflation than permits per se. Tradable permits are also effective in coping with increased activity arising from economic expansion. As economic activity increases, the demand for more permits will rise. In the absence of any new issues, all that will happen is that the price of existing permits will increase.

The operation of such tradable permits as instruments for the management of water quality in South Africa has been extensively discussed in a previous report[106], and the reader is referred to this report for further details. However, tradable permits can also be used for water allocation or abstraction management purposes.

Tradable water rights permits have existed in Australia (the Murray Basin, New South Wales) since 1984. They have been used exclusively for surface water but it seems feasible that they can also be used for groundwater. Tradable water permits have also been proposed in the Western USA as a means of conserving and re-allocating water. This allocation process is of considerable importance since it will allow urban users to benefit from the re-allocation of irrigation water and for conservation and environmental uses.

It must be noted that tradable permits do not usually acknowledge third-party concerns nor do they address externalities arising from environmental impacts except when the price of permits is related to green taxes.

Tradable permits can have quantitative restrictions applied to their trading, which satisfy environmental requirements. Clearly the state could be allowed to out-bid potential permit holders and drive up the price of permits in an effort to ensure that environmental and conservation measures are met.

Any water used beyond the quota allowance would have to be subjected to very high unit prices. What must be avoided, is setting water abstraction quotas too low and the price per unit of water too high. Correct quotas and prices should be determined such that they make recycling and/or reuse of water viable.

For tradable permits to operate effectively, there are essentially two requirements which need to be met.

106 See WRC2.

Firstly, the market for permits should not be too "thin". In other words there should be a sufficient number of players in the market for a competitive price for trading permits to be established. Too few players will lead to a distorted market price, such as in the case of oligopolies.

Secondly permits should be traded regularly. Without regular trade, a true market price for the tradable permits will not be realised.

Tradable permits are however not without problems. For example, the free trading of permits can permit local "hot-spots" to develop where there is localised over abstraction of water. This could create particular problems when considering groundwater abstraction.

It is important to note that the scope for applying either regulatory or economic based water management instruments to poor communities is limited. If such communities were to be prosecuted for contravening regulations, it is unlikely that they would be able to pay a fine. If a fine were paid it would only deprive the community of the funds needed to remedy the problem.

6.3.4 Non-Market Management of Groundwater

It is appropriate to close this brief overview with a few remarks on non-market devices to manage groundwater which are in contrast to the sentiments discussed above. Such non-market means include *inter alia*:

- sanctions,
- persuasion, and
- education.

Sanctions are when users are compelled to conserve or allocate their water by various means dictated by the water supply authorities. Such dictates are currently being considered by the Rand Water Board in the Gauteng area. Such measures are effective but there is no guarantee that they are economically efficient.

Persuasion is usually couched in appeals to people's "public spirit" to conserve water. This can rarely be considered to be anything but temporary since its efficacy is open to serious question.

Education on the other hand stands a much better chance of success in enabling consumers to understand the need to manage water efficiently. Equity issues transcending different socio-economic groups can be explained and the rationale concerning the penalising of profligate water users are put into their proper perspective via an educational programme. Discussions between the authors and a recent World Bank mission to South Africa have indicated that education has played an important role in Israel in promoting water conservation. That education concerning the nature and scarcity of water in South Africa is necessary was demonstrated forcibly to the authors during the tenure of this research project. Education will even allow quite draconian regulations and restrictions to be accepted by water users so long as the need for them is explained.

It is probably safe to say that exhortation has a much smaller chance of successfully curbing the misuse of scarce water resources than does education. Education in how to effectively manage water resources by obtaining more economic efficiency out of a given quantity of water is of prime importance (for example, the promoting of water-efficient appliances, etc). Again the question of price must be mentioned, even in the context of education, since consumers will be more attracted to seeking ways of using water wisely, i.e., in receiving education on water management when the price for water is set to the economic level rather that at some sub-optimal figure.

Finally if markets are to be efficacious they should be used boldly and sometimes it is even appropriate to use a package of market and non-market instruments in tandem thus bringing out the best of both worlds.

6.4 APPLICATION OF ECONOMIC INSTRUMENTS IN SOUTH AFRICA

Based on the above discussion, the following table is put forward as a possible selection of incentives appropriate to each study area.

Study Area	Incentive	Comments
Atlantis	Tradable permits and the establishment of a water market	Many users,
Dendron	Non-tradable permits, taxes or levies	Thin market, control of water mining
De Aar	Non-tradable permits, taxes or levies	Thin market
Indaleni	Command and control	Provision of basic needs
Verwoerdburg	Tradable permits for domestic boreholes	To control abstraction of groundwater

PART SEVEN

CONCLUSIONS AND FURTHER RESEARCH

7. CONCLUSIONS AND FURTHER RESEARCH

7.1 CONCLUSIONS

The literature survey confirmed that in many regions of the world water has been regarded as a free commodity, and this has led in many instances to over-exploitation of the available resources, as well as uncontrolled release of pollutants into water resources by households, agriculture and industry. Well-known groundwater-related issues such as the joint use of aquifers with a limited recharge rate (generally known as the common pool problem) were also frequently cited.

A wide range of opinions relating to the use of economic instruments for groundwater management was demonstrated. These included Chan (1989), who argued that relying on markets for allocating groundwater has some serious defects including impacts on equity, freedom, and community cohesion. He then went on to propose a regulatory approach to the problem. Neher (1990), on the other hand, suggests that where the extraction of water from aquifers is the responsibility of a public agency, or a large private utility, marketable quotas could be assigned.

In general most of the known problems were covered by writers, but no exciting new directions were indicated for groundwater valuation and management.

South African water law is currently in transition and is characterised by a fluctuating focus from public to private ownership, and back to public again. The currently argued common law "absolute ownership" groundwater doctrine fails to recognise the hydrological reality and that legislation is needed to promote the equitable distribution and conservation of a scarce resource. It seems that the right to groundwater is not a "right in property" for purposes of Section 28 of the Constitution. However, if this is not accepted by the Court, it is argued that the individual right to property should in this instance give way to the dire need of 12 million people for access to water.

The quality of groundwater presents many problems, the scope of which spans the physical, biological, political and economic arenas. The brief for this study did not insist on groundwater quality problems being addressed in detail and whilst mention is made in the text of some problems attached to groundwater quality no attempt was made to analyse this situation in South Africa in any detail. It is nevertheless important to mention that in dealing with groundwater quality there will be a basic need for rules and incentives to be put in place that influence groundwater contamination policy options.

The valuation techniques reviewed in the report made use of data culled from the case studies in order to derive some representative values of groundwater. A study of the data collected unveiled several problems.

Firstly there is a lack of information on groundwater demand and the demand-quality nexus in South Africa.

Secondly, because of the lack of such a data-base and to ensure budgetary requirements are kept to a minimum, secondary sources of information such as population census, income forecasts, etc. should be collected with regard to groundwater management. This secondary information should then be supplemented by field surveys.

Thirdly, it was soon realised that for any meaningful data to be gathered that would aid the groundwater valuation process, an educational initiative should be put in place.

Fourthly, it would be appropriate to extend the valuation studies to agricultural irrigation and industrial use of groundwater in depth.

In summary, the sections on the valuation process attempted to illustrate how economic analysis may be used to respond to the problems of groundwater valuation and also to anticipate some of the problems that may arise in the future as far as groundwater valuation and management is concerned.

Whilst there may be many who would suggest alternative approaches, the authors believe that the values arrived at are sufficiently robust to be used for implementing improved groundwater management policies.

When it comes to selecting appropriate incentives for groundwater measurement, it is clear from the case studies that there is no universal incentive which will be effective in every case. The selection process has to be carried out on a case-by-case basis, essentially as demonstrated in this report.

7.2 RECOMMENDATIONS FOR FURTHER RESEARCH

Stemming from the research embodied in this report, and the conclusions drawn above, the following areas of interest for further investigation and research have been identified:

- An economic analysis of private vs. public control of groundwater in South Africa.
- The use of price elasticity of demand as an aid in forecasting possible future groundwater demand.
- A definitive data-gathering exercise to give more clarity to the groundwater demand/pollution debate.
- A monitoring exercise to track the appropriateness of various economic instruments under the changing political, social and economic environment in South Africa.
- The economic effects of the over-exploitation of groundwater resources in South Africa.
- Research into water quality enhancement using demand-side management and pricing policies.
- Educational initiative to create public awareness of the value of groundwater.

APPENDIX A

BRIEF AND PROPOSAL

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RESEARCH PROPOSAL

THE ECONOMICS OF GROUND WATER USAGE:

THE IMPORTANCE OF INTRINSIC VALUE AS A BASIS FOR SUSTAINABLE MANAGEMENT

AIMS

The Water Research Commission funded project on the "Application of Economic Principles to Water Management Decision-Making in South Africa" (currently nearing completion), identified ground water management as being in need of attention from economists if the resource was to be utilised in a sustainable manner. However, the complexities surrounding the ground water issue was such that it was not possible to even begin addressing it in that particular study. Both the Project's Steering Committee and the researchers were of the opinion that, in view of the socio-legal circumstances of ground water usage in South Africa, the issue warranted a dedicated research project. This proposal aims to fulfill that need.

The primary aim of this project is to develop methodologies for placing a value on ground water which is proportional to the importance of the use to which it is put. These values are likely to vary from one ground water use activity to another, and from one location to another. Such values are critical in that they can indicate and justify the nature and extent of ground water management systems. Of course in a perfect market there would be no difference between the price of ground water and that of surface water, as the price would be determined by the use to which the water is put, which would in turn determine what the user would be willing to pay for it. However, perfect water markets seldom occur, and furthermore ground water use in South Africa is strongly influenced firstly by its private water status (which promotes small scale individual use), and secondly by the relatvely low and sometimes uncertain yield of the predominant secondary fractured aquifer systems. It is for this reason that methods for the valuation of ground water are likely to be very site and water use specific, and may not be comparable with surface water valuation approaches.

At this juncture, the distinction must be made between 'value' and 'price'. Although pricing is one way of attaching value to water, it is not the only approach, and not necessarily one which is suitable for ground water. In theory, price and value are only the same when a commodity is offered for sale on an open market, and an acceptable transaction concluded between purchaser and seller. As this seldom occurs with water, other valuation methods have to be employed. Such methods should ideally result in sector specific values, which will vary in monetary amounts, but which will reflect an equitable level of considered usage amongst the different user sectors.

The specific aims of the project are as follows:

(1) To undertake a survey of ground water valuation approaches adopted in other countries, with particular reference to their acceptability, practicality and contribution to improved aquifer management.

(2) To estimate the economic value of ground water to selected user sectors, and estimate the likely economic impact of a sub-optimal water supply resulting from poor aquifer management.

(3) To develop standard methodologies for determining the value of ground water.

(4) To investigate the potential of economic-based incentives to promote a more self-regulatory, localised approach to ground water management.

RESEARCH PRODUCTS

Aim 1 : Survey of overseas ground water valuation approaches and related management systems

Completion of this aim will produce two deliverables. Firstly, an initial literature review will be undertaken to identify promising overseas examples of ground water valuation, particularly where this has provided justification for increased aquifer management. Secondly, a comparative review will be made of the supporting legislation under which the selected ground water systems are managed. Although this will only be a superficial assessment, it will permit the identification of key policy differences between South Africa and those countries which have intensified ground water management on the basis of economic considerations.

Aim 2 : Determination of the economic value of ground water : Case Studies

This aim is intended to support the broad situation and policy analysis with actual examples, as well as provide sample data for the development and testing of economic evaluation methodologies. Deliverables will comprise a series of unit values of water, from which an estimate of the economic value of the water will be attempted.

The following types of ground water utilisation systems have been identified as possible candidates for specific study. The general geology associated with these aquifers is indicated in parentheses:

(1) Proposed or existing low cost and informal housing development situated to the north or north-west of Johannesburg (Dolomite).

(2) Municipality that relies on ground water for all or part of its water supply, eg Graaf Reinet, De Aar (both Karoo) or Verwoerdburg (Dolomite).

(3) Rural developing community(s) relying on ground water for domestic supplies, eg. Northern Transvaal (Basement).

(4) Large scale commercial irrigation project, eg. Dendron (Basement) or Hex River (Karoo)

(5) Sizable coastal community utilising water from primary coastal aquifers, eg. Atlantis.or Cape Flats (Recent).

The selection of all or some of the above sites will depend largely on the availability of existing data relating to the physical characteristics and abstraction rates of ground water. Site selection will be made in consultation with the Project's Steering Committee. The data that will be collected will largely comprise economic information, with less emphasis being placed on the technical data more usually contained in ground water reports. . It is hoped to include about four different examples of ground water use within the research project.

In all of the above examples the issue of ground water contamination and the associated decrease in aquifer value will be addressed. The types of ground water quality problems that are likely to be encountered include seawater intrusion, salinisation from geological strata rich in soluble salts, contamination from nitrogenous leachate, and sulphate enrichment from mining activities.

Aim 3 : Development of ground water valuation methodologies

Using information from the literature review and the experience gained in the case studies described above, streamlined methodologies for the valuation of aquifers will be documented. These methodologies will be specific to the various water uses encountered during the research. However, it is hoped that the successful completion of Aims 2 and 3 will permit the development of a system for classifying aquifers according to their value, and the susceptibility of such values to poor aquifer management.

Aim 4 : Assess the potential of economic instruments to contribute to ground water management

Achievement of this aim will result in an assessment of a number of economic-related measures which may promote the self-regulatory management of aquifers. These measures will be assessed at both a local and a national management level. They include :

- the practicality of abstraction licences and associated fees;
- the marketability of such licences;
- the marketability of the abstracted ground water; and
- the feasibility of introducing levies on the drilling, yield and utilisation of boreholes;
- the introduction of economic incentives to limit the impact of land-use activities on ground water quality.

MOTIVATION

The decision to improve water management systems is invariably prompted by the reduced utility value of the water supply. This is often a result of either a reduction in the assurance of supply or a decline in water quality. Although the utility value of water is seldom calculated with any degree of preciseness, the response from consumers claiming to be disadvantaged by its decline, is usually sufficient to convince water managers of the need to allocate money and manpower to improve its management.

Unfortunately, reductions in the utility value of South Africa's ground water are unlikely to lead to increased aquifer management. There are three primary reasons for this:

Firstly, ground water in South Africa is essentially Private Water, and is therefore the property of the owner of the land under which it occurs. The limited involvement of the State in the management and utilisation of ground water has tended to discourage users from seeking State assistance when aquifer management problems have arisen. Where the State has adopted a more assertive approach to ground water management (ie. the declaration of Ground Water Control Areas) regulatory measures have been found to be expensive and impractical to enforce effectively. Where ground water users have sought the support of the courts to improve aquifer management, this has also proved to be expensive, and often fruitless, due to the inconclusive nature of ground water dynamics, especially in South Africa's secondary fractured rock aquifers. Thus, the current legal status of ground water encourages ad hoc, fragmented approaches to its management, and the prevalence of self-interest in its utilisation.

Secondly, the State's past emphasis on surface water-based solutions to water supply problems, has tended to undermine the potential role and value of ground water in meeting the nation's needs. Although the recent decline in cost-effective and affordable surface water supply options has, to some extent, re-affirmed the importance of ground water, many municipalities and irrigators still view their ground water as a temporary and inferior supply requiring replacement by a surface water supply the moment problems are experienced. Lobbying to this effect continues unabated.

Thirdly, the shortage of holistic ground water management plans which function across individual property boundaries, and which are capable of demonstrating the full potential of properly managed aquifers, has meant that users lack confidence in the ability of ground water to meet their long term needs. Such scepticism is common throughout both First and Third World communities in South Africa.

Apart from the obvious legal problems, the central issue which emerges from the above reasoning is that there is insufficient value placed on ground water by those people who use it and depend on it. If an aquifer were to be correctly valued, users and water managers alike, may review their perception of its role as a water supply, and may even be prompted to address the legal constraints which hamper its proper management. Economists have shown that the level of management accorded a resource is related to the value society attaches to it. Thus, the more realistic valuation of ground water will establish a justifiable basis for its appropriate utilisation and management.

METHODOLOGY

As this proposed research project is largely exploratory, a generalised approach which focuses on technique development and problem identification, rather than detailed accuracy, is deemed to be appropriate. Consequently, with the exception of the data capture work, the project will mostly take the form of a desk study.

The project will be executed in two phases. Phase A will include the achievement of Aim 1 together with the inclusion of some backgound economic theory on ground water valuation. It will also define the scope of the project by describing the various types of ground water use systems in South Africa and from this, drawing up a list of likely candidates for the case studies.

Phase B will comprise the case studies which are intended to reflect several different examples of ground water development and usage in South Africa. The studies will attempt to determine the following:

(1) The broad physical characteristics (quality and quantity) of ground water abstraction and use.
(2) The costs (capital and operational) associated with ground water abstraction.
(3) The role of ground water in production, and the value (direct and indirect) of such production.
(4) Alternative water supplies and associated costs of achieving a similar level of service to the ground water supply.
(5) Relationship between the quality of ground water and utilisation benefits, and the impact on the value of the aquifer of a decline in water quality.

(6) An estimate of the opportunity costs associated with ground water supplies.

By using the case studies as examples, an assessment will be made of the potential of economic instruments to contribute to ground water management and policy-making.

APPENDIX B

INDALENI CASE STUDY:

WAITING FOR THE WATER TO RUN OUT

CONTENTS

1. INTRODUCTION

Indaleni is an extremely poor peri-urban settlement just outside Richmond in the Natal Midlands. Residents rely almost exclusively on local boreholes and springs for their drinking water, and the shortage is becoming acute.

1.1 INDALENI IN CONTEXT

In 1847, a Wesleyan Missionary Society missionary settled in the Richmond area with a group of African followers after fleeing conflict in Swaziland, and established a mission station. An adjacent white farm, known today as KwaMagoda or Newlands, was purchased in 1859, and in 1865 the Colonial Government set aside for 6164 acres for the Wesleyan Church at Indaleni. All this land was subsequently administered under the Natal Native Trust.

By the 1950s Indaleni was regarded as a `black spot' -- an island of African settlement in an area designated for white settlement -- and its residents faced relocation. This policy was subsequently abandoned, and Indaleni was integrated into KwaZulu. Today, part of the land is owned by the Methodist Church, some is freehold, and the rest is communally owned. As a result of the transfer of all tribal land to King Goodwill Zwelethini in April 1994, the King holds title to most land in Indaleni.

Indaleni can no longer be regarded as a rural settlement, in the sense of being one where the majority of its residents derive at least part of their income from working the land. Located 4 kms south-west of Richmond in the southern Natal Midlands, Indaleni is a sprawling peri-urban township, and is almost entirely dependent on remittances from people working outside of Indaleni. Richmond is too small and undeveloped economically to provide many jobs, so the majority of wage earners work further afield, in Durban, Pietermaritzburg or the PWV. Given the low levels of economic activity in the area, most people with education and skills have left.

This report covers the area of settlements known collectively as Indaleni. Technically, it should be called Greater Indaleni, because Indaleni proper is one settlement among several other concentration of dwellings - KwaMagoda, KwaCebelele, KwaVumindaba, eKupholeni and Simozomeni.

Greater Indaleni is very dispersed, with pockets of settlements separated by steep hills, valleys and wattle plantations. Levels of service vary significantly. Simozomeni, for example, is separated from the rest of Indaleni by about 3 kms of steep winding dirt road. It has benefited less from the development of water resources in Indaleni, and no new boreholes have been drilled at Simozomeni. Its residents rely exclusively on two water sources - a spring, which tends to run dry during the day in winter, and a vigorous stream, which looks clear and clean but is in fact contaminated by settlements upstream. This stream is used extensively for washing clothes (and cars), and local residents try to get to the stream very early in the morning, before the washing begins, if they want to draw water for drinking.

Since the mid-1970s Indaleni has fallen under the jurisdiction of the KwaZulu government. There has been virtually no infrastructural development in the settlement for a very long time; indeed, the settlement has seen a steady decay of physical and social infrastructure.

In the late 1980s, discrete tensions between traditionalists and those supporting a more modern social order fed into regional political tensions between the ANC and IFP. This led to an upsurge of violence which peaked in 1991-92 which aggravated the chronic deterioration in physical infrastructure at Indaleni. It is believed that up to 60% of Indaleni's population fled the area; many IFP-aligned area settled in Phatheni, roughly 20 kms west of Indaleni, and many ANC supporters moved to Pietermaritzburg or Durban. The majority have not returned.

The combination of exodus and violence, compounded by criminal opportunism and political thuggery, has tended to undermine any sense of community among local residents. Since the late 1980s -

- for extended periods, particularly in 1991-92, large parts of Indaleni resembled a war zone, and hundreds of houses were destroyed.
- money collected by the local water committee to rehabilitate parts of the water supply system disappeared without trace;
- a grant provided to rehabilitate vandalized spring protection sites was misappropriated;
- a local NGO which provided skills and development training closed down and relocated elsewhere when the violence made its work untenable at Indaleni;
- since 1990, when Indaleni residents made clear their support of the newly-unbanned ANC, the KwaZulu government has largely washed its hands of the settlement. Since 1990 there have allegedly been no inspections of the local clinic or schools, no ambulance services, and no road maintenance. Due to budget and staff constraints the local clinic has closed its maternity section and, since the strike at Edendale hospital, supplies of medicines have been erratic.
- the local Mission Development Centre closed at the end of June 1994, following internal disputes.

Even more serious has been the extent to which local leadership structures have broken down. Although the community is solidly supportive of the ANC, there are divisions within the local ANC. Although these internal tensions seem to be easing, at least three local ANC leaders have been assassinated in the last two years by people believed to support a rival faction within the local ANC. Understandably, this has tended to inhibit new candidates from offering themselves for leadership positions.

The impact of this has been felt in several areas, particularly the Greater Richmond Development Forum, an initiative formed two years ago in an attempt to develop a common development vision for the district. Several development initiatives have foundered because of problems finding people willing to lead and direct projects, problems with continuity of representation within committees, and problems in communicating the Forum's work to the wider population of Indaleni.

1.2 IMPLICATIONS FOR WATER RESOURCE DEVELOPMENT

Any development of Indaleni's water resources will require the consent and support of Indaleni's residents, and their commitment to contribute to the cost of such development. In the absence of trusted leadership structures able to educate local residents about their options, and about the implications of the various options, it is not clear how the necessary consensus and commitment will be achieved.

If a ground water supply scheme is selected as the most appropriate in the short-term, it is likely that such a scheme would place more responsibility on local leadership structures to oversee operation and maintenance than a surface water supply scheme would, based outside of Indaleni. Local residents, moreover, would need to be educated about the need for appropriate sanitation measures, siting of dwellings, care of livestock and so on.

The record to date suggests one should not assume complacently that existing leadership structures in Indaleni will be able to provide the kind of leadership and management required.

2. INDALENI'S CURRENT WATER SUPPLY

2.1 DEMAND WITHIN THE CATCHMENT

At least four major interest groups in the area compete for water:

i) Organized agriculture:

White commercial farmers have historically been the best organized in the vicinity around water, and in the mid-1980s secured the assistance of various state subsidies and loan schemes to construct a large dam - Beaulieu - to provide for their irrigations needs.

In order to spread the cost of repayments, the Richmond Town Board was invited to participate in the scheme, and so domestic users in Richmond also have rights to Beaulieu Dam's water. Beaulieu is unable to service both irrigators and Richmond users at the level they would like in times of drought, and, in a drought, Richmond domestic users have first call on Beaulieu's water. Local irrigators resent this bitterly, despite the fact that Richmond's users lower the cost of water to the irrigators.

Water released from Beaulieu is used primarily to irrigate citrus, vegetables and dairy pastures. Not all irrigation relies on Beaulieu's water, as some local farmers are able to rely extensively on their own boreholes.

Many of the farmers who draw water from Beaulieu also have their own stands of timber, planting trees where the land is not viable for cropping or pastures. As will be shown below, afforestation in the area has severely reduced mean annual runoff (MAR), and depleted local ground water resources and the flow of the Ilovu River.

ii) Richmond's domestic users:

Richmond is a small country town with a population of no more than 500 people, most of whom are white or Asian. The Richmond Town Board draws up to 90% of its water the remainder of Richmond's water comes from local ground water resources - the Glenn App, and four boreholes. The spring's yield is declining noticeably, a fact which local residents attribute to the 100% growth in afforestation in the area in the last ten years.

Richmond has no local industry to speak of. In recent years it has promoted itself primarily as a retirement settlement, and will not be able to attract industry unless it can secure a better water supply. Even without significant economic development, projections suggest that Richmond's existing water supply will be inadequate soon after 2000.

iii) Timber interests:

Forestry permits have been issued liberally in the Greater Richmond area, and Mondi, Sappi and Hunt, Leauchard & Hepburn are well represented. In the Beaulieu sub-catchment, 67,96% of the surface area is afforested; in the Riverlea sub-catchment (within which Indaleni falls) the figure is 47.13%, and in the Commissie Drift sub-catchment, 47.13%.

The area planted to exotic timber has doubled in the last ten years, and there is a good deal of anecdotal evidence suggesting that the sharp rise in afforestation has affected local water resources. Local farmers recall swimming in the Ilovu River as children, when it was deep and vigorous; in the drought of 1982/83, the Ilovu River dried up for the first time, for several hours one day. In the drought of 1992/93 - admittedly one of the worst on record - the Ilovu stopped running for six months.

On the basis of detailed analysis and modelling, consulting engineers BKS (Inc.) estimate the MAR in some parts of the catchment had declined by 1990 by at least a third from the naturalized simulated runoff.[1]

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1 Complex modeling by BKS (Inc) of simulated naturalised runoff for the Beaulieu sub-catchment for the most recent year available (1989/90) gives a figure of 27.52 million cubic metres; annual observed runoff for the same year shows 17.12 million cubic metres, or 62.2% of this figure.

Probability suggests that this decline must affect the recharge rate of local aquifers. Admittedly, the catchment area for deep aquifers is extremely wide - far wider than those for alluvial aquifers like springs. Hence anecdotal data on declining spring yields in the area are not necessarily that relevant to the viability of boreholes tapping deep aquifers - but the long-term implications of this should be considered.

iv) Indaleni residents:

Indaleni is a sprawling peri-urban settlement of roughly 14 000 people at present, who rely exclusively on drinking water fetched from boreholes and springs. This figure of 14 000 represents less than half the number who lived in Indaleni before political violence in the area forced many to flee the area in the early 1990s. As former residents return, the pressure on limited existing water resources rises steadily.

Given the continuity of the water cycle, any solution to the region's water problems will have to take into account the needs of all user sectors.

2.2 Physical Characteristics of the Indaleni Area

The geology of the Greater Richmond area is dominated by the dwyka and ecca shales of the Karoo series, and natural vegetation consists of small pockets of indigenous forest in the kloofs and open grassland in the remaining undeveloped areas. Indaleni is characterized by eroded grasslands and, in some of the higher areas, stands of exotic trees - wattle, eucalypts and gum.

A sketch of the hydrology of the Indaleni area is provided Steffen, Robertson and Kirsten's Durban office:

- *The geology of the area consists of alluvial and colluvial deposits particularly in the low lying areas, underlain by dark grey shale, siltstone and fine grained sandstones.*
- *These rocks are frequently intruded by dolerite sills and dykes.*

- *Aquifers of the fractured type can be found in the contract zones between the dykes and the host rock.*

- *A fault of regional importance is reported on the geological map 1: 250 000, extending E-W approximately 8km north of town, from Byrne and throughout the farms Enon 12784 and Rysfontein and Waltevreden 826. This area is considered of high ground water potential. Another area of high ground water potential is located south of town, where the Lovu River flows through the Richmond Commonage and the farm Beaulieu Estate 1412.*[2]

Most of Greater Indaleni falls into the Riverlea sub-catchment of the Ilovu River catchment area. Part of KwaMagoda and Simozomeni fall in the upper portion of the Mkomazi River catchment.

2.3 Mean Annual Precipitation

There are no rainfall stations located in Indaleni. The nearest, in Richmond, shows a MAP of 983 mm.

2.4 Indaleni's Existing Water Sources

Indaleni residents have access to three sources of water locally: springs, small streams and the Ilovu River, and boreholes:

i) Springs

At least 29 springs at Indaleni have been evaluated. A further number exist, but have not been evaluated. In the 1980s seven of the springs were protected and uncovered reservoirs were constructed; a further three were subsequently protected, but without storage reservoirs.

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2 Exploration of the Ground water Potential in the Richmond Area', letter to Umgeni Water from SRK, 11 April 1994.

At present only one spring is perennial and reliable, and only one spring (not the reliable, perennial spring) can still be regarded as protected. The remainder have been vandalized: the concrete slabs have been broken up, storage reservoirs smashed and taps removed. Most amount to little more than a PVC pipe sticking out of a muddy puddle, and at least one resembles a bog. Residents draw drinking water from all of these sites, and virtually no-one disinfects or purifies this water.

Livestock walk freely in and around these sites, and there is abundant evidence of animal waste. Many of the springs are adjacent to, or downstream of households and pit latrines. Nurses at the local clinic maintain that gastro-intestinal problems among Indaleni residents are more prevalent in summer, because in the rainy season there is greater runoff into the springs, much of it contaminated with human waste.

Attempts were made in 1993 to rehabilitate the damaged springs. These attempts generally did not prove particularly successful. Local labour crews were recruited to work under community supervision, but progress was erratic and led to tension over wage claims. Workmanship proved to be poor, and there is little evidence now of any rehabilitation.

Residents complain that the water from some springs taste foul, smells, or is muddy. In other parts of the settlement, residents describe the spring water as clean and good-tasting.

ii) Boreholes

Throughout the 1980s there were two boreholes in Indaleni, with handpumps - one on the farm Newlands and one on the Richmond Commonage. In 1988 a further six boreholes were drilled, but were not equipped with pumps for some time. At present there are three functioning boreholes in Indaleni:

Borehole B6 at Ndala School: in May 1993 it was pumping 700 l per hour into a covered reservoir at the Police Station. An outlet was connected to two public standpipes - one opposite the police station and one behind the shops at the road junction.

Borehole B3 at the boundary between Indaleni and KwaMagoda: was pumping 2 000 l per hour to an uncovered reservoir. One outlets have been constructed at eKupholeni, and two standpipes have been installed in KwaMagoda.

Borehole R6 on Townlands: Tests suggest this borehole can deliver a safe yield of 1 500 l per hour.

In December 1994, six test boreholes were drilled at Indaleni. Three delivered excellent yields; preliminary tests suggest a safe daily yield of 760 Kl a day - more than three times the current combined yield of Indaleni's other ground water sources. These three boreholes have not yet been equipped, and their water has not yet been made available to residents.

iii) Rivers and streams

Indaleni has riparian rights to the Ilovu River, which forms part of its northern boundary. Indaleni is a member of the Ilovu Irrigation Board, but its residents have no formal rights to Beaulieu Dam's water; representatives of the community were not invited to participate in the scheme when the dam was being planned.

Very few Indaleni residents draw water from the Ilovu River for any purpose. Although the river defines the northern boundary of the settlement, relatively few people live in the area. Where the river is used, this is largely for washing and building water.

Several streams flow through the settlement, but, for the most part, are little more than trickles contaminated with soap and human and animal wastes. Those living within an acceptable walking distance of these streams tend to use them for washing clothes or collecting water for building.

2.5 PRESENT WATER DEMAND

Current water demand at Indaleni seems to be in the order of 274 Kl per day, based on an average of roughly 20 l per person per day, multiplied by 13 700 people. This amount includes water used for drinking, cooking, body washing, home gardens and, significantly, building with *daga* and mudbrick

Daily per capita consumption is heavily constrained by the logistics of fetching and carrying water in plastic containers. As long as residents have to fetch and carry their water in plastic containers, their consumption is not likely to rise above this figure. Added to this is the fact that collecting water is a very slow and tedious business: there are long queues at the more reliable water points, and the flow of water at some points is extremely slow. Respondents commonly reported waiting in queues of up to three hours, and even then they are rationed at some water points to filling no more than two containers at a time because of the length of the queue.

At one standpipe, I timed how long it took to fill a 25 l plastic container from a reservoir outlet pipe: 18 minutes. At another point, I watched a woman fill her container using a cup as a ladle to scoop water from a drum sunk into the bed of a dry stream; water seeped slowly into the bottom of the drum through two holes in its side. It took her well over an hour to fill a 25 l container, and she had four to fill. She assured me this was preferable to walking to the nearest alternative water point.

The vast majority of water points in Indaleni are not reliable. In winter, many dry out completely for weeks on end, and very few can be relied on to provide an assured supply. Consequently residents start to queue for water from 3 am to be assured of getting water - and even then it sometimes runs out before it is their turn to draw.

Local opinion on whether boreholes are preferable to springs varies, apparently in relation to the quality of the nearest borehole and springs. Boreholes are not uniformly regarded as more reliable than springs. In some areas, residents said they preferred to draw from springs because at least they could see how much water was available and judge for themselves whether they would get water. Outside the police station is a pipe outlet supplying water from a borehole at Ndala School; the electricity driving it trips regularly. At another borehole, electricity to drive the pump is switched on only between 2 and 5 pm; if the queue moves slowly, not everyone in the queue gets water before the pump is switched off.

3. A SURVEY OF SOME INDALENI RESIDENTS' NEEDS AND PERCEPTIONS

In late June / early July 1994, field research for this project was conducted by a young social science graduate - a Zulu-speaking man - who travelled around Indaleni on foot. His brief was to survey as wide a cross-section of Indaleni residents as possible, speaking with people collecting water at water points, and to those he encountered casually who were not collecting water. .

3.1 CONSTRAINTS AND LIMITATIONS

The value of this survey is constrained by several limitations:

- Given the recent history of violence in the area, we decided to be extremely undemanding, cautious and low key in our requests for information. No attempt was made to identify respondents by name or address. This means it was not possible to cross check or correlate information, for example, with other members of a respondent's household.
- The survey is insufficiently representative of local residents. Surveys were done exclusively during the week, and during working hours.[3] This means that the perceptions of wage-earners were not recorded; it would have been interesting to see whether their willingness to pay for water was different to that of non-earners, or whether they attached a different value to water.
- The vast majority of respondents - 80% - were women. One reason for this is that the surveys were targeted at two broad groups: those drawing water, and those not drawing water. With two exceptions in the survey, women fetch and carry water, and so responses from this group came mostly from women. There is no

[3] This was not the original intention at all, but circumstances intervened to preclude weekend work.

particular reason why so few men were among those interviewed as not drawing water.

- Most respondents were busy, and were reluctant to spend more than 30 minutes answering the questionnaire. Given time constraints and the absence of clear incentives, it proved to be very difficult to explore respondents' responses in much detail.
- Attempts to explore elasticity of demand at different price levels were not successful. This is a crucial area for further investigation.

3.2 Results of the Survey

Respondents' replies are discussed and assessed below. The responses are divided into several broad categories, with sub-headings relating to the specific questions asked in the survey.

3.2.1 Social profile

The vast majority of people who collect water are female, and range from girls aged from about five years, to elderly women in their sixties at least. Men and boys do collect water, but this is certainly not the norm.

Unemployment is extremely high in Indaleni, and incomes are low. More than half of those who provided information on their income said their total monthly income was below R500 per month.

There are extremely few jobs in Indaleni. Formal sector employment appears to be confined to one small clinic, the mission administration centre, the School for the Deaf and a few small general dealers. Informal sector activity seems to focus on spaza shops, taxis and hawking. Indaleni residents provide the bulk of Richmond's labour force, and many work in the timber industry and surrounding farms as daily and weekly labourers. People seek jobs on farms and domestic work only when they have no other alternative. Only five of the people surveyed worked for an income;[4] four worked as assistants in spaza shops, and one worked at a shebeen.

3.2.2 Education

Education levels among respondents were generally low. Only one respondent had a post-matric education, and five had a completed Std 10. 13 described themselves as having had little or no schooling. 21 had not completed seven years schooling, which is now widely regarded as the minimum necessary to ensure functional literacy. Those with little schooling tended to be older people. There was no significant difference in the education levels of men and women.

3.2.3 Household size

Household size varied widely, from two to 17 people, with 8.4 being the average.

3.2.4 Household income

The average household income is extremely low, and is way below the current household poverty datum line and minimum subsistence level.

%	Income
41%	monthly income is below R500; many rely solely on old age pensions
23%	monthly income is below R800
15%	monthly income is below R1 200.
21%	did not know, or gave no data.

Note:

- Many households rely on remittances sent by family members working outside of Indaleni. Because of possible discrepancies between how much money is earned by people living outside Indaleni, and how much is sent home to family members

4 Note that this survey was conducted during the week, during working hours, which would exclude most wage earners.

living in Indaleni, the question was phrased to ask how much money households in Indaleni received in income.

- The vast majority of respondents were women. It is possible that some of them are not in a position to know what their total household income is. However, even if their responses reflect only *half* the total household income, income levels are still extremely low.

3.2.5 Water consumption and usage

i) How much water does your household use?

This figure varied widely, and was almost certainly influenced by the number of households using water for building.

The standard unit of water is the 25 l plastic container. Most people carry these containers on their heads or in wheelbarrows; the containers are seldom sealed with lids, and so the container is seldom filled right to the top. Thus most households are collecting water in units of 22- 23 litres, rather than 25. A figure of 22.5 l will be used throughout.

Average daily consumption per capita is in the order of 21.3 l. However, if one excludes all households where a portion of that water is used for building, then average daily per capita consumption drops to 18.1.

There is no significant difference in the water consumption of those living close to a water point and those living further away, which suggests that demand for water is not very elastic. As long as people have to fetch every unit of water they consume, they will not fetch more than they need - regardless of whether they live close to a water source or further away.

ii) How long does it take to walk to your water point?

This question was asked in the form, `how long does it take you to walk to where you get your water?' This format addressed the fact that people walk at different paces; what was at issue was the time taken getting to the water point, rather than the actual distance or gradient travelled.

Walking times varied widely, from two minutes to three hours for one frail old woman. Excluding the time taken by the frail old woman, the average time was 50 minutes, each way. However, many people are clearly walking more than the average round trip figure of one hour forty minutes, because 22 respondents regularly use at least one other water point as well. For example, one person draws her building water from a swamp and drinking water from a spring; if that spring has run dry, she then walks to another spring ('Shoba's'). Another usually gets her water from a borehole outlet, but if the queue is too long by the time she gets there (which means she won't get water before the pump is switched off) she walks on to draw from a muddy swamp. And many people collect their drinking water, take it home, and then walk to a spring or river to wash clothes.

iii) How long do you spend queueing for water?

Time spent queueing for water varied widely, and was affected by which water point people went to - which in turn is determined largely by water quality, quantity and reliability. People commonly spend up to three hours queueing; the average among the 15 people who were asked how long they queued was an hour and a half.

In some of the more remote areas, there is no queue. In other areas - such as one spring in Emaswazini, one woman chooses to start queuing at 3 am, so that she only has to spend one hour in the queue; at one spring in Ekupholeni, there is only a small daily yield of water - so that if you are not the first person in the queue at 3 am, you don't get any water there.

Outside the police station is a pipe outlet, leading from the borehole at Ndola school; people queue for up to two hours at a time, and are allowed to fill a maximum of two containers before they have to go to the back of the queue again. At a tap across the road from the police station, there are very few people in the queue because the water pours out so slowly; nonetheless the queue itself moves very slowly; one woman told us it takes up to five hours before it is her turn to fill. If people aren't in the queue for Ekupholeni's borehole by 3 pm, they won't get water before the next day because the borehole pump is switched off at 5 pm.

People don't necessarily spend the full two or three hours standing in a queue. They might take it in turns minding each others' containers and moving them closer to the water point; but because the water point is frequently far away from any other place they need to be, this time cannot readily be used usefully for many other purposes. Obviously the time spent queuing is used to fulfill important social needs - but it is quite possible that many people would prefer to trade some portion of their social time for other pursuits.

Queue-jumping seems to be relatively uncommon, but is enough of a consideration to persuade people to remain in the vicinity to safeguard their place in the queue.

Queuing times are significantly higher at weekends, when family members who spend the week working in neighbouring towns or on farms come home. This raises household water consumption, and means more water needs to be collected and more time spent in queues.

iv) What do you use the water for?

The question was phrased to ask what purposes the water being collected was used for, apart from drinking, cooking and body washing.

No.	Used for
7	watered crops or home vegetable gardens with this water.
22	used some of the water for building.
3	watered a flower garden.
6	specified that they did not use this water for washing clothes

Many people use rainwater they have collected, or go to nearby streams and springs, to wash clothes.

v) Do you grow vegetables?

No.	Response
17	yes (mostly cabbage, maize, beans, with some madumbe, spinach, potatoes, sweet potatoes and carrots
2	yes, but much less than before because of the water shortage
1	yes but cabbages aren't growing because they don't get enough water
1	yes, in summer when it rains
8	no - not enough water
5	no: used to, but don't anymore because of the water shortage
1	not anymore - lazy to fetch and carry water now
8	no - not enough water
2	no - because the water is too far away
2	no - used to sell; not enough water now

Note that at least 20 people said they grew vegetables - compared with 7 in the previous question who used some of the water they were collecting to water vegetables. Clearly at least some people are collecting water from another water source (a muddy spring or stream) or rely on rainfall for their vegetables.

One should not overlook the availability of labour when exploring whether people grow vegetables. In conversation with one respondent it emerged that some family heads are no longer able to command the labour of youths as readily as they did in the past. Previously, if family members were instructed to help in the garden, they did so. Nowadays, younger members frequently refuse. This puts a bigger burden on those who have to do all the work without assistance - and may be a further reason why fewer people grow vegetables than in the past.

vi) Do you use rainwater?

Every person surveyed said they store rainwater, mostly using one or more 200 l plastic drums. This water is used as an emergency water supply, or for washing and building.

This water is seldom used for drinking as it is regarded as dirty, having run off dusty, dirty roofs.

3.2.6 Water quality and quantity

i) Has the water quality changed in recent years?

- 16 said there had been a change.
- 4 said this was a change for the better - because borehole outlets had been constructed near to where they lived, which meant they didn't have to rely on dirty springs.
- 12 said water quality had deteriorated - mostly because spring water was dirtier than in the past. Two cited contamination by livestock as a factor here.

ii) Has the quantity of water changed in recent years?

85% of residents said there had been a change in the volume of water available. Three people (6%) said the quantity had improved, because the boreholes were fixed in mid-1992.

The vast majority of residents (79%) said the volume of water available had dropped in recent years. Explanations of the decline differed:

- 22 people cited the drought as a factor - yet the drought was broken by the 1993/94 summer rains.
- 10 ascribed it to the growing population and the return of refugees

iii) What are your biggest water problems?

- 38 people said there was not enough water - that springs run dry in winter, that the borehole is switched off before they can draw, that the queues are long and the taps deliver slowly.
- 33 people said they had to walk too far to get water

- 15 said the water was dirty - it was contaminated by livestock, tasted bad, smelled or had insects in it.

3.2.7 Health and hygiene

i) Does the water ever make you sick?

Despite the obvious lack of hygiene at many water points - notably the presence of livestock and both human and animal waste in close proximity to unprotected springs - only four people attributed stomach ailments to the quality of their drinking water. All four had sought medical treatment for diarrhea at the clinic. Two people said it was 'possible' that their water was responsible for causing diarrhea.

One person said a family member had had cholera in 1992; further inquiry revealed that the cholera had been contracted elsewhere.

Six people regularly took steps to make their water safe. Three regularly use Jik (chlorine bleach) and three boil their drinking water. Several other people said they added Jik to their water for a while after someone had been sick, but did not do this regularly.

One person said the only water she ever treated was rainwater - if she needed to drink this, she boiled it to kill any insects in it.

Two people said that when they were sick, they were given a white powder at the local clinic to use to disinfect their drinking water. Further investigation at the clinic revealed that this white powder was a concentrate used to make up an electrolytic solution to rehydrate people suffering from acute diarrhea - and was not a disinfectant at all.

When asked whether latrines and settlements sited above the level of springs were polluting local water supplies, the majority of people said no - contamination by human waste was the result of runoff from bushes used as open latrines.

Note: An attempt was made to collect statistics from the Indaleni Clinic and the NPA Clinic in Richmond on the incidence of gastro-intestinal problems. With these statistics, it may have been possible to assess whether Indaleni residents had a higher incidence of stomach problems than people living in a settlement with a cleaner water supply. However the attempt did not prove fruitful. Several factors account for this:

- The system of recording patients' case histories at the Indaleni clinic has changed twice in the past four years, and so it is difficult to compare the number of patients coming for treatment for various ailments over - say - the past five years.
- The number of people coming for treatment at the Indaleni Clinic has fluctuated widely over the past five years. During bouts of `unrest', many people chose not to venture outside their homes except for dire emergencies. The number of patients treated at the clinic during some periods of `unrest' was up to 70% lower than usual.

Medical supplies to Indaleni Clinic have been very erratic over the past year as a result of labour problems within the KwaZulu hospital service. Most Indaleni residents are now aware that the clinic has a very limited range and supply of drugs to help them, and that it is quite likely that on any given day the clinic may be unable to provide any medication at all.

Gastro-intestinal ailments stem from a wide range of problems, many of them unrelated to food or liquid intake. Babies and geriatrics, for example, are prone to bouts of diarrhoea, and often it is not possible to establish the precise cause.

Under the circumstances, one can do little more than note the clinic staff's assessment that the number of gastro-intestinal problems rises in summer. However, in a context where few people have fridges, one cannot attribute this increase exclusively to greater contamination of drinking water.

3.2.8 Preferences for various water sources

i) Which water do you prefer?

The question asked was, 'Which water do you prefer to drink - from a spring, borehole, river or dam? Why?' In translation this seems to have been rendered as 'Where do you prefer to get your water, and why?

Responses focused on cleanliness. Contamination by animals and runoff is a major problem, and many people felt that boreholes were better protected from contamination than springs. Significantly, five people felt that spring water was cleaner than borehole water - which suggests that at least one borehole is patently contaminated.

No.	Where do you prefer to get water
27	from a borehole
15	from a spring
1	from a river
10	no response
2	no preference

No one referred to dam water, presumably because collecting water from a dam is not an option at Indaleni. Reasons for these responses can be grouped further as follows:

a) Cleanliness

- 16 preferred borehole water because it is cleaner than spring water; of those, seven specifically said that boreholes were better protected from livestock. (Note that only one spring in Greater Indaleni is currently protected.
- Five said spring water was cleaner than borehole water
- Two preferred springs because one can see immediately whether the water is clean

b) Reliability

- 5 said boreholes were a more reliable source of water than springs
- 2 said springs didn't dry out so were preferable.

c) Ease of use

- 2 said it was easier to draw from a borehole, as one didn't have to bend, and could just draw from a tap
- 2 said springs were quicker to collect from; at the particular springs these respondents were referring to, the spring is not protected, there are no queues and people just scoop up water with a small basin into their container.
- 2 people said they preferred scooping up spring water rather than using a manual pump at a borehole.

d) Taste

- 3 said borehole water tastes better
- 3 said spring water tastes better.
- 1 person said borehole water is unpleasant because it is `tasteless'.

e) Other

- 2 described spring water as `cooler', and so more pleasant to drink. Given that few people in the area have fridges, this is a significant consideration. However borehole water is unlikely to be a different temperature - unless it has been transported to an outlet via pvc pipes that could heat up where exposed to the sun.

ii) If you could choose, from which source would you like water piped to your house?

No.	Source
18	no preference
8	dam
14	borehole
8	spring
3	borehole or spring
1	river

Reasons given:

a) Dams

No.	Reason
4	a more reliable water supply than springs or boreholes, as it can hold more water
2	is less easily contaminated
1	whites use dam water so it must be the best

b) Boreholes

No.	Reason
2	clean and cold
5	more protected from contamination
2	more reliable than a spring
1	better protected from dust than a spring
3	cleanest
1	taste better than springs
1	springs were poisoned during the violence, so boreholes are safer (note: only one person raised this, and no one else could confirm this).

c) Springs

No.	Reason
1	dams are open to contamination by insects and livestock
2	cleanest
3	`nicest' water
1	more reliable than dams, which run dry
1	comes from underground, so is cleaner
1	always cool

d) Boreholes and springs

1	**underground water is cleaner and more protected**

e) No preference

6	**provided the water is clean, liable and sufficient**

Clearly, people's first choice is for a clean source of sufficient water. Once that is assured, more people opt for a borehole water than any other source, primarily because it is perceived to be cleaner and more protected from contamination.

3.2.9 Paying for Water

i) Do you pay for water ever?

Residents pay nothing for the water they draw. In the past, a tribal levy of R10 a month was payable, to cover various service charges, but no one has paid the levy for at least five years.

One elderly woman hires a child daily to fetch water, and pays R2 per 25 l because she lives quite far from a water point. Four other women hire helpers occasionally, at rates ranging from 50 c per 25 l to R2. On one or two occasions in the past there has been a water crisis where large parts of the settlement have been without water for days a time. At times like that, private vendors set up business, and fetch water from Richmond which they sell for R1 per 25 l.

ii) Are you willing to pay for ground water at its source?

- 42 people (79%) said they would pay at source, if it was reliable and clean.
- 1 person said she would pay for borehole water, but not spring water.

Among those who said they were not prepared to pay, reasons given were:

- 7 said not unless water is piped to individual houses; they would not pay if they still had to fetch the water.
- 1 cannot afford to pay for water at all as she is already in debt

iii) What do you think a fair price would be for the water you draw at a spring or borehole, per 25 l ?

Of the 44 who were willing to pay for water they fetched from a spring or borehole, prices ranged as follows:

No.	Fair price for ground water
3	a R10 a month flat rate
6	5 c or less
11	10c per 25 l
2	15 c
7	20c per 25 l
1	30c per 25 l
9	50c per 25 l
2	R1 per 25 l
1	a once-off payment of R50
1	currently had a fetcher R2 per 25 l and felt cheated; anything less than that would be acceptable.
1	whatever the community agreed was reasonable

If one converts this to monthly expenditure[5], one gets the following figures:

No of people	**Price per 25 l**	**Calculated monthly**
6	5c per 25 l	R11.09 per month
11	10c	R22.18
2	15c	R33.28
7	20c	R44.37
1	30c	R66.55
9	50c	R55.46
2	R1.00	R221.86

Note that these figures probably reflect the value of a secure supply of clean water, rather than the value of ground water *per se*.

Now compare this with the price people are willing to pay for water piped directly to their homes, as shown below.

One would expect people to be prepared to pay more for the convenience of a secure water supply piped directly to their homes. But note that two things happen when people start putting a value to this water they give a total monthly sum, usually a flat rate, rather than a price per unit that monthly figure works out to be significantly lower than the price they were willing to pay per unit they fetched from a borehole or spring. 19 would pay up to R33, fetching and carrying their own water; 34 would pay no more than R30, for water delivered to their homes.

The simplest explanation for this discrepancy is that most people are probably not aware of how much water they use in a month; added to that, local education levels are generally fairly low, and their mental arithmetic is not good.

Would you be prepared to pay for water piped directly to your own house?

5 If one assumes average daily consumption per capita to be 21.3 l (see above), and average household size to be 8.4 people, average household consumption is 7.15 25 l containers per day. Multipied by 31 days, the average household fetches 221.86 containers a month.

51 people said yes. One said she would pay for the reticulation, but not for the water, because the water was a gift from God.

One person said if she was required to pay for water, she would prefer to make her own arrangements to collect from a stream.

iv) *What would be a fair price for water piped directly to your house?*

50 people said they were prepared to pay for water piped directly to their house.

No	Fair price for piped water
3	5c per 25 l container
2	25 c per 25 l container
1	a flat rate of R1 per month
1	R2
2	R4
11	R5
1	R6
6	R10
1	R15
5	R20
3	R25
5	R30
6	R50
2	R60
1	whatever the community agrees is reasonable

While households with incomes below R500 per month tended to give a lower value for water than those with higher incomes, there was no necessary correlation between income and perceptions of a fair price for water:

- A respondent from a household of 11 people, with a total monthly income of less than R500, said R50 was a fair price.
- One person in a household subsisting exclusively on one old age pension (in the order of R350 per month) said R50 was a fair price.

- Two respondents from households earning less than R800 a month said R60 was a fair price for piped water.
- A respondent from a household with one of the highest recorded household incomes in the survey, (less than R1 200) said R10 per month was a fair price.

v) *If you are unwilling to pay for water, what must change before you would be prepared to pay?*

- 5 people said they were not prepared to pay for water. Reasons given were:

No	Reasons for not paying
1	all houses must have hot water and showers installed, and all springs must be protected
3	all houses must be fully connected to a reticulation system
1	willing only to pay for the costs of reticulation, not the water itself

3.2.10 Perceptions of ownership

i) *Who does the water in dams belong to?*

30 respondents (57%) said that the water in dams belongs to whites. Other comments by respondents suggest that the reasoning is that dams are regarded as occuring primarily on farms, where they are built by the owner; the owner is invariably a white farmer, so whites own the dams and the water in them.

- 6 said it belonged to everyone / the community
- 4 said it belonged to the owner of the dam - ie the person who built it.
- 3 people said the water belonged to God
- 1 person said it belonged to no-one

ii) *Who does the water in rivers belong to?*

- 42 people said it belonged to everyone / the community
- 5 said it belonged to God, and therefore to everyone

- 1 person said it belonged to black people (suggesting that whites build dams and blacks draw on what nature provides?)
- 1 said it belonged to the people in the area
- 1 said it was a natural resource, and belonged to no one
- 1 said she didn't know

iii) *Who does spring water belong to?*

- 45 people (85%) said it belonged to everyone / the community
- 5 said it was a gift from God, and belonged to everyone
- 1 said it belonged to the local community
- 1 said she didn't know

iv) Who does borehole water belong to?

Responses here were more undecided. Borehole water is clearly seen as a different category of water, where human agency is required to access it. This human agency confers some rights.

No.	Who does borehole water belong to
1	government and the community
39	the community
3	God
3	didn't know
1	the community in the vicinity
1	either communal or private
1	everyone, but the local community must regulate its use
1	the community, but are newcomers to the area part of the community?
1	the government, because the government drilled them
1	the white town board[6]

6 The Richmond Town Board helped drill six boreholes sunk in 1988.

3.2.11 Water and Development

i) Do you use water for a business, or to make money?

Directly or indirectly, five respondents used water to help make a living. One grew and sold madumbes (ground artichokes), one worked in a shebeen and four worked in spaza shops. No other respondents worked in any form of local trade or enterprise.

There is no evidence of formal agriculture in Indaleni. Fields that were clearly tilled in the past have been abandoned, in part because of several years of drought, and in part because produce was generally stolen before it could be harvested.

ii) If Indaleni had more water, how would Indaleni be different? How would your life be different?

Most people's responses focused on simple aspirations - food, housing, some cattle. Very few people related better water supplies to job creation, development of infrastructure, better health and so on. Many people gave more than one response:

No.	If Indaleni had more water ...
3	livestock wouldn't die
16	could keep livestock
1	could keep large herds of livestock
34	could grow vegetables for home consumption
1	could grow a wider range of veg - not just beans and maize
12	could grow vegetables for home consumption and sale
1	could grow veg for sale and open a spaza
5	could build houses more easily
10	could build a better house
6	could build a bigger house
1	could build houses faster
2	could plaster our houses
1	there would be no crowding at the water points
1	could wash clothes and bodies more conveniently
1	could grow forests for firewood and building
1	there would be happiness in the community
1	could build a big clinic in the community
1	could have a bath and swimming pool at my house
1	could manufacture bricks for resale, build new schools, create jobs
1	could focus on other community development issues apart from water
1	roads wouldn't be so dusty
1	'could work for ourselves, not doing hard manual labour on farms'
1	would not have to wait for school to finish to get help to fetch water
1	Indaleni could develop its own business centre, and not depend on Richmond

3.2.12 Perceptions and awareness of Umgeni Water

17 respondents were aware of, or had heard of, Umgeni Water.

No.	Perceptions of Umgeni Water
6	feel Umgeni Water does a good job supplying water
1	says Umgeni teaches people about using water, but doesn't provide water
1	is unhappy with Umgeni as `we have to pay for everything they provide'
1	`Umgeni is only interested in making a profit'
1	Umgeni concentrates on urban areas, not rural areas where the need is greater
4	Umgeni should come to Indaleni and address its problems

4. AUGMENTING INDALENI'S WATER SUPPLY

There are at least two ways to augment Indaleni's water supply - by tapping new ground water reserves in Indaleni, or by piping in water from a bulk supply of surface water. Each have their merits and demerits.

4.1 SURFACE WATER SUPPLY OPTIONS

A fairly straightforward solution to Indaleni's water problems is to construct a rudimentary supply network, and link it via a pipeline to Richmond's water treatment plant.

James Rivett-Carnac has designed a system which does just this. His scheme is premised on consumption of 50 l per person per day, or 400 l per household - 12 Kl per month.

4.1.1 Linking Indaleni to Richmond

Year	Estimated population	Estimated demand
1994	33 530	1 676 Kl per day
2004	46 840	2 343
2014	65 440	3 272

Infrastructure required to meet this demand is estimated to cost the following:

Item	Estimated cost
Bulk infrastructure - pump station, inlet pipelines and reservoirs	R6 899 110
Reticulation within Indaleni	R4 909 988
Total	R11 809 098

This scheme relies almost exclusively on an external water source, but makes provision for one local spring to be integrated into the scheme. In his opinion, this is the only dependable local water source worth exploiting.

Water will be sold in bulk from the Richmond Water Works at R1.51 Kl. With capital costs of plant and reticulation added in and calculated at recovery over 20 years, Rivett-Carnac maintains that water can be sold at a cost of R2.10 Kl. At consumption levels of 12 Kl per household per month, this works out at a cost of R26 per household per month at 1994 prices.

What this calculation does not include is the cost of upgrading Richmond's bulk water supply and water treatment plant to cope with this level of demand. The Richmond plant has a total treatment capacity of 1.5 Ml/day, but currently purifies only 1,0 Ml/day. This capacity would need to be doubled, at the very least, if it were to meet the needs of Indaleni's residents.

4.1.2 Upgrading the bulk supply to the Greater Richmond area

Beaulieu Dam is the only significant bulk supply of water in the district. In terms of volume, local irrigators are the major consumers of this water, and in times of normal rainfall, claim 90% of its water.

Urban consumers in Richmond rely heavily on water stored in Beaulieu Dam. Up to 90 percent of Richmond's water needs are pumped from water released into the Ilovu River downstream from the dam, with the remainder from four boreholes and the Glen App spring.

Assuming that the amount made available to irrigators does not change, the yield from Beaulieu Dam is insufficient to provide an assured supply to both irrigators and urban consumers in Richmond at the volume they demand.

If Richmond's current urban demand of about 0.5 Mm^3/a (1.4 Ml/d) is supplied at a 1:100 year assurance level, only 3,0 Mm^3/a is available to irrigators at a 1:20 year assurance level. This represents only 56% of the total irrigation demand of 5,38 Mm^3/a. In times of drought, releases to irrigators are cut back severely to conserve water for domestic consumption. This has caused some ill-feeling in the district, particularly in December 1992, when all releases to irrigators were stopped. (On the other hand, Richmond's domestic users draw relatively little water; according to one informant, when releases to irrigators were stopped in December 1992, the level of Beaulieu Dam actually rose.)

Economic development in the Richmond area is being constrained by limited water. Several attempts to attract industry to the area have foundered because the town cannot offer reliable supplies of abundant water, and thus any plans for developing Richmond and Indaleni economically are contingent on augmenting the area's water supply.

If Indaleni's ground water supplies are not deemed to be sufficient or suitable to meet its residents needs, a pipeline will be constructed connecting the settlement with Richmond's water supply plant. According to one calculation by consulting engineers BKS Inc, this would increase Greater Richmond's urban water demand to about 2,0 Mm^3/a by the year 2010 - or a daily average of about 5,37 Ml.

Predicted consumption and return flows - Ml per day					
	1991	1995	2000	2005	2010
Richmond	1.15	1.24	1.38	1.59	1.80
Indaleni	3.02	2.96	3.15	3.35	3.57
Total:	4.17	4.20	4.53	4.94	5.37

Nowhere does the BKS report make explicit its assumptions about Indaleni's current or projected population, nor its estimates of average daily per capita consumption. If one uses a 1995 population of 24 600 people, the BKS figures would allow for daily per capita consumption of roughly 120 l per day. This is more than twice the figure used by James Rivett-Carnac and Lategan, Wagenaar and Fourie.

Note that Richmond's estimated consumption is premised on significant return flows of water, via the Richmond sewage treatment plant. Indaleni does not have a sewage system let alone a treatment plant, and so there would be a no formal return flow at all.

In November 1993 BKS Inc. completed a feasibility study which calculated the cost of possible development options to satisfy the needs of Illovo Irrigation Board irrigators and domestic consumers in Indaleni and Richmond. It explored the feasibility of several construction options, and assessed their cost-benefit ratio. The estimated costs are generally extremely high - in large part because the type of dams it proposes will have to be extremely large to catch five year flood flows, because the average of the Ilovu River is very low

4.1.3 The Commissie Drift Dam option

Construct a dam at Commissie Drift with a capacity of 16.615 Mm^3, to supply raw water to downstream irrigators as well as to the treatment work for supply to urban consumers. Beaulieu Dam would be used solely for irrigation between the Beaulieu and Commissie Drift sites.

Item	Cost
Commissie Drift Dam	R 37 200 000
New Water treatment works	R 8 000 000
Pumpstation and trunk main	R 4 400 000
Total:	R49 600 000

Construction of the Commissie Drift Dam system will cost fractionally under R50-m. This *excludes* the cost reticulation and storage

This is the only option that meets both urban and irrigation demand at the required level of reliability from local resources.

4.1.4 A dam at Riverlea plus a pipeline from Thornville

Construction of a dam at Riverlea with a capacity of 4.8 Mm^3, together with Beaulieu Dam, would meet the full existing demand of the irrigators. Urban consumers would be supplied entirely via a pipeline from Thornville, extending the existing Umgeni Water trunk main to Thornville.

Item	Cost estimate
Riverlea Dam	R12 000 000
Thornville-Richmond pipeline and pumpstation	R 6 800 000
Total:	R18 800 000

Some interest groups in Richmond oppose this on the grounds that there will be a net flow of capital out of the area, into Umgeni Water's coffers in Pietermaritzburg.

4.1.5 A small dam at Commissie Drift

A further option is to construct a small dam at Commissie Drift, which could be raised at a later date. Urban consumers in Indaleni and Richmond would draw their water from Beaulieu Dam exclusively, leaving unresolved the problem of water shortage to irrigators in times of drought.

Item	Cost estimate
Commissie Drift Dam	R37 200 000
New water treatment works	R 8 000 000
Pumpstation and trunk main	R 4 400 000
Total	R49 600 000

4.1.6 A pipeline from the Elands River

The Elands River is a strong perennial river which rises in the same areas as the Umgeni. An 8km pipeline could be constructed through the Byrne Valley to deliver the water into the Lovu, with a pumping head of about 120 to 150 m. A feasibility study is underway, but has not delivered its report yet.

No estimate of costs is available yet. However, inter-basin transfer schemes are notoriously costly. If all residents of the Greater Richmond area were made responsible for cost-recovery, the implications for Indaleni residents could be catastrophic unless enormous subsidies were made available.

4.1.7 A dam on the Mkomazi River

17 km south of Richmond is the Mkomazi River, which has a far more sustained flow than the Ilovu. A feasibility study has been commissioned to explore the possibility of constructing a dam on the Mkomazi, although this would not necessarily be costed with Richmond's needs in mind.

No estimate of costs is available yet.

4.1.8 Assessment of these options

Detailed cost-benefit analysis showed the Riverlea Dam / Thornville pipeline option to be consistently more viable than the Commissie Drift option. Moreover, Richmond would be spared the cost of having to upgrade its water treatment plant - and indeed, the Richmond treatment plant would become largely redundant, as the water conveyed by the Thornville pipeline would arrive already treated, Pumping costs, however, would be high; one estimate puts the final user tariff above R3.00 /Kl.

Objections to the Thornville pipeline have been raised by interest groups in Richmond who saying that this option would make the Greater Richmond area dependent on water from a different catchment area, at high cost.

The Richmond Town Board, meanwhile, is going ahead with a R650 000 scheme to link its water treatment plant directly to Beaulieu Dam. In the very near future, construction is expected to begin on a 3km , R650 000 pipeline linking Richmond's water treatment plant directly to Beaulieu Dam. Instead of the current practice of pumping water from the Ilovu River downstream from Beaulieu, the pipeline will allow for more efficient water abstraction. In times of drought, water is released wastefully into the Ilovu Rivers. The pump at Richmond's water treatment plant cannot abstract as much water as is released, and the excess is effectively lost to the area.

The proposed pipeline offers several important advantages. The most obvious is more efficient water management in times of drought: by connecting Richmond directly to the dam, there will be no wasteful release, and the level of Beaulieu Dam can be controlled better. In times of normal water flow, Richmond will save on pumping costs, because as long as Beaulieu remains above 60% full, gravity will propel the water to town; and purification costs will be less because Beaulieu's water is cleaner than that downstream.

However, if Richmond is connected to the Thornville pipeline at some later date, this pipeline will be largely redundant. More importantly in the short term, this pipeline connecting Richmond to Beaulieu is not designed to accommodate the additional demand of Indaleni residents, should they be linked to Richmond's water system.

The original design specification called for a 250 mm pipeline; when preliminary investigations by Umgeni Water showed that Beaulieu Dam could not meet the combined demand of local irrigators plus Richmond and Indaleni residents, the local Joint Services Board refused to subsidise a 250 mm pipeline; in response, the pipeline has been scaled down to 150 mm to accommodate Richmond's need exclusively.

If Indaleni residents are linked into Richmond's water system in future, this pipeline will probably prove to be inadequate.

4.2 GROUND WATER OPTIONS

Umgeni Water's confidence in Indaleni's ground water resources stems largely from the results of test boreholes drilled in December 1993 by consulting engineers Steffen, Robertson and Kirsten in December 1993. SRK was commissioned to drill six boreholes; three delivered an excellent yield, and, without further drilling, will resolve Indaleni's immediate water problems. Hydrologists involved in the project are confident that additional ground water is readily available in the vicinity. SRK has now been commissioned to drill further boreholes on Richmond Commonage, where excellent ground water resources are believed to exist.

On the basis of this investigation, consulting engineers Lategan, Wagenaar and Fourie have proposed an incremental reticulation network which links these three high-yielding boreholes with existing boreholes and springs in Indaleni, and allows for additional boreholes to be drilled and integrated into the system as demand rises.

Item	Estimated Cost
Preliminaries and preparation	R 74 100
Ground water evaluation and protection of springs	788 629
Equipping of boreholes, construction of reservoirs and mains	3 353 921
Rudimentary network	7 415 785
Further borehole investigation and equipment	1 158 666
Upgrade to a full network	7 932 859
Connection of springs	1 302 614
Total:	R22 028 774

There are a number of serious shortcomings to this proposal. The most important is that the Lategan Wagenaar and Fourie proposal is based on a desk study, using existing engineers' reports. For reasons that remain unclear, it based many of its assumptions about the availability and quality of existing ground water resources on a 1989 description of Indaleni's springs and boreholes. That report is now out of date, as Indaleni's existing water sources have diminished dramatically. The extent to which Indaleni's water sources have deteriorated is documented in a July 1993 report, which paints a very bleak picture of the state of Indaleni's ground water resources.

In 1989 James Rivett-Carnac, a consulting engineer, compiled a report which described Indaleni's existing water resources in detail, and proposed a water supply system based on the yield of existing boreholes and springs, supplemented with up to 2.5 ML water drawn daily from the Ilovu River.

In 1993 Rivett Carnac was commissioned by Umgeni Water to revisit the area and survey available water resources once again - this time in the middle of one of the worst droughts ever recorded. The results showed that many of the springs described in the 1989 report were no longer flowing, that several boreholes that had functioned well in 1989 were no longer delivering water, and that water quality in the area had fallen to the extent that most water available in Indaleni could no longer be regarded as fit for human consumption. It concluded that -

- *the yield of springs and streams had declined significantly*
- *only one spring could still be regarded as `protected', because the rest had been vandalized*
- *only three of the nine boreholes in the settlement were functioning. Four were damaged beyond repair, and one was dangerously contaminated with human waste.*
- *the yield of the remaining boreholes was considerably lower than anticipated.*
- *Of 32 water points tested (both springs and boreholes), 20 were found to deliver water unfit for human consumption, and six would require continuous disinfection to make them potable. Two of the water sources needing continuous disinfection were outlet pipes from boreholes. (Note that this does not necessarily mean the borehole itself is contaminated, but rather that the water is contaminated by the time it reaches users.)*

In his opinion, the solution to Indaleni's water problems no longer lay in the realm of ground water.

The 1994 Wagenaar, Lategan and Fourie report made no reference to this 1993 study, and based its calculations and design proposals on the 1989 report.

4.2.1 Unresolved questions

Before any major decisions are taken on which supply option to pursue, detailed attention will have to be given to the following concerns about ground water, which have not yet been addressed:

The quality and potability of this abundant new supply of ground water tapped by SRK when it drilled test boreholes in December 1994 has not yet been established; due to an apparent administrative misunderstanding, neither SRK nor Umgeni Water commissioned the necessary tests.

Richmond Commonage, on Indaleni's north-eastern boundary, is on lower ground than the settlements at Indaleni. Indaleni has no sewerage system, and latrines in the area are rudimentary. Seepage and runoff from parts of Indaleni will run into the Commonage's ground water catchment area, raising questions about possible contamination of aquifers. Considerable care will need to be exercised to ensure that the area around the borehole is well protected against surface contamination.

Testing of the yield of the new borehole sites has been limited, and there is no indication yet how well these sites will stand up to long-term daily abstraction, particularly in times of drought. Admittedly, these new boreholes were drilled within months of one of the worst droughts on record, and delivered very strong yields; but it is not possible to say, on the basis of limited test results, how sustainable these yields will be.

Intensive afforestation of the Ilovu catchment has had a negative impact on local water resources. Local spring and stream flows are declining, and the Ilovu River is a fraction of its former size. A clearer understanding of the extent of the catchment area of the underground water system of the area is needed before any assumptions are made about ground water yields beyond the immediate future. An additional concern is the possibility of long-term contamination of underground aquifers by agrochemicals - herbicides and fertilizers - used in silviculture

Recognising these limitations, a spokesman for Umgeni Water has said that his company is well aware that utilising ground water at Indaleni probably would not provide the total long-term solution to Indaleni's water needs. However, it is the cheapest and quickest way of providing additional water in the area.

He points out that a basic reticulation network, complete with pumps and reservoirs, will have to be constructed in Indaleni, regardless of whether Indaleni draws its water exclusively from ground water reserves or from a pipeline from Richmond or elsewhere; if Indaleni's ground water proves to be inadequate several years down the line, the settlement will then be connected to an alternative supply source. In the interim, Indaleni residents will have been spared the extra cost of an expensive surface water supply system.

It appears that Umgeni Water views the exploitation of ground water resources as, at best, an interim solution. On the basis of feasibility studies to date, Umgeni Water maintains that the water needs of Indaleni could be satisfied using ground water for the `at least the next ten years'. In the longer term, it maintains that that demand would be better served by a connection from the Umgeni Water supply system.

5. THE SOCIAL CONTEXT

Technical solutions to Indaleni's water problems cannot be viewed in isolation from the socio-economic context in which they will be implemented. Residents in Greater Indaleni have been battered - emotionally, and, in some cases, physically - by several years of politically-motivated violence. Deaths from the violence literally ran into the hundreds, and there is still ample evidence of the physical destruction that accompanied the killings - burnt out houses and shops, abandoned crops, smashed buildings and so on.

The social implications of this violence are enormous. There is evidence of social fragmentation, as residents and households fled in different directions, and of weak and fractured leadership. Indeed, there is scant evidence of any sense of a `community' to mobilize around local development initiatives, or to involve in a competent local water management authority.

5.1 THE VIOLENCE

Serious violence erupted in Indaleni in July 1991. Initially it was portrayed locally as faction fighting between residents of the Magoda and Magobeni sections of Indaleni; in subsequent months it became clear it was motivated by political tensions between the ANC and IFP. Patheni became identified as an IFP stronghold, and all ANC supporters living at Patheni fled - either to Ndaleni, or to Chesterville and Claremont outside Durban. Peace initiatives were started in December 1991, but broke down.

Peace initiatives were revived again in 1992, but it has only been since April 1994 and the elections that any progress has been made. Sifiso Nkabinde, ANC Midlands Regional Secretary and chairman of the Richmond ANC, has met several times with the local IFP leader, Paulus Veli.

In the past Veli worked closely with David Ntombela, MP, regional IFP chairman and widely recognised as a warlord with every interest in prolonging local political tensions. Veli is now pursuing a more independent line; in his view, the IFP failed to provide adequate and appropriate support to him after he was arrested for his role in the massacre of 14 ANC-aligned people at Creighton in February 1994. Veli is the undisputed leader of the Patheni area, and so when Nkabinde approached him about securing not only peace in the area but the return of local people to their original homes, Veli was receptive. The first meeting took place in July.

Since then, Veli has addressed a meeting of ANC people from Indaleni now living in Chesterville and Claremont, and Nkabinde has addressed a gathering of IFP people at Patheni. Nkabinde and Veli have since addressed public meetings in each other's respective strongholds. For the first time in over three years, Patheni people are now allowed to shop in Richmond and catch taxis in the area without fearing for their lives.

Both Vesi and Nkabinde have received several death threats and been warned to halt the peace process; they have ignored these threats, but the danger is real. Underlying these threats, it seems, is Ntombela's outrage that he has lost control of the IFP in the Greater Richmond area, and that the local ANC and IFP are resolving their differences.

5.2 THE RETURN OF REFUGEES

Nkabinde and Veli have now set up committees to explore some of the more tricky issues associated with repatriating refugees. One of the most complex is housing.

At Patheni, houses belonging to ANC people who fled have now been occupied by IFP supporters; the same applies to IFP people who fled Indaleni.

There are no simple remedies to the housing problem. Already 87 ANC-identified people have returned to Phatheni, where they are staying with relatives. Nkabinde reckons that Ndaleni's population could swell by more than 6 000 by the end of 1994; if this happens, it is not clear where they will live. Of course, it is by no means certain that all the people who fled Indaleni will necessarily choose to return to the area. However, two problems will need to be addressed before the housing issue can be resolved:

- more land
- more water.

Gaining access to more land is not too difficult. In terms of the transfer of tribal land to King Goodwill Zwelithini days before the April election, the King is nominal holder of title to a large tract of land in the middle of Ndaleni. Moves are underway at present to explore ways of developing this land.

In the short term at least, water is the more difficult issue to resolve, as Indaleni will need to provide its residents with water not only for subsistence but for building too. Survey responses suggest that the housing shortage at Ndaleni is already acute - even before any refugees return. Respondents cite the shortage of water as a primary reason for the housing shortage: local houses are built primarily of wattle and daub or mudbrick, and both require substantial amounts of water[7]. Unreliable water sources and relatively long distances between residents' homes and their nearest water point, mean that building is slow and exacts a heavy tax in labour and energy.

Rehousing refugees at Indaleni and Phatheni could well spark tension at Indaleni; either the returnees will have to give up their claim to their former houses, or the current occupants will have to move. Either way returnees will aggravate an existing housing shortage - and put further pressure on an already inadequate water supply.

According to Sifiso Nkabinde, one possible interim solution currently being explored is a pipeline linking Indaleni directly to either Beaulieu or Riverlea Dam (both of which are regarded as the property of the local irrigation board). Local engineers deny all knowledge of this plan, and maintain that the idea is impractical.

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7 Mudbrick construction requires more water than wattle and daub, as the walls are generally much thicker, and there is no timbering to provide bulk.

5.3 LOCAL ADMINISTRATION

In the past, Indaleni was divided into various wards, each of which was headed by a headman who reported to the local chief. Headmen were responsible for overseeing the collection of funds and distribution of benefits. This system has broken down entirely; there is no longer a chief, no headmen, no collection of funds and no benefits to distribute.

The administrative head of Indaleni used to be one Chief Majozi, who reported directly to Ulundi. In 1989 he was forced to flee Indaleni, after one too many episodes of corruption. One example: he received R36 000 from the KwaZulu government in the late 1980s to build a sports stadium at Indaleni; although no stadium was ever built, he wrote letters to Ulundi describing it in detail. When residents learnt of this they organized a protest march in mid 1989, and Majozi left. As conflict intensified between the ANC and IFP from 1990, the chief sided actively with the IFP; strong evidence exists that Majozi was actively involved in the violence on the side of the IFP.

Majozi now wishes to return to Indaleni. The local ANC leadership is quite happy for him to do so - provided he returns as a commoner, and abandons all claims to the chiefdom. In their view Majozi proved himself unable to rise above party politics, and has a record of corruption; more importantly, perhaps, the ANC leadership wants Indaleni to be administered by democratic, not tribal, structures.

The KwaZulu government cut virtually all assistance to Indaleni in 1990, after local residents celebrated the unbanning of the ANC exuberantly. Since then there have been no ambulance services, no health and education inspections, no graders to maintain local roads, and no administrative intervention.

Since 1991, the local ANC branch has held elections for a local administrative committee each October. There is little to suggest to outside observers that this committee has been particularly effective in providing leadership and direction to Indaleni residents. In its defence, though, one must acknowledge that Indaleni has been starved of funds and government assistance, and has few resources of its own. Small-scale recent road repairs, for example, were paid for by through a donation by the JSB and DBSA.

The local ANC branch has a water subcommittee, but this seems to be barely functional. It is certainly not playing the kind of pro-active development role adopted by some Water Committees in other parts of the country.

A new form of local administration is currently being negotiated by the Richmond Local Negotiating Forum. Until a new local council is established (which may or may not include Phatheni), KwaZulu government structures remain intact.

5.4 DEVELOPMENT PROSPECTS

Prospects for improving living conditions at Indaleni have been given a powerful boost with the announcement that developing the greater Richmond area has been chosen as a pilot project for the Reconstruction and Development Programme (RDP) in KwaZulu/Natal. A decision on funding is expected soon.

What seems to have clinched the selection of the greater Richmond area is the current peace initiative between the ANC and IFP at Indaleni and Phatheni; Indaleni is one of the few areas in the province where the local ANC and IFP leadership are working together successfully. The importance of this cannot be underestimated - as both the ANC and IFP will be able to share the credit for development in the area.

Development planning for the greater Richmond area is being led by the Greater Richmond Development Committee. Progress within this committee has been severely hampered by the fact that no less than four representatives from Indaleni have been murdered since the committee's launch two years ago.

The local Regional Development Advisory Committee (RDAC) provided secretariat services until the beginning of 1994. When it withdrew its services (in anticipation of major restructuring within the Dept of Regional and Land Affairs), the forum stopped meeting; the Midlands Joint Services Board (JSB) has now stepped into the breach, and indications are that it will provide some momentum to the forum.

There is consensus within the forum that the priority development issues for the area are better water supplies and better roads for Indaleni. Also urgently needed, but less critical, are more schools and clinics, and the establishment of recreational facilities in the settlement to help counter crime.

Until details of the RDP budget for the area are made available, no specific plans are being drafted.

5.5 WEAK DECISION-MAKING STRUCTURES

One of the biggest problems inhibiting resolution of the water shortage in the Greater Richmond area is that local development structures will need the support of Indaleni residents, and their commitment to share the cost if they are to share the benefits. Indaleni's leadership structures at presently appear to be unable to play a constructive role in local decision-making, let alone in educating local residents about the nature of the water debate and its implications for them, in the short and medium term.

Assuming that Indaleni residents were to commit themselves to helping to pay for a new bulk water supply for the Richmond area, a further problem would be the manifest poverty of most residents. Affordability levels in Indaleni will be extremely low.

6. CONCLUSION

Given the amount of time people spend walking to fetch water and standing in queues, the majority of residents would probably not mind where their water came from - provided the supply was clean, reliable and made available closer to their homes.

However it seems the debate will be influenced by the views of the local ANC leadership. Sifiso Nkabinde, the local ANC MP, supports James Rivett-Carnac's view that Indaleni's ground water is inadequate, unreliable and contaminated; his opinions are likely to be extremely influential in moulding local opinion. Once the subject of alternative supply sources is raised formally at Indaleni, it is very possible that the local leadership will persuade residents that ground water is an inferior supply option.

Indaleni was recently selected as a test site for implementing the RDP in Natal. Augmenting the water supply will receive top priority - and almost certainly will get RDP funding. However, both the IFP and ANC will want to be able to point to a success story - and unless incontrovertible evidence is provided that can prove that local ground water is both sufficient and abundant, the local leadership may not want to risk supporting the cheaper ground water option.

A more immediate problem is that local leaders anticipate the return of up to 7 000 people who fled the area, by the end of 1994. This means that the deficiencies of Indaleni's water supply must be addressed urgently if the settlement is to meet the challenge of a potential rise of 50% in local demand for water.

7. APPENDIX

Further discussion of the Rivett-Carnac and Lategan, Wagenaar and Fourie reports The Rivett-Carnac surface water scheme proposal and Lategan, Wagenaar and Fourie ground water scheme differ profoundly, not only in their recommendations but in their estimates of current and projected demand. The reason for this discrepancy stems largely from different assumptions about current and future population size.

The current population of Greater Indaleni is between 13 700 and 14 000 people, according to two recent surveys. One, a house-to-house survey done by the local ANC leadership in early August 1994, gave a figure of 13 700. The other, by a market research company and based on aerial photographs, gave a figure of 14 000 . These figures are considerably lower than assumptions used in several recent project proposals, and have important implications for assumptions about current and future water utilisation.

The supply system proposed by James Rivett-Carnac is designed to cater for a population of 58 600 people by the year 2004. Wagenaar, Lategan and Fourie's is designed for a maximum of 23 812. To understand the discrepancy, one has to appreciate the way demographic surveys have been conducted in Indaleni over the past decade. In May 1984, members of the Departments of Survey and Anthropology, respectively, of the University of Natal in Durban surveyed the area using a combination of aerial photography and house-to-house surveys. Average household occupancy was calculated then to be 7.79 people, giving a population in 1984 of 24 000.

Largely because of the violence in Indaleni between 1989 and 1994, no field surveys were done to update the 1984 figures. In 1991 an aerial survey was commissioned by Lategan, Wagenaar and Fourie; using data on household size based on a comparable settlement outside Pietermaritzburg, a maximum population of 18 504 was calculated for 1991. Taking into account the exodus of people

This figure is less than half the total projected in a separate study by James Rivett-Carnac, based on extrapolating and adjusting the figures in the 1984 survey. Rivett-Carnac assumed an annual population increase of 3.4%, and in-migration of 1 200 people per year. For 1994, this gave a figure of 49 574, rising to 58 594 in 2004. Revising these figures in 1993, he estimated that 50% of Indaleni residents living in the settlement in 1988 had left because of the violence, leaving a population of roughly 17 000 people. Over time, people would return, and thus he maintained his 2004 figure of 58 600 remained valid.

Consequently Rivett-Carnac designed a system in 1993 to provide 50 l of water per person per day in 2 004, which would require 2.93 Ml per day. Lategan, Wagenaar and Fourie, conversely, have designed a system for 2010, based on 50 l per for day 23 812 people - 1.119 Ml per day. The difference is dramatic and has obvious implications for costing, design and policy decisions.

Complicating the issue further is the fact that Rivett-Carnac is convinced that Indaleni's ground water is unreliable, unsafe and inadequate, and cannot meet the settlement's water needs any longer. For this reason he is not interested in explore new borehole sites, and says that the operation and maintenance of boreholes in Indaleni has been extremely problematic; he is not confident that a new structure will resolve this problem.

He is adamant that the settlement must be connected to a secure supply of surface water - perhaps Beauilieu Dam - as a matter of urgency. Rivett-Carnac enjoys the support and respect of the local ANC leadership, who share his views on the inadequacy and unreliability of ground water.

Lategan, Wagenaar & Fourie, on the other hand, maintain that there is every reason to believe that sufficient local ground water exists to provide for the settlement's needs until at least 2010. Their proposal is premised entirely on connecting existing boreholes and strong springs to a reticulation network, and supplementing this with additional boreholes on the north-eastern edge of the settlement. This option, obviously, will be significantly cheaper to construct and maintain. However it does *not* enjoy the support of the local ANC leadership, who are convinced that sooner or later (and possibly `within three months') the boreholes will run dry.

8. SOURCES

Research for this study was greatly facilitated by six reports with a bearing on Indaleni's water supply, written by consulting engineers.

BKS, Inc. Richmond Area Water Resources. November 1993.
Part 1: The Upper Lovu Catchment.
Part 2: Cost Analysis of Augmentation Schemes

Lategan, Wagenaar and Fourie
Provision of Water Supply to the Ndaleni and Kwamagoda areas. Investigation Report. October 1991.
Ndaleni. Provision of Water Supply to the Ndaleni and Kwamagoda areas. July 1994.

Rivett-Carnac, J L
Integrated Water Supply for Indaleni Mission Reserve. March 1989
Indaleni Emergency Water Supply. Final Report. May 1993.
Investigation of Current Water Resources in Greater Indaleni. July 1993.

Many people were generous with their time and information. They include:

John Aitcheson	Centre for Adult Education, University of Natal, Pietermaritzburg (violence monitoring)
Peter Alcock	Water research bibliography project, University of Natal
Sifiso Nkabinde,	MLA, Midlands ANC secretary, chairman of ANC Richmond
Carlos Pinhal	Department of Water Affairs and Forestry, Durban
Gary Quilling	Department of Water Affairs and Forestry, Durban
Hugh Rethven	Chairman of the Greater Richmond Development Forum
James Rivett-Carnac	Appropriate Technology Information
Richard Savage	BKS Inc.
Wayne Schafer	Umgeni Water

Mario Toniolo	Steffen, Robertson and Kirsten (Durban).
Dave Wylie	Lategan, Wagner and Fourie
Margaret Zondi	Member of the Richmond ANC's water sub-committee

APPENDIX C

DE AAR CASE STUDY

CONTENTS

1. OVERVIEW OF REGION B (NORTHERN CAPE PROVINCE)

1.1 LOCATION

De Aar falls within the south-eastern portion of the formerly defined Region B (now known as the Northern Cape Province).

Region B covers the northern portion of the Cape Province, extending from the Upper Karoo in the south-east to Griqualand West and comprising 361 800km2. It includes the Kalahari Gemsbok National Park which borders Namibia and Botswana. Its economic core is Kimberley and it has the smallest population and lowest population density of all the provinces (Reuvid, 1993).

1.2 TOPOGRAPHY

The province is characterised by flat and varying undulating landscape. There are 4 distinctive physiographic regions, namely the two higher plateau regions of the northern Upper Karoo, as well as the Asbestos Mountains and Kuruman Hills of the Cape Middle Veld and the sandy landscape of the Kalahari Basin (approximately 500-1000m above sea level). The southern and eastern portions of the province are higher-lying than the central and north-western parts which can be described as an inland drainage basin (Office for Regional Development, 1991).

1.3 CLIMATE

The climate ranges from semi-arid in the east to an arid desert climate in the west (especially in the north-west). It is situated within the area where the Kalahari high-pressure system is well developed for most of the year and precipitation is extremely low (Office for Regional Development, 1991).

Precipitation of the region declines from 400mm per annum to less than 200mm per annum in the west. However, this precipitation is inconsistent and occurs mostly in the form of thunderstorms in the later summer and early autumn.

Further, relative seasonal variability is in the region of 50 per cent, so that droughts are common. The high average annual sunshine of more than 80 per cent results in an average annual evaporation loss of 2000mm in the east and around 2750mm in the west (Office for Regional Development, 1991).

Higher lying areas are characterised by moderate temperatures. The average annual temperature ranges from 15°C in the south to about 18°C in the east and north-east. The average annual temperature in the north and north-west is 23°C, where daily maximum temperatures of up to 40°C are recorded (Office for Regional Development, 1991).

1.4 Water Resources

There is a shortage of surface water in the Northern Cape Province due to :

- low annual precipitation
- high evaporation loss
- the presence of sandy soils.

Indeed, it is only the Orange and Vaal rivers that provide the Province with a reliable source of surface water. The northern areas are characterised by intermittent rivers (e.g. the Molopo and Kuruman Rivers) (Office for Regional Development, 1991).

In the southern and south-eastern parts we find the Orange and Vaal rivers and the intermittent Harts, Modder, Riet and Brak rivers. Most of the run-offs of these rivers are from catchment areas outside the region (Office for Regional Development, 1991).

Finally, given the lack of surface water it is necessary to rely mostly on underground water. Generally, in the province underground water is readily available and well distributed, except in the westerly and southerly parts (which includes De Aar). The most usable and reliable sources of underground water are to be found in the Kuruman area. In the other parts of the province the salt content of the underground water makes it unsuitable for general use in certain places (Office for Regional Development, 1991).

1.5 PHYSICAL INFRASTRUCTURE

1.5.1 Road and rail network

With the exception of roads feeding traffic through the region very few other roads are tarred. Distances between service points are great and traffic density is low.

De Aar and Kimberley farm important functions for rail transport in the area and, together with the Sishen/Saldanha railway line, the most important service points are catered for by the network (Office for Regional Development, 1991).

1.5.2 Airports and airfields

Over and above the scheduled flights to the airport at Kimberley and the airfields at De Aar, Upington and Sishen, various other landing strips are utilised in the area.

1.5.3 Electricity

Eskom supplies distributors in the Northern Cape Province (i.e. thermally generated power). Eskom's Cape Town distributor is responsible for the area. The Province is served mainly by 400 and 220 kV lines.

1.5.4 Posts and telecommunications

These services are largely underdeveloped in the province.

1.5.5 Human resources

Only 4½ per cent of the economically active population has totiary educaiton (relative to around 9 per cent for the PWV and the Western Cape), with 1 manager per 1 300 people (approximately). Around 2 per cent of the de facto population are manager, 10 per cent are clerical workers, 4 per cent are farmers and 14 per cent are artisans.

The Northern Cape Province has the lowest literacy rate of all South Africa's Provinces (at 59 per cent) and the shortest life expectancy at 62,6 years. The population is also very dispersed and the population density is a mere 2 persons per square km (compared with 86 in KwaZulu-Natal).

The economically active population amounts to only 325 000 (the province has less than 2,5 per cent of the entire South African population and only around 40 per cent are economically active) and grows only at some 1 per cent per annum. By the end of the 1980's formal sector economic activity could only provide employment for some 45 per cent of the labour force (Reuvid, 1993).

Little more than 10 per cent of the population is urbanised (compared with more than 90 per cent in the PWV).

1.6 ECONOMIC ACTIVITY

1.6.1 Background

Economic activity in the region centres around the agricultural and mining sectors. Most of the region is utilised for farming activity.

The Province contains the world's largest sources of manganese in the Kalahari and Postmasburg manganese field, as well as vast deposits of iron ore. Indeed, the mine at Sishen is the largest producer of iron ore in South Africa. Further, diamonds are mined from the kimberlite pipes and fissures east of Postmasburg, north of Barkly West and at Kimberley. Alluvial diamonds are mined along the Vaal River in the vicinity of Barkly West. Also, there are large reserves of limestone, asbestos, tiger-eye, gypsum and pegmatite minerals in the Province (Office for Regional Development, 1991).

The tertiary sector is reasonable well developed with tourism playing an important role. The main tourist attractions are the Big Hole at Kimberley, hunting and nature reserves.

All in all, growth in the Province has been inadequate to provide for even the relatively low growth in the labour force.

The table below serves to summarise the extent of formal economic activity in the Northern Cape Province, by detailing their respective contributions to GGP.

GROSS GEOGRAPHIC PRODUCT
NORTHERN CAPE PROVINCE
RM

SECTOR	Rm	
	1988	1991
AGRICULTURE	514,0	621,8
MINING	1087,7	1591,2
MANUFACTURING	190,7	258,3
ELECTRICITY, WATER	151,5	200,5
CONSTRUCTION	77,8	124,2
TRADE, CATERING	398,9	790,5
TRANSPORT, COMMUNICATION	543.2	654,2
FINANCE, REAL ESTATE	352.6	644,3
COMMUNITY SERVICES	36,4	65,5
GOVERNMENT	575,3	998,2
OTHER	78,3	105,7
LESS IMPUTATIONS	71,0	141.4
TOTAL	3935,4	5913.3

SOURCE: Development Bank of Southern Africa, August 1994

1.6.2 Employment

The table below provides an indication of formal sector employment in the Province per economic sector as listed above. The figures shown are the result of our own calculations utilising employment multipliers (calculated from the 1988 National Input-Output Tables) which were applied to the figures given on GGP in the table above.

Formal Sector Employment

SECTOR	NUMBER EMPLOYED	
	1988	1991
AGRICULTURE	27 262	25 007
MINING	16 814	18 641
MANUFACTURING	4 723	4 851
ELECTRICITY, WATER	1 570	1 575
CONSTRUCTION	2 771	3 354
TRADE, CATERING	8 928	13 416
TRANSPORT, COMMUNICATION	9 982	9 115
FINANCE, REAL ESTATE	3 132	4 340
COMMUNITY SERVICES	542	739
GOVERNMENT	8 567	11 272
OTHER	1 677	1 717
TOTAL	95 950	94 027

As can be seen employment growth is minimal in the different sectors and even declined in the agricultural sector where real economic activity fell over the years viewed.

2. THE DE AAR MUNICIPALITY

2.1 INTRODUCTION

2.1.1 Background

De Aar is situated in the Upper Karoo physiographic region of Southern Africa. The climate is semi-arid, rainfall averages about 290 mm per annum, most of which falls in February and March. The vegetation changes from the Central Upper Karoo type in the west to False Upper Karoo in the east (Ackocks, 1953)and can be described as grassy, dwarf shrubland. The geology comprises Beaufort Group mudstone, siltstone and sandstone east and southeast of De Aar, and Ecca Group shale and subordinate siltstone west and northwest of De Aar. Dolerite sheets and dolerite and kimberlite dykes intrude into the beds. The surroundings of De Aar, from where its ground water supply is obtained, lie at an elevation of 1 200 to 1 500m above sea level, and are part of the catchment of the Brak River. Most of the area is used for grazing purposes, primarily through sheep for the production of mutton, wool and pelts (Karakul).

2.1.2 History

De Aar was declared a municipality in 1904 and was founded on the farm of De Aar. In the early part of the century, growth of the town was impeded by the lack of a municipal water supply. Residents had to obtain water from private boreholes and serious water shortages were experienced. The Cape Government Railways started to search for improved ground water supplies shortly after the turn of the century, and by 1916 the Caroluspoort scheme was instituted. Between the mid-forties and the mid-eighties the total municipal and railway water supply rose from about 1 million m^3 per annum to a peak of 3.4 million m^3 per annum. The volume abstracted by the railways started to reduce in the mid-sixties as a gradual switch from steam to diesel and electric haulage was experienced. Municipal abstraction, on the other hand, started to increase in the early seventies due to the introduction of water-borne sewerage.

2.1.3 Present water use

In the financial year ending June 1994, a total of 2,26 million m^3 of water was supplied by the municipality for use, as compared to 2.39 million m^3 the previous year (see Appendix A). Of this total, 77.3% was used for household and business consumption, 12.7% by Transnet, 6.7% by the SADF and 3.3% by the municipality for park maintenance. A number of studies have been conducted on the assured long term yields of water for the existing development (Vegter, 1990, DWAF, 1991, Vegter, 1992). These average at 2.6 million m^3 per annum and are thus sufficient to meet present day needs.

2.1.4 Future water use

Predictions have been made regarding the population growth of De Aar and these range from 2.7% or less (Stewart Sviridov & Oliver, 1990, Ninham Shand, 1987) to 3.6% (DWAF, 1986). This translates into a population of between 57 000 and 74 400 by the year 2010. Estimated total water consumption by 2010 is approximately 3.8 million m^3 per annum based on a total population of 60 300 people (SS&O, 1990). The ground water potential in the De Aar vicinity has been estimated at between 7.7 and 9.3 million m^3 per annum, far exceeding the predicted demand for 2010 (Vegter, 1992). The existing infrastructure will have to be expanded in order to cope with the increased demand and phased development and introduction of new sources has been recommended..

2.2 WATER SUPPLY SCHEME DESIGN

2.2.1 Supply system

Water is presently supplied to the municipality from five different areas. These are Burgerville in the east, the Southwest scheme, the Southeast scheme, Caroluspoort in the northeast and a few boreholes in the town. Of these the municipality owns the town boreholes, the Caroluspoort boreholes and a few of the Burgerville boreholes. The rest are privately owned by seven farmers. Of the total 2.34 million m^3 extracted for the year ending June 1994, 61.6% came from the privately owned boreholes and 38.4% came from the municipally owned boreholes (see Appendix B). It is thus obvious that the municipality is presently heavily dependent on the farmers for their water supply. It may be interesting to note that the water rights to the municipally owned Burgerville boreholes were bought by De Aar a number of years ago while the small town of Burgerville was still in existence. As a result of losing its water rights, the town gradually depopulated.

Water from the eastern regions flows partly by gravitational feed and is partly pumped into the newer reservoir on the eastern side of the town. Water from the Southwest is pumped into the older reservoir on the western side of the town. The two reservoirs are not linked and thus the reticulation system does not allow for the blending of the water, the implications of which are discussed later in this document. The water is generally not treated in any way prior to consumption.

2.2.2 Institutional management

The management structure that is in place to administer the water scheme is limited to Mr Francois Taljaard, the town engineer, and Mr Stan Morton, the town councillor presently holding the water portfolio. Decisions regarding the water scheme are made by the town council in conjunction with Mr Taljaard.

2.2.3 Technical management

Technical management is headed by Mr Taljaard who is assisted by a foreman. Actual management of the scheme is presently performed on a somewhat *ad hoc* basis. The older pump station is manually controlled by a technician who is able to physically monitor the extraction of water and is able to adjust the number of hours per day that each borehole is used for. However, it has not been established how effective this monitoring is. The newer pump stations are controlled by telemetry and each pump runs for a predetermined number of hours per day. The problem with this system is that due to the extended intervals between monitoring the boreholes, timeous adjustments to the extraction regime are unachievable. In addition to this, it has been reported that a lack of technical expertise in relation to the telemetry functioning prohibits necessary adjustments being made to the system. In some instances, decreases in borehole yield have only been discovered once the pumps have burnt out.

Although the quantity of water extracted from each borehole is monitored by the municipality each month, this is not done in relation to the potentially changing yield of the boreholes and in many cases extraction rates are based on a ground water investigation conducted in the mid-seventies. The Department of Water Affairs conducts regular (monthly to biennially) assessments of the water levels at certain points in the area, the results of which are fed into the national data bank. It would appear, however, that these records are not used by the municipality as an aid to water resource management.

The chemical quality of the water yielded by each borehole is tested prior to it being put to use. Thereafter, boreholes are tested only when it is deemed necessary. Annual tests are conducted on the water from the different schemes or areas as well as on the mixed water entering the two reservoirs. Bacteriological quality tests are conducted biennially on the water contained in the reservoirs. It should be noted that the water feeding from the southwest scheme into the older reservoir is of a lower quality than the water entering the newer reservoir from the eastern schemes. This results in a marked difference in water quality supply to the opposite sides of the town.

Due to a paucity of data relating to the fluctuating potential yields and chemical quality of the different boreholes over time, long-term trends are difficult to identify against the noise of short-term changes that are related mainly to climatic variables, especially rainfall and evapotranspiration. It has been suggested by Vegter (1992) that the "*successful operation of a municipal ground water supply scheme, timeous development and introduction of additional new sources, depends on the continuous observation of ground water levels, the recordings of volumes pumped from individual or groups of boreholes or obtained from springs, the periodic* *local rainfall and river flows. These data should be continually evaluated by a hydrogeologist, and the pumping regime adjusted accordingly.*"

A computerised management system has been designed by Mr Alan Woodford of DWAF, Cape Town, and an accompanying report has been published. This is aimed at regulating water extraction on a sound scientific basis, ensuring an optimal and sustainable yield of ground water both in terms of quality and quantity. The municipality has budgeted for a PC and should be ready to receive training on the use of the software within the next few months. Care should be taken that this management system is correctly and conscientiously utilised.

2.3 SOCIO-ECONOMIC CONSIDERATIONS

2.3.1 Contracts with farmers

Contracts relating to the unit cost of water and the terms of this utilisation by the municipality have in the past and are presently negotiated on an individual basis with the different farmers supplying the municipality with water. No fixed mechanism exists to determine what price should be paid. A general feeling of dissatisfaction is present among the farmers with only one farmer responding that he is happy with arrangements as they stand. It is interesting to note that due to the poor quality of the water obtainable from the municipal boreholes on his property, comparatively little water is extracted from them for the town's use. All farmers said that the remuneration obtained from selling their water does not form a significant part of their income and most feel that it is outweighed by the disadvantages of selling their water.

The most serious complaint voiced by certain farmers was that they had been intimidated by government officials into supplying water to De Aar against their wishes. They felt that they would prefer not to sell their ground water resources at all, the main reason being the fear of a drop in the water table and an associated decline in vegetation productivity and environmental degradation. This would have an adverse effect on their farming operations, reducing their economic viability.

water levels and the concurrent effects on the ecosystem dynamics of the region. A study conducted by Grootfontein Agricultural College indicated that continued extraction of ground water on the present basis should have no effect on the vegetation. However, the farmers had little faith in these conclusions due to the short-term nature of the study and the fact that the college is run be a government department, potentially biasing the results of the study. The present *ad hoc* nature of the management of the schemes added to the farmers worries.

Dissatisfaction was also voiced with the pricing structure of the water. Some farmers feel that they are unfairly locked into contracts that do not pay them a reasonable price for their water. Farms had been purchased with no option to renegotiate existing contracts between land owners and the municipality. Only relatively recently have some of these contracts been renegotiated, but still not to the farmers' satisfaction. Because of the large range in the unit cost of water paid by the municipality and differences in the terms of the contracts, it is felt that the cheapest sources of water (the south-west scheme) are over-exploited, an assertion that is backed up by recent extraction figures (see Appendix B, see Table 1 below). This also being at the expense of water quality which is markedly lower in that area (refer SS&O, 1990 for more detail). It is felt by the farmers that a uniform price for water would be far preferable, with standard terms for all contracts. The price and terms should be participatively decided upon. A similar recommendation has been made by Mr Alan Woodford (DWAF) that all the existing contracts be uniformly renegotiated and that price should not be based on quality. His recommended price for water is 30c per kl with a 10% escalation per annum.

The view was expressed by the municipality that they have an obligation to the community to negotiate the best prices possible and that by further increasing the price paid to certain farmers they would be forced to increase their charges to the town. Due to the long-term nature of some of the old contracts, the municipality had been under no obligation to renegotiate. Although new contracts were prematurely negotiated with two of the farmers receiving the lowest remuneration for their water, the municipality felt that a price rise bringing the amount paid per m^3 into line with that paid to other farmers was asking too much.

TABLE 1: THE CONTRACTUAL ARRANGEMENTS FOR EACH FARM AND THE EXTRACTION FIGURES FOR THE YEAR ENDING JUNE 1994

SCHEME	FARM	93/94 (kl)	PRICE	TERMS
Burgerville	De Kock	120 000	14.64	10% escalation Min: 10 000 kl/month Max: 16 366 kl/month
	Kaffersdam	217 901	12.00	10% escalation Min: 15 000 kl/month
	Jooste	96 000	12.00	Min: 10 000 kl/month Renegotiating contract
South-west	Renosterpoort	225 820	5.00	10% escalation No min, max according to DWAF report
	Vaalbank	475 012	1993:1.6 1994:5.0	Up to 1993: no escalation 1994: 10% escalation No min, max according to DWAF *report, 20yr contract*
South-east	Rietfontein	157 370	12.10	10% escalation Min: R400/month
	Riet	90 765		
	Wag-'n-Bietjie	62 085	3.05	No minimum

2.3.2 Municipal income

The municipality charges between R1.00 and R1.35 per kl of water supplied to the town. The total income from water sales alone for the year ending June 1994 was R2.43 million as compared to the R122 195 paid for the water; R920 514 went to salaries, loans and bonuses, R450 904 went to general expenses, R335 000 went to running and maintenance of equipment, R400 000 went to capital costs and R35 000 to different funds. There are no water treatment costs as the water extracted from the boreholes is considered to be potable.

2.3.3 Meeting the demand for quantity and quality

The present population of De Aar is approximately 31 500. Of this, approximately 18% fall into the higher income bracket, 38% into the middle income bracket and 44% into the lower income bracket. De Aar's water supply is adequate to meet its present needs and the long-term potential of the ground water supply should be more than adequate to meet its needs up until 2010, provided phased extensions to the system are timeously instrumented. Peak season demands are generally the limiting factor and these occur over the hottest months of January and February. There is also an increase in water demand over the summer months as people start to garden. Water restrictions have never been implemented in De Aar. The municipality feels confident that purchasing water from the farmers is a secure means of supply and is happy to rely on it into the future.

The present quality of the water supplied to the town varies depending on the time of the year and from which schemes the water is obtained. It generally does not comply with the Department of National Health and Population Development's recommended limits which are regarded as the maximum levels for no risk during a lifetime's consumption. It does comply with the limits for `no significant risk'. The view is that within this quality range the authority responsible for water supply and treatment, is also solely responsible for decisions regarding the quality of the drinking water supplied (SS&O, 1990).

Various options have been investigated by different consultants over time and different recommendations made. These include blending the water to lower the total dissolved salt (TDS) level, "low" and "high" dose lime softening to remove temporary hardness, ion exchange softening, and electrodialysis and reverse osmosis to reduce TDS (SS&O, 1990). At present the water supplied from the eastern schemes is blended together, slightly lowering the TDS level. However, as previously mentioned, the more brackish water from the western scheme cannot be blended with water from the eastern schemes due to the inadequacy of the existing reticulation system.

The municipality has decided that any treatment of the water quality is both unnecessary and too costly. Although the associated costs of scaling and increased detergent use would be diminished, the municipality still does not feel this to be a viable option. Disparity exists because the lower and medium income population bracket feel that water is already too expensive, many of whom are presently not the higher income population bracket agree that water is expensive but are also dissatisfied with the quality. Neither group appears to be prepared to shoulder a price increase for any reason whatsoever, although a formal investigation into this would have to be conducted for reliable information to be obtained. The municipality expressed the opinion that because many of the town's residents are pensioners (presumably the upper and possibly the middle class is being referred to), an increase in rates would cause them to move elsewhere. The situation does not seem likely to change in the near future unless concerted action is taken by the town's residents.

2.3.4 Development potential

2.3.4.1 Agricultural

The agricultural potential of the area is effectively limited to extensive stock farming activities, the most common being sheep for the production of mutton, wool and pelts. As such, relatively little water is needed for stock watering purposes and all of the farmers feel that selling water to the municipality does not and is not likely to affect their ability to continue providing water to their stock. Very limited crop production takes place in the form of irrigated lucerne production. This is used for feeding sick animals or very occasional supplementary feed. The tendency for soil salinisation to occur as well as low rainfall negates the possibility of any meaningful crop production in the area. Concern was expressed by farmers that continued extraction of ground water may adversely affect the vegetation in the area, so leading to a decline in animal production and the economic viability of their farming enterprises. Most farmers are not aware of the safe yields of ground water below their properties but refer to DWAF reports and municipal records. On the other hand, the municipality does not envisage any problems. In view of the lack of concise information regarding long-term water levels and potential vegetation changes, the farmers fears are not unfounded and it is advisable that this issue be adequately addressed. None of the farmers monitor the exact volume of water they abstract for their domestic or farming needs, but are well acquainted with their own boreholes and check on them regularly.

Apart from buying more land, expansion of farming operations is not perceived as being realistic. Productivity is constrained by the carrying capacity of the land and all the farmers are aware of the land degradation problems associated with overgrazing. None of the farmers feel that their farming operations have changed subsequent to their involvement in the scheme, though it must be remembered that water was in most instances already being extracted from their land when they purchased it. Changes could have occurred prior to this time. Only one farmer has a clear contingency plan in time of prolonged drought. His contract states that should his boreholes fail, the municipality will be obligated to supply him with water until such time as is no longer necessary. It is not clear exactly what the consequences of a prolonged drought would be since, to date, no serious problems have been experienced.

2.3.4.2 Municipal

Municipal growth is predicted by SS&O (1990) to approximate 2.7% per annum. Water supply both in terms of quality and quantity is not perceived by the municipality to be a constraint to this aspect of the town's development. The town is dependent on the farmers' water for this development. However, all the farmers agree that while De Aar is useful as a source of goods and services, it would not make a significant difference to them if the town did not exist. The municipality has considered the option of joining the Orange River Project, something that the farmers are all in favour of. However, attempts to persuade central government to pay for this have so far met with no success and do not look likely to in the future. The costs of joining the scheme would be too great for the municipality and the people of De Aar to pay.

2.3.4.3 Industrial

It would appear that both water quality and the assurance of water supply have been a deterrent to the development of new industries in De Aar. Industries already operating in the town also expressed dissatisfaction with the present situation. Two large manufacturers of reinforced concrete products, Rocla and Grinnaker, have experienced problems as the high TDS level in the water causes the steel reinforcements to deteriorate. Grinnaker was looking at one stage to close their factory down, partly as a result of this problem, an action that would leave many people unemployed. Vleissentraal, the main abattoir for the region, have experienced difficulties with inadequate water pressure leading to potential hygiene problems and thus potential economic losses.

2.3.5 Ownership and water rights

All the farmers that were interviewed are firmly of the opinion that the ground water on their properties belongs to them and should continue to do so. The main reason given for this is that valuation of agricultural land is based to a large extent on the water supply present on the land. Should this asset be nationalised they fear a drop in property value and an inhibition of farming enterprises resulting in decreased productivity. The newly formed town council has mixed ideas on the issue, some of the members feeling that ground water should retain its private water status, and some feeling that it belongs to the people and should not have to be paid for.

2.3.6 Valuation of water

Few clear ideas are held on how water in the area should be valued. The most common suggestion is that it should be based on the alternative agricultural use to which it could be put, for example, the production of alfalfa. Proper evaluation of the total economic value of the resource is necessary, including its use and non-use values.

2.4 ECOLOGICAL CONSIDERATIONS

2.4.1 Impact on vegetation

Farmers and Agricultural Unions have in the past and continue to express concern about the deleterious effects of ground water exploitation for irrigation and urban use on Karoo veld. The lack of monitoring of long-term trends in water levels and vegetation dynamics leaves little conclusive evidence for or against this. The likelihood of a detrimental effect on the vegetation appears greatest on the deep loamy soils flanking water courses where larger shrubs grow and where the ground water lies within one metre of the surface. Root depth of Karoo vegetation has seldom been found at more than 1 200 mm and is generally limited to the top 600 mm. Ground water levels in river valleys should not be lowered below riverbed level such that damage is done to reeds and other stabilising growth.

2.5 ECONOMIC PERSPECTIVE

De Aar was primarily established as a railway junction. Spoornet/Transnet are, thus, important contributors to the economic activity of the town. The town also serves as a commercial/services centre for farmers in the surrounding areas.

2.5.1 Agriculture

Typically for towns within the Northern Cape Province economic activity centres around agriculture - mostly stock farming (with sheep being the most common livestock). Crop production is limited and takes the form of lucerne farming (irrigated land).

Supply-side considerations seem to constrain the development potential for agriculture through:

- overgrazing (insufficient carrying capacity of the land for expansion of livestock farming).
- land degradation difficulties.

2.5.2 Industrial development/manufacturing

Two of the largest manufacturing enterprises are Rocla and Grinnaker - which produce reinforced concrete products. Water quality difficulties are, however, impacting on the quality of their products and contraction, rather than expansion of this industry is likely.

Further, De Aar houses the region's abattoir - again a service centre for farmers.

GROSS GEOGRAPHIC PRODUCT
Rm

Year	Total GGP	Agriculture	Mining	Manufac-turing	Electricity and water
1981	52,64	4,53	0,72	2,32	1,21
1984	80,49	4,82	0,94	2,12	1,30

Year	Construction	Commerce, Catering	Transport & Communication	Finance, Real Estate
1981	4,06	10,00	47,76	12,18
1984	1,43	9,89	52,99	12,85

Year	Community & Social Services	Less Important Financial Services	General Government	Other
1981	0,90	1,43	16,10	1,65
1984	1,02	2,21	13,18	1,68

SOURCE: South African Municipal Yearbook.

The accompanying table shows the sectoral breakdown of GGP for De Aar for the years 1981 and 1984. Clearly, transport and communication dominate economic activity (due mostly to De Aar's status as a major railway junction) at around $^2/_3$ of total economic activity in 1984 (down from 90 per cent in 1981).

Applying estimated real growth rates for De Aar since 1984, we calculate that total GGP amounted to R76,86 m (1984 prices). Hence, during the latter half of the decade economic activity declined in real terms, accentuating unemployment problems. As a result, many members of the labour force migrate elsewhere in search of work. With the "draining" of workers from the area population growth is also declining.

Future economic prospects must be bleak in the face of the above. With the area seemingly on the verge of depopulating to some extent demand-side stimulation of the economy is highly improbable. Further, there is little reason for industries to settle in the area given a declining labour force, no obvious natural resource advantages and vast distances to markets.

2.5.3 Population

Municipal Population

White	Coloured	Asian	Black	TOTAL
5 600	14 000	27	11 000	30 627

2.6 CONCLUSION

The potential ground water supplies that have been identified by various geohydrological reports should be more than adequate to meet the demands of the towns growing population, at least until 2010 and possibly beyond. It is vital, however, that these resources are more efficiently and scientifically managed in order to ensure the sustainability of the supply. Farmers supplying the municipality need to be consulted and their grievances addressed. These relate primarily to the terms of the contracts and the lack of uniformity in them as well as the long-term effects of ground water exploitation on primary productivity and environmental degradation. Until the present time, no change in agricultural productivity as a result of the water supply scheme has been experienced. Water quality issues need to be more comprehensively addressed, especially in relation to the proposed development of the town. These decisions need to be participatively and transparently made and a long-term planning horizon is needed to prevent additional expenditure in the future and to ensure the success of proposed developments. A sound basis for water valuation in the region needs to be developed and the municipal pricing structure needs to be re-evaluated, both in terms of the unit cost of water paid to the farmers and that charged to the public.

3. REFERENCES

Stewart, Sviridov & Oliver. 1990. *Investigation into the utililisation of ground water at De Aar: Report on the technical feasibility and cost of improving the quality of water for De Aar.* Pretoria: Dept of Water Affairs.

Schreuder, A.M. and Forster, S.F. 1987. *A preliminary investigation into the future treatment of ground water for domestic supplies to De Aar.* A report for the Directorate of Strategic Planning.

Stoffberg, F.A., Haasbroek, S.F. and van Niekerk, P.H. 1991. *Aanvullende watervoorsiening aan De Aar.* Pretoria: Dept of Water Affairs and Forestry.

Vegter, J.R. 1990. *Ground Water resources for urban water supply - De Aar: A concise exposition fro planning purposes.* Pretoria: Dept of Water Affairs and Forestry.

Vegter, J.R. 1992. *De Aar's Water Supply: A digest of the past and an outlook for the future.* Pretoria: Dept of Water Affairs and Forestry.

APPENDIX D

DENDRON CASE STUDY

CONTENTS

1. LOCATION

The Northern Transvaal Province is situated in the most northern part of South Africa and as such is the gateway to sub-Saharan East Africa. It includes the magisterial districts of Thabazimbi, Waterberg, Warmbaths, Potgietersrus, Pietersburg, Soutpansberg, Messina, Letaba and Phalaborwa. Specifically the region includes a large section of the Kruger National Park and the former self-governing territories of Lebowa, Gazankulu and Venda.

2. ECONOMIC ACTIVITY/SOCIO-ECONOMIC CONDITIONS

2.1 PHYSICAL INFRASTRUCTURE

2.1.1 Development axes

The N1 national road leading north from the PWV area forms a development axis from the PWV to Messina and includes urban centres such as Warmbaths, Nylstroom, Naboomspruit, Potgietersrus, Pietersburg and Louis Trichardt. In addition, significant urban development also occurs at Northam and Thabazimbi.

From Pietersburg a development axis stretches via Tzaneen to Phalaborwa. Pietersburg is a major commercial centre and seems set for economic expansion. Another development axis reaches from Pretoria to Thabazimbi via Brits.

2.1.2 Electricity Network:

Electrical power was initially supplied to major centres in the region, namely Pietersburg, Messina and Louis Trichardt. This network has subsequently been expanded to include the area around Dendron, the area adjacent to the Limpopo river and some of the Thabamoopo district.

Eskom supplies distributors in the area (i.e. thermally generated power). Eskom Sales and Customer Service North-eastern Transvaal which falls under the Pretoria distributor is responsible for the area. The area is served by 400 kV, 220 kV and 275 kV lines.

The region is serviced by Eskom's national grid and is quite efficient as regards industrial purposes. However, the majority of homes are yet to be electrified, particularly those in the rural areas. Only 1.8% and 7.8% of rural households in Gazankulu and Lebowa respectively, are electrified.

Table below gives details of rural household expenditure on energy sources in Lebowa and Gazankulu, and highlights the lack of electrification.

MONTHLY RURAL HOUSEHOLD ENERGY EXPENDITURE

1990 PRICES in Rands

	Coal	Candles	Gas	Paraffin	Wood	Electricity	Batteries
GAZANKULU	1,83	5,64	9,42	15,10	11,80	0,00	10,97
LEBOWA	0,55	3,31	0,00	5,63	18,00	0,00	n.a.

SOURCE: Norconsult, 1993, p. 10

2.1.3 Road and Rail:

Important transport links to the rest of Africa run through Region G and exert pressure on the transport infrastructure. The region is situated far from domestic markets in South Africa, but does have well developed road and rail links with major centres. The study area is bisected by the main Pietersburg/ Alldays tar road. No railway system exists in and around Dendron.

2.1.4 Airports/airfields:

There are many airfields in the region of which Pietersburg's is the largest.

2.1.5 Post and Telecommunications:

More than a quarter of the telephone exchanges in the region are automated and the service is considered effective for business purposes. Infrastructure for domestic purposes is, however, wholly inadequate.

2.1.6 Demographics:

Population growth in the area is high at a current average compounding annual growth rate of around 4 per cent. The highest percentage of the population (around 78 per cent) lives in the rural areas and semi-urban areas. Typically, there are 5-6 persons per household. Male absenteeism is high, since many males migrate attempting to find employment outside the area. Some $^{2}/3$ of the population is younger than 25 years of age. Employment creation for these persons is a major problem. Education facilities are also wholly inadequate.

Should these circumstances continue population growth rates will of course remain high. A fast growing economically active population would increase unemployment growth. Further, housing allocation (and land allocation for that matter) is inadequate.

2.2 Social Infrastructure

Health care is mostly to be found in urban centres. There is a great need for additional care centres - especially in the rural areas. The Northern Transvaal Province is the only region which has more children than adults, resulting in tremendous pressure on existing inadequate health services. The region has the lowest number of doctors and hospital beds per 1 000 people in South Africa. Part of the region falls in the tropics and typhoid and similar diseases are not uncommon. Life expectancy in this region is the second lowest in South Africa.

2.3 ECONOMIC ACTIVITY

Economic activity in Region G is geographically unevenly distributed. There are no large economic concentrations (relative to the rest of South Africa). Pietersburg - Seshego is the largest economic centre with a share of 60% of the Region's total employment. The economy is dualistic, with the developing component typically comprising subsistence agriculture which maintains a low level of activity. In 1991 the Gross Geographic Product (GGP) was estimated at R7 453 million, 2,3% of South Africa's Gross National Product (GNP).

The table below serves to summarise the extent of the formal economic activities in the Northern Transvaal Province, and to detail their respective contributions to the GGP of the region.

GROSS GEOGRAPHIC PRODUCT				
SECTOR	Rm		% Sectoral Composition	
YEAR	1975	1985	1975	1985
Agriculture	315,1	303,5	16,9	10,5
Mining	609,6	667,5	32,6	23,1
Manufacturing	150,1	234,2	8,0	8,1
Electricity & Water	34,1	49,9	1,8	1,7
Construction	103,6	150,5	5,5	5,2
Trade	205,5	264,0	11,0	9,1
Transport	111,5	174,4	6,0	6,0
Finance	87,3	207,2	4,7	7,2
Other	251,9	841,5	13,5	29,1
TOTAL	1868,7	2892,7	100,0	100,0

SOURCES: Office for Regional Development, 1991
Reuvid, J.: "Overview of the Development Regions", Doing Business in South Africa, Kogan Page Publishers, London, 1993.

In addition to the transport and distribution sectors, the Northern Transvaal Province is an important mining, agricultural and tourism area, with the Kruger National Park being a key drawcard. Traditionally, agriculture and mining have formed the backbone of the region's economy (around 50% of GGP), but the (now hopefully past) long-lasting drought and a decrease in mineral exports (including copper, antimony, chrome, coal and iron) has resulted in a relative decline in the importance of these two sectors. The services sector, notably that of government, has increased steadily as a percentage of economic activity. However, an end to the drought, and improved commodity price forecasts for the late '90's may reverse this position over the next five years. As regards the industrial sector, agro-industries play a key role - accounting for around 40 per cent of total factory output in the region in 1985.

Nevertheless, the problem still remains. The region consumes more than it produces. More than 70% of the region's final demand requirements are satisfied through imports (mostly from other regions, but also internationally). Also, employment creation has not kept pace with population growth as indicated, partly because of capital deepening (i.e., an increased capital-labour ratio) in the economy. Poor education and skills levels impact negatively on productivity.

It is important to note that economies are not driven by demand-side factors alone. Rather, the success of any economic region is critically dependant on supply-side factors such as the real wage rate, productivity, the capital-labour ratio, etc. These effects, in relation to several of the critical economic sectors in the region, are examined below.

2.4 MINING

One specific problem in the Northern Transvaal Province is the distance between mines and the export harbours, which has contributed to the poor performance by the Region's mines during the 1980's.

Nonetheless, the influence of mining on the regional economy is significant. Mining is concentrated in the south-west at Thabazimbi, Waterberg and Ellisras (platinum and coal) and in the eastern part of the region at Phalaborwa and Giyani (copper and phosphates). Of these minerals, platinum makes the most significant contribution to GGP and is found, along with chromium, in the central and southern areas near Potgietersrus and Steelpoort.

The Grootgeluk Colliery and Eskom's Matimba Power Station both have large capacity by world standards. Middle-grade coal from the colliery is used to generate electricity at Matimba. High-grade coking coal from Grootgeluk is used for Iscor's furnaces at Pretoria, Vanderbijlpark and Newcastle. Thabazimbi is a leading supplier of iron ore. Furthermore, in the north-east, Venda's Tshikondeni Coal Mine has adequate reserves of coking coal to increase production substantially.

Large deposits of copper and phosphates are to be found near Phalaborwa. These are mined by the Phalaborwa Mining Company and Foskor. One of the world's largest producers of antimony is located nearby.

De Beers' Venetia Diamond Mine, which opened in late 1992 is located some 80 km west of Messina and exerts a major impact on the economy of the Northern Transvaal Province.

Other minerals which are mined in the area, although not in significant quantities include gold, scheelite, magnetite, emeralds, vermiculite, silicon and mica. Base commodities which are mined include block granite, corundum, feldspar and salt.

In 1985, mining contributed R667,5m to the GGP of the Northern Transvaal Province (some 23 per cent). This contribution is however expected to fall to 20 per cent by next year with a concomitant decrease in employment by the mining industry from 34 500 to 30 500.

2.5 AGRICULTURE

The Northern Transvaal Province is considered one of South Africa's richest agricultural regions, producing around 70 per cent of the country's avocado and tomato crops in the sub-tropical lowveld areas of Venda and the Letaba District (of which Tzaneen is the commercial centre).

Other produce of the lowveld areas includes coffee, nuts, guavas, sisal, cotton and tobacco. The escarpment is timber country, while the highveld areas produce maize and wheat, with some cattle and game ranching. Highveld crops also include cotton, citrus fruit and sunflower seeds.

Of course, crops were severely affected by the drought of 1991/1992. Even during non-drought conditions there is limited water available in the Northern Transvaal Province. Water development and its astute management is a key feature of the region's agro-economic development.

2.6 MANUFACTURING

Manufacturing plays a relatively small role in the region in terms of GGP, but does seem to be labour intensive. More important products are food, beverages, wood and wood products, rubber, pottery and glass, non-ferrous metal products and non-electrical machinery.

Other less "important" manufacturing activities include textiles, furniture and printing. All in all, the industrial base of the region is relatively undiversified.

The gearing of manufacturing products towards agriculture deserves emphasis. Manufacturing activity related to agriculture and forestry products (given as a percentage of total manufacturing output for the region) are shown in table below.

PERCENTAGE OF REGIONAL MANUFACTURING OUTPUT	
Wood products	17
Meat	9
Other foods	7
Fruit preserving	6
Other	1
TOTAL	**40**

Other manufacturing is geared towards the refining of minerals, for example the manufacturing of non-metal products, iron and steel products and structural metal products which, when combined, comprise 8 per cent of manufacturing output.

Given that rural-urban migration is a function of wages, employment and social factors, it can be expected that land hunger and the gap in agricultural/urban earnings will prompt migration to urban areas (not necessarily within the region) on a large scale should the unemployment situation not be brought under control. Ever since the removal of influx controls, wives and children have been left in rural areas to subsist and this has exerted an eroding effect on family life and the management of agricultural resources (due to split responsibilities of the remaining spouse). This, in tandem with the land tenure system has acted to push agriculture into low productivity, poverty and resource degradation (Kassier and Groenewald (1993)).

The tables below refer to the developing rural areas of the Northern Transvaal Province as represented by Gazankulu and Lobowa.

THE ECONOMICALLY ACTIVE POPULATION IN AGRICULTURE			
	GDP per Capita (monthly)	**% of GDP contributed by Agriculture**	**% of Economically Active population in Agriculture**
LEBOWA	**R101,00**	**29,40**	**20**
GAZANKULU	**R103,00**	**25,00**	**21**

SOURCE: Kassier and Groenewald, 1993

AGRICULTURE LAND USE							
	Crop land ha (x 1000)	**%**	**Natural grazing ha (x 1000)**	**%**	**Wood & forest ha (x 1000)**	**%**	**TOTAL ha (x 1000)**
LEBOWA	336	16,3	1677	81,5	44	2,2	544
GAZAN-KULU	82	15,1	462	84,9	0,0	0,0	354
SOURCE: Kassier and Groenewald, 1993							

FARM LAND PER CAPITA OF RURAL POPULATION			
	Farm land* **(ha x 1000)**	**Rural population (x 1000)**	**Farm land per capita**
LEBOWA	2057	1718	1,20 ha
GAZANKULU	544	477	1,14 ha

Note: * Crop land, natural grazing, woodland and forests

SOURCE: Kassier and Groenewald, 1993

2.8 ESTIMATING THE SIZE OF INFORMAL SECTOR ACTIVITY

In referring to unaccounted informal activities one should refrain from using the word sector. "Sector" usually refers to activities which are homogenous. Rather, the informal sector consists of a variety of activities which relate to different sectors of the economy. For example, spaza shops form part of the retail sector, while taxis and sub-contractors belong to the transport and construction sectors respectively.

Ideally, emphasis should shift from measuring the size of the informal economy to establishing the technical and economic links that exist amongst the different informal activities and formal enterprises. The resultant input-output table will have clear policy and analytical value. In the absence of such data our attempt here at assessing the size of such activity within the catchment area amounts to little more than hypothesising.

In their paper "The Informal Economy in South Africa", Abedian and Desmidt (1990) put forward a convincing argument that the growth of the informal economy is primarily determined by

(i) the conditions in the formal economy (real average formal income);
(ii) the growth of urbanisation;
(iii) the growth of that portion of the labour force that cannot find occupation in the formal economy (potential informal labour force);
(iv) factors that support informal activity (real pensions per population).

However, in determining the actual size of the informal economy, Abedian and Desmidt use the idea of the theoretical maximum size of informal income in urban communities. This assumes that:

(i) all labour not formally employed must be involved in the informal economy (that is, the economy is always at full employment output); and
(ii) operators are indifferent between the formal and informal economy so that average earnings in the informal economy must be equal to those of the formal economy (that is, the economy is in a steady state equilibrium).

On this basis, the size of the informal economy in the Northern Transvaal Province is estimated to be worth R509.2m or 22,2% of GGP.

It is, perhaps, unlikely that the total informal economy will account for as much as 22% of GGP, since State pensions play a large role in income generation. In other words, we need to relax our first assumption that all labour not formally employed must be involved in the informal economy.

2.9 EMPLOYMENT

Table below provides an indication of formal employment growth rates for the different economic sectors in the Northern Transvaal Province.

EMPLOYMENT INDEX IN 1990 BY ECONOMIC SECTOR (1980=100)		
	INDEX	**AVERAGE ANNUAL GROWTH RATE**
AGRICULTURE	77	-2,58
MINING	78	-2,45
MANUFACTURING	123	2,09
ELECTRICITY	212	7,80
CONSTRUCTION	165	5,10
COMMERCE	113	1,23
TRANSPORT	108	0,77
FINANCE	192	6,74
SERVICES	140	3,42
TOTAL	**111**	**1,05**

SOURCE: MERG, 1993

Growth rates are the author's calculations

Clearly, an average annual employment growth rate of 1,05% cannot keep apace with the population growth rates described earlier. Further, the table above shows that most of the economically active population (which can find employment) is employed in formal agriculture (around 40%, while less than 10% are employed in manufacturing). This is unfortunate in that manufacturing is seen as the engine for economic growth and employment creation in economies around the world. Although mining represents more than 30% of economic activity in the region it employs less than 10% of workers, due to the highly capital-intensive nature of mining operations.

The Northern Transvaal Province has the third highest population density of all the provinces in South Africa, but also has the lowest functional urbanisation rate and amongst the lowest employment potential. Only 22,9 per cent of the potential labour force of some 1,37 million can find employment in the region. The region itself has the third highest unemployment rate (17 per cent) of all the regions, while having the highest male absenteeism rate (about 37 per cent). The dependency ratio (i.e., the number of people dependent upon a formal wage earner) is 4,8, although this figure is distorted by the absence of male magrant workers.

The table below provides sectoralised estimates of employment in the Northern Transvaal Province.

EMPLOYMENT IN THE NORTHERN TRANSVAAL PROVINCE				
	1985		1990	
	No (x 1000)	Sectoral %	No (x 1000)	Sectoral %
AGRICULTURE	144,50	40,20	140,77	38,51
MINING	34,50	9,60	33,65	9,21
MANUFACTURING	33,00	9,20	33,69	9,22
ELECTRICITY & WATER	1,10	0,30	1,19	0,33
CONSTRUCTION	26,50	7,40	27,86	7,62
TRADE	19,90	5,50	20,14	5,51
TRANSPORT	14,40	4,00	21,43	5,86
FINANCE	5,20	1,50	5,55	1,52
OTHER	80,40	22,30	81,24	22,22
TOTALS	**359,50**	**100,00**	**365,51**	**100,00**

SOURCE: Office for Regional Development, 1991 and own calculations

It should be noted that table above refers to the formal sectors of the economy, i.e., employment in the subsistence agricultural and informal sectors is excluded.

2.9.1 Per Capita Income

The disposable per capita income in South Africa for 1994 is estimated at R7 320 with the highest figures being recorded in the PWV (R16 570) and the Western Cape (R12 387). This contrasts starkly with the estimate for the Northern Transvaal Province of R2 112. Effectively, per capita incomes in the Northern Transvaal Province are a mere 30% of the national average.

The Black population of the Northern Transvaal Province earns an average per capita income which is 7 per cent of White income (i.e., R1 543 p.a.), while Whites, in turn, have a per capita income that is only 75 per cent of the earnings of Whites in the rest of South Africa. This serves to show the skewness of the distribution of income in the region as well as the relative poverty of the Northern Transvaal high unemployment rates in the region. It further underlines the poverty in the region which places an immediate threat on the chances for sustainable development. Mostly, poverty leads to indiscriminate use of resources in an attempt to ensure survival.

2.10 HOUSEHOLD EXPENDITURE

National household expenditure patterns are shown in the table below and refer to expenditure (both cash and in kind) of private households on goods and services, irrespective of durability.

DISTRIBUTION OF HOUSEHOLD EXPENDITURE IN SOUTH AFRICA, 1994 (Total expenditure estimated at R287,8bn)	
	% OF TOTAL
PWV	35,7
KWAZULU-NATAL	14,9
WESTERN CAPE	14,6
EASTERN CAPE	8,2
ORANGE FREE STATE	6,8
EASTERN TRANSVAAL	6,4
NORTH-WEST	6,2
NORTHERN TRANSVAAL	5,1
NORTHERN CAPE	2,1
TOTAL	100,0

SOURCE: Bureau of Market Research, 1994

From table above it can be deduced that the household expenditure of the persons living in the Northern Transvaal Province is around R14,7 billion.

Further analysis of the source data reveals that food comprises an important part of total expenditure, while the opposite holds true for more luxurious items such as insurance and pension funds. This is indicative of survivalist expenditure patterns rather than hedonistic attitudes. Although expenditure on housing and electricity is relatively high on the priority list, the expenditure on these items in the Northern Transvaal Province is the lowest of all regions except the Northern Cape. This points to a considerable lack of infrastructural development as regards housing and energy (particularly in rural areas) leading to the conclusion that the area will be targeted as a high priority for infrastructural investment expenditure (services and housing).

THE DORINGLAAGTE SUB-CATCHMENT

3. GEOGRAPHY

3.1 Topography:

Dendron lies some 60 km north of Pietersburg in the Northern Transvaal Bushveld. Relief maps show that the area is relatively flat (sloping around 0,004 to the North).

Height above sea level ranges from 1070m in the south to around 850m at Vivo in the north. The countryside has a couple of koppies here and there, reaching heights of 1400m at Loskop.

The area of Dendron has two catchment areas, namely the Brak River in the west and the Hout River in the east. A sub-catchment Doringlaagte is to be found within the Hout River catchment. The two rivers mentioned here are tributaries of the Sand River. The Doringlaagte Catchment with an area of $509km^2$ drains to the north-east with a length of 35km and an average width of some 15km.

Dendron lies in the centre of the Doringlaagte drainage basin.

3.1.1 Climate:

The climate is semi-arid. Annual mean temperatures range from 18°C - 19°C.

3.1.2 Geology:

The area is covered by Archaean rocks (of the Kaapval Craton). These rocks consist of leucocratic granites and gneisses of the Bandelierkop Complex. The Bandelierkop Complex, together with the Beit Bridge Complex and the Sand River gneisses make up the Limpopo Metamorphic Province. Shales, calcareous shales, dolomitic limestones and sandstones which were originally laid down upon a graniitoid basement have been folded (together with concordant basic intrusions) and repeatedly metamorphosed to produce the existing para and ortho-rocks. The high silimanite content of the rocks proves that metamorphism was of the highest regional grade (Jolly, 1986).

The Bandelierkop Complex in the study area consists of the Baviaanskloof granite-gneisses and the Bandelierkop Formation, with the granite-gneisses consisting of pink to grey granites (the latter revealing greater foliation and a more gneissic nature). The Bandelierkop Formation consists of original greenstone material which has been subjected to at least three phases of deformation, producing pelitic gneisses, mafic gneisses and metaquartzites, plus ultramafic rocks. Other than the metaquartzites, outcrops are few and far between. The surface is covered by red-brown sand with minor calcrete horisons. (Jolly, 1986).

3.1.3 Rainfall:

The table below shows the mean annual average precipitation (MAP) in mm as measured at different rainfall stations in the area for selected periods. The main rainfall season occurs between October and March.

	1926-47	1926-65	1965-85	1971-92
SOHO	411,4	-	-	-
REDHILL	402,5	427,5	-	-
WALDBURG	348,0	356,7	374,5	-
DENDRON	-	-	-	432,4
JAN ANTONIE	-	-	409,4	-

SOURCE: Bertram, W.E., 1993

4. THE ECONOMY

4.1 AGRICULTURE

4.1.1 Crops:

Agriculture (mostly the production of potatoes) is the main economic activity in the area. This industry was originally established due to the high availability of water (fountains) and an ideal climate. Under irrigation this industry is expanding, but other crops, namely mealies, onions and pumpkins are now also being planted (Bertram, 1993).

Mechanised farming began after the Second World War. This period saw the utilisation of groundwater for irrigation. Higher returns from crop cultivation relative to stock farming (particularly during the 1950's) resulted in the present extensive irrigation projects along the Sand River around Dendron (and Pietersburg, Kalkbank and Vivo) (De Wet Shand Inc., 1992).

4.1.2 Forestry:

The climate in the area is not suited to forestry. The impact of foresting in the area on the hydrology and water potential is non-existent.

4.1.3 Livestock:

The area is best suited for cattle farming (and game). Goats and sheep are also reasonably well adapted. Game farming has flourished since the 1970's. Drought has, however, adversely affected this industry through:

(a) veld management which has been adversely impacted. Optimum livestock numbers have not been maintained;

(b) during drought over-supply of livestock has occurred on markets, thereby depressing prices (De Wet Shand Inc., 1992).

Farming practices are the factor responsible for the greatest impact on the hydrology and water availability of water in the Dendron area.

IRRIGATION AREAS & WATER USE

Sub-catchment Doringlaagte

Irrigated Areas (ha)		Gross Annual Water Use ($m^3 10^6$)	Average Annual Water Use ($m^3 10^6$)
Winter	Summer		
1220	1220	17,7	14,9

SOURCE: De Wet Shand Inc., 1992.

WATER DEMANDS: STOCK WATERING

Sub-Catchment Doringlaagte

Veld type	**Area (km2)**	**Livestock Units (No)**	**Annual Consumption ($m^3 10^6$)**
False grassveld; Sour, sourish mixed, Mixed and acid sweet bushveld	523	5230	0,15

SOURCE: De Wet Shand Inc., 1992.

4.1.4 On Irrigation:

The catchment is highly dependent on groundwater.

The following irrigation equipment is generally used:

(a) Centre pivots
(b) Movable sprinklers
(c) Microdip
(d) Flood

In summer the entire irrigated area is cultivated for maize. During winter the main crops cultivated are as follows:

Potatoes	50%
Wheat	10%
Tomatoes	40%

(De Wet Shand Inc., 1992)

Throughout the area, however, the amount of land suitable for irrigation far exceeds the area for which water is available. And, although the geology is suited to groundwater storage, the low rainfall experienced in the area has meant that recharge has been limited. Over-abstraction of ground water has also led to boreholes drying-up.

4.1.5 Sectoral Contributions to GGP

The table below shows the contribution of different sectors to GGP in the catchment and surrounding areas. Specifically, the catchment falls within the Pietersburg district.

DORINGLAAGTE CATCHMENT AND SURROUNDING AREAS

Gross Geographic Product (1990)

Constant 1985 prices (RX1000)

MAGISTERIAL DISTRICT	AGRI-CULTURE	MINING	ELECTRI-CITY	CON-STRUC-TION	TRADE	TRANS-PORT
PIETERSBURG	33383	6973	9791	24808	107541	77918
	MANU-FACTU-RING	**FINANCE**	**COMMU-NITY & SOCIAL**	***LESS*** **FINAN-CIAL CHARGES**	**GOVERN-MENT**	**OTHER**
	67098	107875	9842	16101	184238	12637

TOTAL R626 003 000,00

SOURCE: Development Bank of SA., 1994

The picture sketched by the table above is, of course, highly distortive of the spread of GGP within the catchment. Rather, within the catchment agriculture dominates, with trade (including game farming) playing a lesser role. Community and social services that do exist are centred in the town of Dendron and there is some activity by the government sector.

This is not to say that we must ignore the figures presented above. We have indicated that there is a high male absenteeism rate in the catchment due to lack of employment opportunities. Obviously these persons are migrants seeking work in larger centres such as Pietersburg, Tzaneen, Messina and further afield. Also, through the well-known economic multipliers there will be significant "knock-on" effects into the area given, for example, the wages that the migrant workers earn and send home.

As indicated, the inclusion of mining, manufacturing, finance and construction in the figures, in particular, distorts the figures notably for the reader who is trying to assess relative contributions of different sectors to GGP in the catchment itself. Most manufacturing within the greater Sabie River Basin within which the catchment falls occurs at Pietersburg and Louis Trichardt.

4.1.6 Employment

As per the analysis of sectoral economic activity in the Doringlaagte Catchment above we have analysed employment in the catchment by referring to the greater Pietersburg district - the smallest geographical level to which official data is available. These are shown in the table below.

DORINGLAAGTE CATCHMENT AND SURROUNDING AREAS

Formal Sector Employment

MAGISTERIAL DISTRICT	YEAR	AGRI-CUL-TURE	MINING	MANUFAC-TURING	ELEC-TRICITY	CON-STRUC-TION	TRANS-PORT	FI-NANCE	COM-MUNITY SER-VICES
PIETERSBURG	1980	6036	251	1582	151	882	1326	981	5970
	1991	5875	459	2268	136	1039	1179	2309	8907

<u>SOURCE</u>: Development Bank of SA., 1994

Clearly agriculture and community services (including government) and to a lesser extent finance and manufacturing employ the greater part of the formal labour force. This is in line with the analysis on economic activity presented. However, employment in formal sector non-agricultural activity has stagnated somewhat, and even declined during the past decade. This is also true of the Catchment itself. No doubt drought conditions (which have adversely impacted ground-water reserves) have played a key role in determining this trend.

Employment in the government sector, which for the most part falls outside the sector has, however, increased markedly.

Manufacturing created no new employment opportunities to speak of in the formal economy within the catchment, but perhaps one should not be overly critical if specific areas in South Africa do not have employment creating manufacturing activity. Manufacturing is not suited everywhere.

All in all, employment creation in the formal sectors of the economy has not been sufficient to absorb the ever-increasing labour force in the area. Moreover, the analyses above refers to the decade up to and including 1991. It does not include the negative impacts of the recent recession and drought. The result of the formal employment situation has been significant expansion of the informal sector in the catchment, mostly in subsistence agriculture.

Again, a severe problem is high population growth and, more importantly, a lack of skills development which makes it even harder to stimulate value-adding economic activity.

4.1.7 Informal Employment

The table below provides an indication of the extent of participation in the informal and subsistence sectors of the catchment and surrounding districts.

By adding columns (c) (d) and (e) one obtains (a) which is the labour force. By dividing column (c) into (a) one can, of course, calculate the official unemployment rate for the entire Pietersburg district which stands at 24,3 per cent. Some 6346 persons are involved in subsistence agriculture and non-market activities (i.e. 15 per cent of the labour force). Note that subsistence agriculture and non-market activities (i.e. running the home and family) is undertaken by a wide range of people, some of whom are classed as not being economically active. Thus column (b) is composed of people in columns (a), (c), (d), (e), and more.

DORINGLAAGTE CATCHMENT AND SURROUNDING AREAS

Distribution of Labour Force, 1991

	(a)	(b)	(c)	(d)	(e)
MAGISTERIAL DISTRICT	LABOUR FORCE	SUBSISTENCE AGRICULTURE & NON-MARKET ACTIVITIES	FORMAL EMPLOY-MENT	UNEMPLOY-MENT	INFORMAL SECTOR
PIETERSBURG	34420	6346	26043	1474	6903

SOURCE: DBSA, 1994

Notes to Table:
1. Labour force.
2. Subsistence agriculture & non-market activities: Marginal sector.
3. Formal employment: Formal sectors of economy.
4. Unemployment: Persons actively looking for a job.
5. Informal sector: All persons involved in unregistered enterprises.

4.2 WATER RESOURCES AND USE

4.2.1 Groundwater Resources

All the major water users (agriculture and rural and urban settlements) in the Sand River Basin (including the Doringlaagte Catchment) depend mostly on groundwater as a water source. Some 88 per cent of the total amount of water consumed is groundwater. Around 2 per cent of consumption is met by locally developed surface water sources.

We know that transmissivity determines the degree of ease with which groundwater can be abstracted from an aquifer. In turn the volume of water stored in the aquifer is important in order to determine how much groundwater can be extracted during the dry season or during drought periods.

In the Doringlaagte Catchment aquifers generally have high transmissivities and, therefore, high yielding boreholes often occur (in these aquifers).

The table below details the groundwater balance as per the Doringlaagte Sub-Catchment.

DORINGLAAGTE CATCHMENT

GROUNDWATER BALANCE

Catchment	Estimated Recharge **($m^3 10^6$/annum)**	Present Abstraction **($m^3 10^6$/annum)**	Potential for Development **($m^3 10^6$/annum)**
A734	11,8	18,1	Nil

<u>SOURCE</u>: De Wet Shand Inc., 1993

In the greater Sand River Basin the water infrastructure includes dams, borehole schemes, conveyance systems and distribution networks that impact on water resource abstraction and water use. Other infrastructure (roads, railways and power supply networks) also influence water use.

Water supply comes from surface and groundwater sources. Surface water run-off is particularly variable and is made available through the construction of dams. Most dams are small and used for agricultural purposes.

Groundwater has been used in the area since the beginning of the century. Groundwater development for domestic purposes has been low. Demand for irrigation water, on the other hand, has been high. Large quantities of groundwater have been abstracted to meet this demand. In some instances, the rate of extraction has exceeded the recharge rate.

Groundwater is abstracted by means of

1. wells
2. concentrations of boreholes
3. dispersed boreholes

for use by major towns, farmers (irrigation) and the rural population.

The total volume of groundwater abstracted: $110m^3 10^6/a$ plus.

This is abstracted through more than 1 000 boreholes (many of which were developed before 1970). The most significant development of groundwater occurs along the middle and lower reaches of the Hout River where in excess of $55m^3 10^6/a$ is abstracted for irrigation purposes (De Wet Shand Inc. 1992).

Several water distribution systems are commonly used, namely

1. sophisticated fully reticulated systems
2. more primitive erf standpipes
3. street water supplies (town of Dendron)
4. windmills
5. hand pumps
6. springs and streams

DORINGLAAGTE CATCHMENT

	IRRIGATED AREAS (ha)		GROSS ANNUAL WATER USE	MAP (mm)	AVERAGE ANNUAL WATER USE
SUBCATCHMENT	Winter	Summer	$m^3 10^6$		$m^3 10^6$
A734	1220	1220	17,7	380	14,9

SOURCE: De Wet Shand Inc., 1992

Around 10 per cent of the population in the basin has access to fully reticulated water supply. More than 30 per cent (located mainly in Lebowa and Venda) have access to only hand pumps, streams and springs.

It seems that the rate of water extraction is related mostly to the ease with which water can be obtained from the distribution system.

Water use from rudimentary systems is reasonably low (at around 8λ/c/d) in the case of springs and streams to about 30λ/c/d for street supplies. Upgrading from street supplies to erf connections results in an increase in water demand to around 90λ/c/d (De Wet Shand Inc., 1992).

Towns which can be classified as major urban areas in the Sand River Basin are

- Pietersburg
- Louis Trichardt
- Messina

Less significant urban users are

- Seshego
- Mankweng
- Dendron
- Vivo
- Soekmekaar

The two mines in the Sand River Basin area requiring water are Silicon Smelters near Pietersburg and Messina Copper Mine. There are also four military bases, namely Messina, Louis Trichardt, Pietersburg and Soekmekaar.

Persons with access to fully reticulated water supply use between 200λ/c/d to 1500λ/c/d. Those with erf pipes and street pipes use between 20λ/c/d and 100λ/c/d. In the case of hand pumps, windmills and direct abstraction from streams and springs less than 20λ/c/d is used.

Water restrictions have only ever been applied in the major towns (where there is a high level of control). It is estimated that some 30% water savings were achieved during the severe drought of the 1980's. In some towns a system of surcharges has

4.2.1.1.1 Groundwater Use

Within the Sand River Basin towns have been reliant on groundwater as a water source since the end of the nineteenth century. Currently, however, much of this water is imported. Groundwater now meets only a small proportion of requirements.

Most rural and farming communities rely on groundwater for domestic use.

The rate of development of groundwater for irrigation use has increased dramatically since the 1930's, especially in the Vivo/Dendron area (and also along the Sand River, north and south of Pietersburg).

The quality of the groundwater is tolerable, although agricultural development in the Dendron-Vivo area has caused degradation in water quality.

There is groundwater monitoring in Dendron (and also Pietersburg, Louis Trichardt and Messina). This monitoring nonetheless needs to be expanded to enable more effective management of groundwater resources and to prevent over-exploitation.

It was estimated in 1992 that some $140m^2 10^6/a$ of the available $170m^3 10^6/a$ groundwater has been developed in the Sand River Basin. Most high potential areas have been exploited.

Future Demand

Expected future demand for water in the entire Pietersburg district (which includes the Doringlaagte catchment) is expected to grow as follows under a scenario of improving economic conditions with higher per capita demand.

WATER DEMAND ($10^6 m^3/a$)

Pietersburg District

1990	2000	2010	2020
11,70	19,00	31,00	50,40

SOURCE: De Wet Shand Inc., 1992

4.2.2 Valuation of Groundwater

Unlike say De Aar where it can be argued that, to a certain extent, a market exists for groundwater (where farmers and the local authority negotiate contracts) there is no market mechanism in Dendron that establishes prices for groundwater.

As discussed, farmers and the local authority in Dendron make use mostly of groundwater - and to a much lesser extent surface water. Users of groundwater, say the farmers for irrigation purposes, extract as much water as they like at no cost other than the initial capital costs for pumps, etc., and, of course, maintenance costs.

The above has resulted in the present groundwater abstraction rate of 18,1 $m^3 10^6$/annum, And, with the potential for development at nil there exists a finite, and, therefore, vertical inelastic supply curve for groundwater in the area.

However, as stated there exists no market where prices are determined for groundwater. Further, it would be extremely difficult to establish willingness to pay curves in an environment where no attempt has been made to price groundwater. In this regard the current water shortage has prompted the local authority at Dendron to rely on physical water restrictions rather than price increases to regulate water demand.

In valuing groundwater in the area we, therefore, propose to evaluate the value of groundwater by assessing the consequences of the supply of this water reaching its production and the maintenance of livestock would cease. And, since agriculture forms the backbone of the economy in the area this would remove the very reason for the existence of the town of Dendron and economic activities within the Doringlaagte sub-catchment. Hence, the value of groundwater can be equated to the value of agricultural output or, indeed, the entire economic activity of the catchment.

APPENDIX E

VERWOERDBURG CASE STUDY

CONTENTS

1. BACKGROUND.

The Department of Water Affairs and Forestry (DWAF) commissioned the surveying and drilling of the boreholes in this area as part of the emergency water supply scheme during the drought of the mid 1980's. Verwoerdburg Town Council (VTC) then acquired the use of three boreholes from DWAF and developed the current ground water supply scheme to augment the existing supply from Rand Water (RWB). Verwoerdburg is a rapidly expanding town with a current population of 90,000.

In the area serviced by VTC, there are eleven 'reservoir areas' or separate reticulation systems. Of these, three receive mixed water (Ground water and RW water in a 50/50 mix), whilst the rest receive only RWB water. The industrial/commercial areas of Centurion Centre, (Eastern side), Technopark, and Lyttelton Manor Extensions 6 and 3 receive mixed water, but do not seem to have any 'water-quality sensitive' industries located there. The industrial areas of Gateway, and Sunderland Ridge lie within reservoir areas served only by RWB water. This was a factor in the positioning of two breweries in the Gateway Industrial Area.

The Municipality's main abstraction boreholes and their respective yields are as follows:-

a. ZP13 - Clubview/Eldoraigne 50 litres/second.

b. ZP16 - Lyttelton 70 litres/second.

c. Kentron - Irene/Doringkloof 60 litres/second.

These three boreholes are relatively small (200-250mm dia.) Bubble sensors to monitor water levels were tried but were not very successful. A monitoring borehole was drilled, and is logged in order to determine waterlevels. Ultimately, each borehole will have a pressure sensor installed. Since monitoring began six years ago, there has been virtually no drop in water level. Recharge seems to be immediate.

At present ground water meets 21% of the town's demand of 14.5 million m^3 per annum. There is sufficient ground water yield to increase this amount.

2. COSTS

Annual operation and maintenance costs of ground water abstraction are approximately 5% of the capital costs. A small cost (2-3 cents/litre) is incurred for treatment with chlorine gas.

In 1991 RWB water cost 63.46 cents per kilolitre, which was approximately the same unit cost as water from the Kentron borehole. Water from ZP13 and ZP16 cost only 33.5 cents per kilolitre by comparison. The cost of RWB water continues to rise at a comparatively higher rate than that of the ground water due to the depreciation over ten years of the original loan for the ground water scheme. At present the use of ground water saves Verwoerdburg about R1 million per annum.

No assessment has been undertaken by VTC with regard to scaling problems experienced by users. The water supplied meets the standards for drinking water in all respects, including hardness. The mixing ratio of RWB water to ground water is monitored on a weekly basis to try to maintain a 50/50 mix. However, depending on factors such as consumption, rainfall, etc., the proportion of ground water can sometimes be as high as 80%. At these levels, some negative feedback from domestic consumers reflects dissatisfaction has been received.

3. DWAF ABSTRACTION GUIDELINES.

There are no applicable DWAF limits to ground water abstraction. The only limitation which DWAF sets is that, due to possible sink-hole effects from dewatering, the abstraction of ground water must cease if the level falls more than 5 meters in any period. As stated above, recharge in this system seems to be immediate.

4. FUTURE USE

Future use of ground water in Verwoerdburg is dependant on the economics of the situation, and on the policy of RWB, since it is they who indirectly regulate use of ground water by the price of their water and through their regulations which accompany the provision of connection points. Ground water will continue to be used as long as it remains the cheaper source of water, although the borehole equipment is scheduled for renewal in 1997.

5. SURVEY

Against this background a survey was conducted among the residents of Verwoerdburg. Two suburbs were selected: Rooihuiskraal, to the West of Verwoerdburg, which receives RWB water only. Doringkloof, to the South of Verwoerdburg, which receives GW/RWB mix.

5.1 AIMS

The purpose of the survey was to compare and contrast the responses from the residents of these two suburbs, with particular reference to:

- Their knowledge and awareness of water source and price,
- Their perceptions regarding quality, and
- Their willingness/ability to pay, or to conserve, or to use sources other than the Municipal supply, with a view to determining the value of the resource to the consumer.

5.2 METHODS

100 responses were sought from each area. The Municipal Valuation Roll and Pretoria Telephone Directory were used as information sources. Potential respondents were selected from the Valuation Roll based on their physical address, and the size of their plot. Plot sizes between 900 and 1200 m2 were selected to try to present a uniform data set across the two suburbs.

The survey was conducted telephonically, with no attempt being made to specifically target male or female respondents, or those owning a pool or borehole. Telephone calls lasted between five and ten minutes, with the initial responses being generally positive, i.e., once contact was made, most people were willing to be interviewed. The main difficulty lay in making the initial contact at a convenient time, owing to the 'dormitory' nature of the suburbs, particularly Rooihuiskraal.

The data was stored and processed using Microsoft Access Software.

5.3 Results

The attached figures and appendices show the results of the survey. It would be possible to interrogate the dataset in other ways, should the need arise, but owing to the extremely small initial sample size, and resulting sub-sets, analysis should be conducted with caution. Broad assumptions should not be too readily made with reference to this data. It is stressed that this is the most basic of pilot studies. Validation of the trends revealed by this study would require a survey sample orders of magnitude larger.

5.4 Conclusions

In light of the results of this survey, it would seem reasonable to conclude that owing to the community's low awareness of it's water supply, it is not possible to put a consumer-derived value on Verwoerdburg's ground water

6. ANNEXURE A

DATA SET CHARACTERISTICS

Total sample = 200 responses

Doringkloof = 100

Rooihuiskraal = 100

Males = 65

Females = 135

Average residence period = 10 years

Average plot size = 1123 m2

Average value of improvements = R 80332

Pool ownership DKF = 65, RHK = 53

Borehole ownership DKF = 8, RHK = 27

7. ANNEXURE B

KNOWLEDGE AND AWARENESS OF SOURCE AND PRICE

Question:- Do you know where the Municipality gets its water from in your area?

Response:- Don't Know Male = 22, Female = 96

Incorrect Male = 24, Female = 16

Correct Male = 19, Female = 23

Question:- Which do you think is the cheaper source of water?

Response:- Don't Know 115

RWB Water 34 (Incorrect)

Borehole 51 (Correct)

Question:- What is the cost of Municipal water per 1000 litres?

Response:- Don't Know Male = 59, Female = 130

Incorrect Male = 6, Female = 4

Correct Male = 0, Female = 1

Question:- How much is your monthly water account?

Response:- Don't Know Male = 35, Female = 80

Estimate Male = 30, Female = 55

THE "TOTAL IGNORANCE" FACTOR

The following numbers of respondents:-

(a) Didn't know where their water supply came from, *and*

(b) Didn't know whether borehole water or RWB water was cheaper, *and*

(c) Didn't know the unit cost of municipal water, *and*

(d) Didn't know what their monthly water account was.

Male = 10, Female = 43

8. ANNEXURE C

PERCEPTIONS REGARDING QUALITY

Question:- Does your family drink plain tapwater?

Response:- Always DKF = 96, RHK = 84

Sometimes DKF = 0, RHK = 15

Never DKF = 4, RHK = 1

Question:- Do you experience any of the following:-

(a) Dry itchy skin after bathing?

Response:- Always DKF = 19, RHK = 29

(b) Flakes floating in water?

Response:- Always DKF = 10, RHK = 7

(c) Clogged plumbing?

Response:- Always DKF = 2, RHK = 8

(d) Stains on bath, basins etc.?

Response:- Always DKF = 12, RHK = 7

(e) Furring of appliances?

Response:- Always DKF = 50, RHK = 42

(f) Noticeable taste of water?

Response:- Always DKF = 4, RHK = 0

(g) Noticeable colour of water?

Response:- Always DKF = 0, RHK = 3

(h) Noticeable smell of water?

Response:- Always DKF = 0, RHK = 0

Question:- Are you satisfied with the quality of your water?

Response:-	Yes	DKF = 95, RHK = 98
	No	DKF = 3, RHK = 2
	Unanswered	DKF = 2, RHK = 0

9. ANNEXURE D

WILLINGNESS/ABILITY TO PAY, OR TO CONSERVE.

Question:- Do you think that R1.50 per 1000 litres is cheap, reasonable, or expensive?

Positive response:- Cheap Male = 12, Female = 15

Reasonable Male = 39, Female = 68

Expensive Male = 12, Female = 39

Unanswered Male = 2, Female = 13

Question:-If the cost of water were to rise, which uses would you restrict?

(a) Pool filling?

Positive response:- Male = 7, Female = 27

(b) Toilet flushing?

Positive response:- Male = 20, Female = 50

(c) Car washing?

Positive response:- Male = 34, Female = 66

(d) Re-using bath-water?

Positive response:- Male = 24, Female = 88

(e) Garden watering?

Positive response:- Male = 41, Female = 85

Question:- At what price of water would you take further water saving measures?

Positive response:-	R1.65	Male = 13, Female = 25
	R1.75	Male = 9, Female = 9
	R1.95	Male = 11, Female = 38
	R2.25	Male = 8, Female = 8
	R2.55	Male = 3, Female = 8
	R3.00	Male = 7, Female = 13
Unanswered		Male = 10, Female = 18
Unable to take further measures		Male = 4, Female = 16

10. ANNEXURE E

QUESTIONNAIRE DETAILS.

VERWOERDBURG QUESTIONNAIRE

- The results of this survey will be incorporated into a report to the Water Research Commission, making recommendations for ground water management.
- The names of the respondents will not be recorded on the answer forms, they have been chosen only to ensure that our respondents are resident in the target areas for our survey.
- The areas involved are Rooihuiskraal/The Reeds, and Doringkloof.
- responses are sought from each area.
- Information was derived from the Valuation Roll and the Pretoria Telephone Directory. No 'marketing lists' were involved.

1. MALE/FEMALE________

2. How long have you lived at this address?
   ______YEARS

33. Do you know where the Municipality gets its water supply from in your area?
   A. BOREHOLES.
   B. RAND WATER BOARD
   C. MIXTURE OF ABOVE
   D. HARTEBEESPORT DAM
   E. DON'T KNOW

4. Which do you think is the cheaper source of Municipal water,
   A GROUND WATER
   B RWB WATER?
   C DON'T KNOW

5. What is the cost of Municipal water per 1000 litres? (R1.50)
   A._______ RANDS
   B. DON'T KNOW

6. Do you think this is
   A. CHEAP
   B. REASONABLE
   C. EXPENSIVE

77. How much is your monthly water account?

A._________RANDS
B. DON'T KNOW

8. Do you own a pool?

9. Do you have a borehole on the property?
A. YES
B. NO
If yes, go to next question
If no, go to Question 11

10. Do you use the borehole water for any of the following:-
- A. GARDEN WATERING
- B. CAR WASHING
- C. POOL FILLING
- D. NONE OF THE ABOVE

111. Do you use Municipal water for any of the following:-
A. GARDEN IRRIGATION
B. CAR WASHING
C. POOL FILLING
NONE OF THE ABOVE

12. Do you consciously conserve water?
A. YES
B. NO

13. If the price of water were to increase, which uses would you restrict?
- A. GARDEN WATERING
- B. CAR WASHING
- C. POOL FILLING
- D. TOILET FLUSHING
- E. RE-USING BATH WATER

14. At what price of water would you take (further) water saving measures,
A. R1.65 (10% increase),
B. R1.75 20%;
C. R1.95; 30%
D. R2.25; 50%
E. R2.55; 70%
F. R3.00, 100%
G. CANNOT TAKE FURTHER MEASURES

NEXT QUESTION FOR BOREHOLE OWNERS ONLY

1515. At what price increase of municipal water would you use your borehole for domestic supply?
A. R1.65 (10% increase),

B. R1.75 20%;
C. R1.95; 30%
D. R2.25; 50%
E. R2.55; 70%
F. R3.00, 100%
G. ALREADY DO
H. NEVER WOULD

16. Does your family drink plain tap water?
A. NEVER
B. SOMETIMES
C. ALWAYS.

17. Do you use a water filter pot?

18. Do you experience any of the following,

Dry itchy skin after bathing
A. NEVER
B. SOMETIMES
C. ALWAYS

I. Flakes floating in water
A. NEVER
B. SOMETIMES
C. ALWAYS

Clogged plumbing (shower heads, taps etc.)
A. NEVER
B. SOMETIMES
C. ALWAYS

Stains on baths, basins, taps
A. NEVER
B. SOMETIMES
C. ALWAYS

Furring of appliances (kettles, irons replaced geysers etc.)
A. NEVER
B. SOMETIMES
C. ALWAYS

Noticeable taste If yes,(a) bitter (b)metallic (c)chlorine (TICK)
A. NEVER
B. SOMETIMES
C. ALWAYS

Colouration of water. If yes, What colour?

A. NEVER
B. SOMETIMES
C. ALWAYS
D. WRITE COLOUR

Smell of water. If yes, (a) chlorine (b) earthy (TICK)
A. NEVER
B. SOMETIMES
C. ALWAYS

19. Are you satisfied with the quality of your water?
A. YES (go to 31)
B. NO

20. If no, has it become
A. BETTER
B. WORSE
in recent years?

21. What do you believe to be the cause of water quality problems?.
A. POLLUTION
B. TREATMENT PROCESS
C. SOURCE OF WATER SUPPLY

22. Would you be prepared to pay more for a better quality Municipal water.?
A. YES
B. NO

23. If yes, how much more?
A. R1.65 (10% increase) ,
B. R1.75 20%;
C. R1.95; 30%
D. R2.25; 50%
E. R2.55; 70%
F. R3.00, 100%

24. Do you buy bottled mineral water?
A. NO
B. YES.

25. If yes, Do you think bottled water is
A. SAFER
B. HEALTHIER
C. TASTES NICER?

26. Do you have any other comments concerning your water supply?

Thank you very much for your time, and the valuable information you have given us.

APPENDIX F

ATLANTIS CASE STUDY

1. BACKGROUND

Atlantis lies some 45km north of Cape Town, close to the West Coast. Atlantis residents have suffered high unemployment levels, poverty, increasing social problems and a lack of adequate services. From 1989 to 1991 21 factories closed and 2 000 industrial jobs were lost. Health workers reported an increased incidence of poverty related health problems.

2. DEMOGRAPHICS

Atlantis is located within the Malmesbury Magisterial District. In examining its demographic profile it is necessary to consider it within the context of the Magisterial District. Please note that a characteristic of demographic data in South Africa is that usually data is provided on a regional basis and that accurate and up to date data on towns like Atlantis is not always readily available.

2.1. POPULATION

The following table reflects the adjusted enumerated population of Atlantis as adjusted by the Central Statistical Service (1980) and the Bureau for Market Research (1985). Also included in this table is the enumerated population of the Malmesbury Magisterial District as reflected in the unadjusted 1991 census.

POPULATION OF ATLANTIS

YEAR	RACE	ATLANTIS
	TOTAL	13 660
1980 CSS ADJUSTED	White	30
	Coloured	13 610
	Asian	6
	Black	14
	TOTAL	30 451
1985 BMR ADJUSTED	White	155
	Coloured	30 266
	Asian	21
	Black	9
	TOTAL	Not Available
1991 CENSUS UNADJUSTED	White	Not Available
	Coloured	Not Available
	Asian	Not Available
	Black	Not Available

SOURCE: Atlantis Development Forum, 1992

The Development Bank of Southern Africa (DBSA) calculates a growth rate of 11.55[1] for the period 1985 - 1990 for Atlantis. Based on this growth rate, the population of Atlantis for 1992 is 65 896.

2.2. Age Distribution

The age breakdown of the Malmesbury Magisterial District reflects a typically young coloured population with 49% of the population being between the ages of 0 and 20

1 Development Bank of Southern Africa - A Regional Profile of the Southern African Population and its Urban and Non Urban Distribution, 1991, p. 133.

years. The potentially economically active population (20 -64 years) represents a further 49% of the total coloured magisterial district population.

Atlantis reflects a similar trend.

1) Development Bank of Southern Africa - A Regional Profile of the Southern African Population and its Urban and Non Urban Distribution, 1991, p. 133.

AGE BREAKDOWN IN ATLANTIS

0 - 15 YEARS	35%
15 - 59 YEARS	61%
60 + YEARS	04%

SOURCE: Population Development Programme, 1990

2.3. EDUCATION LEVELS

LEVEL OF SCHOOLING IN ATLANTIS

Secondary School and Higher	45%
Primary School	33%
Not Schooled	22%

SOURCE: Population Development Programme, 1990

12 792 children attend school in Atlantis, some 20% of the total population. The majority are in primary school. Matric students only represent 3% of the total school going population in Atlantis.

2.3.1. Tertiary Education Facilities

Atlantis Technical Institute is run by the Department of Education and Culture. The institute offers courses in:

- Commercial Studies
- Educare Studies
- Secretarial Studies
- Management Studies
- Technical Studies
- General Studies

3. HEALTH SERVICES

There is one Day Hospital, the Wesfleur Day Hospital, which is controlled by the Cape Provincial Administration (CPA). The hospital is staffed by two to three doctors.

3.1. Clinics

There are two clinics in Atlantis, one situated in Protea Park and the other in Saxon Sea. Both clinics have an average staff size of seven people. Doctors attend the clinics twice a week. The rate of TB is high.

3.2. PRIVATE HEALTH PRACTITIONERS

There are a total of 35 health workers operating in the community; including

- 17 General Practitioners
- 6 Dentists
- 4 Medical specialists

4. THE ECONOMY

Atlantis falls within the economic fringe of Greater Cape Town. It is located in the southern part of the 03 Planning Region and is adjacent to Greater Cape Town Planning Region. It is joined by a group of several medium sized fringe towns. The group includes Paarl, Stellenbosch, Strand, Somerset West, Wellington and Kuils River.[2]

In Atlantis the manufacturing sector is particularly strong, producing some 66% of the geographical product. Commercial and community service sectors are underdeveloped.

ECONOMIC STRUCTURE AND GROWTH

	ATLANTIS
Population in urban centre '000 (1980)	65
1990 GDP (%)	
- Agriculture	1.5
- Manufacturing	65.5
GDP Growth Rate % per annum	
- 1970 - 1980	3.8
- 1980 - 1985	3.1

SOURCE: WESGRO, 1992

[2] WESGRO South Africa's Leading Edge, 1992. p. 17.

5. INDUSTRY

TYPES OF INDUSTRIES IN ATLANTIS

INDUSTRY TYPE	TOTAL FACTORIES	TOTAL EMPLOYEES
Automotive & Engineering	17	3 117
Food	6	749
Electrical Engineering	3	1067
Light Engineering	7	335
Plastics	5	420
Furniture	5	419
Paper & Packaging	5	880
Drugs & Chemicals	7	277
Building Materials	10	518
Household Goods	4	265
Clothing	12	1 434
Textiles	14	2 083
Transport	1	100
Printing	1	125
Miscellaneous	9	612
TOTAL	106	12 401

SOURCE: Atlantis Development Forum, 1992

The single largest sector is the automotive and engineering sector which is represented by some 17 firms employing 3 117 people (25% of the total labour force). The two other largest sectors are clothing and textiles. Other sectors are food, electrical and light engineering, plastics, furniture, paper and packaging, drugs and chemicals and building materials.

Of the total number of people employed in Atlantis, 60% of people are employed in the manufacturing sector, 1.4% in agriculture and mining, 16.3% in electricity, transport and construction, 13.5% in community services and 9.3% in commerce and finance.

5.1. SECTORAL ANALYSIS

i) Automotive and Engineering

ADE is the prominent company in Atlantis. It accounts for a large percentage of total employment and investment in the town. The attached graphs show the company's profits and turnover. A diagram on distribution of sales (including exports is also shown). ADE produces under license from Mercedes Benz AG, Perkins Engines and Volkswagen South Africa.

Closely linked to ADE is Probuilt Diesel and Atlantis forge, the latter producing crankshafts and other aluminium castings.

Alongside these firms are factories producing steering wheels (Bremco), air filters (GUD), silencers (Grapnel) and safety belts (Intersafety Transport). Grapnel has two plants, which service a network of the company's Kwit Fit service workshops.

ii) Food

Three of the six food processing plants are owned by Bocomo (which produces Weetbix amongst other products). The other plants all use fish as ingredients.

iii) Clothing and Textiles

Together the clothing and textile sectors represent the largest sector in Atlantis with some 26 factories employing some 3 517 people which represents 28% of the work force. This sector is vulnerable because of the following:

* The industry is in decline in retreat in South Africa, not least because of the threat of Tariff Protection reductions.
* This sector is very sensitive to changes in the national economy as a consumer driven sector. To an extent, the fortunes of the sector go along with real disposable income which has been squeezed in recent years.

6. EMPLOYMENT

The attached table provides a detailed breakdown of employment per firm in Atlantis. The figures do not quite add up to those on page 5, since some firms (albeit a minority) are not included. Collectively, the following table describes the economically active population.

THE DE FACTO LABOUR FORCE IN THE MALMESBURY MAGISTERIAL DISTRICT

YEAR	DE FACTO LABOUR FORCE	ECONOMICALLY ACTIVEPOPULATION	MINIMUM INVOLVEMENT IN PERIPHERAL SECTOR	AVERAGE ANNUAL GROWTH RATE OF THE ECONOMICALLY ACTIVE POPULATION (1980-1990)
1980	35 758	30 482	5 276	5,6
1985	46 670	41 722	4 948	5,6
1990	57 920	52 419	5 501	5,6

SOURCE: DBSA, 1991

THE LABOUR SUPPLY AND DEMAND FOR THE MALMESBURY MAGISTERIAL DISTRICT

YEAR	ECONOM-ICALLY ACTIVE POPULA-TION	PARTICI-PATION RATE	DE FACTO SUPPLY OF LABOUR	UNEM-PLOYMENT	DEMAND FOR LABOUR	UNEM-PLOYMENT RATE
1980	30 482	66.2	30 482	1 244	29 238	4.1
1985	41 722	68.0	41 722	2 231	39 491	5.3
1990	52 419	68.7	52 419	3 309	49 110	6.3

SOURCE: Atlantis Development Forum, 1992

Most of the firms in Atlantis are large, employing more than 99 workers. Firms employing less than 15 are in the minority.

EMPLOYERS IN ATLANTIS

LARGE (more than 99 employees)	35
MEDIUM (50 to 99 employees)	25
SMALL (10 to 49 employees)	29
VERY SMALL (1 to 9 employees)	16

SOURCE: Atlantis Development Forum, 1992

Unemployment is a critical issue. The employment capacity of Atlantis decreased steadily from 1989 to 1992.

6. AGRICULTURE

Though the soil in the district is poor and sandy, the district has many farms. The district produces fruit, grain and vegetable crops. The most common fruit crops are pears, apples, grapes, plums, nectarines, apricots and prunes. The grape harvest, of mainly table grapes, represents some 13% of the total Western Cape harvest. The region produces a wide range of grain crops characterised by wheat, maize, oats, barley, and rye. Maize dominates grain production with 995 000 ha. Fresh produce in the form of vegetables is limited because of the poor state of the soil. The exception to this is potato production with some 46 000 ha under cultivation. Cattle farming is not prominent. Chicken farming is well developed with one million fowls under production. Atlantis has no harbour. The fishing industry in the region is dominated by Saldanha and Cape Town. The two fish processing firms located in the Atlantis Industrial area source their supply of raw material elsewhere.

There are several small holdings close to Atlantis ranging in size from 23 acres to 100 acres. Most are not commercial producers.

7. WATER SUPPLY[3]

Atlantis is supplied with water from two ground water aquifers located between the existing town and the coast. One of these is located at Silwerstroom and the other to the south at Witzand. There is potential to develop a new aquifer at Yzerfontein. The present and predicted capacities of the well fields at these aquifers as given below:

'WELL FIELD CAPACITY (MILLION CU.M/YEAR)

	WELL FIELD	CUMULATIVE
PRESENT		
Silwerstroom 1 and 2	2,1	2,1
Witzands 1 and 2	5,6	7,7
FUTURE		
Witsands 3	2,0	9,7
Silwerstroom 3	1,7	11,4
Yzerfontein	5,6	17,0

SOURCE: Atlantis Development Forum, 1992

The peak annual demand to date has been 5,1 million cu.m/year. Well fields have adequate capacity for the medium term.

From the well fields the flow is pumped to 5 reservoirs which have a combined capacity of 90 000 cu.m. The combined capacity of the pumping system is 370 litres/s.

Initially no treatment of the water was necessary. However, problems have been experienced with hardness of the water from the Witzands well field, and a softening plant was therefore installed there during the late 1980's.

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[3] All data and information obtained from: Atlantis Profile Base Document, Atlantis Development Forum, November 1992.p.p. 126-132; except data on individual consumption per firm and tariffs which were obtained from the Regional Services Council.

7.1. BULK DEMAND

Demand grew steadily in the period 1980 to 1987 when the demand stabilised and subsequently decreased in 1991 and 1992. Residential demand makes up approximately two thirds (66%) of total water demand in Atlantis with industry accounting for the remaining one third. The attached table shows water consumption by the industries of Atlantis for the period May 1992 - January 1993. The figures were sourced from Regional Services Council data.

Industrial demand stabilised in 1988 and has declined slowly since then. The Residential water demand peaked in 1987 and has decreased slightly since.

7.2. HOUSEHOLD CONSUMPTION

There are 8 424 housing units in Atlantis and each has a metered water supply. With total residential demand currently at 3,3 million cu/m/year, the average consumption per household is currently 1 000 litres/day.

On a per capita basis, water is currently being used at a rate of 145 litres per capita per day.

7.3. INDUSTRIAL CONSUMPTION

There are approximately 140 consumers using water for industrial purposes. The average consumption is approximately 35 kl/day (1 000 kl/month). However, the consumption is skewed with a few very large consumers (see attached figures). About half of industries consume between 100 and 1 000 kl/month and a further quarter between 10 and 100 kl/month.

7.4. INSTITUTIONAL ARRANGEMENTS

The bulk water supply is the responsibility of the Waterworks Branch of the WCRSC who carry out this function on an agency basis for the House of Representatives.

TARIFFS (1994/95)

Consumption Tariffs (per kl)

First 12 kl per month	R1,25
Next 23 kl per month	R1,65
More than 35 kl per month	R1,75
Service Charge (per month)	R2,50
Availability charge (per annum)	R30,00
Standpipes	Normal Tariffs

ATLANTIS INDUSTRIAL WATER CONSUMPTION
Kl MAY 1992 - JANUARY 1993

	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.'93
Flexo Products	386	490	509	569	547	186	196	230	215
Strebel Trading	*	*	*	*	*	*	*	*	*
Stripform Packaging	93	169	77	99	107	100	95	67	65
Structa Industries	*	*	*	*	*	*	*	*	*
Summertime	120	202	250	256	472	445	294	157	113
Sun Packaging	362	524	958	514	408	564	669	1134	2013
Super Service Plus	*	*	*	*	*	*	*	*	*
Swartland Wines	*	*	*	*	*	*	*	*	*
Technoserve	*	*	*	*	*	*	*	*	*
Tedelex	2374	2805	2624	2576	2817	3243	3600	4082	4316
Tensilon	1138	966	1140	976	564	2742	2107	1837	766
Tiger Tiles	222	190	191	210	199	278	215	192	189
Today's Frozen Foods	4059	6568	6553	6029	6738	6051	9068	8255	15251
Tommy's Hire	*	*	*	*	*	*	*	*	*
Transcope Steel	*	*	*	*	*	*	*	*	*
Transnet	*	*	*	*	*	*	*	*	*
Unita Planned Furniture	1930	490	818	995	2401	2823	2866	3620	4002
Van Leer	2823	2989	3262	3415	3461	4161	4516	4478	4468
Vita Foam	4	118	113	120	174	349	1231	5170	6451
Vrede Textiles	203	279	316	204	259	265	243	373	554
Wesfleur Scrapyard	*	*	*	*	*	*	*	*	*
Winsters	*	*	*	*	*	*	*	*	*
Atlantis Forge	1385	1132	346	377	346	1146	1285	1807	1701
Atlantis Import & Export	105	118	118	201	936	1366	756	245	161
Atlantis Ind. Textiles	*	*	*	*	*	*	*	*	*
Atlantis Panels	*	*	*	*	*	*	*	*	*
Atlantiserve	*	*	*	*	*	*	*	*	*
Baja Industries	*	*	*	*	*	*	*	*	*
Barbican	*	*	*	*	*	*	*	*	*
Bio Polymers	*	*	*	*	*	*	*	*	*
Bokomo Weetbix	*	*	*	*	*	*	*	*	*
Braitex	*	*	*	*	*	*	*	*	*
Bremco	249	270	348	348	219	332	259	153	271
Brits Textiles	0	0	0	0	0	0	0	0	0
Broadway Footwear	322	438	393	387	484	439	268	408	397
Cape Gaslet	*	*	*	*	*	*	*	*	*
Cape Town Manufact.	*	*	*	*	*	*	*	*	*
Carlec Auto Electrical	*	*	*	*	*	*	*	*	*
Continental China (Stoneware)	1750	1750	1450	1445	1872	1804	1512	1060	1425
C.K. Manufacturing	265	472	355	271	451	319	360	176	183
De Kocks Welding	*	*	*	*	*	*	*	*	*
Desire Quilted Prod.	130	195	180	227	387	288	243	356	309
Duncker & Louw (Uphol) } (Wood) }	252	274	65	50	230	210	1028	1100	1664
Elegant Development	*	*	*	*	*	*	*	*	*
Elvinco Plastics	698	911	753	842	803	784	666	583	518
Epping Handling Systems	20	21	13	15	67	119	61	60	60
Eversteel	*	*	*	*	*	*	*	*	*
Express Coal Co.	*	*	*	*	*	*	*	*	*
Flame Candles	18	31	65	26	37	43	72	45	118

ATLANTIS INDUSTRIAL WATER CONSUMPTION
KI MAY 1992 - JANUARY 1993

	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.'93
Forest Woodcraft	*	*	*	*	*	*	*	*	*
GR Pharmaceuticals	257	309	46	635	493	461	879	1004	556
Garex Enginnering	4	4	6	4	8	6	5	3	2
Golden Arrow	*	*	*	*	*	*	*	*	*
Grapnel	881	905	1225	899	812	897	824	420	741
GHK Perrins Agencies	*	*	*	*	*	*	*	*	*
GUD Filters	677	676	607	751	1004	844	855	746	678
HK Manufacturing	192	263	498	634	603	617	632	330	860
Jiffy Manufacturing	128	135	122	42	53	52	83	116	120
Jointech	*	*	*	*	*	*	*	*	*
KAS Construction	*	*	*	*	*	*	*	*	*
Kaymac Industries	444	454	267	435	778	556	694	745	680
KNK Enterprises	*	*	*	*	*	*	*	*	*
Link Sportswear	*	*	*	*	*	*	*	*	*
Luomo Atlantis	215	213	189	143	151	170	145	120	167
Macplant	172	200	201	189	199	168	198	181	128
Mary's Creations	*	*	*	*	*	*	*	*	*
Minus 40	*	*	*	*	*	*	*	*	*
Muller Knitwear	232	210	175	183	51	376	398	200	659
Nelco Furniture	*	*	*	*	*	*	*	*	*
Neutran Paints	138	102	111	124	309	1114	1957	1430	632
Orion Organisation	30	0	38	55	74	64	168	179	98
Overpart & Bearing	*	*	*	*	*	*	*	*	*
Packem CC	*	*	*	*	*	*	*	*	*
Palco Motors	21	13	10	13	24	45	92	0	67
Pine Doors	*	*	*	*	*	*	*	*	*
Plastic Furniture	126	128	134	214	245	295	242	918	846
Poggenpoel Transp.	*	*	*	*	*	*	*	*	*
Poolbrite Chemicals	*	*	*	*	*	*	*	*	*
Powdermet	213	140	115	119	113	119	107	64	59
Prima Tyres	7	9	7	9	11	02	18	21	29
Prime Brick	*	*	*	*	*	*	*	*	*
Promeal	*	*	*	*	*	*	*	*	*
Rosty Distri	*	*	*	*	*	*	*	*	*
Rotex Fabrics	12831	12765	15435	16434	1756	17426	15433	16021	7197
SA Fine Worsteds	15522	16466	16877	14707	15412	18949	17773	11652	1257
Safety Transport Inter.	*	*	*	*	*	*	*	*	*
Saxonsea Hardware	*	*	*	*	*	*	*	*	*
SBDC	566	683	620	649	722	185	356	408	250
Seagull Industries	*	*	*	*	*	*	*	*	*
Software Automation	*	*	*	*	*	*	*	*	*
3M Company	55	0	0	14	24	28	18	9	6
A1 Workwear & Safety	*	*	*	*	*	*	*	*	*
Abrahams Signs	*	*	*	*	*	*	*	*	*
AEG Energy Control	*	*	*	*	*	*	*	*	*
AMC Classic	*	*	*	*	*	*	*	*	*
Anglomar	1366	729	1120	571	88	1410	1388	126	134
ARD Concrete	581	466	314	153	99	76	65	71	74
Aries Packaging	300	339	365	351	404	394	348	360	318
Arrow Carpets	*	*	*	*	*	*	*	*	*
Arwa Consortium	*	*	*	*	*	*	*	*	*
Arwa Yarns	584	492	301	12	277	1415	464	881	541
Atlantis Diesel Engines	731	836	778	780	868	954	1071	1308	1295

INDUSTRIAL WATER CONSUMPTION
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ROTEX

12431	12599	15236	16045	1320	17135	14860	15305	6515
400	166	199	389	436	291	573	716	682
12831	**12765**	**15435**	**16434**	**1756**	**17426**	**15433**	**16021**	**7197**

ARIES PACKAGING

54	65	69	74	63	46	55	60	38
119	136	177	170	219	223	194	195	143
127	138	119	107	122	125	99	105	137
300	**339**	**365**	**351**	**404**	**394**	**348**	**360**	**318**

DUNCKER & LOUW

220	128	46	38	199	167	931	1054	1135
32	146	19	12	31	43	97	46	529
252	**274**	**65**	**50**	**230**	**210**	**1028**	**1100**	**1664**

ELVINCO

118	168	56	105	62	48	48	32	41
580	743	697	737	741	736	618	551	477
698	**911**	**753**	**842**	**803**	**784**	**666**	**583**	**518**

SUNPACKAGING

0	0	3	1	0	0	1	0	0
264	452	482	431	305	404	385	479	716
0	0	0	0	0	1	58	299	506
35	0	0	0	0	0	0	0	0
0	0	0	0	0	0	4	0	0
0	0	0	0	1	1	0	2	0
0	0	5	0	0	0	0	0	0
63	72	51	81	101	157	184	354	791
0	0	417	1	1	1	37	0	0
362	**524**	**958**	**514**	**408**	**564**	**669**	**1134**	**2013**

ARWA YARNS

64	0	10	1	2	17	0	447	116
283	100	88	0	41	52	106	254	194
227	382	192	0	223	1335	345	150	225
10	10	11	11	11	11	13	30	6
584	**492**	**301**	**12**	**277**	**1415**	**464**	**881**	**541**

SA WORSTEDS

143	151	154	190	250	212	556	1166	1209
15379	16315	16723	14517	15162	18737	17217	10486	48
15522	**16466**	**16877**	**14707**	**15412**	**18949**	**17773**	**11652**	**1257**

SBDC

0	0	0	0	15	21	102	42	20
29	43	35	50	54	55	66	151	103
1	2	1	0	0	0	3	0	0
0	1	1	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
489	596	542	555	611	63	113	132	82
39	41	41	43	42	36	72	81	45
0	0	0	1	0	0	0	2	0
566	**683**	**620**	**649**	**722**	**185**	**356**	**408**	**250**

INDUSTRIAL WATER CONSUMPTION
Kl MAY 1992 - JANUARY 1993

GUD FILTERS									
	526	447	393	559	782	603	644	544	540
	151	229	214	192	222	241	211	202	138
	677	**676**	**607**	**751**	**1004**	**844**	**855**	**746**	**678**
TEDELEX									
	1735	2052	1825	1866	1887	2091	2465	2737	2767
	639	753	799	710	930	1152	1135	1345	1549
	2374	**2805**	**2624**	**2576**	**2817**	**3243**	**3600**	**4082**	**4316**
TENSILON									
	639	656	894	765	337	2459	1803	1441	506
	499	310	246	211	227	283	304	396	260
	1138	**966**	**1140**	**976**	**564**	**2742**	**2107**	**1837**	**766**
TIGER TILES									
	19	15	13	19	5	12	9	9	5
	203	175	178	191	194	266	206	183	184
	222	**190**	**191**	**210**	**199**	**278**	**215**	**192**	**189**
TODAY's FROZEN FOODS									
	0	0	0	0	175	0	20	0	0
	3518	5820	5418	5298	5624	5120	8187	7286	14030
	541	748	1135	731	818	931	861	930	1221
	0	0	0	0	121	0	0	39	0
	4059	**6568**	**6553**	**6029**	**6738**	**6051**	**9068**	**8255**	**15251**
VAN LEER									
	2683	2989	3217	3163	3250	3329	3719	3450	2992
	140	0	45	252	211	832	797	1028	1476
	2823	**2989**	**3262**	**3415**	**3461**	**4161**	**4516**	**4476**	**4468**
VITA FOAM									
	0	118	113	120	174	349	1231	5129	6232
	4	0	0	0	0	0	0	17	219
	0	0	0	0	0	0	0	24	0
	4	**118**	**113**	**120**	**174**	**349**	**1231**	**5170**	**6451**

GLOSSARY

Price Elasticity of Demand: This is the percentage change in the quantity of a commodity demanded divided by the percentage change in its price at that that level of demand.

Property Rights: These define and limit the rights of members of society with respect to resources and allow the right holders to form secure expectations regarding benefits stemming from these right.

Scarcity: The situation which arises when demand for any given commodity outstrips the supply of that commodity.

Social Welfare: This is the total well-being of a community. It comprises the sum of the benefits enjoyed by the community. Social welfare cannot be measured because it is not possible to sum the benefits enjoyed by the individuals composing the community. *(See also Consumer Surplus.)*

Sustainability: This concept captures the view that there is a need to treat environmental protection and continuing economic growth as mutually compatible rather than as necessarily conflicting objectives.

Tradable permits or consents: are permits to discharge effluent which initially may be sold or auctioned or granted free of charge. They may then be traded according to certain rules, but may be recalled in part by the issuing authority without compensation.

SELECTIVE BIBLIOGRAPHY

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Neher, Philip A., Natural Resource Economics - Conservation and Exploitation, chapter 14, Cambridge University Press, Cambridge, 1990.

Fano, E. and Brewster M.M., Issues in Ground water Economics, in: E. Custodio and A. Gurgui (eds.), Ground water Economics, Developments in Water Science, No. 39, Elsevier Publishers, Amsterdam 1989, pp. 485-507.

O'Mara, Gerald T., Issues in the Efficient Use of Surface and Ground water in Irrigation. Wold Bank Staff Working Paper No. 707, The World Bank, Washington DC, 1984.

Chakravorty, Ujjayant, Roumasset & James, Efficient Spatial Allocation of Irrigation Water, in: American Journal of Agricultural Economics, Vol. 73, No. 1, February 1991, pp. 165-173.

Rosen & Sherwin, Hedonic Prices and Implicit Markets: Product Differentiation in Pure Perfect Competition, in: Journal of Political Economy, No. 82, January/February 1974, pp 34-55.

Crouter, Jan P., Hedonic Estimation Applied to a Water Rights Market, in: Land Economics, Vol. 63. No. 3, August 1987.

Torell, L. Allen, Libbin, Janes D. and Miller, Michael D., The Market Value of Water in the Ogallala Aquifer, in: Land Economics, Vol. 66, No. 2, May 1990, pp. 163-175

Chan, Arthur H., To Market or Not to Market: Allocation of Interstate Waters, in: Natural Resources Journal, Vol. 29, Spring 1989, No. 2, pp 529-547.

Charney, Alberta H. and Woodard, Gary C., Socioeconomic Impacts of Water Farming on Rural Areas of Origin in Arizona, in: American Journal of Agricultural Economics, Vol. 72, December 1990, pp 1193-9.

Chan Arthur H., Rural Community Values in Ground water Marketing, in: Journal of Economic Issues, Vol. 24, No. 2, June 1990, pp 463-472.

Tsur, Yacov, The Stabilization Role of Ground water When Surface Water Supplies Are Uncertain: The Implications for Ground water Development, in: Water Resources Research, Vol. 26, No. 5, May 1990, pp. 811-818

Howitt, Richard E. and Mean, Phillippe, An Economic Approach to Ground Water Quality Management.

Harris, R.C. and Skinner, A.C., Controlling Diffuse Pollution of Ground water from Agriculture and Industry, in: Journal of the Institution of Water and Environmental Management, Vol. 6, No. 5, October 1992, pp. 569-575.

Raucher, Robert L., The Benefits and Costs of Policies Related to Ground water Contamination, in: *Land Economics*, Vo. 62, No. 1, February 1986, pp. 33-45.

Norris, Karen H., 'The Stagnation of Texas Ground Water Law: A Political v Environmental Stalemate' (1990) 22 St Mary's Law Journal 493 at 507-509

Hahlo and Kahn. The South African Legal System and its Background

Hayton, Robert D., 'The Ground Water Legal Regime as Instrument of Policy Objectives and Management Requirements' (1982) 22 Natural Resources Journal 119 at 131.

Kyl, Jon L., 'The 1980 Arizona Groundwater Management Act: From Inception to Current Constitutional Challenge' (1982) 53 University of Colorado Law Review

Canaille 'A History of the Arizona Groundwater Management Act' (1982) Arizona State Law Jornal

Gray, Kevin, 'Property in Thin Air' (1991) Cambridge Law Journal 252.

Carole Lewis 'The Right to Private Property in a New Political Dispensation in South Africa' (1992) SAJHR

Lewis, Carole, "The Modern Concept of Ownership of Land" (1985) Acta Juridica

Lyster, Rosemary, '"Protected Natural Environments": Difficulties with environmental land use regulations and some thoughts on the property clause' (1994) 2 De Jure

Chaskalson, Matthew, 'The Problem With Property: Thoughts on the Constitutional Protection of Property in the United States and the Commonwealth' (1993) SAJHR 389.

Murphy, J., 'Property Rights in the new constitution: an analytical framework for constitutional review' (1993) THRHR 608

Bauman, Richard W., 'Property Rights in the Canadian Constitutional Context' (1992) SAJHR 344

Chaskalson, Matthew, 'The Property Clause: Section 28 of the Constitution' (1994) SAJHR 131.

Steiner, P.O., The Role of Alternative cost in Project Design and Selection, Quarterly Journal of Economics, Vol 79, No 3, August 1965.

Williams, CJ et al, "Input-Output Tables and Linear Programming techniques as applied to Constrained Water Supply Conditions", , NPI Conference on research in Economics, Business Economics and Manpower.