THE POTENTIAL FOR THE USE OF ECONOMIC INSTRUMENTS TO PROTECT THE QUALITY OF WATER RESOURCES IN SOUTH AFRICA

FINAL REPORT

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EXECUTIVE SUMMARY

Background

It is generally accepted that the traditional legislative, or command-and-control, approach to managing water quality faces many difficulties. The need to prescribe standards and procedures individually suited to the circumstances of various polluters presents daunting administrative problems. The policing of direct controls is often difficult and costly, and can be inequitable, with widely differing consequences for those subjected to them. They may also have dubious incentive effects, failing to achieve additional pollution abatement even when this could be done at minimal additional cost.

These difficulties led environmental economists world-wide to develop an alternative approach, based on the use of economic incentives. Theory suggests that the greater flexibility that these offer could lead to significant cost savings, and a series of empirical studies has born this out. These results were documented in the Water Research Commission (WRC) project report entitled "The Application of Economic Principles to Water Management Decision-making in South Africa", which was published in 1994, and which concluded by saying, *inter alia*, that economics could make a significant potential contribution by providing an alternative to the traditional command-and-control macro management approach to deal with water quality problems.

Thus the economic approach to water quality control may offer significant benefits by way of enhanced effectiveness and reduced costs in South Africa, although to date there had been little attempt to examine the pros and cons of the approach empirically. It is the purpose of this report to make such an empirical examination, and to build upon it in a practical situation in South Africa.

Detailed Statement of Objectives

The aims of this research project as set out in the contractual brief are as follows:

- To investigate the practicality of employing economic measures to protect water quality in South Africa;
- to determine the benefits by way of cost savings to either the public or private sectors, that could result from adopting an economic approach to water quality management as a complement to the more traditional approach embodied in current water quality management plans;

- to analyse in detail criteria for successful implementation of the economic approach; and
- to compile a detailed economic strategy for a selected catchment to serve as a demonstration project.

During the execution of the project the four aims set out above were interpreted to comprise the following tasks:

Task 1: Provide a literature survey (focusing on practice rather than theory) from which a toolbox of economic instruments for water pollution control relevant to South African catchments could be assembled.

Task 2: Postulate economic instruments suitable for controlling sulphate pollution in the upper Olifants catchment, and to test their feasibility by simulation. For the simulation to be meaningful, it would need to use a data set that was truly representative of the activities taking place in the catchment. (In the event the data collection task proved to be unmanageable, and recourse was made to a dummy data set, where some data was be simulated. It was felt that this would not detract from the value of the exercise, as it would provide an opportunity for the principles of the chosen economic instruments to be observed in action.)

Task 3: Exercise two models designed and implemented to demonstrate the efficacy of the chosen economic instruments in the relevant catchment.

Task 4: Combine the conclusions from the literature survey and the outcome of the simulation exercise.

ECONOMIC INSTRUMENTS AND WATER QUALITY MANAGEMENT

South Africa's total exploitable water resources, both surface and ground water, are estimated to be 38 000 million cubic metres per annum. The current demand for water is 18 500 million cubic metres per annum. Whilst this suggests a situation of surplus, it must be remembered that this water is poorly distributed relative to areas experiencing economic growth. Only a comparatively narrow region along the eastern and southern coastline is moderately well watered, while the greater part of the interior is semi-arid.

Water is used as an essential input into most production processes. Its excessive use and abuse can lead to increased pollution run off. Water pollution can be point source (easily monitored and measured) or non-point source (not so easily monitored or measured). Controlling point-source pollution from industry and agriculture has been widely discussed in the literature. In recent years market-based instruments have proved to be the most cost-effective and beneficial tools for the implementation of point-source pollution control.

Non-point sources of pollution cannot be monitored on a continuous and widespread basis with reasonable accuracy or at reasonable cost. This makes the application of economic-based policy instruments, which are used for point source pollution control and which rely upon relatively accurate and broadly accepted information, difficult.

None of the policies reported in the literature were found to use pure market mechanisms to control non-point pollution, although policies are often assessed to determine their economic efficiency.

Methods of controlling water demand in order to control pollution are simple and basic; for example, correct pricing and recycling water.

The earlier mentioned WRC project emphasises the importance of water pricing and has said in this regard that it is widely recognised that one of the best ways to improve water use efficiency, and thus control demand, is to increase the price of water.

Apart from the use of water pricing, one of the more innovative economic instruments that has the potential for controlling water pollution, from both point- and non-point sources, is water marketing.

The arguments for water marketing as a means to control pollution are similar to those for restrictive water allocations. The opportunity to market water merely acts as an incentive to ensure that those who have more water than they really require are encouraged to determine their real needs and then sell the remainder for a market related price, thereby increasing and diversifying their income.

In the literature, it is however, pointed out that unrestricted water markets can impose significant costs on other water users, such as rural communities and the environment. An analysis of the impact of water marketing on water availability and environmental quality found that water marketing can lead to a reduction in water use by agriculture.

Property rights are also important so far as water marketing is concerned: they define and limit the rights of members of society with respect to water resources and allow the right holders to form secure expectations regarding benefits stemming from their rights.

The literature on water rights is to a large extent concerned with the efficiency of allocations of water where there are legal and institutional constraints on the trading of water rights.

From a legal perspective, water in South Africa is regarded as being either public or private. Private individuals and organisations, however, cannot sell public water. The private sale of water rights is permitted in South Africa. Unfortunately, as agricultural land without water rights is only worth a fraction of land with rights, the purchasing of water rights invariably means purchasing the land to which such rights pertain. This latter option is referred to in the USA literature as water farming, and is often practised by municipalities and industries in South Africa which are situated in water scarce areas.

Water allocation, water pricing and water marketing are all demand management strategies that can add value to water, thereby ensuring its more considered utilisation. A crucial question is to what extent these strategies can be used to control water pollution in South Africa.

Water pricing increases can encourage better water use efficiencies by placing pressure on input production costs. In First-World South Africa it is the policy of the Department of Water Affairs and Forestry (DWA&F) that water supplies to urban consumers be priced such that the full cost of providing the service is recovered. Existing urban water supplies are therefore probably under-priced. Although water tariffs are used widely they are usually viewed as a means of cost recovery rather than as a way of managing demand.

In forecasting the way the demand for water varies with price the price elasticity of demand is an important parameter. There is, however, a dearth of information on water use and price elasticities of demand among agricultural and urban consumers in South Africa which severely hampers using this parameter in water pricing analysis.

The traditional view that water is price inelastic is based on a legacy of low prices being paid for water in most countries, particularly for agricultural use. Where water prices have been raised they have shown considerable price elasticity of demand.

Generally price increases will only be effective in conserving water and controlling pollution if the price exceeds the marginal value of the water to the user. Theoretically economic efficiency in the pricing process for a commodity will be achieved when the necessary assumptions underlying the formation of a competitive market are met.

Achieving efficient pricing which internalises economic externalities requires a certain amount of effort on the part of both government and the private sector. It involves some study of the costs of the specific economic activities and social goals at stake, which enables the trade-offs involved to be identified and valued in monetary terms.

Two important market-based instruments that can be used to manage water pollution are taxes and subsidies and it has long been recognised by economist that a subsidy per unit of pollution emission abatement provides the same incentive as a tax to entrepreneurs to internalise pollution externalities.

There are however, some subtle and important economic differences between these two policy instruments. In the first instance subsidies increase profits whilst taxes decrease them. Consequently the instruments provide opposite signals to firms regarding entry and exit to a particular market.

Pollution taxes or charges are command and control instruments that come in many forms and could be introduced into the water economy of South Africa in several different ways.

Before the likely impact of a pollution tax can be estimated, however, the objective and level of tax must first be determined.

Pollution taxes can have a number of objectives some of which may have nothing to do with pollution control. For example they may be used to raise revenue, prevent pollution from increasing any further and reduce pollution to a predetermined level.

So far as the level of the tax is concerned, experience from countries that have used pollution taxes for several years has shown that it is not so difficult to introduce a tax for revenue generating purposes, - one simply begins with a low level tax and periodically increases it until pollutant discharges start to fall.

Another economic instrument, which has a place in South African pollution control activities, is emission charges. So far as point source pollution is concerned, charges should be levied on the volume of water discharged and the pollutant concentration. Thus it requires good monitoring facilities at the point of discharge.

So far as non-point source pollution is concerned, it is possible to introduce and indirect emission charge for more insidious types of pollution by levying charges or taxes on the activities which give rise to this type of pollution. For example, a charge could be levied on fertiliser used by farmers.

In 1991, the DWA&F introduced a new approach to water pollution control. This stated that, in certain catchments, effluents should be discharged to the surface drainage system without the quality specifications of the receiving water (based on the needs of downstream users) being exceeded. These specifications are more commonly known as Receiving Water Quality Objectives (RWQOs) and are described in more detail in the Department of Water Affairs and Forestry publication, *Water quality management policies and strategies in the RSA*, (1991).

The RWQO approach was intended to overcome deficiencies in the existing water pollution control policy, i.e. returning effluents to the channel of origin, and the polluter pays principle.

Pollution control and environmental protection are costly: the selection of environmental quality standards to do this can illustrate some of the issues involved in using cost-benefit analysis for environmental policy making.

An environmental (or water) quality standard is either a legally established minimum level of cleanliness or a maximum level of pollution in some part of the environment. Cost-benefit analysis provides a basis for determining at what level an environmental quality standard should be set.

The research undertaken in this study also examined the use of economic instruments for water quality management in the Olifants River Catchment

The geographical extent of the upper-Olifants river, upstream and including Loskop dam incorporates several drainage basins, including the Olifants River catchment, the Klein-Olifants River catchment, the Wilge River catchment and the Klipspruit catchment, giving a mean annual run-off of some 469 millions of cubic metres per annum.

An investigation by Wates, Meiring and Barnard (WMB) confirms that the Olifants river catchment upstream of Witbank Dam is the single largest source of sulphate pollution. The sources of this pollution have been analysed by the Department of

Water Affairs and Forestry and Eskom, and the findings are that agriculture, power generation and coal-mining activities are responsible for the major sulphate pollution in the Witbank dam.

However, WMB conclude that non-point sources of pollution associated with coal mining activity constitute the single largest sulphate load contribution to Witbank Dam. The total impact of power station effluents was judged to be small. Furthermore, diffuse source pollution control on coal mining complexes was identified as the most attractive approach to salinity management.

Tradable permits are particularly powerful economic instruments for water quality management and they allow a polluter to discharge a certain amount of pollution over a given period of time into the water system. For permit trading to be considered, it is necessary to have a geographic collection of emission points whose total emissions are regulated. Such areas are referred to as bubbles. Permits can then be traded by players within bubbles to alter individual source emissions whilst keeping the overall emission from the bubble constant. The upper Olifants catchment is an ideal candidate for the establishment of a bubble.

As there is only one type of pollutant that is being targeted in this study, the trading of permits is probably a feasible option, despite the possibility of a "thin" market. The reason for this is that the various polluters are all known, as are their respective contributions to sulphate pollution. Thus information about trading partners, which is one of the requirements for a market to function effectively, can be obtained fairly quickly.

Effluent charges must be imposed on all monitored effluent discharges for which permits are not held. These must eventually be set at a level that discourages all but the most accidental and unforeseen discharges.

An economic instrument or mix of instruments that could best meet the needs of water quality management requirements in the Upper Olifants catchment should be able to offer:

- Effective management of non-point source pollution discharge;
- Ease and cost-effectiveness of administration;
- A measure of autonomy for each individual player in determining his pollution management strategy in order to minimise his costs;
- A revenue neutral system;

Whilst tradable permits as management instruments will fulfil most of the needs mentioned above, it is felt that the addition of a green tax to add urgency to the requirements of rationalising diffuse source pollution would be an advantage.

The theory of using green taxes and tradable permits was explored and their operation in conjunction with each other was demonstrated by using a pair of models. The object of the exercise was to illustrate that these two instruments are viable in a simulated situation, and that economic benefits do in fact accrue.

Crucial to an understanding of market clearing prices in the case of tradable permits is the concept of marginal costs. Ideally marginal cost is a measure of the value to society of the extra resources required to produce another unit of output in a particular time period. In terms of economic efficiency the general presumption is that if the price which a consumer is willing to pay for another unit exceeds the value of the extra resources required to make it, then the allocation of resources will be improved if that unit is produced and vice versa.

Exactly the same logic applies when we consider using tradable permits for water quality management. When the marginal costs of abatement for any particular player are greater than the prevailing costs of permits, he will choose to buy permits rather than institute the required abatement measures himself, and a demand for permits is thereby created.

If his marginal costs of abatement are less than permit costs, then he will rather choose to carry out abatement measures and sell his excess permits. A supply is thus created.

In this way permits will be traded until no player perceives an advantage in acquiring more permits, or indulging in additional abatement in order to be able to sell permits.

It will be demonstrated when the trading model is exercised that the actual costs of abatement will tend to fall in individual cases (or the outcome may be neutral) and any savings from instituting abatement measures obviously translate into additional profits. In addition, the control of the abatement initiatives remains in the hands of the individual players insofar as the decision as to whether to abate or go the permit route is theirs alone, and depends upon their individual production functions.

A green tax would operate on a sliding scale and work in the opposite sense from abatement costs. At zero abatement levels, the green tax is pitched at an extremely high level to obviate the possibility that players may choose simply to pay the tax rather than to implement abatement measures. In practice each player will play off the rise in his abatement costs against the fall in green tax until some equilibrium level is demonstrated.

Two models were developed to demonstrate the action of economic instruments. The first, a Marginal Cost Model (MC model) is effective in demonstrating graphically in a spreadsheet environment the mathematical and economic principles involved in the application of green taxes, and creating a market for emission permits. However, this model gives no intuitive feeling for what is happening during the trading process, and it is also somewhat restricted as to the number of players it can accommodate.

For this reason, the second model, a Simulation Model was developed in parallel. This model, which takes the trading process from the point where the first permit changes hands through to where market equilibrium is achieved, also serves to validate the results generated by the spread-sheet model. In addition, it is able to accept more wide-ranging and sophisticated data sets and it should be able to be used effectively should on-the-ground problem solving be required.

The following goals were desired from running the models:

- to demonstrate a market for tradable permits in action;
- to determine whether there are circumstances under which the market fails;
- to determine whether, or under what circumstances, costs of abatement measures are minimised;
- to explore the implications of the green tax, and to establish appropriate values for it; and
- to investigate to what extent the system can suffer perturbations and still remain stable.

It was found that the market price of permits calculated by both models over a range of abatement levels agreed consistently. The actual amount of abatement implemented by each mine also agreed for the two models when rounding and truncation errors were taken into account.

The final critical issue is to determine whether the trading of permits has resulted in any benefits to the players, vis-à-vis what would have occurred under a command and control approach. These benefits are calculated by taking the difference between the cost of the legislative approach (where abatement requirements are equally spread) and the outcome after trading has taken place. It was shown that a benefit does accrue, both to the bubble as a whole, and to the individual players.

Admittedly, the benefit to individual mines is sometimes minimal, and the outcome from their point of view could be regarded as neutral. However, a non-trivial potential saving to the complete bubble was consistently demonstrated.

Having outlined the original brief and the brief as modified by the steering committee, and having discussed the essential features of the research carried out, it is now appropriate to consider how effectively the research has met the modified brief.

It will be recalled that the first task was to undertake a literature survey of the subject. A significant amount of international literature was found on the use of economic instruments, and this was able to provide appropriate guidance in setting up a toolbox of instruments for water quality control relevant to the South African situation. No mention of any instruments currently in place in South Africa was found, although the Department of Environment Affairs and Tourism is currently conducting a research project on the use of economic instruments for environmental management. The international survey was thus used as the basis for our toolbox.

The next task of the study was to postulate economic instruments suitable for controlling sulphate pollution of the upper Olifants catchment. From the toolbox mentioned above, green taxes and tradable emission permits were identified as being the two most appropriate instruments.

The next phase of the project involved simulating the use of these instruments using actual data relevant to the upper Olifants catchment. In practice it proved impossible to compile a data set which could be regarded as truly representative of the area chosen. A reason for this was that much of the data required had to come from the mines operating in the catchment, and this data was commercially sensitive and not readily available to the researchers. However, at this stage of the project it had become clear to both the researchers and the steering committee that the operation of economic instruments was generally not understood. The aim of the modelling exercise therefore focused on facilitating an understanding of these two instruments, and making them accessible to a wider audience.

The outcome of the modelling exercise satisfactorily illustrated the underlying theory of tradable permits used as water quality control instruments, and also demonstrated that their use can bring economic benefits to the trading partners. This exercise was supported by a workshop, attended by representatives of various sectors of the economy, which was aimed at widening understanding of the operation of tradable permits. It was generally agreed that this workshop achieved its objectives.

RECOMMENDATIONS FOR FUTURE RESEARCH

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

- Taxes can have a detrimental effect on some industries if indiscriminately applied. Particular cases in point are older industries, and mining industries where prices are set internationally. An in-depth investigation into the effects of a green tax on these industries is recommended. However, a study such as this would have to get very close to potentially sensitive financial information in the relative industries, and the full co-operation of the industries concerned would be a pre-requisite. Without this co-operation such a study would not be of great value.

- A knowledge of both income and price elasticities of demand enables more effective forecasting to be done for water management purposes. Countries such as the USA (Howe and Linaweaver, 1967) and the OECD Countries (Bhatia, 1992) have carried out studies to determine these parameters from the '60s to the present. These studies have included the determination of elasticities of both industrial and household (municipal) water demand. A similar study in South Africa should be undertaken, and might commence by looking at municipal elasticities of demand.

- Reliable and extensive time-series data is an important pre-requisite for any forecasting exercise, and indeed for establishing elasticities of demand. A database extending for at least five years and containing information on water usage, water price, and pollution control activities and their costs in all sectors of the economy could be considered to be a minimum requirement. It is recommended that existing data of this nature should be gathered together in a database form which would make it useful to economists, and that a programme should be established to continue accumulation of similar data over the forthcoming five years.

- Whilst accepting that the research carried out in this report had as its aim to educate rather than to solve specific problems, it is nevertheless felt that a pilot study using tradable permits and green taxes and incorporating real data should be carried out before any recommendation to implement these instruments on a widespread basis could be made. Such a pilot study should investigate the effects of these instruments on a specific community or "bubble" and should report on the effects of levying taxes at different levels. This study would however also involve the use of sensitive financial data and its success would be heavily dependent upon the total co-operation of the players in the chosen bubble.

- Water pricing and tariff-setting, and demand-side management are issues, which ought to be receiving urgent attention in South Africa. Appropriate pricing of water would have direct effects on both its allocation and the management of its quality. As mentioned this report, this is a wide field of research, but it is clear from feedback from the Steering Committee that it is a subject that needs urgent investigation.

RECOMMENDATIONS FOR FURTHER TECHNOLOGY TRANSFER

It has been found that a more accessible précis of research such as that just described has proved to be popular. Cases in point are "Economics and Water Management" Prepared by the Institute of Natural Resources, which stemmed from the Water Research Commission Report No 415/1/94 "The Application of Economics to Water Management in South Africa", and "Managing SA's Environmental Resources: A Possible New Approach" which was written in response to the Department of Environment Affairs report "General guidelines for a policy on the use of fiscal instruments in environmental management".

This "popular" document was well received, and won an EPPIC Award in for the best South African Environmental publication in 1994. It is recommended that a similar brief document aimed at a wider audience be prepared, based on this research report.

It is also recommended that further workshops, similar to the one mentioned above, could materially assist in the technology transfer effort. These workshops could be of an educational nature, or of a problem solving nature. In the latter case, co-operation would be required from the relevant sectors of the economy in providing robust and appropriate data to be run through the models.

PREFACE

Prior to this study there has been little attention paid to analysing water management issues from an economic perspective. Also it is known that a considerable body of work linking water management and economics has been undertaken internationally from about 1980. It seems logical, therefore, to consider whether lessons can be learned from this work that are appropriate to South Africa.

Three basic aims guided the research. The first was the quest for useful and generally applicable international experience and methodologies. The second aim was to identify appropriate instruments for use in the South African context. The final aim was to test the applicability of the chosen .instruments in a South African environment by means of mathematical modelling.

In the course of the project, a great many problems associated with the availability of robust data were encountered, and these were instrumental in shaping the course of this study and the final product.

After extensive research, it was concluded that the most promising contribution to be made by economic instruments to water quality management in South African lay in an alternative to the traditional command-and-control macro management approach to deal with water quality problems by means of market based economic instruments. As such the content and structure of this report and its appendices reflect this conclusion.

This document is not aimed specifically at economists. The methodologies it contains will likely prove somewhat conventional to practitioners of this discipline. It is primarily intended for water managers and decision-makers, particularly those who have had limited exposure to economic concepts. Moreover, this report is not a comprehensive manual on the economics of water quality management or water project planning. Although these may be worthwhile products for future consideration, the purpose of this project is to introduce, in broad terms, the potential application of market based economic instruments to water quality management in South Africa.

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  - ◊ Arthur Kamp....................... Eskom
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PART ONE

INTRODUCTION

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1. INTRODUCTION

1.1 BACKGROUND TO STUDY

At the time that this research project was mooted, Economic Project Evaluation (Pty) Ltd (EPE) had just concluded a project for the Water Research Commission (WRC) entitled "The Application of Economics to Water Management in South Africa" (henceforth referred to as WRC 1993). The brief for WRC1 provided the researchers with the opportunity to develop statements of broad economic principle, which after further investigation and debate, could lead to their adoption in finding solutions to water management problems. WRC1 concluded that economics' most significant potential contribution lay in providing:

1. An alternative (to the traditional supply-fix) macro management approach to deal with water quantity (allocation) problems;
2. An alternative (to the traditional command-and-control) macro management approach to deal with water quality (pollution) problems; and
3. Methods to assist in the piecemeal implementation of macro-economic approaches, whether these were the ones advocated, or the more traditional ones.

The object of the present project is to augment contribution number 2 mentioned above. In this regard four aims are postulated, these being:

1. To investigate the practicality of employing economic measures to protect water quality in South Africa;

2. To compile a detailed economic strategy for a selected catchment to serve as a demonstration project;

3. To determine the benefits, by way of cost-savings to either the public or private sectors, that could result from adopting an economic approach to water quality management as a complement to the more traditional approach embodied in current water quality management plans; and

4. To analyse in detail criteria for successfully implementing the economic approach.

1.2 THE DEVELOPING BRIEF

Under the guidance of the project steering committee the four aims were interpreted to comprise the following tasks:

Task 1: Provide a literature survey (focusing on practice rather than theory) from which a toolbox of economic instruments for water pollution control relevant to South African catchments would be assembled.

Task 2: Postulate economic instruments suitable for controlling sulphate pollution in the upper Olifants catchment, and to test their feasibility by simulation. For the simulation to be meaningful, it would need to use a data set that was truly representative of the activities taking place in the catchment.

Task 3: Exercise two models designed and implemented to demonstrate the efficacy of the chosen economic instruments in the relevant catchment. (In the event the data collection task proved to be unmanageable, and recourse was made to a dummy data set, where some data was simulated. It was felt that this would not detract from the value of the exercise, as it would provide an opportunity for the principles of the chosen economic instruments to be observed in action.)

Aim 4: Combine the conclusions from the literature survey and the outcome of the simulation exercise.

It is clear that Aims 2 and 3 overlap to the extent that it is not practical to regard them as separate issues. This report therefore combines them, and it is structured to focus upon three principal aims only.

1.3 SCHEMA OF THE REPORT

The report is divided into four parts. The first part comprises this introduction.

Part two discusses water quantity/quality relationships, point and non-point source pollution, water quality standards and the selection of the most appropriate economic instruments for dealing with these issues in the South African context.

Part three looks at the selection of apprOpriate economic instruments for South Africa.

Part four is a practical application of the use of economic instruments in the Olifants River catchment.

Part five discusses and analyses the issues raised, draws conclusions and points to future possible areas of research.

PART TWO

WATER, POLLUTION AND ECONOMIC INSTRUMENTS

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FIGURES

2. WATER QUANTITY - WATER QUALITY RELATIONSHIPS

2.1 INTRODUCTION

This chapter offers a general introduction to water quality and quantity management. The main topics of importance are identified, and these are developed further later in this report.

2.2 WATER DEMAND

South Africa's total exploitable water resources, both surface and ground water, are estimated to be 38 000 million cubic metres per annum (m^3/a). The current demand for water is 18 500 million m^3/a, of which 9 300 million m^3/a, or 50 per cent, comes from irrigators. Demands from other sectors include 3700 million m^3/a (20%) from urban industrial users, 470 million m^3/a (2%) from mining, 440 million m^3/a (2%) from Eskom power-stations, 1400 million m^3/a (8%) from forestry, and 3000 million m^3/a (16%) from nature conservation. Whilst these figures suggest a situation of surplus it must be remembered that this water is poorly distributed relative to areas experiencing economic growth. Only a comparatively narrow region along the eastern and southern coastline is moderately well watered, while the greater part of the interior is arid or semi-arid. Furthermore, Gauteng, the nation's economic 'power house' developed around mineral reserves and not water sources as is the case for most other large metropolitan centres in the World. Additionally, the supply of water from many catchments in South Africa is becoming insufficient to meet demand.

Water is used as an essential input into most production processes. Its excessive use and abuse can lead to increased pollution run off. Methods of controlling water demand in order to control pollution are simple and basic, for example:

1. The imposition of restrictions on water extraction from a river system, through correct pricing and/or stricter withdrawal permits, has the potential to induce users to utilise water more conservatively, thus increasing the availability of dilution water in the system.

2. Such restrictions may induce a given user to consider recycling water. Although the overall consumptive use might not necessarily be reduced by other measures, extractions, return flows and pollutant loads can be curtailed. Reducing wastewater volumes can also facilitate improved pre-discharge storage and treatment.

Economic instruments that may lead to the control of water demand will be identified in sections 2.3 and 2.4 below.

The following criteria have to be considered when evaluating the cost-effectiveness of using water demand control mechanisms:

- a given user's specific *water demand function*,
- the price elasticity of demand for water, and
- the nature of the use of water in different sectors of the economy, e.g., domestic and industrial.

Discussing aggregate demand for water across a region is not really practical, since each user displays very different water demand characteristics, and water utilisation systems are highly disaggregate.

Price elasticity of demand for any commodity (including water) is, however, an important economic indicator that can be used for the planning of future water demand. It is appropriate therefore to briefly discuss this subject. Figure 2.1 depicts the elasticity of water demand in relation to its price.

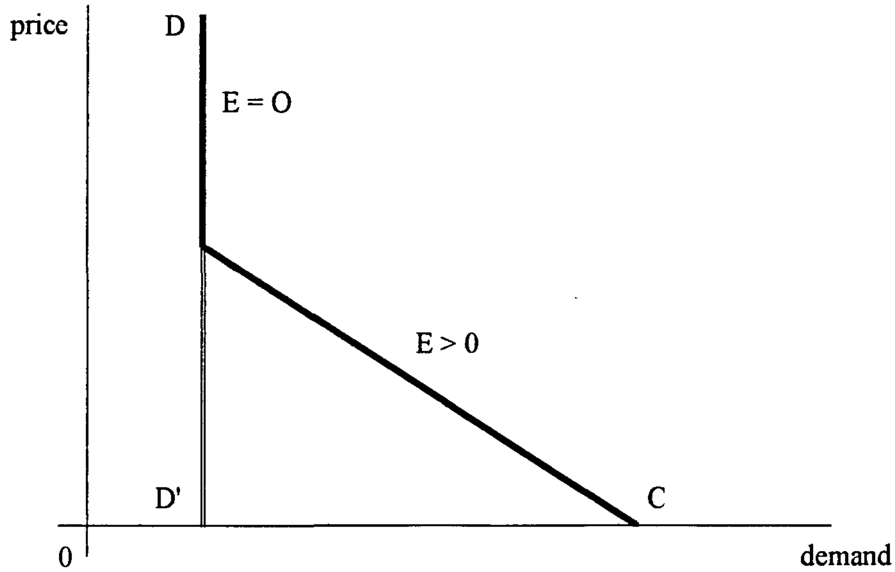

FIGURE 2.1: ELASTICITY OF DEMAND

The elasticity of demand for a commodity depends mainly on the range of available substitutes. The better the substitutes available, the more elastic will be the demand for the commodity. Water is one of the commodities that have few substitutes and demand for water is therefore perfectly inelastic up to a certain amount. Consider Figure 2.1: up to a certain point D' on the demand axis, water demand is perfectly inelastic: E = 0, which means that no matter how high the price, the user is willing to pay for it, as water has no substitutes and is a necessary input into production and life support processes. Beyond D', however, the demand for water becomes elastic, E>0, which means that the demand for water becomes a function of its price, i.e. Q = fD (P). Beyond D' consumers begin to respond to price changes for water: i.e. the higher the price per unit of water beyond D', the less consumers will be demanding the commodity. To sum up, it is suffice to recognise that water demand is determined by its price elasticity of demand and its marginal utility[1].

1 **Marginal Utility** is defined as the extent to which a consumer's satisfaction would be increased or decreased if he had one more or one less unit of a commodity.

2.3 THE ROLE OF WATER PRICING IN WATER QUALITY MANAGEMENT

The importance of water pricing has been emphasised previously in Water Research Commission report "The application of Economic Principles to water management decision-making in Southern Africa"[2]:

> "The pricing of water is possibly one of the most under-used, but potentially most effective, demand management tools available to the water manager. Apart from providing the necessary revenue from which water schemes can be financed, it has the potential to (1) ensure the maximum beneficial use of water, (2) accurately control demand such that the timing of new schemes can be postponed until they are absolutely necessary, (3) curb demand during periods of shortages, and (4) raise revenue (possibly for the subsidisation of water services to the very poor). In South Africa pricing is used primarily to recover scheme costs and, in some instances, to penalise excessive use during droughts. In view of the economic and physical limitations on further water resource development in South Africa, there would seem to be merit in considering the application of demand management strategies such as water pricing more seriously: it could have advantages in terms of reconciling supply and demand and the production of revenue.
>
> More specifically, given the State's urgent need for new revenue sources, pricing could be considered in water-scarce regions where continued supply augmentation is extremely expensive. It could be very useful to evaluate the revenue yield, and demand reduction, that could result over the long term from, say, introducing water pricing at modest rates (which would prevent a disruption of the economy over the short term) but with the clearly stated intention of escalating those rates annually. In this respect it should be noted that by using the accepted equivalent basket of goods and services approach as a basis for comparison, South Africa's municipal water tariffs are far cheaper than those of many well-watered European nations are. In practice, though, pricing water such that the price reflects its correct economic value is rare."

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2 Hereinafter referred to as WRC 1993.

Numerous studies on aspects of water quality have shown that the issue of the unit price of water is of considerable importance. If the price for water does not reflect its scarcity, water use becomes indiscriminate, wasteful and leads to increased wastewater discharge. The optimal pricing of water has been dealt with in detail in WRC 1993. The following section discusses how water has been priced through the market place in other countries and how this pricing has been used as a means to conserve water and to improve water quality. Water pricing issues will be discussed further in Chapter 4 of this report.

2.4 WATER MARKETING

One of the more innovative economic instruments that has the potential for controlling water pollution, from both point and non-point sources, is water marketing.

In the Western part of the United States, where water marketing has been practised for some years to price and allocate water more efficiently, a number of water resources have been involved in transactions. These include groundwater, native and imported surface water, artificially recharged and recovered water and effluent and conserved water.

The potential use of such water markets to control water pollution will be considered briefly. At present the 'beneficial use doctrine' in American water law, for instance, contains the 'use it or lose it'[3] component which can promote extravagant use of water and discourage conservation, since water saved by conservation is typically forfeited. What is needed therefore, is to allow users to realise the value of water saved, by permitting them to sell excess and conserved water. This would stimulate water conservation, encourage higher valued uses and raise revenue for improved utilisation methods.

Unrestricted water markets, however, may pose a problem of third-party costs. As Colby (1988)[4] points out, unrestricted water markets can impose significant costs on other water users, such as rural communities and the environment.

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3 Tietenberg, Tom, Environmental and Natural Resource Economics, Harper Collins Publishers Inc., New York 1992 (3), p 236.

4 Colby, Bonnie G., Economic Impacts of Water Law - State Law and Water Market Development in the Southwest, in: Natural Resources Journal, Vol. 28, No. 4, fall 1988, October 1988, pp 721-749.

Finally, Dinar and Letey (1991)[5] analysed the impact of water marketing on water availability and environmental quality. They found that water marketing could lead to a reduction in water use by agriculture. Through water marketing farmers are encouraged to use only water necessary to satisfy crop requirements and to make part of their quota (allotment) available for sale in the market. Thus excess irrigation could be discouraged, the drainage volume could be reduced and environmental pollution and social costs associated with drainage could be diminished. If the farmer's profit increases, he is more likely to invest in improved irrigation systems, for instance lined canals, thereby contributing to water conservation.

Furthermore, a positive effect on water quality can be expected: reduced water input would lead to reduced drainage water and reduced dissolution and mobilisation of problematic salts from the drainage pathways. Also water marketing can serve as a further source of income for farmers.

The net outcome, under perfect conditions (i.e. no political, legal and implementation barriers), would be that the farmer is faced with increased net returns, water consumption would be reduced and water quality improved.

Water marketing is discussed further in Chapter 4.

2.4.1 Property rights

One of the most basic functions of water law regarding markets is the definition of property rights. They define and limit the rights of members of society with respect to water resources and allow the right holders to form secure expectations regarding benefits stemming from their rights. Property rights thus provide an essential base for market exchanges. In the western parts of the United States five basic types of water rights exist:

- riparian rights
- appropriative rights
- permits
- allotments
- mutual stock.

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5 Dinar, Ariel, Letey, J., Agricultural Water Marketing, Allocative Efficiency, and Drainage Reduction, in: Journal of Environmental Economics and Management, Vol. 20, Issue 3, May 1991, pp 210-233.

The literature on water rights is to a large extent concerned with the efficiency of allocations of water where there are legal and institutional constraints on the trading of water rights. Economists argue that it is exactly these constraints that prevent water from moving to its socially highest valued uses and that under these conditions the allocation of water is economically inefficient. It is further argued that if water were sold separately from land in a perfectly competitive market, then the allocation of water would be efficient.

2.4.1.1 Experiences in the United States

Miltz et al mention that:

> "A further incentive to the relinquishing of generous water rights, would be to permit them to be traded. This approach is now used extensively in the USA where irrigation water rights have been purchased at very high prices by municipal authorities on behalf of urban consumers. (The system is also to great effect in Chile where it is supported extensively by legislative and self-funding institutional structures.) The outcome of this system has been a marked increase in water use efficiency as well as an overall shift towards the allocation of scarce water to more economically beneficial uses."

Shupe et al. (1989)[6] look at mechanisms through which water rights are reallocated in the Western part of the US and consider in particular voluntary transfers:

Leases for Fixed Term

The city of Albuquerque issues leases of surplus water, for instance, to vineyard owners in Southern New Mexico (1100 acre foot per year - af/y) at a charge of $40 af/y which is roughly equal to the payment of the Bureau of Reclamation which provides the city with water surplus.

Dry-Year-Option

Negotiations of dry year options between some cities and farmers in the West led to the city of Utah paying $25 000 for an option to lease senior irrigation water rights.

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6 Shupe, Steven J., Weatherford, Gary D., Checchio, Elizabeth, Western Water Rights: The Era of Reallocation, in: Natural Resources Journal, Vol. 29, spring 1989, No. 2, pp. 413-434.

In return the city agreed to supply the farmers, the owners of the water rights, with 300 tons of hay and $1000 in any season that the city exercised this option. For the first 25 years that the scheme was in operation, the city used the option three times. The net results were that the farmers received a cash payment, hay without harvesting and some pasture production from non-irrigated farming. Other examples of such a scheme exist in California: with different payment schemes but based on the same idea

Subordination Agreements

Subordination agreements are based on the idea that the major attribute of an appropriated water right is its relative priority, which can be marketed separately from the right itself, which is similar to the dry-year-option.

A senior priority right, as opposed to a junior right, which is not deemed reliable enough, may be compromised for something other than money. The Navajo Indian Reservation, for instance, has senior priority claim on the San Juan River. The Reservation agreed in 1968 to share shortages during droughts in order to obtain federal authorisation for a Navajo Indian Irrigation Project. This allowed the construction of the San Juan-Chama Project delivering trans-basin water into the Rio Grande drainage basin to serve Central New Mexico.

Conservation Offsets

Conservation offsets are used as a reallocation strategy for junior municipal and industrial users who are in need of a more reliable supply by making water conservation investments in a senior use. By financing the modernisation of old irrigation systems by junior users, surplus water is made available to junior users while senior users irrigate the same amount of land with less water.

Exchanges

The exchange of water supplies (temporarily, seasonally or permanently) can prove advantageous if water rights of respective parties are, for some reason, not appropriate to their needs - for instance the need for water of different quality.

Blocks of Water District Shares

The purchase of shares of agricultural water district stock, independent of land, has been in effect in north-eastern Colorado since the 1960s. In Colorado-Big-Thompson (CBT) an active market for shares has been in operation. The scheme started in 1960 at an initial share price of $11/af, which rose to $3000/af in the late 1970s. After the prices had plummeted in 1981, the market was still existing in 1986, at prices of *circa* $1000/af.

Individual Sales

Costs of individual sales can be very high as the following example shows: water prices in the Park City area in the mountains above Salt Lake lie at and above $4000/af. In the mountain resort area in Colorado, the price per acre foot lies in some instances at almost $10 000.

2.5 Point-Source Pollution

Water that is clean and safe to use is essential to man's existence. So why, as man becomes wiser and wealthier, does he continue to degrade this basic element? There is a basic reason for this. The emissions which are discharged are seen as having no value, and the environment into which they are discharged is seen as being a free good, thus the economic impact of such discharges is perceived to be zero. These beliefs are obviously erroneous, yet they are reflected in the pricing mechanisms that form part of the current policy and legislation governing the use and protection of our natural resources.

If water is cheap, the tendency will be for users to discard used water and buy more clean water. Also, if there are no incentives to minimise the degree to which the discarded water is polluted then it is inevitable that our rivers will gradually become more degraded as water use increases.

One obvious way to place a tangible value on water resources is to levy a charge on activities that degrade them. In other words, charge for the privilege of using surface water for waste disposal.

Controlling point-source pollution from industry and agriculture has been widely discussed in the literature. The command-and-control and market-based instruments to achieve this have been used world-wide. In recent years market-based instruments have proved to be the most cost-effective and beneficial tools for the implementation of point-source pollution control. However, the effectiveness of economic instruments is, to some extent, dependent on legislation and standard setting. Appendix B discusses appropriate economic instruments and the legislation used in other countries that has not only formed the basis for pollution control, but in some instances has given rise to pollution control through the market.

2.6 NONPOINT-SOURCE POLLUTION

The control of nonpoint source pollution[7] is an important aspect in water quality management. Policy-makers have been faced with severe difficulties in determining the most appropriate and economically efficient policies for water pollution abatement from nonpoint sources.

Nonpoint sources of pollution cannot be monitored on a continuous and widespread basis with reasonable accuracy or at reasonable cost. This makes the application of economic-based policy instruments, which are used for point source pollution control and which rely upon relatively accurate and broadly accepted information, difficult. Agricultural nonpoint source pollution control has been the main focus of research in the literature and in the design of nonpoint water pollution control policies world-wide, since agriculture is considered to be the largest contributor to nonpoint source pollution. Consequently, policies will be considered here which have been used to abate water pollution from agricultural runoffs.

None of the policies reported in the literature were found to use pure market mechanisms to control nonpoint pollution, although policies are often assessed to determine their economic efficiency.

Appendix C discusses economic approaches for controlling non-point source pollution.

7 Point sources are predominantly industrial and municipal pipe discharges. Nonpoint (or diffuse) sources are discharges carried by storm runoff.

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FIGURES

TABLES

3. ECONOMIC JUSTIFICATION OF WATER QUALITY STANDARDS

3.1 EXISTING SOUTH AFRICAN POLICIES, LEGISLATION AND REGULATIONS: RECEIVING WATER QUALITY OBJECTIVES

Effluent discharges are controlled by the DWAF in terms of the Water Act. Until recently, the DWAF applied the Uniform Effluent Standards (UES) approach to water pollution control by enforcing compliance with the General and Special Standard for Effluent Discharge. Two policy principles dominated this approach. The first was that, due to the arid nature of South Africa's climate, wastewater must be returned to the channel from which the water supply originated. The second principle was that the polluter must pay for the abatement of his own pollution. These principles are described in more detail in DWA (1986)[1].

In 1991, the DWAF introduced a new approach to water pollution control, which embodied a third fundamental principle. This stated that, in certain catchments, effluents should be discharged to the surface drainage system without the quality specifications of the receiving water (based on the needs of downstream users) being exceeded. These specifications are more commonly known as Receiving Water Quality Objectives (RWQOs) and are described in more detail in DWA (1991)[2].

The RWQO approach was intended to overcome deficiencies in the existing water pollution control policy. These deficiencies can be considered in terms of the two original policy principles, i.e. returning effluents to the channel of origin, and the polluter pays.

Returning effluents to the channel of origin

The increased utilisation of surface water resources meant that there was insufficient dilution water present in many of South Africa's rivers to ameliorate the water quality impact of the returned effluent, even if the effluent met the required quality standard. Thus, while striving to conserve as much water as possible for reuse, this policy was actually promoting the quality deterioration of the country's water resources.

The 'polluter pays' principle

The problem with the 'polluter pays' principle is that it becomes difficult to justify forcing the effluent producer to treat his waste water to a specified standard if there are no downstream users disadvantaged by the discharge of the effluent, or if the quality of the receiving water is similar or worse than the effluent. Such justification becomes even more difficult to establish when it threatens the viability and employment capabilities of certain industries.

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1 Department of Water Affairs, Management of the water resources of the Republic of South Africa, Department of Water Affairs and Forestry, Pretoria 1986.

2 Department of Water Affairs and Forestry, Water quality management policies and strategies in the RSA, Department of Water Affairs and Forestry, Pretoria 1991.

The RWQO approach allows DWAF officials to modify these two principles on a catchment basis so that the quality of the receiving water does not deteriorate beyond the water quality requirements of downstream users, and so that the costs incurred by the effluent producer can be justified in terms of meeting such requirements. This approach also permits officials to deviate from the General Standard for Effluent Discharge, which has been criticised for its limited scope in accommodating water supply and demand variations from one catchment to another.

3.1.1 Application of the RWQO approach[3]

Whilst the RWQO approach is a major policy advancement, its operationalisation is proving to be more difficult than was originally anticipated. Its application currently focuses on the determination of the water quality requirements for each and every downstream user, followed by the selection of the most suitably stringent requirements to calculate, by means of a waste load allocation (WLA), the quality and volume of the effluent that can be discharged upstream.

The problem with this approach is that most downstream users do not know what their water quality requirements are, and when urged to adopt a specification they tend to play safe and opt for overly stringent values. As the long term low level impacts of marginally unsuitable water quality are largely unknown for many uses, it is difficult to challenge such values. This problem is compounded by the fact that there is no incentive for downstream water users to be more precise about their water quality requirements. Nor is there any incentive for them to quantify the impact of a less than ideal water quality, or to even consider some form of compensation from upstream polluters for agreeing to an inferior RWQO.

Another uncertainty surrounding the RWQO approach relates to the allocation of waste discharge permits in a multi-polluter system. As yet no official policy has been tabled to guide the allocation of waste permits in systems where the present or likely future amount of effluent exceeds the total WLA. Some of the important questions that have to be answered in this regard are: Should allocations be made on the basis of priority in time, or the economic importance of an effluent producing industry, or should they perhaps be auctioned off to the highest bidder? Can WLA permits be traded amongst effluent producers, and if not, what alternative incentive

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3 Refer to: "Use of Economic Instruments to Control the Discharge of Effluent from Sappi's Ngodwana Paper Mill to the Elands River: A Case Study", in preparation for Department of Environment Affairs by Economic Project Evaluation (Pty) Ltd., 1993.

mechanisms need to be introduced to encourage the consideration and possible adoption of new waste management technology by industry? Will effluent producers be eligible for compensation if downstream RWQOs become more stringent and existing allocations have to be adjusted? Finally, should the agency administering the permit system retain some permits for future economic development, assuming that it may not be possible to purchase these from existing permit holders?

In addition to the issues raised above, a major problem with the RWQO approach is the determination of the minimum flow regime on which to base the WLAs. RWQOs and WLAs are water quality management tools that were developed in the temperate climates of Europe and North America on large rivers with substantial dry-weather flows. South Africa has a predominantly semi-arid climate and the dry-weather flow for many rivers is often zero. The logical way to overcome this problem would be to adopt a probabilistic approach to selecting a minimum flow, whereby the risk of a flow occurring, which is less than the minimum, is acceptable to downstream users who will have to bear the consequences of transient exceedences of the RWQO. By using stochastic hydrology to select minimum flow regimes for WLAs, it would be possible to estimate the frequency, duration and severity of RWQO exceedences over a given period of time. However, for such risks to remain constant, upstream abstractions from the river must also remain constant. For this to occur the relevant authorities would need to implement diligent abstraction control, thereby placing additional pressure on overstretched resources. This aspect also emphasises the inseparability of pollution control and abstraction control functions for the maintenance of water quality in riverine systems.

Overseas experience indicates that these problems are not insurmountable. However, while they remain unresolved in South Africa, the RWQO approach risks becoming an over-simplified 'top-down' regulatory mechanism. Actions based on the approach are likely to possess debatable justification and may therefore command variable support from effluent producers and water users alike.

Clearly, the success of the RWQO approach to pollution control is dependent upon the introduction of appropriate incentives which encourage the joint development of more optimal, self-regulatory solutions by both effluent producers and water users. As such solutions will invariably be the product of some form of economic optimisation, it follows that the incentives to participate in such an activity should be of an economic nature and not based on command and control.

3.1.2 Economic aspects of the RWQO approach

In certain circumstances, RWQOs may be more successfully implemented using economic approaches applied in a deregulated environment, as opposed to a technically based implementation using CAC approaches. For example, if one were to view an insufficient amount of effluent discharge permits (relative to the quantity of effluent to be discharged) as a scarce resource, then the efficient allocation of that resource can only be achieved by the market. To allocate permits in any other way will introduce bias, inefficiency and controversy into the process. It should be noted however, that the comments made in Chapter 4 about satisfactory operation of markets would also be relevant here.

Figure 5.1 demonstrates the economic relationship between an upstream effluent producer and a downstream water user. The benefits curve for the water user is characterised by significant increases associated with more stringent RWQOs at the lower levels. These benefits gradually taper off as the RWQO resulting in maximised benefits is reached. The costs curve for the effluent producer is characterised by steeply rising costs, as the RWQO becomes more stringent. Q_2 represents the RWQO at which the net social welfare is maximised. Although neither the polluter nor the receiver may appear to have optimised his situation, the *net benefit to the economy* occurs when the difference between the benefits and costs is greatest, and positive. This occurs where the vertical distance between the benefit curve and the cost curve is greatest[4].

[4] It can be shown by considering the first derivatives of the benefit and cost curves that this is also where the marginal benefits (or willingness-to-pay) equal the marginal costs.

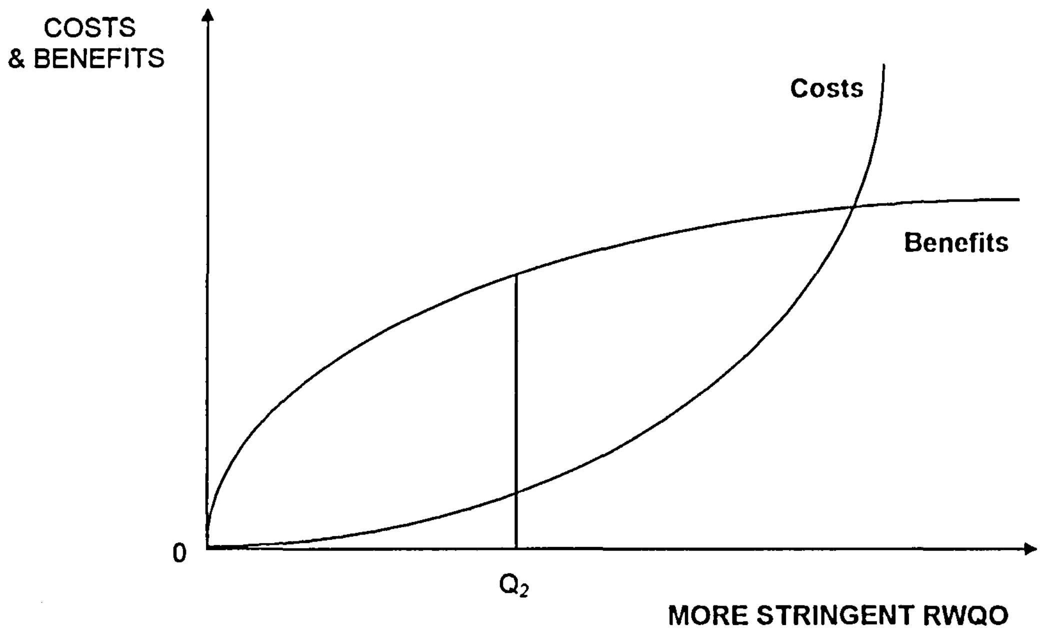

FIGURE 3.1: ECONOMIC IMPLICATIONS OF THE RWQO APPROACH

Determining the benefit curve of the receiver will place a financial burden on the taxpayer for the funding of the relevant investigations. An alternative approach would be to allow the effluent producer and the downstream water user to determine the optimal position of Q by means of negotiations conducted in a free market environment. Such an arrangement would automatically lead to a measure of independent monitoring/policing by the producer and the receiver, thereby reducing the pollution control cost burden on the State.

Figure 3.1 presents a simplified situation that would be complicated in the real world by multiple user and multiple polluter circumstances. However, if appropriate local institutional arrangements existed in which polluters and water users could reach agreements, then the same economic principles would apply.

3.2 THE USE OF COST-BENEFIT ANALYSIS IN STANDARD SETTING

Pollution control and environmental protection are costly. To maximise social welfare in this regard policy decisions should be underpinned by economic theory. This is true in two senses:

1. Resources devoted to pollution control and environmental protection have to be compared with depriving these resources from other uses. Pollution control activities should only be undertaken, if the results are worth more than the resources applied. This is essentially the purpose of cost-benefit analysis (CBA).

2. No matter what pollution targets are chosen, the means selected to achieve these targets should be chosen on the basis of cost-minimisation. Many environmental protection and pollution control policies adopted throughout the world are wasteful, since they use more resources than are necessary. One of the major contributions of economic analysis to environmental policy is that it reveals when and how these policies can be made more cost-effective.

CBA is a set of analytical tools designed to measure the costs and benefits, hence the net contribution that any public policy makes to the economic well being of society. The analysis seeks to determine whether the aggregate of the gains to those made better off is greater than the aggregate of losses to those made worse off. The gains and losses are to be measured in terms of each individual's 'willingness to pay' to receive the gain or to prevent the policy-imposed losses. The selection of environmental quality standards can illustrate some of the issues involved in using cost-benefit analysis for environmental policy making.

An environmental (or water) quality standard is either a legally established minimum level of cleanliness or a maximum level of pollution in some part of the environment[5]. Cost-benefit analysis provides a basis for determining at what level an environmental quality standard should be set. In general, economic principles require that each good be provided at the level for which the marginal willingness to pay equals the good's marginal cost, i.e. the cost of providing one more unit of the good.

An environmental standard set by this rule will almost never call for complete elimination of pollution. As the worst of the pollution is cleaned up, the willingness to pay for additional improvement will decrease, while the extra cost of further cleanups will increase. Seldom will it be worth it in terms of willingness to pay or in terms of environmental benefits.

3.2.1 Experience

United States

The US Environmental Protection Agency is required by law to establish maximum allowable levels (ambient air quality standards) for major air pollutants such as sulphur dioxide and ozone. A standard, once established, can be the basis for

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5 Refer to the discussion on the optimal level of pollution in chapter 3.2.1.1 of this document.

enforcement actions against a polluter whose discharges cause the standard to be violated.

In a 1987 report[6] EPA's experiences with cost-benefit analysis are recounted. CBA has influenced the development of regulations at EPA in a number of ways:

- to guide the regulation's development,
- to add new alternatives,
- to eliminate non-cost-effective alternatives,
- to adjust alternatives to account for differences between industries and segments, and
- to support decisions.

In some instances the use of CBA has resulted in more efficient regulations, since analyses had shown that stricter alternatives could lead to greater reduction in pollution without a proportional cost increase. Table 3.1 gives some indication of the potential increases in total net benefits of regulations:

Applying cost-benefit analysis to lead in fuel, for instance, led to introducing regulations that were more stringent than initially proposed. On the other hand CBA also showed that the costs of stricter regulations would be higher than the expected benefits. The relaxation of standards for used oil and premanufacture review, for instance, led to reduced regulatory burdens without significantly reducing environmental improvements.

6 United States Environmental Protection Agency, EPA's Use of Benefit-Cost Analysis, US EPA, Washington DC, August 1987.

Environmental Impact Assessment	**Change in regulation**	**Potential increase in total net benefits of regulations**
Lead in fuels	more stringent standard, greater health and welfare benefits	$6.7 billion
Used oil	reduced regulatory cost, greater reduction risk	$3.6 billion
Premanufacture preview	reduced regulatory costs, no significant reduction in effectiveness	$ 40 million

TABLE 3.1: POTENTIAL INCREASES IN TOTAL NET BENEFITS OF REGULATIONS THROUGH APPLYING CBA.[7]

Although the use of cost-benefit analysis was not the only factor bringing about such cost savings, it is fair to assume that the analyses played major roles in improving regulation.

As a result of a series of Presidential Executive Orders, the formal requirements to support regulation through cost, economic impact and benefit analyses have increased steadily. Executive Order 12291, issued by President Reagan in 1981, for instance, requires the preparation of a Regulatory Impact Analysis (RIA) for every major rule. Section 2 of the Order provides that "Regulatory objectives shall be chosen to maximise the net benefits to society" and that "Regulatory action shall not be undertaken unless the potential benefits to society for the regulation outweigh the potential costs to society."[8]

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7 Source: Pearce, David, Markandya Anil, Barbier, Edward B., Blueprint for a Green Economy, Earthscan Publications Ltd, London 1989, p 123.

8 United States, Presidential Executive Order 12291, Washington D.C. 1981.

There is therefore little doubt that CBA has an important role to play in the setting of standards for water pollution and control. Despite certain problems, which will always exist with data collation and the choice of the discount rate to use in a particular analysis, the technique is a powerful aid in economic decision-making. It is recommended that in future regulators should be guided by full CBA analyses before revising standards and regulations.

PART THREE

SELECTION OF ECONOMIC INSTRUMENTS FOR SOUTH AFRICA

CONTENTS

TABLES

4. SELECTION OF APPROPRIATE ECONOMIC INSTRUMENTS FOR SOUTH AFRICA:

Having discussed economic instruments for water quality management in an international context in the previous chapter, this chapter will focus on the appropriateness of some of these instruments in South Africa.

Specifically, the chapter will consider water pricing, taxes and subsidies, tradable discharge permits, and emission charges.

4.1 WATER DEMAND MANAGEMENT

4.1.1 General

Water allocation, water pricing and water marketing are all demand management strategies that can add value to water, thereby ensuring its more considered utilisation. South Africa is a semi-arid country, in which water is a scarce resource and unevenly distributed relative to areas of development. Despite this situation, water in South Africa is generally considered to be undervalued. This is supported by the fact that it is readily available in many areas (due to extensive storage and infrastructure), it is far cheaper in South Africa than in many well-watered countries (partly because of State subsidies), it is often used in a wasteful manner, and is invariably disposed of in a polluted condition with little thought given to its potential in-situ or downstream reuse. Consequently, there is clearly scope for the control of pollution by increasing the inherent value of water. The question now arises as to what extent, if any, can these strategies be used to control water pollution in South Africa.

4.1.2 Restrictive water allocation

Interestingly, the impact of restrictive allocations on water quality has already been demonstrated in South Africa. The 1960s and 1970s saw a rapid increase in the area of land under irrigation as a result of the development of a number of large water storage and transfer projects, e.g. Fish-Sundays, Greater Brandvlei, Vaalhaarts etc. During this period there was a concomitant increase in the salinity of the rivers draining these newly irrigated areas. The rate of increase in river salinity was a major cause for concern, and resulted in the funding of numerous projects to investigate the causes of the increase and develop ameliorating strategies.

However, towards the mid-1980s and early 1990s the increase in river salinity tapered off, despite the continued increase in irrigated areas.

Several theories have been advanced as to the reason for this, including the belief that the availability of soluble salts in the newly irrigated lands had been greatly reduced due to the leaching action of percolating irrigation water, and that the reduced availability of water meant that if a farmer wanted to continue to expand his irrigated lands, he had to do so without increasing his water requirement.

This reduced availability of water was brought about in some instances by the full allocation of the safe yield of dams, while on other schemes the cost of purchasing further water rights was deemed by farmers to be expensive. In addition, water restrictions brought about by droughts during this period also forced many irrigators to produce crops with far less water than they were normally used to. These circumstances demonstrated to farmers the benefits of improving water use efficiency and subsequently resulted in a rapid shift away from inefficient application methods such as flood irrigation and overhead sprinklers to the more efficient drip and under canopy microjets. Not only was the application of water per unit area of land greatly reduced, but the volume of soil (containing soluble salts) which came in contact with percolating irrigation water was also curtailed. As the salinity of irrigation drainage water is a function of both the volume of the wetted soil and the quantity of water flowing through it, the increased efficiency in irrigation water use offset the expected increase in the salinity of those rivers draining areas where irrigation expansion continued.

On the basis of the above experience and from similar overseas examples, some general guidelines can be developed when considering the use of restrictive water allocations to control water pollution. These are as follows:

(i) The best results will be achieved with users who

- require large quantities of water,
- use it in an inefficient manner,
- use it in such a way that the quality is impaired, and who
- discharge a significant portion of the intake volume as waste.

(ii) In order to avoid a negative economic impact on a water user, the technical and financial scope for improving water use efficiency in a cost-effective manner should be predetermined. (It should be noted that the irrigators in the above example were all cultivating high value crops.)

(iii) There will be no water quality benefits in instances where improved water use efficiency does not alter the pollution load.

(iv) Additional incentives/penalties may need to be introduced in situations where existing water allocations are protected by water rights. It may be necessary in such circumstances to couple allocation restrictions with water use levies, emission charges or permits, or surplus water marketing systems.

(v) The impact on receiving waters of reduced effluent discharges with possibly higher pollutant concentrations should be investigated. (It should be noted that the dry weather flow of many rivers is dependent upon return flows).

(vi) It is important to be able to justify targeting a specific water user/polluter for allocation restriction, especially where problems of perceived bias arise in the selection process. Such justification should be based the estimated water quality improvements and possibly the increased availability of water.

4.1.3 Water pricing

4.1.3.1 General

Water pricing increases can encourage better water use efficiencies by placing pressure on input production costs. In the case of wastewater price hikes not only increase the value of the intake water but also the value of the effluents. If the value of the effluent is increased to the point where it is too valuable to discharge it into a drain or a river (i.e. higher than the cost of treating it to a condition where it can be reused), then reuse becomes financially viable and significant water quality benefits can be expected.

In First-World South Africa it is the policy of the Department of Water Affairs and Forestry (DWAF) that water supplies to urban consumers be priced such that the full cost of providing the service is recovered[1]. A problem arises when the time-value of money, in an inflationary economy, reduces the cost (in real terms) of water supplied

1 Department of Water Affairs, 1986.

by the older schemes to a level well below one that reflects any significant value of the resource.

When introducing financial penalties to curb household water consumption during droughts, some municipalities found that in order to have any discernible restriction effect, severe penalties were necessary. It has since been speculated that most First-World consumers may only start considering permanent water saving measures when the price reaches about R2.50 per cubic meter, well in excess of the current R1.20 to R1.60 paid by most domestic and industrial consumers. If correct, this would mean that existing urban water supplies are probably underpriced. This in turn suggests that a significant price increase (>50 per cent) may be required before industrial users would consider the cost effectiveness of wastewater treatment and reuse.

It should also be noted that the issue of water pricing is a sensitive one among farming and developing communities, and that any attempt to increase water prices to encourage effluent recycling could be met with resistance. There is also the problem of how to dispose of the additional funds generated by such price increases. Should they be used to subsidise (and artificially devalue) supplies to other user sectors, should it be used for intensified pollution control activities or should it go to Treasury?

Although water tariffs are used widely they are usually viewed as a means of cost recovery rather than as a way of managing demand. Even then, the water supplier does not always successfully cover, costs, since the long-run marginal costs of supply (LRMC) is typically higher than average current costs charged for water. Metering is essential in calculating LRMC and where metering is not available pricing according to LRMC principles cannot be applied

For reason of public health and equity there is a strong case for supplying a minimum amount of water at a nominal low unit rate. Higher consumption of water should attract higher charges to reflect the higher costs involved in providing more water and of course to encourage consumers to use less water for non essential purposes. The water-pricing regimen can of course be fine-tuned and involve deferent tariff structures to encourage off-peak consumption. Where households share a single water connection such as exist in many rural areas of South Africa differentiated tariffs will not work, however. In forecasting the way the demand for water varies with price the price elasticity of demand is an important parameter. There is, however, a dearth of information on water use and price elasticities of demand among urban consumers in South Africa which severely hampers using this parameter in water pricing analysis.

Where it is assumed that charging higher prices for water is effective this means that the price elasticity of demand for water must be significant. There is evidence to suggest that this is the case (Gibbons (1984)). In Australia, Canada and the UK it has been shown that the price elasticity of demand for household water consumption falls within the range -0,3 to 0,7 Bhatia et al., (1993). This means that demand will fall by between 3 and 7 per cent in response to a price increase of 10 per cent.

There is then a growing empirical body of evidence that demand for water will respond to high unit prices in metropolitan areas of developing countries. Industrial users also have a potential to respond to water price increase by reducing demand. Further, where effluent restriction and pollution charges are imposed, which effectively increase the price of water, there is evidence of reduced consumption. Some studies in this respect have forecast that in many OECD countries average industrial water use is expected in the year 2000 to be 50 per cent of what it was on 1975: and in the USA it may be only 33 per cent Bhatia et al., (1993).

The traditional view that water is price inelastic is based on a legacy of low prices being paid for water in most countries. Where water prices have been raised they have shown considerable price elasticity of demand. One factor determining the price elasticity of demand of household consumers is the margin for cutting back water consumption in outdoor use. Industrial use of water is less able to observe such discretionary behaviour and the price elasticity of demand is dependent on the scope for recycling water.

Generally price increases will only be effective in conserving water if the price exceeds the marginal value of the water to the user. In irrigation schemes, for example, price increases are an uncertain way of ensuring conservation practices, where prices have an exceedingly low base to begin with. In such cases the marginal value of the water simply remains above its marginal cost to the user. Here the price of water should be raised to its shadow price, at a maximum and clearly this depends on many factors such as types of crop, location of schemes etc.

It is important to acknowledge that active pricing requires political involvement otherwise water utilities will not readily overcome consumer resistance to price increases for a commodity that is generally considered to be a basic right.

Theoretically economic efficiency in the pricing process for a commodity will be achieved when the necessary assumptions underlying the formation of a competitive market are met.

To establish such a market the rate of water substitution in production must equal the rate of water substitution in consumption and each is equal to a common price. When this equilibrium position is reached a further reallocation of water would make some consumers worse off than they are at the equilibrium price and such a reallocation is therefore inefficient in economic terms.

The important point arising from this result is that both competitive equilibrium and an equality between the marginal costs of supplying water and corresponding prices for water satisfy the commonly held definition of economic efficiency.

There is, however, no market for water in South Africa and therefore these conditions cannot come about unaided. To overcome this restriction a simulated market has to be established. This would require ensuring conditions (a) and (b) above would be met and could be achieved if the supplier of water priced the commodity at its marginal cost of supply. This price would clearly equal the last unit of water purchased and used by each consumer in the South African water economy. Condition (b) above would then be fulfilled. With regard to condition (a) Samuelson (1980) showed that competitive equilibrium in a simulated market would come about between prices and commodity allocations between economic sectors when the sum of the social payoffs throughout the economy minus the transport costs involved in moving the commodity between different sectors was maximised.[2]

4.1.3.2 Pricing goods and services having a polluting effect

Government can affect consumer behaviour and also producer behaviour by fixing the prices of goods or services at levels other than the market-clearing price. Low prices encourage consumption but will discourage investment in productive processes by entrepreneurs if they are set low enough to jeopardise profits. Conversely, prices that are set at too high a level will discourage consumption but encourage production and investment particularly if they result in excess profits.

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2 For details of a water pricing and allocation model based upon these principles, cf., The Application Economics to Water Management in South Africa, WRC Report No 415/1/94, pp. A3.16-A3.36.

Price setting schemes therefore invariably affect supply and demand and can result in imbalances. The effect of pricing schemes although not specifically initiated for environmental reasons may be found in energy industries. The pricing of natural gas is an example. In the USA it was set below the market-clearing price until 1980's and in Japan prices for kerosene have been kept low. Conversely oil prices have usually been set above the marginal costs of production which has resulted in supply/ demand discrepancies.

The market also sets prices, and to this end the government can deliberately foster market driven pricing regimens. Such market pricing can internalise economic externalities arising from pollution. For example where market intervention has effectively set a price or created a market for otherwise freely available goods. An example would be tradable emission permits.

Efficient pricing can then include market values or at least proxy prices for the use and depletion of the environment. Using proxy prices for scarce and costly "clean" environmental resources can encourage the use of freely available common resources under the discipline of market forces e.g., the "correct" pricing of water. Effluent charges, permit fees, and tradable permits are examples of proxy pricing techniques for controlling the allocation of goods and services that have a polluting effect. Proxy prices can also be based on expressions of "willingness-to-pay" to preserve or to pollute, or as some notion of acceptable avoidance costing.

As mentioned above achieving efficient pricing which internalises economic externalities requires a certain amount of effort on the part of both government and the private sector. It involves some study of the costs of the specific economic activities and social goals at stake, which enables the trade-offs involved to be identified and valued in monetary terms.

Capturing economic externalities in pricing systems is an iterative process because externalities usually lie outside the producer-pricing scheme but have to be brought into the pricing process - usually by government intervention. The process is seldom accurate or complete and this is perhaps the prime reason for utilising standards and regulations which can create or reinforce the market approach to the pricing of goods and services which have a polluting effect.

4.1.4 Water marketing

The arguments for water marketing as a means to control pollution are similar to those for restrictive water allocations. The opportunity to market water merely acts as an incentive to ensure that those who have more water than they really require are encouraged to determine their real needs and then sell the remainder for a market related price, thereby increasing and diversifying their income.

In order for water marketing to be efficient economically, a number of legal and political requirements are also necessary. Theoretically, for the economically efficient functioning of water transfers via markets, the following requirements are necessary:

1. The value of water must be recognised as being distinct from the value of land. Water should be bought and sold for its own sake, not merely as an incidental part of a land transfer.

2. Buyers and sellers must voluntarily agree to the reallocation of water, both parties believing it to be in their own best interest.

3. Price (and other terms of water transfer) are negotiable by the buyer and seller and are not constrained to 'non profit' or 'at cost' considerations.

4. As in any other theoretical market, water markets are required to display 'perfect' attributes, which include the existence of a large number of agents, the availability of complete information and minimal transaction costs.

Transactions may include the sale or lease of fee titles, water use permits, conservancy district shares and project contract rights. Further transactions can be in the form of conditional water leases for drought year uses, the exchange of water rights with varying priority dates and arrangements to use conserved water.

From a legal perspective, water in South Africa is regarded as being either public or private. Public water is that which flows in a public stream, whereas private water includes most ground water and the water flowing in private streams, i.e. streams which rise on, and flow across a single property. Private water can be sold for industrial, urban and agricultural purposes, providing a permit is first obtained from the Department of Water Affairs and Forestry. Private individuals and organisations cannot sell public water[3]. When an individual is granted or purchases a water right permitting the abstraction of public water from a public stream, that person does not own the water and is therefore not at liberty to sell it. The owner of a water right merely has the right to use public water for the purpose specified in the right. If he

3 Water Boards, Irrigation Boards and Municipalities are deemed to be public bodies.

chooses not to use it for that purpose it must remain in the public stream whereupon it becomes available to the holders of downstream water rights.

This does not mean that consideration should not be given to the marketing of some or all of the water that forms part of a water right. As this water cannot be taken back and used by the State, unless the right is revoked (something that very seldom happens), it may as well be considered as private property. Therefore any mechanism which discourages the misuse and abuse of this water and which promotes its better utilisation, should be considered. Clearly the purchase of water from farmers by municipalities at urban water prices, has been shown in the USA to be a highly successful way to increase agricultural water use efficiency, reduce pollution from farmlands, and improve farmer incomes, whilst at the same time averting the need to construct new urban water supply schemes.

The private sale of water rights is permitted in South Africa. Unfortunately, as agricultural land without water rights is only worth a fraction of land with rights, the purchasing of water rights invariably means purchasing the land to which such rights pertain. This latter option is referred to in the USA literature as water farming, and is often practised by municipalities and industries in South Africa that are situated in water scarce areas. Because water users get land with their newly acquired water rights, which they neither want nor need, the risk of non-beneficial land use is very real. The primary difference between the sale of water and the sale of water rights is that the latter is a single payment for a right that may be exercised in perpetuity, whereas the former is a series of payments for the sale of a given volume of water. The main attraction of purchasing a water right is that it has a greater measure of supply security than is provided by an agreement to purchase water from an individual who may one day increase the price, sell to someone else or even resume irrigating.

As the term implies, market based control mechanisms require a viable market in which to function properly. Thus, for water marketing to have any beneficial effect on water quality and water use efficiency, there must be a regular demand for water from a number of independent buyers, and an adequate number of independent water sellers prepared to meet that demand. Only in such a market can security of supply be established.

4.2 TAXES AND SUBSIDIES

4.2.1 Policy Implications of Taxes and Subsidies

The policy implications of taxes can be expressed as a "price" that polluting agents are confronted with to induce them to internalise at the margin the full social costs of their activities and to modify their polluting behaviour. This price can take the form of a tax equal in magnitude to the marginal social damage. Such a tax, commonly called a "Pigovian" tax, should be attached directly to the polluting activity and not to some other related activity.

The Pigovian tax should ideally take the form of a levy per unit of pollution emitted into the natural environment not as a tax per unit of the firm's outputs or inputs. An example of such inputs would be coal bought by Eskom for power generation.

It is important to note that the Pigovian tax solution to externality generation has been the subject of critical analysis by Coase (1960). Coase maintains that the government should not become embroiled in the externalities debate and the economic distribution created by externalities can be overcome by private sector negotiation or bargaining.

It is difficult to see this approach being totally successful, however, since problems associated with identifying the polluting agents and the costs involved in the bargaining process are too difficult to overcome to permit a practical solution to the problem of pollution externalities along Coasian lines.

Now it has long been recognised by economist that a subsidy per unit of pollution emission abatement provides the same incentive as a tax to entrepreneurs to internalise pollution externalities: this is because a subsidy of 50 cents per kg of sulphur emission reduction, for example, creates the same opportunity costs for sulphur emission as a tax of 50 cents per kg.

There are however, some subtle and important economic differences between these two policy instruments. In the first instance subsidies increase profits whilst taxes decrease them. Consequently the instruments provide opposite signals to firms regarding entry and exit to a particular market.

Subsidies have the effect of shifting the industry supply curve to the right since a firm will try and increase its output to collect greater subsidies and increase their profit. Taxes on the other hand shifts the supply curve to the left since firms will try to limit their output to the optimal level and reduce their tax burden as much as possible.

These supply curve shifts clearly have an effect on the numbers of firms wishing to enter or leave the market. Subsidies would tend to expand the number of players whilst taxes would tend to reduce the number of players a priori. A problem may now develop since as the number of firms in a particular market increases, pollution emissions may also increase and the possible benefits of subsidy so far as pollution abatement is concerned may be undone.

It seems from the above argument that to obtain the optimally current number of firms in a particular market it is essential that each firm should be forced to pay the total costs of the marginal damages caused by their pollutants and also the total costs of their waste emissions in the form of a tax since only if the total cost of the externality to society is charged will the profitability of each firm reflect the correct benefits of entering or leaving a particular market.

Taxation schemes can change the relative cost of consumption or corporate behaviour by raising costs, which will induce less production of the taxed product. Prices will be raised by taxation schemes hence there will be less consumption of the taxed product. Because of these price and income effects taxes can induce more efficient use of resources.

Taxes on business, including taxes levied to combat pollution, simply raise the cost of doing business and a portion of the tax will invariably be passed on to consumers in the form of higher priced goods or services. Who ultimately bears the burden of the tax depends on the price elasticity of supply and demand in the market for the affected product.

Tax differentiation can lead to relatively lower prices for less environmentally damaging products. Differential taxes tend to bring about substitution among goods consumed rather than reductions in overall consumption levels. Differential taxes for different fuels tend to encourage substitution effects rather than an overall reduction in energy use. Whilst tax differentials directly affect only consumption at first, the shift in effective demand will ultimately affect investment decision-making in production processes.

The other aspect of tax differentiation policy is "forgiveness". This is essentially a reward or incentive to encourage certain behaviour. This mechanism means absolving one group of taxpayers from all or some of their obligation to provide a share of the government's revenue. The remaining revenue is made up by other taxpayers. This allows enterprises to have more money available for investment but it does not necessarily mean that it is the most efficient method of allocating resources.

4.2.2 Types of pollution tax

Pollution taxes or charges are command and control instruments that could be introduced into the water economy of South Africa.

Pollution taxes and effluent charges come in many forms, and are often tailored to specific circumstances. They include:

- Volume of effluent related charges.
- Charges levied on the pollutant concentration, usually based on the amount by which an effluent exceeds some predetermined threshold concentration limit.
- Pollutant load related charges.
- Sliding scale charges, i.e. the more you discharge the more you pay.
- Flat rate charges for certain sizes or categories of industry.
- Annual fixed fee for being permitted to discharge an effluent.

In this chapter a simple tax on the per-unit pollutant load that is discharged to streams and rivers, will be considered. The pollutants considered are the total dissolved salt content (or salinity) of an effluent and the quantity of oxygen demanding waste. The tax will be levied on the tonnage of salt and oxygen demanding waste discharged at a known and measurable point. It is assumed that tonnages will be calculated by means of periodic volumetric flow and pollutant concentration measurements.

The first criticism of such a tax that may be raised is - 'how does that help control pollutant concentrations in effluents, after all it is the concentration that results in an impact on down-stream water users and not necessarily the pollutant load? This is why the General Standard for Effluent Discharge specifies permissible pollutant concentrations.' The response to this is that:

- So long as water remains under-priced and is not considered a major cost factor in industrial processes (even wet processes), the manipulation of effluent concentrations will always be a possible way of complying with effluent concentration standards, especially if a pollution tax incentive is introduced.

- Pollutant loads are an important consideration in the maintenance of environmental quality, particularly in river systems that are heavily impounded and where pollutant accumulation can take place.
- Pollutant load taxes are more equitable in that they are volume independent; thus they penalise polluters rather than industries with a high water consumption. They also do not interfere with water pricing strategies or consumption control mechanisms.
- The discouragement of pollution loading to the environment encourages the treatment of pollution at source. Because of the assimilative limitations of the environment (which are rapidly being reached), this approach is recognised internationally as the direction in which pollution control strategies should develop.
- Pollution taxes can still be imposed in conjunction with Receiving Water Quality Criteria in order to control pollutant concentrations in those flowing rivers into which effluents are discharged.

An additional query that may be raised is why not tax the volume of effluent, as this would create a water conservation incentive? As indicated above, multi-objective taxes may lose their original focus, i.e. a volumetric-based pollution control tax may interfere with the achievement of water pricing objectives. Also, in a hot, semi-arid country such as South Africa, there is considerable potential for effluent volume reduction through evaporation and irrigation, thereby reducing the volume of water in the system without reducing the pollution loading. Volumetric taxes may encourage the use of volume reducing methods.

Another issue that is often raised, - is who should the tax be targeted at? There are instances in other countries where certain industries, which are causing major environmental problems, are taxed whereas other industries which produce the same pollutant but in much smaller quantities, escape tax. This situation often has more to do with the cost of tax collection and effluent discharge monitoring than the respective impacts of the effluent discharges. It is generally more cost-effective (but sometimes inequitable) to collect taxes from a few major polluters than from a large number of very small polluters, particularly in developing economies which possess a sizeable informal and entrepreneurial sector. Hence volumetric sliding scales or threshold volume levels are sometimes found in pollution tax systems. This is an option that might be employed if South Africa were to adopt a system of pollution taxes, although it should only be considered after detailed sectoral analysis of the socio-economic impact of the tax. Pollution tax impacts are discussed in the next section.

4.2.3 Impact of Pollution Taxes

Pollution taxes can impact enterprises and South Africa's economy in the following ways:

- Company profits and enterprise viability;
- Sector competitiveness;
- Employment levels;
- Pollution emission levels and subsequent tax revenue;
- Likely environmental benefits.
- Opportunities for new enterprises.
- New marketing opportunities.

To undertake a quantitative assessment of anticipated impacts requires a very different type of study to this research project. Extensive interviews would need to be conducted with politicians, business, organised labour, and environmentalists to determine the likely responses to a policy of pollution taxation. Furthermore, as such a survey will at best encounter a sceptical response, and at worst, predictions of disaster, (few people are positive at the prospect of new taxes) the results may not be encouraging. Consequently, it was deemed necessary in this section to include a brief discussion on the nature of both the positive and negative impacts often associated with pollution taxes.

Before the likely impact of a pollution tax can be estimated, however, the objective and level of tax must first be determined, the latter being entirely dependent on the former. The next section will discuss these issues.

4.2.3.1 Taxation Objectives

Pollution taxes can have a number of objectives, some of which may have nothing to do with pollution control. For example they may be used to:

1. Raise revenue to:

    - Increase income for the general fiscus.

- Fund pollution control administrative and technical services.
- Establish a fund from which subsidies could be awarded to industry to install pollution control equipment.
- Establish a fund with which to assist poor communities to properly treat and dispose of their waste.
- Establish an insurance fund from which downstream water users who are impacted by upstream effluent discharges can be compensated.

2. Prevent pollution from increasing any further; i.e. maintain the status quo.

3. Reduce pollution to a predetermined level.

4.2.3.2 Selecting tax levels

Whilst these three objectives are all achievable with pollution taxes, the policy-maker has no way of knowing at what level to set the tax in order to achieve any given objective.

Experience from countries that have used pollution taxes for several years has shown that it is not so difficult to introduce a tax for revenue generating purposes, - one simply begins with a low level tax and periodically increases it until pollutant discharges start to fall. Just prior to this is the point where tax revenue is maximised without any pollution control benefits. In other words the revenue base is not threatened by pollution reductions. This does not mean that the revenue per se is maximised. The tax level that yields the maximum revenue may well be associated with significant reductions in discharge; i.e. the remaining polluters are prepared to pay a high tax without altering their discharge. In such circumstances, maximum revenue would only be attainable with a pollution reduction objective and not with a revenue generating objective. This debate will be briefly discussed next.

4.2.3.3 Revenue generation versus pollution control

Problems may be experienced with multi-purpose pollution tax systems. However, this does not seem to discourage policy-makers for opting for the so-called 'double-dividend' in pollution taxes whereby the level of the tax reduces pollution emissions and the revenue generated is used to further reduce pollution by means of pollution control subsidies for industry, waste management assistance for poor communities, and intensified pollution monitoring.

The problem arises when self-funding pollution control agencies start to depend on the revenue from a tax which was introduced to reduce pollution. Such a revenue base is vulnerable to one of two developments.

- Abatement costs fall due to new technology, resulting in some industries preferring to treat effluent rather than discharge it and pay tax. This occurrence is often prevalent in situations where industrialists anticipate regularly increasing tax levels and invest in treatment technology either early or at the point where it becomes cost-effective.
- The pollution control benefits of the tax prove insufficient thereby forcing an increase in tax levels to a point where the discharge deterrent is sufficient to reduce total revenue.

The problems described above have occurred in Europe and have led to some interesting consequences.

In one instance in the Artois-Picardie River Basin in France the tax level was set quite high resulting in an effluent discharge reduction of 45% between 1975 and 1984. However, this was associated with a reduction in industrial and municipal water abstractions from 560m^3 per year in 1970 to 479m^3 per year in 1989 due to greater water use efficiency and wastewater recycling[4].

In the Netherlands[5], an industrial wastewater discharge levy was introduced in 1970 with the intention of raising revenue to help fund the administration of a wastewater licensing and monitoring system. However, the levy was set too high and industries started treating their effluent in-house to avoid paying the tax. Between 1970 and 1976 industrial water consumption fell 30% while industrial productivity grew. As wastewater discharges fell the tax was increased to preserve the revenue for water pollution control administration. Since 1980, the levy has increased 100% and has

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4 Tuddenham, M (1994) The System of Water Charges. In - *The Greening of Government Taxes and Subsidies: An International Casebook on Leading Practices.* IISD.

5 OECD (1987) Pricing Water Services, OECD, Paris.

resulted in a 65% reduction in the discharge of oxygen demanding waste. Between 1971 and 1993 the Dutch water authorities have collected effluent taxes totalling Df 11.4 billion or R25.88 billion.

Whilst a well-considered, gradual 'trial and error' approach to the setting of pollution taxes appears to be called for, determining an introductory level of tax is still a problem. Studies similar to this one can be undertaken to estimate sector by sector revenue from a specific pollution tax. This revenue can then be compared with the declared profit margin of each sector to see if the impact is likely to be significant or not. Alternatively, the marginal cost of abatement could be calculated for each individual discharger, however this is likely to be a major task and may not represent the real response of industrialists.

4.2.3.4 Likely Impacts of Pollution Taxes

Pre-pollution tax investigations conducted in other countries have often predicted a wide variety of negative consequences, most of which were intended to discourage government from introducing pollution taxes in the first place. Predictions of the collapse of entire industrial sectors and the subsequent swelling of the ranks of the unemployed, were not, and are not, uncommon. However, most of these types of studies are generally too narrow and demonstrated too superficial a knowledge of the workings of the economy, to be of any real value. One of the commonest oversights is the employment opportunities that are created by changes in government policy on pollution, particularly when greater responsibility is placed on the polluter to either clean up or pay up. Such policy changes have led to the creation of entirely new industrial sectors offering advice, products and services relating to waste management.

Another common omission is the adaptability of the private manufacturing sector to a changing production environment whilst maintaining competitiveness. There are a growing number case studies which demonstrate that being forced to consider the level of emissions also forces a company to consider its consumption of raw materials, the associated wastage and inefficient use of materials, the streamlining of production processes, and the actual value of what was originally considered waste substances. By undertaking life cycle analyses and internal environmental audits, and by implementing the recommendations of these studies, companies not only become more efficient, but their products may also become more acceptable to markets with high environmental production criteria.

Another spurious objection to pollution taxes is the argument that industrial development will be suppressed in an area where such taxes are imposed, leading to industries migrating to neighbouring countries where pollution control is more lenient and less expensive. An investigation into the primary facets of industrial location analysis will reveal that the cost of complying with pollution control requirements is often a minor consideration compared with the cost of site development, electrical energy and distances to and from markets. In any case, new industries can generally meet high levels of effluent treatment at a fraction of the cost of established industries.

However, the impacts of the introduction of pollution taxes may not always be positive and the anti-pollution tax lobby may well possess good arguments as to why the imposition of such taxes should be reconsidered. Whilst appearing to be fair and adhering to such sound principles as the 'polluter must pay', pollution taxes are quite capable of exerting an inequitable impact on certain industrial sectors and on certain sectors of society.

Pollution taxes, like most environmental regulations, hit older industries the hardest. Indeed. Given the age and low resource use efficiency of older manufacturing plants, taxes which are based on pollutant loads, as opposed to concentrations, are likely to have a greater negative impact because of the higher throughput of raw materials and waste generation per unit of production. Moreover, both volumetric and pollutant load sliding-scale taxes (i.e. the more you discharge the more you pay), are going to penalise old industries even further. Old industrial plant is also difficult, expensive and sometimes non-cost-effective to upgrade.

But it is the labour issue that discourages governments the most from imposing potentially harmful pollution taxes on old industries. Old industries are generally more labour intensive than their newer, automated and more efficient counterparts. Thus factory closure, due to the imposition of pollution taxes and resulting non-viability, can exact a high social cost. Even factory modernisation, prompted by environmental policy changes, can result in job losses due to the introduction of more labour-efficient production systems. The theory is frequently advance by environmental policy-makers that old industry welcomes the introduction of new and more stringent environmental regulations as it presents an opportunity to refurbish manufacturing plant, reduce the labour force, and place the blame for redundancies firmly on the shoulders of the government.

Another negative aspect of pollution taxes is their potential for stimulating price increases, and thus inflation, when applied to monopolistic industries. If pollution taxes are imposed on monopolies, the pollution deterrent effects are likely to be zero and the cost of the tax could well be passed directly onto the consumer, often with an explanation as to why the price is being increased. Therefore, unless government can control price increases in monopolies, very careful thought should be given to the imposition of pollution taxes. Pollution taxes actually work best in highly competitive systems where manufacturers have to internalise as much of the tax as possible in order to maximise their competitiveness.

Clearly, while there may be winners in the introduction of pollution taxes, there may also be genuine losers. It is the task of government to decide whether it will accept the losers as a victim of economic progress, compensate them, or tolerate old polluting and inefficient industries. One frequently adopted option for ameliorating the negative impacts of pollution taxes is to use the tax revenue to issue subsidies to older industries to help them install pollution control equipment. Whilst this can be, and is in many countries, a highly successful strategy, and one that is still permitted under the recently signed GATT treaty, it also has numerous pitfalls many of which pertain to the limited thought that governments often give to the targeting and administering of subsidies. Inappropriately handled pollution control subsidies can quickly erode any existing incentive mechanisms for effluent discharge reduction and result in increased levels of pollution. It can also lead to a demand for subsidies which exceeds the available revenue base resulting in one group of effluent dischargers paying increasing taxes to subsidise a growing number of less profitable polluting industries.

Government must always be careful to restrict pollution control subsidies to a narrow category of worthy industrialists. It is far easier to broaden the range of subsidy beneficiaries than it is to restrict it. Whilst employment criteria can be useful in targeting pollution control subsidies, governments must be careful not to fall into the trap of supporting so called 'lame duck' industries, i.e. those that are in decline and will eventually close with or without subsidies.

4.2.4 Estimated Revenues from the Introduction of Liquid Effluent Taxes in South Africa

The following is the approach adopted in estimating the possible revenue from the imposition of a liquid effluent tax.

- The tax is imposed on all liquid effluents discharged by the manufacturing sector at a measurable point into rivers and streams.
- Discharges to sewers, solid waste sites, irrigation sites and the marine environment are not considered.
- Discharges by other sectors of the economy (e.g. mining, agriculture and municipal) are not considered.
- The tax is imposed on the pollutant load, (i.e. the volume of effluent multiplied by the pollutant concentration.
- A tax of R10 per ton is imposed on both total dissolved salt loads and oxygen demanding waste loads.
- The revenue is calculated for the level of production achieved in the 1992/93 financial year.

The manufacturing industries included in this analysis are those contained in Major Division 3 of the Central Statistical Service's (CSS) Standard Industrial Classification of Economic Activities (Fifth edition). The effluent discharge data was obtained mainly from the Water Research Commission's (WRC) Natsurv Project and other WRC sectoral studies on industrial effluents such as leather tanning and textiles. The effluent discharge data was converted to discharge per unit of production and then used in conjunction with the CSS's sectoral production data for the 1992/93 financial year to calculate annual effluent volumes and qualities. This calculation, which involved the processing of considerable quantities of economic data, was performed using the Development Bank of Southern Africa's (DBSA) SANEEP Model. This model permits the imposition of pollution taxes in order to estimate revenues and to determine the distribution of revenues among the different types of polluting industries.

The results of the effluent tax revenue simulation are presented in Table 4.1 (total dissolved salts) and Table 4.2 (oxygen demanding waste). The contributions of the various industrial sectors to the total revenue are ranked in order of magnitude.

It will be immediately noticed from Tables 4.1 and 4.2 that the tax burden is not evenly distributed. Indeed, it is highly skewed with 94% and 91% of the revenue respectively coming from the same four industries, i.e. textiles, leather and tanning, metals and petro-chemicals. There is also considerable skewness within these four sectors. For example, in the case of total dissolved salts, the textile industry would be responsible for over 60% of the national revenue from this pollutant. While for oxygen demanding wastes, the petro-chemical industry would be responsible for almost 49% of revenues.

The other point that may be noticed is that the top four sectors are all quite old South African industries. They most likely possess ageing plant that is probably inefficient in terms of resource use, outmoded in terms of cost-effective pollution control, and expensive to upgrade. Furthermore, with the exception of petro-chemicals, they are all labour intensive. Indeed, in the case of the textile industry, major policy issues have recently been raised concerning the Government's future support for this sector, particularly in view of the need to remove all the protection it enjoys within 15 years to comply with the conditions of the GATT treaty.

This raises the question of whether these industries would be able to pay pollution taxes of the amounts shown in Tables 4.1 and 4.2, bearing in mind that the amount of R10 per ton for TDS and oxygen demanding wastes is purely arbitrary.

The amount of R130 million for the textile industry represents approximately 7.8% of the sector's R1652 million turnover in 1992/93. However, as the sector's contribution to Gross Domestic Product (GDP) for that year was only R225 million, it is reasonable to assume that its profit margins were quite small in relation to its turnover. Hence, an additional tax burden of R130 million may be difficult for it to accommodate, particularly since the sector is striving for improved competitiveness.

The petro-chemical industry is of course far wealthier than the textile industry, although it is also confronting the possibility of deregulation and increased competition. It must be pointed out however, that the data used for the petro-chemical industry is of a very poor quality compared to that for the textile industry. Estimates of pollution discharge have been drawn from the international literature and could be highly unrepresentative of the South African situation. It does however raise the issue of how serious the pollution is from this sector given that it has been shrouded in secrecy for the duration of the sanctions era.

The R49 million the petro-chemical industry would have to pay if a R10 per ton tax were imposed on the discharge of oxygen demanding waste, represents 0.3% of the sectors annual turnover in 1992/93. As the sector contributed over R7289 million to

GDP in that year it is safe to assume that such a tax would be quite affordable and may not result in any further abatement measures by the industry.

SECTOR	REVENUE (R)	%
Textiles	130 171 400	60.29
Leather and Tanning	36 560 700	16.93
Metals	19 425 000	9.00
Petro-chemicals	16 840 500	7.80
Tiles, Bricks and Cement etc.	3 982 800	1.84
Sugar and Sugar products	3 523 500	1.63
Rubber products	1 783 000	0.83
Food processing	1 379 500	0.64
Wood, Pulp and Paper	1 223 700	0.57
Glass and Pottery	326 800	0.15
Beverages	189 000	0.09
Plastics	175 500	0.08
Grains, Starches and Feeds	168 500	0.08
Paints and Detergents	144 000	0.07
	215 893 900	100.00

NB: The secrecy surrounding the production and pollution levels in the petro-chemical industry has only recently been lifted. As such the availability of South African data is still very poor. Consequently, international data on pollutant emissions for this sector have been used.

TABLE 4.1: ESTIMATED SECTORALISED REVENUE FROM IMPOSING AN EFFLUENT TAX ON TOTAL DISSOLVED SALTS FOR THE YEAR 1992-93

SECTOR	REVENUE (R)	%
Petro-**chemicals**	105 252 800	48.79
Textiles	60 074 600	27.85
Leather and Tanning	18 093 800	8.39
Metals	12 723 600	5.90
Food processing	4 312 100	2.00
Tiles, Bricks and Cement etc.	3 982 800	1.85
Sugar and Sugar products	3 915 000	1.81
Rubber products	2 971 600	1.38
Wood, Pulp and Paper	1 748 100	0.81
Beverages	1 347 600	0.62
Glass and Pottery	454 500	0.21
Paints and Detergents	385 700	0.18
Plastics	292 500	0.14
Grains, Starches and Feeds	168 500	0.08
	215 723 200	100.00

NB: The secrecy surrounding the production and pollution levels in the petro-chemical industry has only recently been lifted. As such the availability of South African data is still very poor. Consequently, international data on pollutant emissions for this sector have been used.

TABLE 4.2: ESTIMATED SECTORALISED REVENUE FROM IMPOSING AN EFFLUENT TAX ON OXYGEN DEMANDING WASTE FOR THE YEAR 1992-93

The interesting feature of the exercise carried out and described in the last chapter was the way in which the pollution tax targeted old and weaker industries such as textiles and tanning. Both industries have a long history of polluting surface water resources in South Africa and the search for affordable pollution control strategies has been ongoing for well over a decade. It must be pointed out that much of the research that has gone into finding pollution control solutions for these industries has come from the Water Research Commission. Perhaps what is required now is an incentive system to encourage the widespread implementation of the wastewater treatment technology that has been developed for these industries.

The analysis documented in this report has shown that great care is required in taking successfully working economic-based pollution control systems from other countries and applying them to the South African situation. The possibility of a combined objection from industry and organised labour to the introduction of fiscal instruments for pollution control is very real. However, there is also little doubt that effluent taxes, used both as a discharge deterrent and as a means of raising revenue, do have an important role to play in the pollution control of our water resources. The key would seem to lie in structuring the tax package such that it includes subsidies that are targeted at those industries that are inequitably disadvantaged by the tax. Clearly, the selection, targeting, and level of introduction of pollution taxes must be preceded by the necessary socio-economic investigations to avoid unintentional negative impacts.

It should be noted that, should the introduction of a pollution tax result in failure and embarrassment for the implementing agency, it will be very difficult to re-introduce it at a later date. As such a useful water quality management tool will be lost.

4.3 TRADABLE DISCHARGE PERMITS

4.3.1 Conditions needed to support permit trading

The points made in the last paragraph of 4.1.4 offer an appropriate introduction to a discussion on the application of tradable effluent discharge permits in South Africa. Tradable permits are, in principle, an equivalent alternative to taxes. Hence instead of setting the optimal (Pigovian) tax and reaping an economically efficient level of pollution discharge, the environmental authority could issue the efficient number of tradable permits and allow firms to compete for them. This would generate a market clearing price for the permits, an outcome that satisfies the economic argument for pollution abatement activities in the short run, and equally important, for the entry and exit conditions of firms into the market in the long-run. Further, the regulator has the option of setting either price or quantity constraints for the permits to achieve the desired result.

There is, as in all things economic, a caveat to this suggestion: it is based upon the tenuous assumption of perfect knowledge. Considering the imperfect information usually attached to firms' costs functions, and societies' damage functions, this is of course difficult to justify as being extant.

Any investigation on the workability of a tradable permit system for waste water discharges within catchment-based bubbles[6] must focus on one single issue: - is there a viable market for permits to be traded efficiently and effectively to the ultimate benefit of society? By analysing the examples of permit trading as reported in the literature, one starts to suspect that tradable permits are best suited to air pollution control strategies rather than those for water pollution control. This seems to contradict the widely held belief that good accurate information (such as that collected for point source effluent discharges to rivers) is an important prerequisite for permit trading. But, as indicated previously, the existence of a viable market populated by an adequate number of active and independent players is more important than the availability of accurate information.

The problem with many South African situations where permit trading may prove beneficial, is that catchment based bubbles are too small, in terms of the number of emission point sources of a particular pollutant, to support a viable market. By contrast, air pollution bubbles are, by virtue of the nature of the pollutants, much larger and can thus include a greater number of independent players. In theory, one could conceivably establish a global air pollution bubble for managing greenhouse gas emissions. There would certainly be sufficient players to create an active market.

4.3.2 Possible application of permit trading in South Africa

Two categories of water pollutants may be suitable for permit trading in South Africa. These are nutrients and oxygen demanding wastes. Unfortunately, the primary

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6 Bubbles are geographic collections of emission points whose total emissions are regulated. Permits can be traded by firms and plants within bubbles to alter individual source emissions whilst keeping the overall emission from the bubble constant.

dischargers of these types of wastes are municipalities, particularly those serving the poorer communities, who do not have the capital resources to afford adequate oxidation and maturation treatment facilities. It is unlikely that these dischargers will be in a position to compete in a free market for permits. If they fail to acquire permits they will merely continue to discharge effluent illegally. Should the State intervene to assist such communities by either buying or reserving permits for them, then the incentive for minimising pollution will be destroyed.

The scope for applying either CAC (command-and-control) or economic based pollution control instruments to poor communities is limited. If such communities were to be prosecuted for contravening pollution 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 pollution problem.

There are other categories of pollutant such as saline wastes in Gauteng, and sulphate waste in the Upper Olifants catchment (which will be discussed in more detail in this chapter). However, both have a significant non-point source component, thus a tradable permit system may not achieve the water quality goal that was intended, a factor which may tempt point source dischargers to disguise their effluent emissions as non-point source pollutants (e.g. effluent irrigation and dust suppression) in preference to having to buy additional permits.

4.4 Emission Charges

4.4.1 Merits and suitability

The main criticism of emission charges used to be that the cost of determining, imposing and collecting the charge was so great that the income it generated was hardly worth the effort. Then administrators increased the efficiency of emission charge systems by targeting them more specifically at those polluting activities which were widespread and on which charges could be levied with relative ease and at low cost. Hence, as has been shown earlier, the situation exists in many countries where emission charge systems are used largely to generate revenue for funding other public sector environmental control responsibilities. Few such systems have a pollution deterrent purpose, as the charges are usually set too low. Whether this is a result of political lobbying by polluters or concern that revenues may fall if charges are increased to the point where polluters reduce discharges to avoid levies, is probably a complex issue. Given such a dubious history, do charges have a place in South African pollution control activities?

The answer is undoubtedly yes? Indeed, charges are probably more suited to South Africa, with its mix of First and Third World economies, than they are to the USA and Europe. It has been demonstrated over the last eight years that environmental management is far down the South African Government's list of priorities when it comes to the allocation of State funds. There are just too many other important issues that require scarce financial resources, and this situation is likely to continue for some years. Therefore any system which generates revenue for pollution control activities, either at a national or local level, must surely be worth considering, regardless whether or not there are pollution control spin-offs.

Charges can be levied on both point and nonpoint sources; however the nature of the charge is different for each type of pollution.

4.4.2 Point source pollution

Water pollution control charges should be levied on the volume of water discharged and the pollutant concentration. Thus it requires good monitoring facilities at the point of discharge. This limits the range of South African polluters to the wealthier municipalities and wet-industries (e.g. textiles, tanning, food and beverages, power generation etc.). Unfortunately, these are also the industries that have made good pollution control advances in recent years, and it could be argued that the authorities, in introducing charges on emissions from these industries, are merely aiming for a 'soft' target from which it is easy to collect revenue. In other words, these industries would be penalised for having well-managed and well-monitored effluent systems. In addition, those activities which carry a heavy responsibility for water quality deterioration in South Africa (e.g. farming, abandoned and some working mines, informal settlements etc.) would probably be exempt from charges because of the difficulty and expense in determining and collecting the amounts payable.

Therefore care must be taken when imposing charges on point source pollution to ensure that the system is equitable and justified. For this reason point source effluent charges are probably best implemented at a local level for specific pollutants or groups of pollutants (e.g. nutrients, oxygen demanding wastes etc.). The system should also be applied to pollutants that result in a low-level impact on downstream water users, as it is probably inevitable that administrators will set charges to generate revenue rather than discourage discharges. Like many economic instruments for environmental management, emission charges alone are not a solution but are best used in conjunction with other instruments (both economic and CAC).

4.4.3 Nonpoint source pollution

As indicated in the last section, emission charges are best suited to well-monitored point sources of pollution. However, it is possible to introduce an indirect emission charge for more insidious types of pollution by levying charges or taxes on the activities that give rise to this type of pollution. As shown previously, these taxes (sometimes referred to as 'Green Taxes') have and are being applied to air pollution by means of a levy on the carbon, lead, and sulphur content of various fuels. Can these approaches be applied with any significant benefit to water pollution in South Africa?

A charge could be levied on the use of fertilisers by farmers in those areas where the eutrophication of rivers and dams is an expensive problem for water treatment plants. Such a charge would have to be combined with a charge on point sources of nutrients. Levying charges on activities that merely exacerbate natural levels of contamination may prove problematic in that it is the activity and not a polluting substance used by the activity that must be taxed. For example, irrigation releases more inorganic salts into the drainage system than would otherwise have been released by natural rainfall. Thus a tax would have to be levied on processes which mobilise excessive quantities of salts (e.g. over-irrigation, the irrigation of soil which does not contribute to crop growth etc.). Such a levy may be imposed in the form of a tax on flood irrigation, the salt content of certain soils, the quantity of water used per unit area of irrigation or, on certain well-organised irrigation schemes, the quality and quantity of return flows.

An alternative and lower cost approach to the taxing of specific practices which give rise to nonpoint pollution would be to introduce a flat rate tax for the activity in question, regardless of what practices are employed, and then offer pro-rata rebates on those practices which reduce nonpoint pollution or convert it to point source pollution. In other words, by using the above example, a tax would be levied on irrigation per se and rebates offered for that portion of the irrigation that employs efficient water application techniques.

The use of charges in controlling nonpoint pollution from mining operations will be discussed in the following section.

4.5 CONCLUDING REMARKS

This chapter has looked at the strengths and weaknesses of a range of economic instruments. It is clear from the discussions that water pricing emerges as a formidable management tool. However, this topic has been covered in greater or lesser detail in other reports referred to, and it was desired to focus more strongly on other instruments which have as yet not had significant exposure. Furthermore the subject of water pricing remains a vast one, and it would not be feasible to do it greater justice within the confines of this report.

The remaining instruments considered fall into two categories; market and non-market related instruments. Market related instruments (such as tradable permits) have demonstrated their ability to allocate scarce natural resources in an economically efficient manner, provided that the market is not too thin and they are traded regularly. They therefore show promise as potential instruments for managing water quality.

Non-market related instruments are essentially charges, subsidies and taxes. These are command-and-control instruments and they have both strengths and weaknesses. Amongst their weaknesses is their inability to control players' entry to and exit from the market, and the fact that they do not intrinsically engender entrepreneurial activity. On the other hand, one of their main strengths is their ability to redistribute income, and they are therefore powerful instruments for dealing with issues of economic equity. A tax which is proportional to pollution discharge would be effective in motivating pollution abatement measures since reduced pollution discharge would lead to lower tax rates. If the onus were on the polluter to demonstrate this reduction in pollution discharge, then the administrative burden would also be lessened.

Economists generally favour market-related instruments over command-and-control instruments because they are considered to be cheaper to put in place and to administer. However, even given a market-friendly environment, tradable permits will not necessarily emerge as suitable instruments for water quality management, unless their performance can be properly monitored. In other words, it has to be demonstrated that the holders of permits are not exceeding the discharges allowed them in terms of their permits.

At this stage it cannot be categorically recommended that any one instrument, or in fact a mix of instruments, be used. Each proposed application would need to be considered individually. The next chapter examines a specific area and investigates a suitable mix of instruments for that specific application.

PART FOUR

A Practical Application

CONTENTS

FIGURES

TABLES

5. ECONOMIC INSTRUMENTS AND THE OLIFANTS RIVER CATCHMENT

5.1 INTRODUCTION

The primary thrust of this chapter of the report is to examine the Olifants River Catchment, its water quality problems and to postulate and test an appropriate set of economic instruments.

The overview of the study area establishes that sulphate emissions (both point source and non-point source) from mining activities in the catchment play a determining part in the water quality of the Witbank Dam, so economic instruments which can assist with management of this problem have been focused upon. Appropriate instruments are selected, and these are tested using two models that simulate market forces in operation in conjunction with these instruments.

A representative simulation exercise presupposes two main data sets, one relating to emission levels into Witbank Dam, and the other relating to emission abatement costs on the part of the mines. The first data-set uses information assembled by Wates, Meiring and Barnard (WMB)[1] and posed no particular problems. Data relating to individual mines' abatement costs, however, proved less tractable, despite efforts made by the researchers and members of the steering committee. As a result it was decided that the simulation should be used as an educative device aimed at increasing understanding among interested parties of the operation of economic instruments, rather than as a definitive problem solving exercise. Consequently a dummy data-set was postulated which enabled the integrity of the simulation models to be tested, as well as to clearly demonstrate the action of the instruments in practice. This having been done, the models are ready to accept real data sets (which would need to be assembled together with interested parties in a workshop-like environment) and they could then be used in an interactive, problem-solving mode.

5.2 OVERVIEW OF THE STUDY AREA

WMB have summarised the regional context as follows:

1 Water Quality Management of Water Resources in South Africa, Department of Water Affairs and Forestry Report No. 1505/611/1/W, September 1993.

"The geographical extent of the upper-Olifants river, upstream and including Loskop dam is shown in Figure [5.1]. Several drainage basins, including Olifants River catchment, Klein-Olifants River catchment, Wilge River catchment and Klipspruit catchment are located upstream of Loskop Dam.

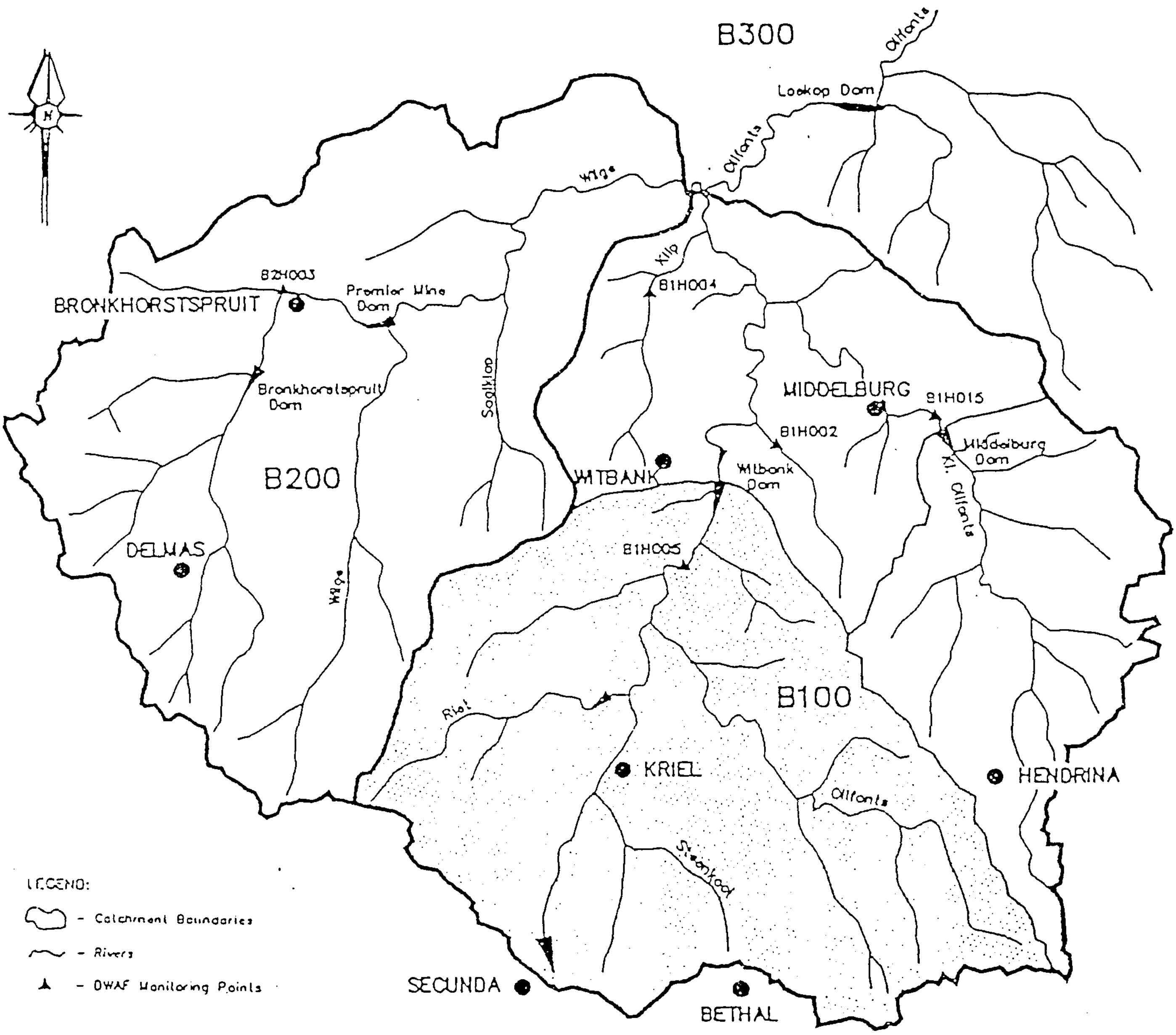

FIGURE 5.1: THE UPPER OLIFANTS CATCHMENT

An investigation into the sources of salinity and of specifically chloride and sulphate was conducted in the Olifants River upstream of Loskop Dam (WMB Report - Historical Water Quality Status and Trends in

> Middelburg Dam dated November 1992). The investigation confirmed that the Olifants river catchment upstream of Witbank Dam is the single largest source of sulphate and chloride pollution; it is estimated that the Witbank Dam catchment contributes 41% of the chloride load exported to Loskop Dam."

In addition to the WMB report, the sources of sulphate[2] that are located in the catchment, and which result in the high sulphate levels of the Witbank Dam, are analysed in a Department of Water Affairs/ and Forestry/Eskom report dated 1989[3].

The findings are that agriculture, power generation and coal mining activities are responsible for the major sulphate pollution in the Witbank dam: their various contributions are discussed below.

Agriculture is believed to have the least impact, because agricultural activities are limited mainly to dryland farming and grazing. It must, however, be stated, that some irrigated agriculture can be found in the northern part of the catchment, downstream of Witbank Dam. It can be assumed that in this particular region the impact of polluted water on agriculture will be larger than the impact on water by agriculture itself.

Coal fired power stations emit sulphates in four ways:

1. particulate matter from smokestacks forms a minor source since the electrostatic precipitators are 95-99% effective.
2. discharge of excess blowdown to the streams
3. seepage from ash dams and coal stock piles
4. dust blowing from ash dumps and stockpiles onto the surrounding land

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2 It is estimated that the sulphate contribution form the Witbank Dam Catchment amounts to 44% of the total load exported from the Upper Olifants River to Loskop Dam. (Personal communication with Mr AM van Niekerk of Wates, Meiring and Barnard, 25/1/96).

3 Department of Water Affairs/Eskom, Investigation into water quality problems at Duvha, Arnot and Hendrina power-stations, Confidential report of the Joint Working Group on Water Supply Quality to the Transvaal Power-Stations, Report. No. E B100/00/0189, 1989.

Coal Mining contributes sulphates through:

1. mining operations such as excavation and blasting, which introduce sulphate rich dust into the atmosphere
2. point sources such as leachate and runoff from both active and abandoned spoils dumps and stockpiles, as well as pumped discharges from active open cast and underground mines.
3. non-point sources which essentially consist of runoff from areas immediately surrounding the active mining area.

WMB conclude that:

> "Non-point sources of pollution associated with coal mining activity constitute the single largest sulphate load contribution to Witbank Dam. Technology exists to reduce this source of pollution in the form of stormwater control, rehabilitation of waste dumps, collection and re-use of seepage and of polluted drainage. Diffuse source pollution control on coal mining complexes was identified as the most attractive approach to salinity management."

In total, the impact of power station effluents is judged to be small, estimated at 6.5% of the sulphate load entering Witbank Dam, while approximately 70.6% of the sulphate load entering Witbank Dam does so by way of drainage from areas influenced by mining activities. A large portion of this mining activity is concentrated in five zones, covering approximately 6% of the total catchment area. In the subcatchments affected by these zones, sulphate concentrations ranging from 200 to 2000 mg/l were measured during a 1987/88 survey, whereas in the subcatchments devoid of mining they ranged from 10 to 55 mg/l.

The increase of the sulphate content in Witbank Dam brings about considerable costs. One area in which increased cost can be attributed directly to the increasing sulphate content of the catchment is that of electricity generation.

Duvha power station, one of the important elements of Eskom's supply capability because of its ability to provide large quantities (3600 MW) of baseload power that is amongst the cheapest in the grid, was designed to draw a substantial quantity of its water requirements from Witbank Dam. In really severe drought conditions, Duvha would draw 100% of its water from the Witbank Dam.

However, Duvha was designed to accept water of the quality that pertained at the time construction of the station commenced in 1977, namely approximately 25 mg/l of sulphate concentration. This quality has subsequently declined to sulphate concentrations in excess of 100 mg/l, as a result of increased open cast coal mining, power generation and other land uses in the catchment, and there are fears that the quality could fall further as the expansion of coal mining continues.

This presents Eskom with three options: either to infringe the zero effluent standards to which the station was designed, to upgrade the station to deal with the reduced quality of intake water, or to bring in Komati System Water.

The first of these options is unacceptable to the Department of Water Affairs and Forestry (DWA&F), because any effluent discharged from Duvha would cause further deterioration in the quality of the water in Loskop Dam, which is used for the irrigation of salt sensitive crops. Consequently, in practice the increased sulphate loading confronts Eskom with whatever costs will be associated with the technical remedies that may exist.

5.3 SELECTION OF ECONOMIC INSTRUMENTS FOR CONTROLLING SULPHATE POLLUTION IN THE UPPER OLIFANTS CATCHMENT

5.3.1 Administrative options

In Chapter 4 and Appendix B the concept of a bubble, and the application of various economic instruments within bubbles, are discussed. Although the Water Quality Management Plan for the Witbank Dam identifies a number of Management Units, The catchment is still an attractive candidate for such a bubble, for the following reasons:

- the bubble outlet may be clearly demarcated by the Witbank Dam, or the inflows thereto, and monitoring facilities exist for pollution sources;
- the upstream polluters are essentially private sector organisations such as coal mines and possibly certain Eskom power stations; and
- the users affected by the sulphate pollution are limited to Eskom's Duvha Power Station, Highveld Steel and Vanadium and the Municipality of Witbank, both of whom abstract water from the Witbank Dam.

In other words, it is a system in which the main players are all capable of competing in a market-based system for pollution control.

Two possible administrative options exist for controlling sulphate pollution within the Upper Olifants bubble:

1. Control by a public sector authority using a combination of command-and-control and economic instruments to ensure the attainment of water quality goals, achieve a measure of cost-recovery and the establishment of incentives for self-regulation;
2. Autonomous control by a private sector body created by the polluters to manage emissions and achieve water quality goals on their behalf in an equitable manner.

The economic instruments that may be used by either the public sector authority or the private sector body are discussed in the following sections.

5.3.2 Operational costs of Economic Instruments Vs Command and Control

An important issue in considering the impact of using economic instruments, is the impact which the use of economic instruments may have on administrative cost structures vis-à-vis the impact of the existing control-and-command approach.

This section analyses the costs of the following approaches to water quality management in the Witbank Dam catchment:

- The conventional command-and-control approach i.e. total control by the water authority
- A joint venture between the water authority and the polluters as proposed by WMB
- An economic based approach using 'green taxes' and tradable emission permits

The cost analysis focuses on the financial costs of establishing and operating the various systems and takes into account issues such as cost of monitoring and administration expenses.[4]

In the CAC approach the authority takes total responsibility for setting maximum emission standards for each polluter, monitoring the levels of emissions by each polluter, and setting an appropriate penalty if maximum emission standards are exceeded.

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4 Full details of the scope and calculations involved in this analysis can be found in Appendix A of this document.

In the economic based approach rather than set a maximum emission standard for each polluter, the authority would set a water quality standard for the catchment. Each polluter in the catchment would then be allocated a tradable permit that would allow a certain amount of emissions, with a penalty being imposed for exceeding this limit.

The analysis assumes data as presented in WMB, that data needs will not differ for the various management approaches, and that existing infrastructures will be used as far as possible.

If it is accepted that the data requirements for the various management approaches are the same, it follows that the costs for establishing infrastructure and operation of the systems will also be the same. The allocation of the costs will however differ.

The only difference between the CAC approach, the joint venture approach and the economic based approach will be the costs associated with permit trading, and these would in any case be reflected in the permit trading price, and would not influence institutional administration costs.

The total costs incurred[5] were calculated and distributed between the players. The results are summarised in Table 5.1 below.

Item	Cost R million DWA&F	Cost R million Role Players	Total Costs
Building of Weirs	R 0,176	R 5,280	R 5,456
Cost of Instrumentation *	R 0,458	R 1,533	R 1,991
Operational Expenses	R 1,865	R 6,244	R 8,109
Total (1994 Rand)	**R 2,499**	**R 13,057**	**R 15,566**

* Includes Replacement Costs

TABLE 5.1: ALLOCATION OF WATER QUALITY MANAGEMENT COSTS

5.3.3 Water demand management instruments

Pricing as a water quality management instrument has been discussed in section 6 in general terms, but brief mention needs to be made here in the context of the mining community in the Olifants River catchment. Since water only constitutes a

[5] These operational expenses are the capitalised costs discounted over 45 years.

small proportion of the production cost, the mining industry may be able to absorb substantial price increases without significantly increasing production costs. In 1986 the Directorate of Planning of the then Department of Water Affairs commented "The cost of water to the mining industry is 0.7% of the total cost of stores purchased. The Chamber of Mines has stated that the cost of water as an input to the mining industry is minimal in comparison to other inputs and even a doubling of tariffs would be acceptable." [6] Thus appropriate pricing levels for water could help to reduce pollution by promoting it to the status of a valuable resource which it is not economic to pollute and discard, whilst still not increasing production costs significantly.

A viable water market is often seen to go hand-in-hand with pricing reforms. Reference has been made to the water quality benefits of water marketing in Chapter 2 section 2.4. This possibility can now be examined for the Upper Olifants catchment. In mining, wastewater is either discharged to the stream of origin or recycled. Also contaminated water drains from the surface of the mine into natural watercourses. Assuming a theoretically 'perfect' market, i.e. a deregulated market with many players, no monopolies, and complete information availability, the control of pollution by water marketing could be a useful option for the Upper Olifants catchment. By selling a limited amount of surface and ground water abstraction quotas at a market price, an incentive would be created to maximise water utility and thus reduce mine drainage. It is worthy of note that it is not advisable to create a water market in areas where the market is "thin" (i.e. too few completely independent players). This may indeed be the case in the upper Olifants river basin.

5.3.4 Water quality management instruments

Before embarking on a discussion of water quality management instruments, it is well to bear in mind that for any system of management to be effective, it is necessary to be able to measure the results of any activities or results in order to be able to assess the effectiveness of the management system, and to provide the feedback signals to keep the system on track. This is equally true when using economic instruments as management tools. Unfortunately, non-point (or diffuse) source pollution features greatly in the discussions to follow, and this is notoriously

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6 Department of Water Affairs, Directorate of Planning, BE Hollingworth, Vaal River System Analysis, Review of User Economics, prepared by BLS in association with SS&O, Johannesburg May 1986, report 4161/20.

difficult to measure and accurately apportion. Whilst not militating against the use of economic instruments, this measurement problem needs to be borne in mind at all times, and will be revisited from time to time as the discussion evolves.

5.3.4.1 Water quality standard setting

The first step in the establishment of a bubble is the determination of the "optimal level" of pollution that must emanate from it. The optimal level of pollution in a bubble can be equated with the optimal aggregate discharge level, which considers all dischargers of a specific pollutant, in this case the sulphate emitters of the Upper Olifants catchment. However, it must be borne in mind that "hot-spots" or areas of high pollution concentration may occur within the bubble, as the individual emission levels are not prescribed, but only the total emission from the bubble. Each proposed bubble needs to be analysed individually to ensure that unacceptable hot-spots are not likely to occur in practice.

5.3.4.2 Tradable permits

In order to disaggregate the total pollutant load, discharge permits have to be allocated to the various point sources of sulphate pollution. These permits allow a polluter to discharge a certain amount of pollutants over a given period of time into the water system. It is envisaged that these permits should be marketable instruments and that trading of them should be able to take place. It is a debatable issue whether these permits should in the first instance be sold, auctioned or issued free of charge to the respective polluters in the bubble[7]. Following the arguments of pollution permit trading, polluters with a comparative advantage with respect to effluent reduction could gain from selling permits - or parts thereof - to polluters with a comparative disadvantage within the bubble.

As there is only one type of pollutant that is being targeted in this study, the trading of permits is probably a feasible option, despite the possibility of a "thin" market. The reason for this is that the various players are all known, and their respective contributions to sulphate pollution should be capable of being determined. Thus information about trading partners, which is one of the requirements for a market to function effectively, ought to be accessible. In order to avoid monopolisation of and covert lobbying for permits in a "thin" market, the permit trading controlling body

7 For a discussion of benefits and disadvantages of different methods of issuing pollution permits, see WRC 1993.

should either be completely neutral or should represent the interests of all the polluters.

Any effluents discharged without a permit allowance should become subject to charges imposed by the body controlling pollution within the bubble. These are discussed in the next section.

5.3.4.3 Effluent charges

Effluent charges must be imposed on all monitored effluent discharges for which permits are not held. These must eventually be set at a level that discourages all but the most accidental and unforeseen discharges.

However, to ease the burden on polluters in the initial stages of a charge system, (i.e. when they are least prepared for the likely costs) a transition period is envisaged. For example, charges could be introduced in three phases:

- **Period A:** set a very high standard for unpermitted effluent discharges but adopt a relatively low pollution unit price;
- **Period B:** lower the standard set in Period A but increase the pollution unit price; and
- **Period C:** impose target standard and unit price.

This periodic phasing-in of charges has the advantage that the cost burden on polluters is phased in gradually. The costs during the first period will be relatively low, giving industry time to adjust to the additional responsibility and potential costs, whilst giving emphasis to the control of point-source effluents.

As indicated in the preceding sections, the enforcement of effluent charge systems, is a major concern and has led to a number of pollution charge policies becoming unviable. As the only way to enforce a charge system cost-effectively is to require the polluter to declare any unpermitted discharges on a regular basis, some sort of penalty/incentive mechanism needs to be in place. A combination of the following two penalties have been used to great effect in Germany:

1. If companies fail to comply with the requirements of the system, a high financial penalty will be imposed on them;
2. The regulatory authority is given powers to estimate the unpermitted effluent discharge level for non-complying firms and to set charges retrospectively.

To support the authenticity of the effluent discharge declarations, environmental audits, carried out either at random or when the need arises, by an independent organisation, would serve as a good monitoring instrument. Such audits could be commissioned by the bubble controlling authority, but financed by the polluter.

5.3.4.4 Taxing polluting activities (Green Taxes)

Controlling non-point source pollution in the Upper Olifants catchment is an important aspect of water quality management, since the pollution from the mining activities can be, to a significant extent, of a non-point nature.

If the findings of Chapter 4 on use of economic incentives to control non-point source pollution from agriculture are transferred to the upper Olifants catchment, a set of strategies can be developed which may prove cost-effective.

Since authorities find it difficult and expensive to monitor non-point pollution, the introduction of a 'Green Tax' on the extent and severity of the polluting activity is a viable idea. This can and is achieved in a number of ways: the tonnage of coal mined, the sulphate content of the coal mined, or the spatial extent of the mining activity (i.e. area of sulphate rich material exposed to rainfall). However, it should be understood that green taxes represent a 'stick and carrot' approach to non-point source pollution control. Thus, while taxes are levied on activities which result in non-point source pollution, tax rebates must be given for those activities which reduce non-point source pollution or convert it to point source pollution to be controlled by permits and charges, i.e., the tax applied is related to the pollution abatement activities implemented. These activities could include mine management practices such as drainage works, overflow basins, interception of runoff from spoil dumps or their rehabilitation etc. Mines that can demonstrate that they are applying sound management practices to counter sources of non-point pollution would thus be taxed at a lower level, thereby giving them a comparative advantage over mines that have poorer management practices so far as pollution control is concerned. A similar result would be achieved by coupling non-point and point source pollution and allowing offsets between the two (e.g. permit for one free unit of point source discharge for every two units of non-point source pollution halted or converted.

The important issue is that it is the mines themselves that have the technical expertise to know which practices will be most cost-effective in achieving a given standard. Of course standards have to be set so as to offer guidelines for mine-based pollution abatement policies. Consequently, the controlling agency should determine the estimated pollution run-off from mines including the relative contribution of non-point and point sources to deteriorating water quality. Based on this assessment target levels for point source and non-point source pollution can be set.

5.3.5 An Economic Instrument Mix

It is now sought to seek an economic instrument, or mix of instruments which could best meet the needs of water quality management requirements in the Upper Olifants catchment. The main characteristics of the area for the purpose of this exercise are:

- Only one type of emission (sulphates) is being considered;
- The pollution dischargers are engaged in similar activities, using similar production processes;
- The area can feasibly be regarded as a bubble; and
- There is a high percentage of non-point source pollution.

The chief benefits sought from a water quality management system in the catchment would include:

- Effective management of non-point source pollution discharge;
- Ease and cost-effectiveness of administration;
- A measure of autonomy for each individual player in determining his pollution management strategy in order to minimise his costs;
- A revenue neutral system;

Careful examination of the economic instruments described reveals that a judicious choice of a mix of instruments could well go a long way to satisfying these requirements.

One of the chief difficulties in managing pollution in the catchment is the fact that so much pollution is of a non-point source type. This means that measurement of discharges cannot by done directly, and without measurement, it is not possible to exercise any control over discharges. Indirect measurement of non-point source discharge can be made, for example, by taking the difference between up-stream and down-stream pollution measurements. However, it is not necessarily simple to apportion this burden to any specific players, since by the time the run-off reaches the dam, there may have been several contributors. There is thus a compelling need either to encourage conversion of non-point source pollution into point source, or to develop methodologies which would allow these non-point source emissions to be allocated amongst the players so that when changes in emissions occur, those responsible can be clearly identified. A "green" tax which is related to abatement practices would encourage this aim, since reduction in emissions would have to be demonstrated to gain any relief from the tax.

However, as will be demonstrated later in this section, these green taxes will interact with individual players' abatement costs, and will only stimulate abatement to a certain level, beyond which there is no motivation to go. Any changes in the level of abatement desired by the authorities would have to be accompanied by a change in the tax structure - not leading to very easy or efficient administration.

An instrument is required which will result in greater motivation amongst individual players to meet (or even exceed) the emission standards set, whilst also providing a measure of individual autonomy to the players, is required. Tradable permits fit these requirements well. Provided that a bubble with sufficient players can be established, and that overall emission standards are met, permits can be bought and sold, thus leaving the decision as to whether to institute abatement or purchase permits up to the individual players. Market forces govern these exchanges, so additional administration is not required. An additional advantage, which is not intuitively obvious, is that efficient trading of permits will also yield a financial advantage to players vis-à-vis the command-and-control system.

Tradable permits may be used on their own, or used in conjunction with other instruments. Whilst tradable permits as management instruments will fulfil most of the needs mentioned above, it is felt that the addition of a green tax to add urgency to the requirements of rationalising diffuse source pollution would be an advantage.

It is thus intended in the ensuing discussion to explore the theory of using "green" taxes and tradable permits, and to demonstrate their operation in conjunction by using a pair of models. The object of the exercise is to convince the reader that these two instruments are viable in a simulated situation, and that the economic benefits mentioned above do in fact accrue.

5.4 ECONOMIC INSTRUMENTS IN ACTION

5.4.1 Philosophy

Later in this section two mathematical models which demonstrate the action of "green" taxes and tradable permits operating together in an area such as the Upper Olifants catchment will be presented. The purpose of this discussion is to provide a basic understanding of the principles that underlie these models.

5.4.1.1 Marginal Costs

Crucial to an understanding of market clearing prices in the case of tradable permits is the concept of marginal costs. Ideally marginal cost is a measure of the value to society of the extra resources required to produce another unit of output in a particular time period. It is a money measure of the value of the output sacrificed elsewhere by producing another unit of the good. In terms of economic efficiency the general presumption is that if the price which a consumer is willing to pay for another unit exceeds the value of the extra resources required to make it, then the allocation of resources will be improved if that unit is produced and vice versa. In other words, in any production process, a manufacturer will make a component in-house if his marginal production costs are less than the market price of that component, if not he will buy it in.

5.4.1.2 Tradable Permits

Exactly the same logic applies when we consider using tradable permits for water quality management. All that is needed is to be able to imagine a market in "clean-ups" and how it might work[8]. In this instance a "clean-up" is nothing less than a unit of pollution abatement, and it is analogous with any component produced in-house in any production process.

In explaining this concept in further detail, reference is made to Fig 5.2, which is an idealised curve relating the price of clean-p to the quantity of emission abatement. The underlying assumption is that cost will in an exponential fashion as emission abatement increases.

Consider "clean-up" units in conjunction with pollution permits. If a mine has, for example, permits which allow 10 units of pollution to be discharged and it is currently producing 10 units of pollution, it does not necessarily need to discharge all of those units. If it has the ability, and this were economically viable, it could instead control 6 units of pollution by way of abatement measures. This means that there are now permits for 4 units of emission which are not being used. These could be sold at an appropriate price to another player who was not able to implement sufficient abatement measures. In so doing 4 units of clean up would effectively be changing hands.

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8 This description is deliberately kept qualitative. A quantitative description with a numerical example is included in Appendix A.

When the marginal costs of abatement for any particular player are greater than the prevailing costs of permits (i.e., point D on the marginal cost curve in Fig 5.2), he will choose to buy permits rather than institute the required abatement measures himself (his saving will be DE), and a demand for permits is thereby created.

If his marginal costs of abatement are greater than permit costs (i.e., point B on the marginal cost curve in Fig 5.2), then he will rather choose to carry out abatement measures and sell his excess permits (his profit will be AB). A supply is thus created.

In this way permits will be traded until no player perceives an advantage in acquiring more permits, or indulging in additional abatement in order to be able to sell permits.

It will be demonstrated when the trading model is exercised that the actual costs of abatement will tend to fall in individual cases (or the outcome may be neutral) and any savings from instituting abatement measures obviously translate into additional profits. In addition, the control of the abatement initiatives remains in the hands of the individual players insofar as the decision as to whether to abate or go the permit route is theirs alone, and depends upon their individual production functions.

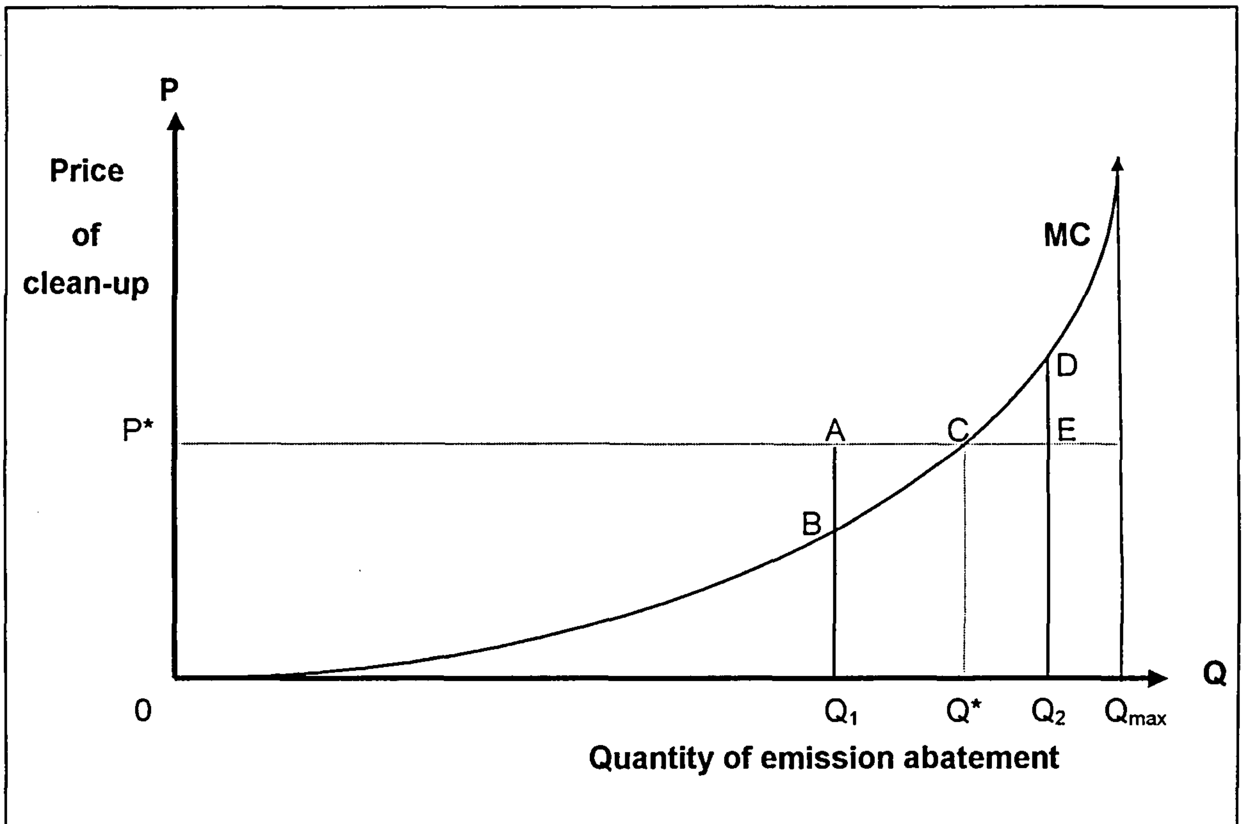


FIGURE 5.2: MARGINAL COSTS OF EMISSION ABATEMENT

Any would-be new entrants to the market in a bubble would have to draw on the same stock of permits available at the time to meet their pollution discharge needs. It is not envisioned that the authority would issue more permits to allow for additional players; this would in fact be sanctioning increased pollution activities when the drive should be for reduced activities. New players would therefore increase the demand in the market place for permits, thus driving their price up. The increased price should spur existing players to seek new abatement techniques in order to release permits for sale at this increased price. Thus new players are not excluded, as they might well be under a control and command system where allowable pollution discharge is fully subscribed. What happens instead is that market forces stimulate more efficient abatement techniques by driving permit prices up, thus creating "space" for more players.

It is possible that there will be a temptation for some players to buy and hoard permits, either as a speculative activity, or to attempt to keep new players out of the market. Anyone wishing to do this would of course have to take into account the costs associated with holding unused permits. One form of hoarding which could occur, and which would be difficult to combat, would be the buying-up of permits by green movements with the express intention of keeping them out of circulation, and thereby forcing a reduction of pollution levels in the dam. Whether or not such movements would be capable of raising the necessary funds to undertake such a venture is problematic, but in theory the system gives them the opportunity to "put their money where their mouths are".

5.4.1.3 "Green" Taxes, and Abatement Costs

A green tax would be of the form shown in Fig 5.3. It will be seen that the green tax operates on a sliding scale and works in the opposite sense from the abatement cost curve. At zero abatement levels, the green tax is pitched at an extremely high (punitive) level to obviate the possibility that players may choose simply to pay the tax rather than to implement abatement measures. As increasing levels of abatement are introduced and their effectiveness demonstrated, the green tax falls off.

The effect of an additional (green) tax on industries whose prices are set internationally, rather than by local markets (for example gold mines) requires serious consideration by authorities. Such industries are not able to adjust their selling prices to accommodate the extra drain imposed by additional taxes. They can only offset the effect by means of increased efficiency or reduced profits. Should there come a time when these courses of action are no longer possible, then the only way open may be to cease production.

In practice each player will play off the rise in his abatement costs against the fall in green tax until some equilibrium level is demonstrated. If the green tax and the cost of implementing abatement measures are both regarded as costs of discharging pollution, then a composite cost curve emerges, as shown in Fig 5.4, with the equilibrium position being the lowest point on the curve. Such a composite cost curve will form the basis of the tradable permit model.

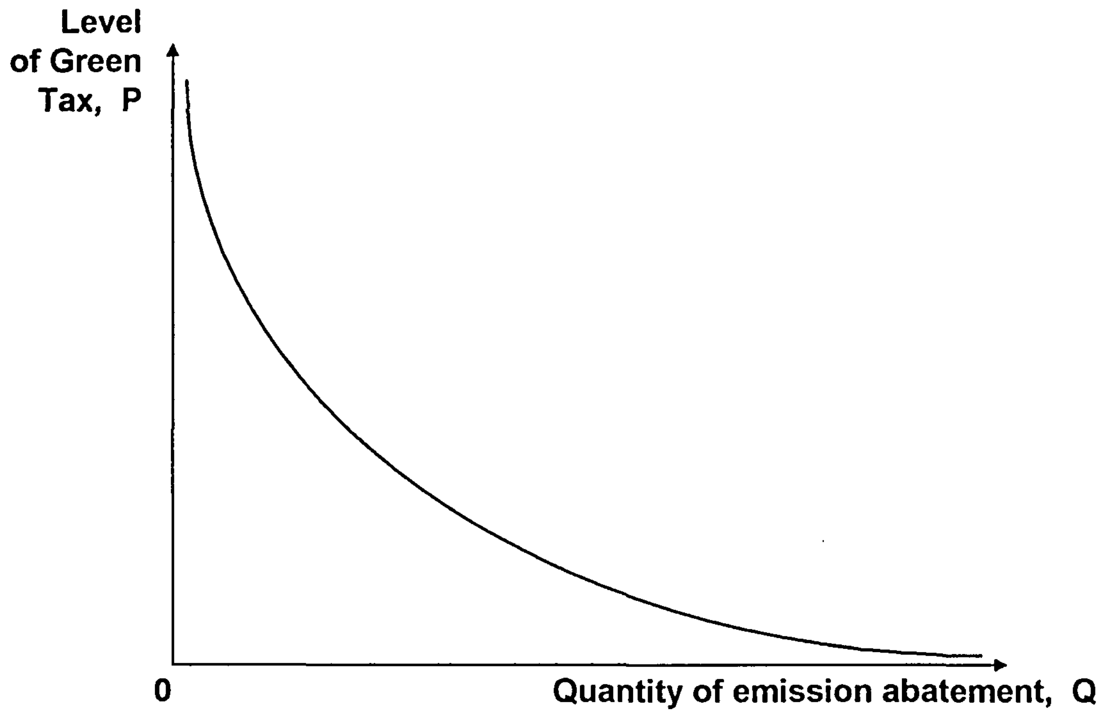


FIGURE 5.3: TYPICAL GREEN TAX CURVE

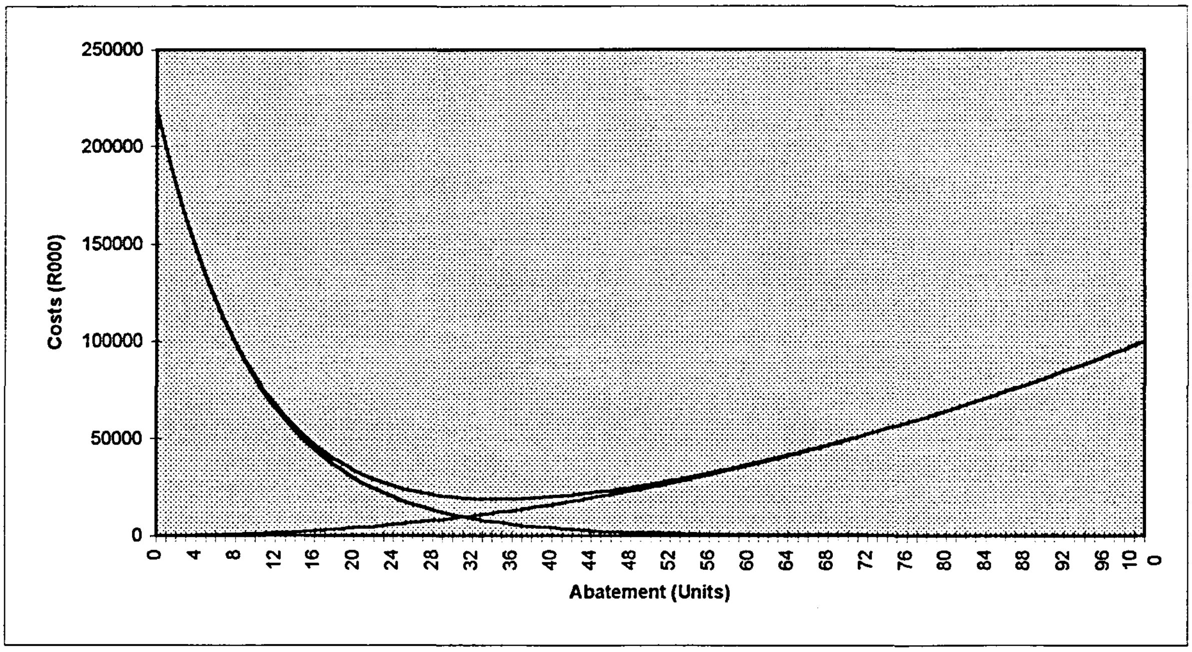


FIGURE 5.4: COMPOSITE GREEN TAX - ABATEMENT COST CURVE

5.4.2 The Players and the arena

5.4.2.1 The Pollution scene

5.4.2.1.1 The environment

Wherever economic activity is taking place, there is likely to be some adverse effects on the environment. Consequently, there is ongoing conflict between those who seek to preserve the environment, and those whose aim is to promote economic growth. Resource economics seeks to mediate in this conflict by looking for trade-offs between these two apparently incompatible goals. The very word trade-off implies some compromise, so clearly the aims of neither party can be completely met.

From an economic viewpoint, therefore, a total absence of pollution is not the primary objective: it involves no trade-off. The environment generally has the ability to absorb a certain amount of pollution without necessarily setting it on an irreversible downhill journey to destruction. This pollution burden, which we will refer to as the maximum sustainable pollution load (or MSPL) should be what we strive to maintain. If acceptable economic growth can take place without exceeding the MSPL then the environment will not sustain irreversible damage; i.e., the situation will be sustainable.

5.4.2.1.2 The polluters

The mining of coal entails the release of sulphate rich material that tends to be transported into natural waters. Where these waters empty into dams that are used by a community for various purposes, great attention must be paid to the control of such pollution.

To preserve the ecology of the dam environment, and maintain the quality of the water drawn off from the dam, the pollution discharge must never be allowed to exceed the MSPL. Excessive pollution of the dam can result in irreparable damage to water using activities and the economy of the region.

To control this pollution, however, presupposes some knowledge of the actual discharges from various sources. Since pollution is normally of two types, point source and diffuse source, this is not always the case. Point source pollution emanates from a known point and is therefore capable of being monitored. Diffuse source pollution, which is created by leaching through soil or dispersion through the air does not lend itself to easy measurement. Clearly, the more pollution that can be of the point source type, the easier it is to assess whether the MSPL is being exceeded.

5.4.2.1.3 Sustainability

Where there are several mines operating in the same area, the MSPL must be divided between them in some equitable fashion if sustainability is to be achieved. Each mine should be assessed for its pollution potential. This potential could be based on the area of the mine, the average sulphate concentration of the soil and the natural slope of the land towards the water, amongst other things. (Pollution potential here means the expected tonnage of sulphate to be released during mine operation).

This activity, however, only sets the limits that are necessary for sustainability. Unless pollution can be monitored, as indicated earlier, it is not possible to ensure that these limits will be observed.

5.4.2.2 The Environmental Management Problem

5.4.2.2.1 The Authority

The message that emerges from these discussions is that there is a need to monitor pollution discharge if there is to be any control of water quality by the authorities. A key issue for them is to try to convert as much diffuse source pollution into point sources, so that effective monitoring can be carried out, or to implement methodologies for tracing diffuse source pollution back to its originators. The focus can then shift to the introduction of abatement measures to reduce the actual discharge from these point sources.

5.4.2.2.2 The Players

The mines, whilst they may be sympathetic to environmental sustainability desires, have rather different goals. They want to maximise profits. Seen in the light of environmental sustainability, this means that they want to minimise the costs of pollution abatement measures.

The mines also desire to maintain their autonomy in the matter of environmental management. That is they wish to minimise interference by authority on how they manage their abatement practices. They also want to able to use any competitive edge they may have in their individual abilities to implement abatement strategies to their own advantage (and profit).

5.4.2.2.3 Modus Operandi: interaction between players and authority

These sometimes-conflicting requirements can be satisfactorily addressed through the medium of fiscal instruments. The choice of appropriate instruments can:

- permit individual autonomy of individual mines in planning their approach to pollution abatement;
- encourage pollution abatement using profit motives; and
- minimise administration by authority.

The key to success in the use of fiscal instruments is to select the most appropriate instrument in each case for the job in hand. Previous sections of this project identified a combination of two instruments as being the most suited to this situation, and these are:

- *green taxes* for the control of *diffuse source pollution*; and
- *tradable permits* for the control of *point source pollution*.

5.4.3 The Models

5.4.3.1 Introduction

Two models have been developed to demonstrate the action of economic instruments. The first, a Marginal Cost Model (MC model) is effective in demonstrating graphically in a spreadsheet environment the mathematical and economic principles involved in the application of green taxes, and creating a market for emission permits. However, this model gives no intuitive feeling for what is happening during the trading process, and it is also somewhat restricted as to the number of players it can accommodate.

For this reason, the second model, a Simulation Model was developed in parallel. This model, which will take the trading process from the point where the first permit changes hands through to where market equilibrium is achieved, will also serve to validate the results generated by the spread-sheet model. In addition, it will be able to accept more wide-ranging and sophisticated data sets and it should be able to be used effectively should on-the-ground problem solving be required.

5.4.3.2 Principles

The following broad principles apply to both models as presently implemented.

Each player will have a maximum pollution emission level that he may not exceed.

In the absence of point source (measurable) discharge, total pollution load will be taxed at green tax rates. These rates will be pitched sufficiently high to encourage conversion from diffuse source to point source pollution.

As abatement takes place and reduction in pollution discharge is demonstrated, the green tax is reduced. Green tax will thus be the first motivation for mines to institute demonstrable abatement measures. Balance sheet bottom-line considerations will automatically drive all players to this abatement level, as can be seen from Fig 7.4 above. Pollution permits become effective at this point, and from there on, any player may only discharge effluent *provided* that he has sufficient permits to cover the discharge.

Permits will be then be traded according to the economic precepts laid down above. The motivation to trade will be the decrease in abatement costs and consequent increase in profitability.

In order for trading to be possible, there must be differences in the abatement costs of each player, and these are simulated in the models.

5.4.3.3 The models in action

The models will accordingly be run as follows:

- Permits are distributed according to the criteria mentioned above.
- The model trades permits until equilibrium amongst the players is achieved.
- Perturbations are introduced (new players, players falling out, authority moving the goalposts, etc.).

The goals that can be achieved are:

- to demonstrate a market for tradable permits in action;
- to determine whether there are circumstances under which the market fails;
- to determine whether, or under what circumstances, costs of abatement measures are minimised;
- to explore the implications of the green tax, and to establish appropriate values for it; and
- to investigate to what extent the system can suffer perturbations and still remain stable.

5.4.3.4 Assumptions

- The game will be played strictly according to market principles: There will be no hoarding or speculation.
- All mines will be assumed to be equal except with regard to their abatement costs, surface area and sulphate richness.
- Production functions (i.e. abatement costs) will be quadratic, and green tax curves will be exponential.
- The field will be restricted to five players.
- Initial distribution of permits will be free.

5.4.4 Operation of the models

5.4.4.1 The Marginal Cost Model

The philosophy underlying the operation of the Marginal Cost Model is described in some detail in Appendix A. In summary, the system of equations presented in Figure A2 of Appendix A is augmented to incorporate a green tax, and to allow for five rather than two players. The green tax curve is common to all mines, but abatement costs differ for the individual mines. This difference in abatement costs between mines is necessary to allow permit trading is to take place.

In order to demonstrate the principals of permit trading, the curves chosen have been given rigorous mathematical forms, but it should be noted that in practice abatement curves are likely to be non-linear and probably discontinuous. However, the spreadsheet approach can accommodate itself readily to virtually any data set, since solution is dependent upon look-up tables and not mathematical solutions. Thus data which would arise in practice can be readily incorporated into the model when they become available.

The procedure adopted in the MC model is to use spreadsheel lookup tables to parallel the graphical procedure which was detailed in section A.3 of Appendix A. To accomplish this, the curves shown graphically in Figure A4 are converted into tables that are accessible to, and can be manipulated by, macros embedded in the spreadsheet model. However, whereas graphical curves are continuous, look-up tables comprise a finite number of discrete points. The fact that the tables thus represent non-continuous curves introduces truncation errors into the look-up process. The severity of these errors can be lessened by making the intervals between individual entries in the tables as small as possible. Additionally, in order to reduce these errors, it is necessary to allow the model to deal in fractions of a permit. This would not occur in real life, but the problem is readily overcome by issuing, say, 100 permits instead of only one for a given amount of pollution emission. Nevertheless, this truncation error, combined with rounding errors introduced in getting back to whole numbers of permits, accounts for differences in results between this model and the Simulation model described below.

5.4.4.2 The Simulation Model

The Simulation model uses the same data-set and curves as described above for the MC model. However, solution is found not by table look-up, but by simulating successive rounds of trading between the players. There are two main reasons for setting up this parallel model in support of the Marginal Cost model:

- To provide a demonstration of the trading process which is intuitive in its operation, and divorces itself from the principles of marginal costs; and
- To provide an alternative calculation of the clearing price of permits, which can be used to verify the results obtained from the Marginal Cost model.

Having established the desired level of abatement desired, the model operates by postulating the presence of an Auctioneer who proposes a market price for permits and calls for offers to buy and sell at that price. The individual mines then calculate their abatement costs at the given level of abatement and determine whether it is cheaper for them to implement the abatement required, or not to abate and to buy additional permits to cover excess discharges.

If there is an excess of potential buyers over sellers, then the price set by the Auctioneer is too low, and he proceeds to set a higher price and vice versa. The calculation to determine potential buyers and sellers proceeds again based on the new permit price, and the ratio of buyers to sellers is once again observed. This process proceeds, with a change of permit price at each round, until there is an equal number of potential buyers or sellers at the given permit price. In economic terms this is now the situation where supply equals demand, and the price arrived is in fact the equilibrium price, or the market clearing price.

5.4.5 Comparison of Output from Models

The workings of the models are described in greater detail in Appendices A and F, but to expose the reader to their implications and to compare their output, one case of pollution abatement will be examined in detail here.

The following input data was run through both models:

- Maximum potential pollution from each mine .....100 units
- Abatement desired per mine ....70 units
- Number of permits issued to each mine 30
- Number of mines 5
- Total abatement required for bubble ....350 units
- Total number of permits issued to bubble 150

The amount of abatement desired was entered, and the models then calculated the market price of permits. Additional calculations included the number of permits changing hands, and the potential savings brought about by trading permits as opposed to being subject to a CAC regime are detailed[9].

The output data as obtained by exercising both models is presented in Tables 5.2 and 5.3. An identical format has been chosen for the presentation of the output from both models so that inconsistencies in the output can be more readily detected and discussed.

It will be seen from the summary block at the bottom of Tables 5.2 and 5.3 that the market price of permits calculated by both models for an overall abatement level of 350 units is the same, viz. R955. The actual amount of abatement implemented by each mine also agrees for the two models, if the results for the MC model are rounded to the nearest permit.

The output from the two models which is set out in the upper block of tables 5.2 and 5.3 will be seen to contain some discrepancies. In the case of the MC model, calculations are based on the trading of fractions of permits as described above. This approach is unfortunately necessary in order to contain the truncation errors as much as possible, but this, together with the discontinuous nature of the look-up tables inherent in the MC model, does contribute to discrepancies between the two models. However, it can be seen that the total difference in potential savings between the two models is R887, which is less than the cost of a single permit. The overall resolution cannot be expected to be better than ±1 permit, so this deviation is to be expected. Furthermore, this represents an error of only 3% of the total number of permits traded.

The final critical issue is to determine whether the trading of permits has resulted in any benefits to the players, vis-à-vis what would have occurred under a command and control approach. This information is encapsulated in the last line of the first block of Tables 5.2 and 5.3, where the potential savings are detailed. These savings are calculated by taking the difference between the cost of the legislative approach (where abatement requirements are equally spread) and the outcome after trading has taken place. It will be seen that a benefit does accrue, both to the

9 The cost of the legislative (command-and-control) approach assumes that the abatement requirement (350 units) is divided equally between all players, giving 70 units per mine.

bubble as a whole, and to the individual players. Admittedly, the benefit to mines B and C is minimal (less than the cost of a single permit), and the outcome from their point of view could be regarded as neutral. However, the potential savings to the complete bubble is of the order of the cost of 10 permits, and therefore not trivial.

More data from various runs of both models are contained in Appendix E, should the reader wish to carry out similar analysis to that described above on a more diverse range of output[10].

10 If this data is examined, it will be observed In general that in all cases there is a saving to the economy as a result of trading, and a saving (or a neutral outcome) to the individual players. The instances where a small loss is shown to accrue to some players (notably mine C) can be attributed to truncation errors in the look-up procedure employed in the MC Model.

TABLE 5.2: OUTPUT FROM THE MARGINAL COST MODEL

MARGINAL COST MODEL OUTPUT 350 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 24 690.86	**R 30 815.86**	**R 36 940.86**	**R 43 065.86**	**R 49 190.86**	**R 184 704.28**	Cost of legislative approach
R 45 702.33	R 37 241.31	R 32 672.44	R 30 282.01	R 29 274.63	R 175 172.72	Cost of abatement instituted
25.66	7.16	(4.24)	(11.74)	(16.84)	0.00	Number of permits sold (bought)
R 24 505.30	R 6 837.80	R (4 049.20)	R (11 211.70)	R (16 082.20)	R (0.00)	Cost of permits sold (bought)
R 21 197.03	**R30 403.51**	**R 36 721.64**	**R 41 493.71**	**R 45 356.83**	**R 175 172.72**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 3 493.83	**R 412.34**	**R 219.21**	**R 1 572.15**	**R 3 834.02**	**R 9 531.56**	Potential savings (cost of legislative approach less actual abatement costs)
30.06	30.06	30.06	30.06	30.06	150.30	Permits issued to cover allowable emissions
4.40	22.90	34.30	41.80	46.90	150.30	Actual emissions (based on marginal costs)
95.60	77.10	65.70	58.20	53.10	349.70	Actual implemented (based on marginal costs)
25.66	7.16	(4.24)	(11.74)	(16.84)	0.00	Excess (deficit) of permits

Abatement desired	350
Permits issued	150
Market price of permits	955

TABLE 5.3: OUTPUT FROM THE SIMULATION MODEL

SIMULATION MODEL OUTPUT — 350 UNITS OF ABATEMENT DESIRED

COSTS												
MINE A		MINE B		MINE C		MINE D		MINE E		TOTAL		EXPLANATIONS
R	24 691	R	30 816	R	36 941	R	43 066	R	49 191	R	184 705	Cost of legislative approach
R	46 085	R	37 146	R	32 960	R	30 092	R	29 179	R	175 462	Cost of abatement instituted
	26		7		(4)		(12)		(17)		0	Number of permits sold (bought)
R	24 830	R	6 685	R	(3 820)	R	(11 460)	R	(16 235)	R	-	Cost of permits sold (bought)
R	21 255	R	30 461	R	36 780	R	41 552	R	45 414	R	175 462	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R	3 436	R	355	R	161	R	1 514	R	3 777	R	9 243	Potential savings (cost of legislative approach less actual abatement costs)

30	30	30	30	30	150	Permits issued to cover allowable emissions
4	23	34	42	47	150	Actual emissions (based on marginal costs)
96	77	66	58	53	350	Actual implemented (based on marginal costs)
26	7	(4)	(12)	(17)	0	Excess (deficit) of permits

Abatement desired	350
Permits issued	150
Market price of permits	955

PART FIVE

CONCLUSIONS AND FUTURE DIRECTIONS

CONTENTS

6. CONCLUSIONS AND FUTURE DIRECTIONS

6.1 CONCLUSIONS

This report has examined current literature on water pollution and economic instruments that can be used to control it. Of the instruments reviewed, water pricing, green taxes and tradable pollution permits were recognised as being appropriate for use in the South African context.

Water tends to be seen by the public in general as a "free good". It is seen as having been placed on earth for the use of its inhabitants, and therefore no price should be associated with it. As a result of this perception, water users are not motivated to conserve water (there is no price signal to assist them) and there is a tendency to use water, pollute it, and return it to source. Once again there is no price signal to indicate that it is a scarce resource, or that there might be economic benefit in recycling it.

Water pricing strategies can be used to redress this situation by adding value to the resource. This of course makes for more considered water usage and introduces economic efficiency into the water management process. It is important to note that water-pricing strategies can be very sensitive, particularly amongst farming and developing communities. In the case of the former this is because traditionally the price of water for irrigation has been kept at a very low level and an ethic has developed that farmers have a right to low-cost water. In a similar way, developing communities view water as a free good and any attempt to price it at its real economic value would meet with considerable resistance.

In South Africa, water pricing has been based on cost-recovery principles, and has not been viewed as a potential water management tool. There is evidence in the international literature, however, to show that water pricing is a powerful method of controlling demand, and both industrial and municipal users have been shown to respond appropriately to its use. Studies in this respect have been carried out both in the OECD countries and the USA. It must however be pointed out that price elasticities of demand underpin all studies of the demand for water and its related price. Studies to determine the price elasticity of demand have been carried out, but unfortunately not in South Africa, so this is clearly a promising area for future research.

Any attempt to increase the price of water must include a political initiative, and it is imperative that the community and the industrial sectors be kept involved. This means that an educational programme would be necessary to inform them of the real economic value of the resource. The market mechanism is an ideal vehicle for arriving at the economically efficient price for a commodity, and water of course is no exception to this. Economists have therefore reworked economic theory to allow a market mechanism to be put in place for water. How economists have put this in place has been discussed in the text.

Pricing has the effect of changing user behaviour, low prices encouraging mis-use of water with high prices encouraging conservation. Thus price-setting invariably affects supply and demand and can therefore be used to implement governmental policies in the management of water.

Green taxes are a special form of tax insofar as the underlying rationale is that they should act as a behaviour modifier, and that they should ultimately be self-eradicating in nature. This means in practice that as the desired level of pollution abatement is approached, the level of taxation reduces until it disappears altogether. (At this stage economic efficiency, or Pareto optimality, has been achieved.) Thus the temptation to view a green tax as a permanent source of revenue for the fiscus after it has achieved its objectives should be avoided, as this will have the effect of diminishing economic efficiency.

From an economic point of view there would be great advantages if the market mechanism could be brought in to assist with water quality management. Tradable permits are powerful instruments for bringing this about. The market mechanism's power to allocate resources efficiently rests on the fact that all the trade-offs required to produce efficiency are taken account of when individuals make decisions to buy or sell commodities. Exactly the same logic applies when we consider using tradable permits for water quality management. All that is needed is to be able to envisage a market in pollution abatement units. To make a tradable permit viable, i.e., to introduce the market mechanism into the pollution control system there must be sufficient users of the permits and they must be traded on a regular basis. Traditionally tradable permits have been used for air pollution (where these requirements are properly met), but there is no reason why they could not be used equally effectively for water management.

Because of the inherent problems associated with water pricing in South Africa, and the need for more research into the subject, this report focused on the use of green taxes and tradable permits. These two instruments are able to be put into place relatively easily and do not place excessive burdens on the administration.

Two models were designed and implemented to demonstrate the efficacy of these instruments in the area of the Witbank Dam, an area that is heavily polluted by sulphates.

An important economic debate revolves around whether the public sector or the private sector should administer the economic instruments mentioned above. The answer to this question is dependent upon which of the approaches yields the greatest economic benefits. This issue was examined in some depth, and it was concluded that the outcome was neutral in the case of a green tax / tradable permit mix. However, it is important to remember that the indiscriminate levying of a tax (such as a green tax) may diminish social welfare by financially burdening older industries to the extent that they reduce their production capacity, or in the extreme case, cease to trade. The result of this is increased unemployment, hardship and poverty. As a consequence, great care must be taken in designing the tax structure that is to be used for pollution control. The models described in this report, whilst not used for designing a tax structure due to lack of robust data, could nevertheless be used as a scenario generator to examine the impact of green tax structures in the area.

The applicability of economic instruments in the South African context was only partially addressed in this report. The reason for this is that the South African economy is undergoing change as a result of the momentous political reform currently under way. This is demonstrated by the direction that is being provided by the RDP. It would therefore be inadvisable to be too prescriptive in this regard. It was however felt that the choice of instruments was not inappropriate to the situation, and that the analysis to which they were subjected would at least provide an enhanced understanding of their operation and usefulness in practice.

Because the environment into which polluted water is discharged is seen as a free good, and wastewater itself is seen as having no economic value, water pricing and water marketing are frequently neglected as water pollution management tools. We conclude, however, that they have great potential in this regard, but as they are not intrinsically economic instruments, the issue was not pursued in any depth.

Although the focus of this report has been on economic instruments, it is nonetheless true that command and control measures (such as regulation) do have a role to play. For example, control measures for pollution emissions that can cause grievous suffering (such as toxic waste) need to be prescriptive.

Tradable permits offer a wide range of benefits to both the private and public sectors. They are able to offer a high degree of autonomy to the private sector, whilst still remaining economically efficient. Despite their attractiveness, they have not been well tested internationally, so it is somewhat premature to comment on their effectiveness in South Africa. However, our modelling exercises have indeed demonstrated economic efficiency so we conclude that they are potentially powerful instruments for pollution emission control, and that their possible use should be pursued vigorously.

In summary, after extensive investigation of both the economic instrument toolbox and the study area and its problems, two economic instruments (green taxes and tradable permits) were selected for further study. This study was not as in-depth as could be desired, due to data gathering problems, but our simulations have indicated considerable promise for these instruments and it is recommended that every effort be made at this stage to bring them to the attention of both public and private sector decision-makers and policy formulators.

6.2 Recommendations

- This report has dealt with the operation of green taxes and tradable permits as instruments of water quality management, and has found them to be viable under ideal simulated conditions.

  It is recommended that serious consideration be given by decision-makers to using these instruments for this purpose in future. However, it is clear that considerable additional research will be necessary before this aspiration can be realised, and this issue is addressed more fully in the following section of this report.

- The issue of water pricing as an instrument of water quality control has also been touched upon in this report, but not dealt with in great depth. However, even from the fairly shallow discussions above, it is clear that pricing is a critical issue and deserves to have its place in a properly constituted toolbox of economic instruments for the management of water quality. Once again, a great deal more work needs to be done, and this is also addressed in the next section of this report.

- Additionally it is recommended that no new regulations should be promulgated without a comprehensive cost-benefit analysis having been carried out. Executive Order 12291 issued by President Reagan in 1981 requires the preparation of a Regulatory Impact Analysis (RIA) for every major rule. Section 2 of the Order provides that "Regulatory objectives shall be chosen to maximise the net benefits to society" and that "Regulatory action shall not be undertaken unless the potential benefits to society for the regulation outweigh the potential costs to society"

- The mines also desire to maintain their autonomy in the matter of environmental management, by minimising interference by authority on how they manage their abatement practices. This means that they would wish to be able to use any competitive edge they may have in their individual abilities to implement abatement strategies to their own advantage (and profit). It is therefore recommended that this be taken into account when implementing economic instruments for water quality management, in order to encourage mine "buy-in" to the scheme.

6.3 FUTURE DIRECTIONS

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:

- As pointed out above and in Chapter 5, taxes can have a detrimental effect on some industries if indiscriminately applied. Particular cases in point are older industries, and mining industries where prices are set internationally. An in-depth investigation into the effects of a green tax on these industries is recommended. However, a study such as this would have to get very close to potentially sensitive financial information in the relative industries, and the full co-operation of the industries concerned would be a pre-requisite. Without this co-operation such a study would not be of great value.

- A knowledge of both income and price elasticities of demand enables more effective forecasting to be done for water management purposes. Countries such as the USA and the OECD Countries have carried out studies to determine these parameters from the '60s to the present. These studies have included the determination of elasticities of both industrial and household (municipal) water demand. A similar study in South Africa might commence by looking at municipal elasticities of demand.

- Reliable and extensive time-series data is an important pre-requisite for any forecasting exercise, and indeed for establishing elasticities of demand. A database extending for at least five years and containing information on water usage, water price and pollution control activities in all sectors of the economy could be considered to be a minimum requirement. It is recommended that existing data of this nature should be gathered together in a database form that would make it useful to economists, and that a programme should be established to continue accumulation of similar data over the forthcoming five years.

- Whilst accepting that the research carried out in this report had as its aim to educate rather than to solve specific problems, it is nevertheless felt that a pilot study using tradable permits and green taxes and incorporating real data should be carried out before any recommendation to implement these instruments on a widespread basis could be made. Such a pilot study should investigate the effects of these instruments on a specific community or "bubble" and should report on the effects of levying taxes at different levels. This study would also involve the use of sensitive financial data and its success would be heavily dependent upon the total co-operation of the players in the chosen bubble.

- Water pricing and tariff-setting, and demand-side management are issues which ought to be receiving urgent attention in South Africa. Appropriate pricing of water would have direct effects on both its allocation and the management of its quality. As mentioned this report, this is a wide field of research, but it is clear from feedback from the Steering Committee that it is a subject worthy of investigation.

APPENDIX A

MARGINAL COSTS, TRADABLE PERMITS AND A MARGINAL COST TRADING MODEL

CONTENTS

FIGURES

TABLES

A. MARGINAL COSTS AND TRADABLE PERMITS

A.1 MARGINAL COSTS

The principles underlying the economic approach to the regulation of sulphate emissions can be explained quite simply. Figure 1 will be used to analyse a typical mine's behaviour.

The horizontal axis of this diagram shows the extent of emissions abatement undertaken by the mine and the vertical axis the cost of achieving that abatement. The abatement can be described as units of "clean-up" produced, and can be analysed much like any other market commodity. OQ_{max} indicates the total amount of clean-up that could be produced, equal to total current emissions. The MC curve represents marginal costs: the additional cost of producing successive units of clean-up.

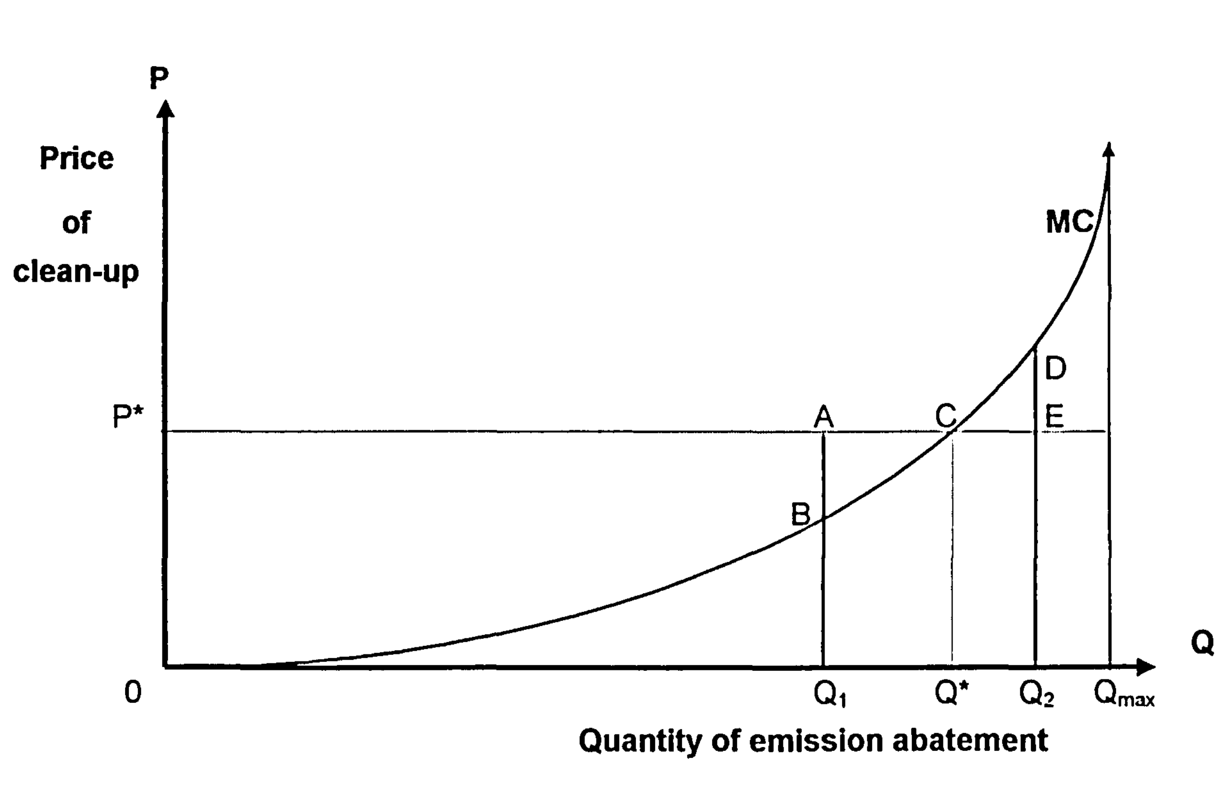


FIGURE A.1: ABATEMENT COST CURVE

As the amount of clean-up produced increases, it becomes more and more expensive to increase it further. In this diagram, the rate of increase in marginal costs is assumed to be exponential, hence the curved shape of MC.

Assume now that a market is created for clean-up, and that the mine can produce and sell units of clean-up on that market. Assume further that the prevailing price of clean-up is as shown by OP* in Figure 1. It is now possible to determine how much clean-up the mine will sell.

Consider an abatement level of OQ_1. The cost of producing the last unit of clean-up is Q_1B, and it can be sold on the market for a price Q_1A, thus producing a profit equal to AB.

If OQ_2 units of clean-up were to be produced, however, the cost Q_2D of the last unit produced would be higher than the market price of clean-up as indicated by Q_2E, and a loss of DE would be made.

In general, it can be said that profits can be made for all quantities of clean-up to the left of point C, or OQ*, but that losses are made for quantities of clean-up greater than OQ*.

Assuming that the mine wishes to maximise its profits, it will produce and sell OQ*, where the price is equal to the marginal cost. Generalising this conclusion, it can be said that production of clean-up by the mine will always be determined at the point where the prevailing market price is equal to its marginal cost of producing the clean-up. This means that the curve MC is also the mine's supply curve, showing how much clean-up it will produce at any given market price.

A.2 A MARKET IN PERMITS

Now assume that the mine is obliged by legislation to curtail its emissions, in other words, produce clean-up. If the target it is set equals OQ_2 units of clean-up, the mine would prefer not to produce all these units itself. Instead of producing the last unit required at a marginal cost of Q_2D, it could buy it on the market for the price OP*, thus saving DE. Similar savings could be made on all units of clean-up in excess of quantity OQ*.

By contrast, if the mine's target were OQ_1, it would be willing to produce a surplus of clean-up of Q_1Q^* in order to profit by selling it on the market for price OP*.

This opens the way for trade to occur on the market between mines wishing to produce surpluses or deficits relative to their legislated targets, as shown by OQ_1 and OQ_2 in Figure 1 respectively. Mines in both categories could benefit from trade, the former by increasing profits and the latter by minimising the costs of abatement. This can be illustrated by a numerical example.

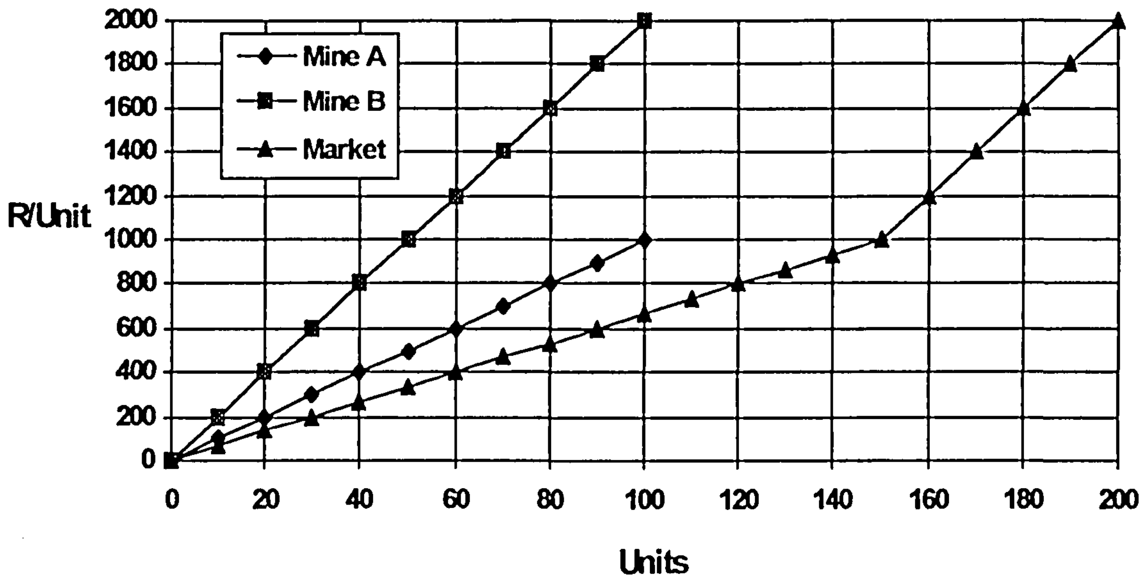


FIGURE A.2: EXAMPLE OF CLEAN-UP COSTS FOR TWO MINES

In Figure 2, two mines and the market for clean-up are shown. To simplify the example, the marginal cost, or supply, curves are now drawn as straight lines.

Mines A and B are assumed to be identical, except for the marginal costs they incur to produce clean-up, mine B finding clean-up to be twice as expensive. Their differences in this respect are shown in Schedule 1 as well as Figure 2. Each mine's current emissions equal 100 units of clean-up.

The market supply curve is by summing the mines' individual supplies; for example, at a price of R800, Mine A will supply 80 units and Mine B 40 units of clean-up, providing a total quantity on the market of 120 units.

Now suppose that the authorities require a reduction in emissions of sixty per cent. A legislative approach would impose a derived common clean-up target on each mine, probably - as the mines are identical in all respects but their marginal costs - of sixty percent or 60 units each.

Units of clean-up	MINE A		MINE B	
	Marginal cost	Cum. cost	Marginal cost	Cum. cost
10	R 100	R 500	R 200	R 1 000
20	200	2 000	400	4 000
30	300	4 500	600	9 000
40	400	8 000	800	16 000
50	500	12 500	1 000	25 000
60	600	18 000	1 200	36 000
70	700	24 500	1 400	49 000
80	800	32 000	1 600	64 000
90	900	40 500	1 800	81 000
100	1 000	50 000	2 000	100 000

TABLE A.1: SCHEDULE OF MARGINAL AND CUMULATIVE CLEAN-UP COSTS

Table 1 shows that to produce six units of clean-up would cost:

Mine A	R18 000
Mine B	R36 000
Total	R54 000

The required clean-up could be produced in another way, however. On the market, a total of 120 units of clean-up are needed to satisfy the authorities' requirement. The market supply curve shows that this would be forthcoming at a price of R800/unit. Assume now that this price is in fact set. Both mines would react by producing the quantities of clean-up where this price is equal to their marginal costs. In the case of Mine A, 80 units of clean-up would be produced, with 20 of those units being surplus to the mine's own requirements and available for sale. Mine B would produce only 40 units, and would have to buy 20 more units to make up its deficit.

The total cost of producing the clean-up has now fallen in comparison to the legislative approach. To produce the clean-up costs:

Mine A	R32 000	for 80 units
Mine B	R16 000	for 40 units
Total	R48 000	

The total saving produced by the economic approach is therefore R6 000. Of this, R2 000 accrues to Mine A as increased profit; it produces 20 surplus units of clean-up for (R32 000 - R18 000 = R14 000) and sells them to Mine B for (R800 x 20 = R16 000). Mine B saves R4 000; instead of having to produce them itself at a cost of (R36 000 - R16 000 = R20 000), it buys its deficit 20 units of clean-up from Mine A for R16 000.

As long as the mines' marginal cost curves for clean-up are different, it is generally true to say that savings can be obtained by moving from the "legislative" approach to the "economic" one, as shown by the above example.

This outline of how an "economic approach" might work in allocating pollution abatement efforts to meet some exogenously imposed target, overly simple as it might be, does point to both the major benefit and a significant difficulty of the approach. The major benefit is the savings that could be achieved by the industry as a whole. The difficulty is in inducing some mines to participate in trading when trade itself holds out no particular benefits for them, particularly when the beneficiaries may be their competitors.

A.3 A MARGINAL COSTS PERMIT TRADING MODEL

The Marginal Cost (or MC) model is essentially the incorporation of the concepts presented in Figure A.2 and Table A.1 into an extensive spreadsheet. The spreadsheet concept appeals for this purpose as the solution of the system of equations lends itself to look-up tables rather than to direct mathematical solution.

For the MC model, the system of equations presented in Figure A.2 is augmented to incorporate a green tax, and to allow for five rather than two players. The results of combining a green tax with representative cumulative abatement cost curves to provide composite abatement cost curves is illustrated in Figure A.3 at the end of this appendix. The green tax curve has been chosen to have an exponential shape in order that the tax may be extremely onerous under very low abatement regimes, but markedly less so as full abatement is approached. The green tax curve is common to all mines. The abatement cost curves for the individual mines were chosen to have a quadratic form. These curves will also rise rapidly as the level of abatement rises, but the effect is not as dramatic as with the green tax curve. As has been stated previously, it is necessary for abatement costs to differ between mines if permit trading is to take place, so different coefficients have been chosen for the five abatement curves. The curves are of the form $y=ax^2$, and the different *a*'s have been allocated in the range 5 to 10. It should be noted that in the absence of actual costs, these curves are arbitrarily chosen, but are nevertheless considered to be sufficiently representative of the real-life situation to enable some meaningful conclusions to be drawn. Furthermore, the curves are unlikely to be smooth mathematical functions as here presented. However, the spreadsheet approach can accommodate itself readily to virtually any data set, since solution is dependent upon look-up tables and not mathematical solutions. Thus the non-linear and probably discontinuous functions which would arise in practice can be readily incorporated into the model if they become available.

The operation of the model is encapsulated in the marginal cost curves as presented in Figure A.4. In order to ascertain what the market clearing price for permits will be at any given level of pollution abatement, and how much abatement will be implemented by each player, the following procedure is adopted:

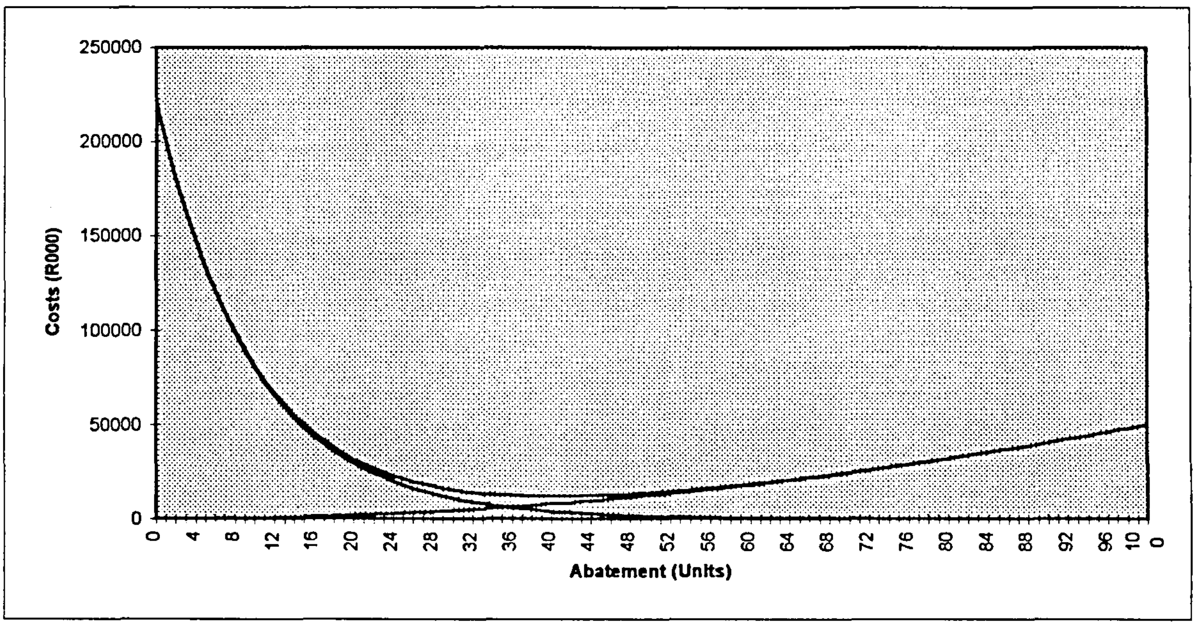
- Identify the total amount of abatement required on the Y-axis (Units of Abatement).
- Draw a line parallel to the X-axis (Marginal Abatement Costs) to cut the market curve.
- Drop a perpendicular from the point of intersection to the X-axis.
- This perpendicular indicates the market clearing price for permits, for the given level of abatement, on the X-axis.
- The point where the perpendicular cuts the individual mines' marginal abatement cost curves indicates the amount of abatement that each mine will implement, since the market curve simply represents the sum of the abatement activities of the individual mines.

In Figure A.4, an abatement level of 350 units was chosen to demonstrate this operation. It can be seen that the permit price is R955, and the abatement implemented by Mines A, B, C, D and E respectively is 95 units, 77 units, 66 units, 58 units and 53 units. The total (allowing for rounding error) is the 350 units that were required. Under a control and command system, each mine would have been required to implement 70 units (350/5) of abatement. The buying and selling of permits makes up the differences between this figure and the actual abatement figures. In practice, this procedure is carried out by the computer using look-up tables on a spreadsheet. In addition the model readily calculates other statistics at the same time. An output sheet provided by the model for the same data discussed above is given in Table A.2. The results discussed above can readily be confirmed from this table. In addition it can be seen that all players (last line of the upper box) demonstrate potential savings. This is as expected from the discussion of the philosophy above.

Further representative output from this model is provided in Appendix E, so that the reader may examine and verify further scenarios should it be so desired.

A notable drawback with the MC model is that a tremendous amount of data has to be available and entered if the table-lookup procedure is to produce without unacceptable truncation errors. This places a heavy recalculation load on the spreadsheet as new scenarios are investigated, and calculation times, even on fast PCs, can grow alarmingly[1].

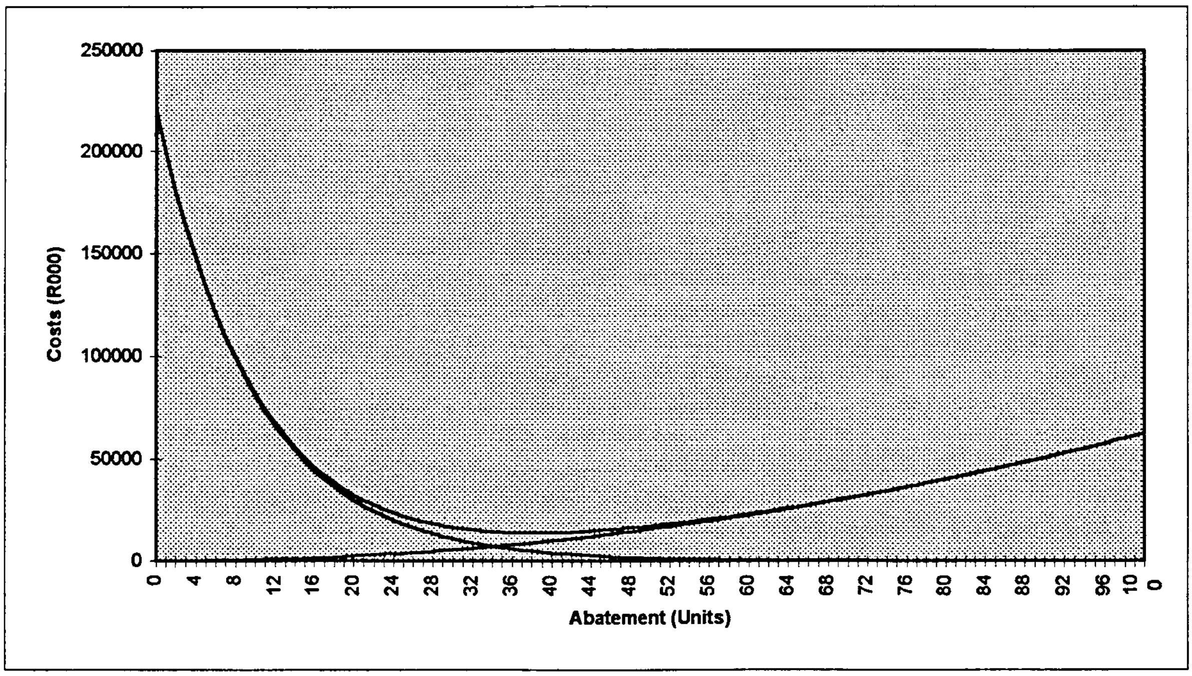
FIGURE A.3: COMPOSITE CUMULATIVE ABATEMENT COST CURVES



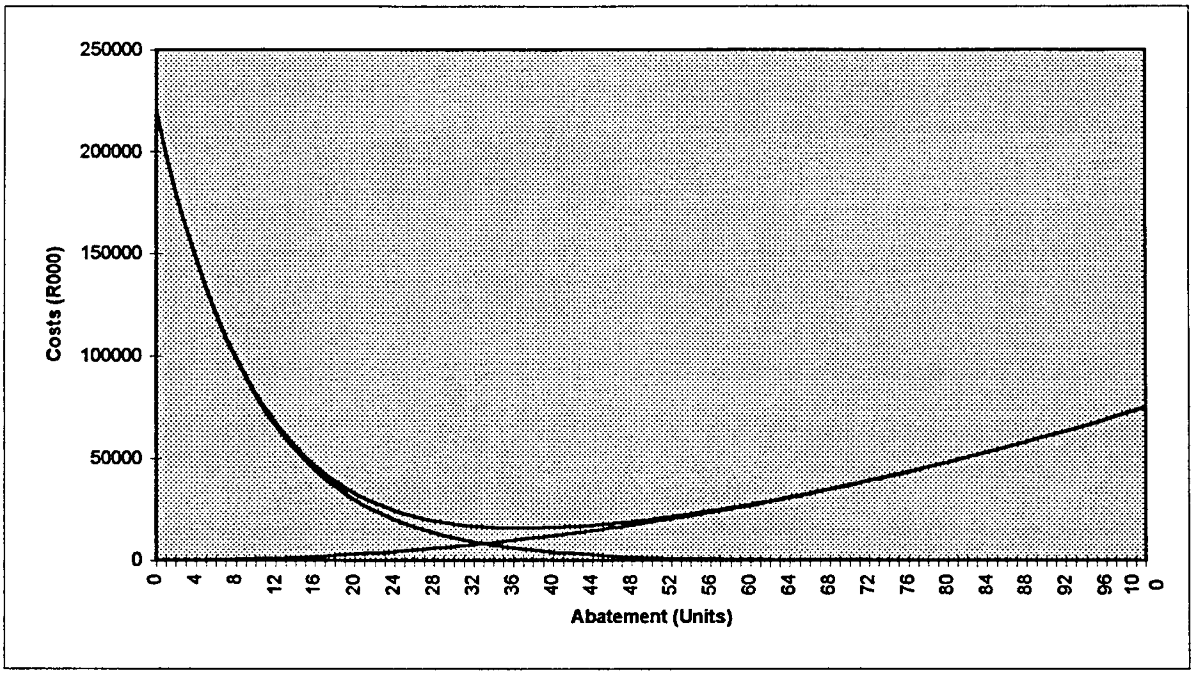
Coefficient of abatement cost curve: a = 5

1 The spreadsheet model used to generate the data presented here used two matrices, one of 1 000x11 elements and the other of 2 000x8 elements. Recalculation times using a 486DX2/66 PC were of the order of 90 seconds for each new scenario generated.

FIGURE A.3: COMPOSITE CUMULATIVE ABATEMENT COST CURVES (CONTINUED)

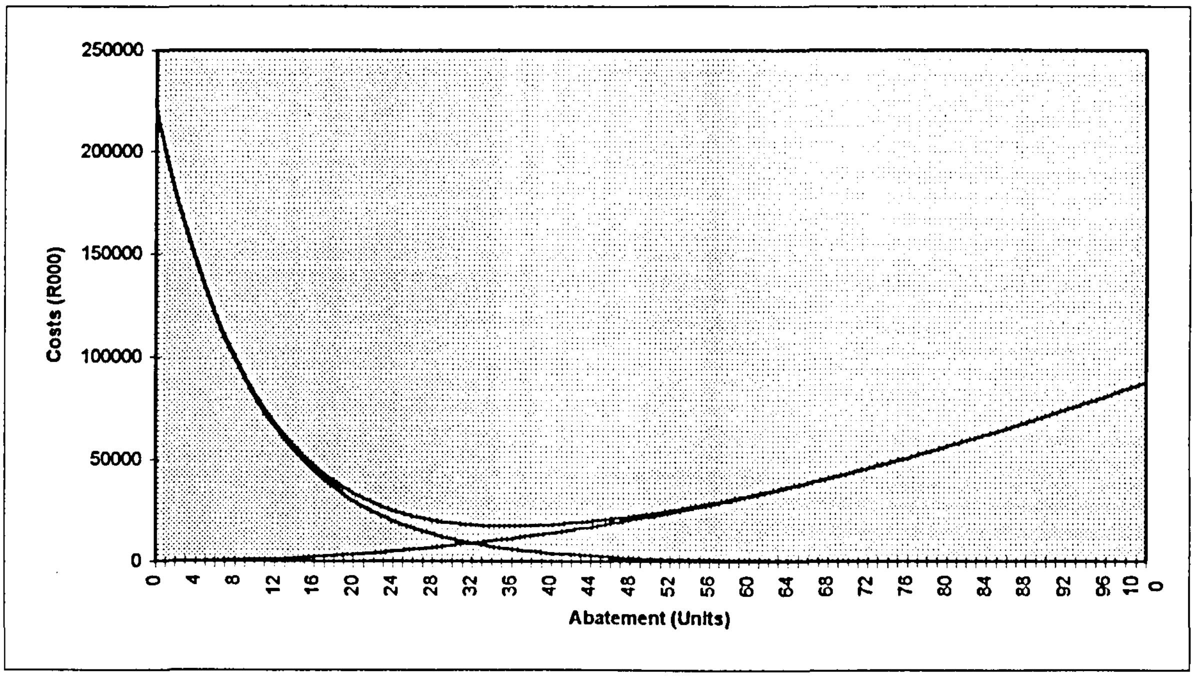


Coefficient of abatement cost curve: a = 6.25

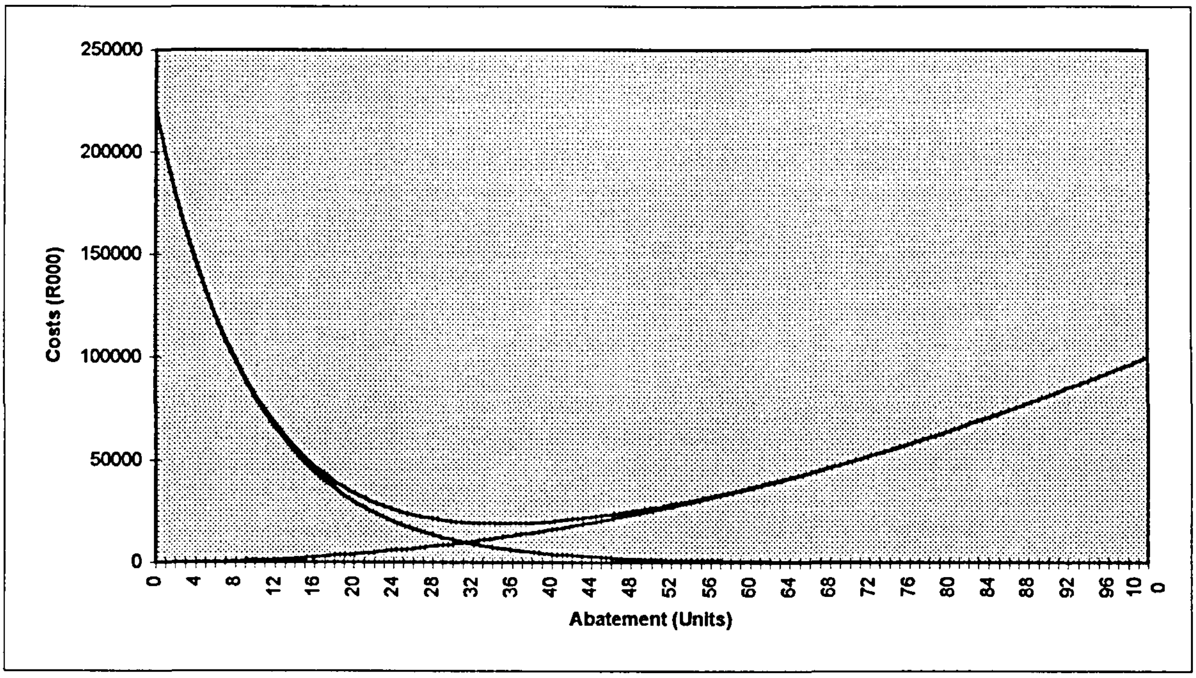


Coefficient of abatement cost curve: a = 7.5

FIGURE A.3: COMPOSITE CUMULATIVE ABATEMENT COST CURVES (CONTINUED)



Coefficient of abatement cost curve: a = 8.75



Coefficient of abatement cost curve: a = 10

FIGURE A.4: MARGINAL ABATEMENT COST CURVES FOR 5 PLAYERS

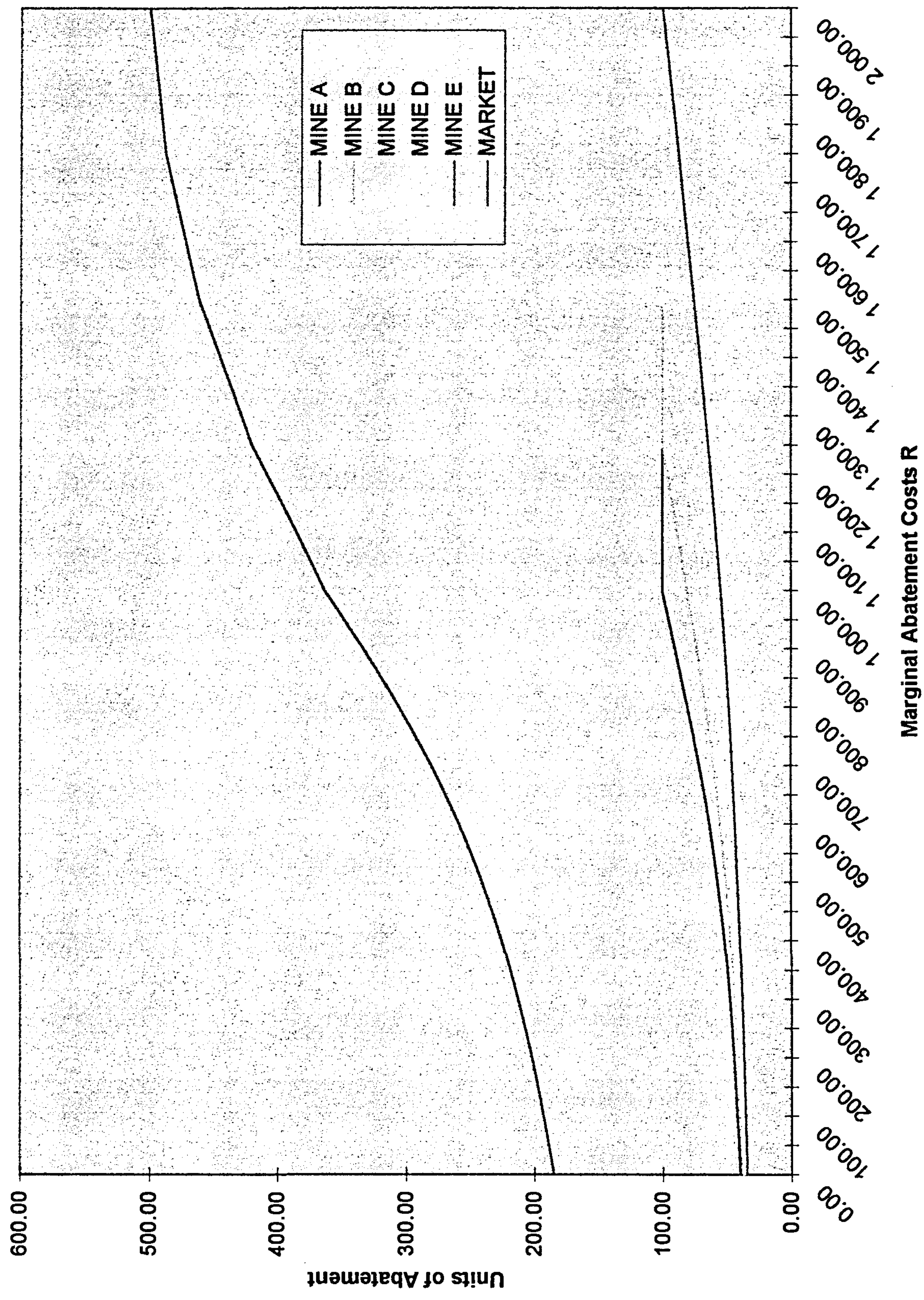


TABLE A.2: OUTPUT FROM THE MARGINAL COSTS MODEL

MARGINAL COST MODEL OUTPUT 350 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 24 690.86	R 30 815.86	R 36 940.86	R 43 065.86	R 49 190.86	R 184 704.28	Cost of legislative approach
R 45 702.33	R 37 241.31	R 32 672.44	R 30 282.01	R 29 274.63	R 175 172.72	Cost of abatement instituted
25.66	7.16	(4.24)	(11.74)	(16.84)	0.00	Number of permits sold (bought)
R 24 505.30	R 6 837.80	R (4 049.20)	R (11 211.70)	R (16 082.20)	R (0.00)	Cost of permits sold (bought)
R 21 197.03	R 30 403.51	R 36 721.64	R 41 493.71	R 45 356.83	R 175 172.72	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 3 493.83	R 412.34	R 219.21	R 1 572.15	R 3 834.02	R 9 531.56	Potential savings (cost of legislative approach less actual abatement costs)
30.06	30.06	30.06	30.06	30.06	150.30	Permits issued to cover allowable emissions
4.40	22.90	34.30	41.80	46.90	150.30	Actual emissions (based on marginal costs)
95.60	77.10	65.70	58.20	53.10	349.70	Actual implemented (based on marginal costs)
25.66	7.16	(4.24)	(11.74)	(16.84)	0.00	Excess (deficit) of permits

Abatement desired	350
Permits issued	150
Market price of permits	955

APPENDIX B

ECONOMIC INSTRUMENTS FOR POINT SOURCE POLLUTION

CONTENTS

B. ECONOMIC INSTRUMENTS FOR POINT SOURCE POLLUTION

This section will consider the theory and practical application of a number of economic instruments that have been used worldwide to abate pollution of point origin.

B.1 DISTRIBUTIVE CHARGES[1]

B.1.1 Theoretical Considerations

One means of controlling effluent is the use of charges. Under the Standard Polluter Pays Principle (Standard PPP), the polluter is required to pay for controlling effluent discharges to a given level, but not for environmental damage caused by the optimal

1 For a detailed discussion of the theory of distributive charges, refer to WRC 1993.

effluent load[2]. Effluent standards would have to be set such that the effluent discharged equalled the optimal pollution level. The optimal level of pollution is depicted in figure 3.1.[3]. At Q*Y the maximum allowable pollution would be set at the pollution level associated with output Q*. Hence, public regulators could induce firms to produce at the socially optimal output level.

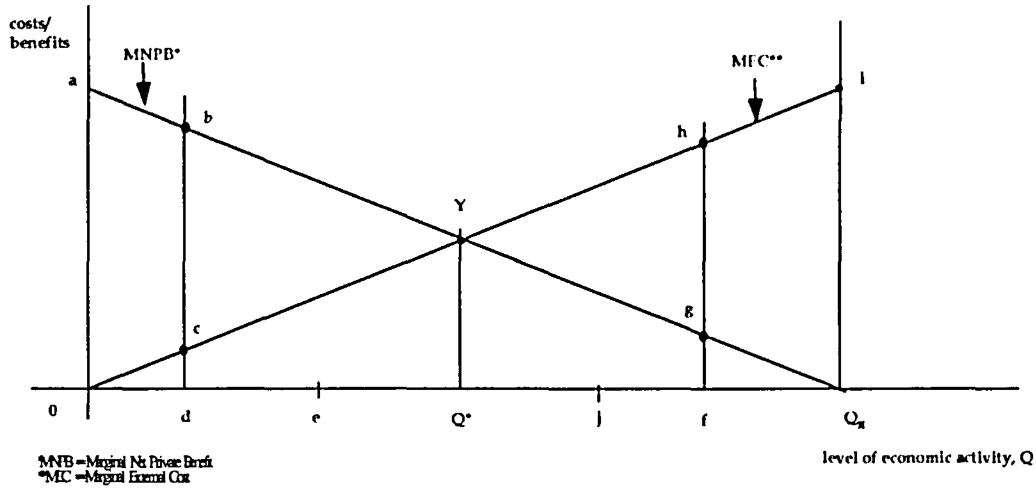


FIGURE B.1: OPTIMAL POLLUTION BY BARGAINING

Two policy choices are open: either a direct regulation of the total discharge to the optimal level or the imposition of a tax or charge on each unit of the polluter's discharge. This latter approach forms the basis of the distributive charge.

The effect of a tax or charge is to shift a firm's marginal net private benefit curve downward by the amount of the tax or charge. If the tax level or charge is selected appropriately, the polluter's behaviour will be modified in such a way that the effluent discharge will move to the optimal level.

There are several difficulties associated with the introduction of distributive charges, of which the most pertinent and immediate ones are:

- the difficulties to properly calculate the optimal level of tax/charge

- possible strong opposition from industry, and

---

2 For a more detailed discussion of the 'polluter-pays-principle' see: WRC 1993.

3 Refer to WRC 1993 for a discussion of the optimal level of pollution.

- potentially high transaction costs.

Despite associated disadvantages relative to the theoretical optimum, various charge systems have been used worldwide to curtail water pollution from effluents. These experiences can serve to illustrate the practicability of the theoretical considerations discussed above.

B.1.2 Practical Implementation

So far, most governments trying to correct market failures have turned to regulations, dictating specifically what measures must be taken to meet environmental goals. This approach has improved the environment in many cases, and is especially important where there is little room for error, such as in disposing of high-level radioactive waste or safeguarding an endangered species. Taxes or charges would be a complement to regulations, not a substitute.

A survey by the OECD revealed more than 50 environmental charges among 14 of its members, including levies on air and water pollution, waste, and noise, as well as various product charges, such as fees on fertilisers and batteries. In most cases, however, these tariffs have been set too low to motivate major changes in behaviour, and have been used instead to raise a modest amount of revenue. A number of representative experiences with charges levied on water pollution will be discussed in the following sections.

(a) Bulawayo[4]

> "Bulawayo is a relatively affluent city with well established water supply and sewerage systems. Nearly all of the population is connected to piped water and sanitation services. Good housekeeping has been the policy of the local authority in reducing water losses. However, the authorities have always been aware of the scarcity of water, and as such all houses are metered for their water consumption and charged.
>
> Until recently, water charges were based on an estimated water ration regardless of the true use. Despite this, water charges were increased 7 times during the last decade. During the severe 1991 to 1992 droughts, charges on excessive water uses were increased 20 to 30

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4 Miltz et al. Source?

times. This led water consumption to decline by 50%, showing how sensitive consumption is towards price.

In 1992, the government changed from the ration pricing to volumetric pricing. It is too early to make an estimate of the effect of this new pricing system. However, the new system will create important reductions in water use as well as raising substantial amounts of revenue. Excessive uses such as car washing are going to be hit hardest and hence will decline the most.

Industry is happy to pay more for the water provided that this means a more reliable supply. Thus, they support this new policy. In the residential sector, the change should not bring too much resistance since water expenditures consist of 1% of their spending. However the poor will be hardest hit since for them water expenditures form 3% of their budget. So, the protection of the poorer sections of the society is a crucial point. The government has responded to this concern by providing a free entitlement to a minimum amount of necessary water."

***(b) Shanghai*[5]**

"The purpose of the Shanghai system is to promote conservation and minimise water use. A wastewater discharge fee of Y0.12/tonne is payable by all enterprises, public agencies and institutions. Households, schools, nurseries and old people's homes are excluded from the system. There are also fines if an enterprise does not comply with the system. For late payments, the fine increase 0.2% each day after the due date. If the authorities find out about an understatement regarding the amount of discharge, the enterprise becomes liable to pay three times the fee.

Revenue from discharge fees can be allocated for innovation and operation and maintenance of the sewer system. Thus, the fee system makes the polluter pay for the sewerage system and decreases the financial burden on the local government."

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5 Miltz, et al, op. cit.

(c) *France*[6]

The French charge system consists of a two-tier system: pollution charges and consumption charges on surface and ground water supplies. Anyone who pollutes sea or fresh water incurs pollution charges. Household charges are calculated each year while other sources are charged on the basis of a flat rate estimate or by actual measurement. Rates vary by agency and are chosen on the basis of budget neutrality rather than on an environmental cost estimate.

The function of the French charge system, implemented in 1969, is purely revenue raising. Total revenues raised under the charge program in 1986 were US $274m. These are used to provide financial aid to local authorities and industry for constructing infrastructure projects, related to water supply and quality management.

There are, however, a number of disadvantages associated with the French charge system, which diminish its incentive effect.

- pollution charges are set too low to have much of an impact on firms,
- according to an OECD estimate in 1989[7] the investment aid provided to firms offsets the abatement costs by about 12%. In other words, the programme appears to have mainly a subsidy rather than a charge effect.

Since charges are set too low and industry is vehemently opposing a charge increase, it is doubtful that charges will reach a level where they have an incentive effect.

Partial positive effects on water quality have been recorded: Organic pollution has been significantly reduced while other substances require further attention.

This charge system is not found to be economically efficient, since it does not result in the lowest cost to society. Its simplicity and administrative efficiency is, however, appealing and there is some degree of adherence to the polluter pays principle.

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6 Further discussion can be found in Miltz, et al, Department of Environment Affairs, 1994.

7 OECD, Economic Instruments for Environmental Protection. OECD, Paris 1989.

(d) *Netherlands*

The Dutch charge system, in place since 1969, is considered to be the world's best administered system and is a mixture of user/effluent charges and direct regulations. Like the French system, the main purpose is to raise revenues for financing projects that will improve water quality. The level of charges is determined by the Dutch water boards who are responsible for maintaining balanced budgets.

Biodegradable matter, suspendable solids, toxic substances and heavy metals are liable to charges; households and small firms pay a standard charge, whilst medium firms are charged according to a table with unit rates for different industries. Large firms are monitored individually. If the pre-treatment of effluents takes place, a rate-reduction for all cases is possible.

Unlike in other charge systems, the effluent charges are relatively high. Thus the incentive factor is well over the intended revenue generating effect.

Between 1969 and 1975 water pollution decreased by 50% with a further 20% fall up to 1980. Another 10% reduction was estimated to 1986. The abatement was expected to be a direct result of increasing and anticipated increases in charge rates.

Furthermore, this system is found to be highly efficient in terms of the administrative costs as it runs on only 4-5% of the revenues collected.

In terms of economic efficiency, in the sense of reducing the overall cost of reaching pollution targets, it is only moderate however. This is because, with the exception of large firms, a dynamic relationships between charges and pollution discharge is absent in the system.

(e) *West Germany*

The West German charge system was announced in 1976 and implemented in 1981. The level of the charge is related to the degree of compliance with the standards. Firms failing to meet their required standards pay a charge on all actual emissions. The German charge system is discussed in detail in chapter 3.3 of this document.

(f) *Czechoslovakia*

Czechoslovakia - up until 31 December 1992 - used effluent charges to sustain water quality at predetermined levels since 1976. A basic charge was placed on

BOD (biological oxygen demand) and suspended solids. Depending on the contribution of the individual discharge to ambient pollutant concentrations, the charge was complemented by a surcharge ranging from 10 to 100%. To reflect the quality of the receiving waters, the basic rates could be adjusted. In its concept the system was very close to the US ambient emission charge system. It is also considered to be cost-effective. No further information on the present form of water pollution control in the new countries is available as of yet.

(g) *East Germany and Hungary*

Until 1990 East Germany and Hungary used a system which combined effluent charges with effluent standards. The charge was levied on discharges in excess of fixed effluent limits. In the Hungarian system the charge level was based, among other factors, on the condition of the receiving waters. At first the charges had little effect; however, when charge levels were raised waste-treatment activity increased.

Conclusions

Nowhere do charges operate alone. All existing systems have linked effluent charges to a regulatory permit standards system. In most cases the primary goal has been to raise revenue for abatement programmes and subsidies. One generally reported result has been that environmental quality has improved.

Some degree of economic success can also be attributed to the charge systems discussed. Incentive mechanisms have been observed, particularly in Germany and the Netherlands.

In addition, despite their differences in terms of application and success, the mere existence of such charge systems may suggest that there is scope for possible and practical implementation in South Africa. The German Council of Experts on Environmental Questions, for instance, estimated that the German effluent charge system is about one-third cheaper for the polluters as a group than an otherwise comparable uniform effluent treatment policy. Additionally, the system encourages firms to go beyond the uniform standards when such an effort can be justified on cost-grounds. Finally charge systems in general have gained wide acceptability as a means of environmental regulation.

B.2 TRADABLE PERMITS[8]

B.2.1 Theoretical Considerations[9]

"A number of economists have suggested the sale of pollution permits as an alternative to effluent taxes. This approach involves the sale of permits, which allow the owner a specified amount of effluent emission.

Both taxes and permits have essentially the same outcome in practice, and share many characteristics. They are both dependable in that they are relatively automatic and routine), they are permanent (they remain in force until explicitly repealed) and they are equitable in that they follow the polluter pays principle. Taxes tend, however, to be more politically acceptable than permits.

If one is prepared to consider the auctioning of permits (tradable permits) then several shortcomings inherent in both taxes and ordinary permits will fall away, as the following list will reveal:

- Tradable permits are not vulnerable to inflation. As they are marketable instruments, they may be bought and sold just as any other marketable securities, and their trading price will always be set by market forces provided that they are traded frequently.
- As economic activity increases, the demand for more permits will undoubtedly rise. In the absence of any new issues, all that will happen is that the price of existing permits will increase. The allowable levels of pollution remain the same in any area, and would-be polluters are faced with the alternative of paying the going price for a permit (if there are any on the market) or of avoiding pollution.
- The differences in the ability of the environment to absorb pollution in different regions are quite readily coped with using permits. Permits can be made region specific, and the number of permits sold for various pollutants can vary from region to region. Permits can also be made seasonal, so that during dry seasons when water

8 For a detailed discussion of the theory of tradable permits, refer to WRC 1993.

9 Baumol, WJ and Oates, WE, *Economics, Environmental Policy and the Quality of Life*, Prentice Hall, 1979.

levels are low, an appropriate seasonal permit would be required in order to discharge any effluents.

- Effluent taxes tend to introduce uncertainty about the final levels of emission, as they are based on a per unit system. If the amount of tax is correctly set, then the right levels of emission will ultimately be achieved. This uncertainty is avoided with permits, as they are based on actual emission levels. This does assume, of course, that no illegal emission is taking place outside the amount sanctioned by the permits.

It has been noted that pollution permits put an upper limit on the amount of pollution permitted. This does, of course, have its downside, in that there is no limit put on the costs that may be incurred in staying within that limit. Although it may be argued that the polluter himself is paying for his own pollution, it must be recognised that money spent on pollution abatement is money withdrawn from the economy as a whole, and is therefore unavailable for other investments. Effluent taxes tend to operate in the opposite sense, by directly controlling the amount of money spent on abatement.

Two possibilities exist for the initial issuing of emission permits. They may either be sold or auctioned to polluters, with the resulting revenue entering the general treasury. Alternatively consent s can be issued free of charge to polluters. The latter is the method generally used, and the permits are known as granted tradable consents.

A number of problems are associated with tradable consents, the most relevant being that:

- there may be a danger of unrestricted permit trade between polluters, which may result in localised undesirable increases in emissions;
- imperfect competition in a market may prevent pollutant levels being achieved in the moist efficient manner; and
- thin markets may undermine the system, (i.e., trade in discharge permits may occur so rarely that there is no opportunity for a proper competitive price to be established)."

For this type of economic instrument to be effective in assisting South Africa's water pollution abatement, it has to be borne in mind that many of our water pollution problems are:

- non-point source in origin and therefore unsuited to tradable permits;
- stem from polluters who are not driven by the profit margin and would thus be unable to compete for permits;
- occur in small catchments where there are too few independent polluters to constitute a viable market.

The rationale behind tradable permits is, as in the case of distributive charges, to restrict the total effluent discharge to the optimal level of economic activity. This requires each polluter to possess a permit allowing the discharge of a maximum quantity of effluent. The total effluent permitted under all consents will amount to the economically optimal pollution level.

As the term indicates, such permits may be tradable. Firms that can abate pollution relatively cheaply are thus enabled to sell their excess "pollution right" to another firm that may find the purchase of a consent cheaper than abatement. This would achieve the reduction of pollution to the optimal level in the most efficient manner.

Although the use of tradable permits has been discussed world-wide, only the United States have so far implemented a workable pollution permit trading system. This will be discussed in chapter 3.4.

With regards to tradable permits, Tietenberg (1992)[10] holds:

> "In the absence of a marketable permit program, a control authority would not only have to keep abreast of all technological developments so emission standards could be adjusted accordingly, but it would also have to ensure an overall balance between effluent increases and decreases so as to preserve water quality. This tough assignment is handled completely by the market in a marketable permit system, thereby facilitating the evolution of the economy by responding flexibly and predictably to change. Marketable permits encourage, as well as facilitate, this evolution. Since permits have value, in order to minimise costs firms must continually be looking for new opportunities to control

10 Tietenberg, Environmental and Natural Resource Economics, 1992, p.505-6

emissions at lower cost. This search eventually results in the adoption of new technologies and in the initiation of changes in the product-mix, which result in lower amounts of emissions. The pressure on sources to continually search for better ways to control pollution is a distinct advantage that economic incentive systems have over bureaucratically defined standards."

B.2.2 Enforcement and Implementation

Although it is still too early to assess permit trading under the Clean Water Act, some enforcement procedures have already been reported: In 1992 the EPA enforcement under the Clean Water Act focused on cases of major non-compliance. In addition, EPA regional offices developed geographic enforcement initiatives, such as the Grand Calument River initiative, to improve water quality of the Great Lakes.

In one major case, *United States v. City of Beaumont, Texas* (E.D. Tex), which is representative of recent enforcement procedures under the Clean Water Act, the district court awarded a penalty of $400,000 against the city. The penalty represented the savings to the city of non-compliance with the CWA ($316,000) and a gravity component ($84,000). The court found that the city had failed to complete key pre-treatment tasks on time. These included sampling and analysis of industrial users, issuing permits requiring industrial self-monitoring, taking enforcement actions, and not publishing a list of significant violators in the newspaper.

Trading of Water Pollution Rights, Fox River, Wisconsin: a failed approach ***(Hahn et al, 1989)***

This case study of a failed trading scheme, shows that as restrictions on trading activity increase, the more trading activity decreases.

Since 1981, Wisconsin's permit programme has allowed point sources of water pollution to trade rights to discharge into the Fox River. The permit system relies on the existing regulatory programmes, and standards such as the Clean Water Act. The main sources of pollution into the river are paper mills and municipal wastewater plants.

However the scheme has proved an outright failure. It has fallen far short of the expected high savings in abatement costs and low monitoring costs. Indeed potential annual cost savings from marketable permits were estimated at $7 million, based on the industry abatement costs estimated by EPA in 1979. Monitoring of trade and discharges was expected to be relatively easy and cheap due to the fact that most pollutants were point sources, i.e. mills and plants.

There are, however, three restrictions on trading. Firstly, the buyer firm has to be a new or an expanding firm, otherwise the trading is not allowed. Secondly, the firm has to prove the need for additional permits and authorities have to approve the trade. This process can take up to 6 months. It is both costly for firms to comply with the regulations and may force them to reveal commercial information that they would prefer to keep confidential. Finally, permits are allocated to their initial owners only for a five-year period, and a bought permit has to be in use at least for a year. Thus, short term trading which is very essential, is not allowed.

With this over-regulated framework, it is not surprising that by 1989, seven years after the start of the scheme, only one trade had taken place. It was between a paper mill that was closing its treatment plant and a municipal plant that was taking on this treatment.

B.2.3 EPA Emissions Trading Program

Although the emissions trading programme has its foundations in US Clean Air Act of 1955 it will be discussed briefly, since it provides some further insights into pollution permit trading in the United States.[11]

The EPA emissions trading program, introduced in 1974, has four distinct policies: netting, offset, bubble and emission banking policies, which all apply to emissions of single pollutants. The four policies are linked by a common element: the emission reduction credit (ERC), which is essentially a currency, used in trading among emission points. Does a polluter decide to control any emission point to a higher degree than necessary to fulfil its legal obligation, he can apply to the control authority for certification of the excess control as an emission reduction credit.

1. Netting or internal trading allows single firms to create new emissions at a plant by reducing emissions from another source at the plant.
2. Offsets are emission reduction commitments by existing firms which must be obtained before major new or expanding sources can begin emissions in "non-attainment" areas, which are regions where the ambient air quality is less than that required by the standards.

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11 For a detailed description of the EPA Emissions Trading Program and its evaluation, refer to WRC 1993.

3. Bubbles are geographic collections of emission points whose total emissions are regulated. ERCs can be traded by firms and plants within bubbles to alter individual source emissions while maintaining the overall bubble emission constant.
4. Banking allows firms to store unused ERCs for future use or sale in the netting, offsets or bubble programmes.

B.3 THE GERMAN EFFLUENT CHARGE LAW

B.3.1 Description

The German effluent charge system (Abwasserabgabengesetz) is unique in a way, as it is the only known charge system with a clearly stated incentive purpose. It was introduced by law in 1976 and implemented in 1981. At first the law was met with strong opposition by industry, which later shifted to discussions over implementation issues, such as criteria for setting charges, the level of charges and dates when the system would go into effect.

It is interesting that the system was actually supported by some industries, notably the newer plants with new waste-saving production processes and the latest pollution control equipment and older plants with recently installed new pollution control equipment. Their support was founded on the belief that their charges would be relatively smaller and would thus give them a competitive edge over industrial facilities with less up-to-date equipment. It was the proactive companies that eventually derived more relative benefit from the effluent charge system. Although based on a command-and-control strategy, this particular system was one, in which market forces began to play a role at a very early stage of implementation.

The 1976 German Federal Water Act - FWA (Wasserhaushaltsgesetz) was a continuation of the operation of a permit system that had been in effect in the Länder since 1957. The FWA empowers the federal government to establish uniform discharge standards for certain major pollutants and to determine the level of technology that must be achieved by municipalities and industries. Furthermore the FWA grants the federal government the authority to establish a minimum national water quality goal for receiving waters. This was set at the 'quality level II' (Gütezustand II) which meant moderately polluted water with good oxygen supply, capable of supporting a large variety of shell-fish, insect larvae and fish.

The effluent discharge law was introduced in September 1976 and enacted in 1981 and empowered the Länder to levy charges on direct dischargers for specified effluents into public waters. Firms and households discharging into municipal sewerage facilities, however, are not charged directly. The system is essentially based on the extended polluter-pays-principle, where charges are levied on the basis of the amount that firms will pollute if they adhere to federal minimum emission standards.

The law consists of two parts:

1. The first part establishes a *discharge right*, containing all physical, chemical and biological data and monitoring procedures pertaining to waste and water quality. It legislates the maximum discharge of wastewater in specified time periods for which the quality must be better or equal in quality to the minimum requirements of the federal administrative regulation.
2. The second part provides all the data necessary to calculate the wastewater *discharge bill*. The charge is normally based on the expected rather than the actual level of discharge and contains an economic incentive for polluters to meet the federal minimum standard. Dischargers in compliance with the federal minimum standards will have the charge halved. If the Länder impose stricter standards than the federal government, Länder requirements have to be met to qualify for the 50% discount. The charges are based on the toxicity of the effluent. The federal government has powers to adjust procedures of testing according to new scientific development.

B.3.2 Enforcement and Implementation

One of the problems associated with any pollution control instrument (economic or regulatory) is the problem of enforcement. The German effluent charge law provides some scope for rigorous enforcement, since the law states that producers must declare all effluents. Should polluters fail to declare such effluents, the regulatory authority has the powers to estimate the pollution units (§ 12(2)) and a fine can be imposed of up to DM 5000 (ca. R10 000) (§ 15(2)).

Implementation Pitfalls

Brown and Johnson (1984)[12] assessed the German charge law, before its amendments in 1987 and found that there were a number of problems associated with this law. These problems were not redressed in the 1987 amendment. They were as follows:

1. about 90% of all firms in West Germany discharged their effluent into sewerage systems of municipalities and were thus not directly liable for the effluent charge. Questions arising from this relate to finding ways of how to charge these firms and whether their costs should resemble the costs of direct dischargers.
2. There is limited recourse of appeal if a firm's economic viability is threatened by charges imposed by the municipality for the firm's discharge.
3. The law is enforced by the 'Länder' and refers to domestic, commercial, agricultural and other uses that change the quality of ground and surface water. However, the agricultural pollution of groundwater is exempt.
4. The system has proved to be quite inefficient with more than half the revenues being spent on administration costs.
5. Charges are set at levels well below the true cost of the environmental damage being wrought by the emissions.

Despite the above problems, experience has shown that the German effluent charge system has had a clear beneficial impact on the environment and that public and private enterprise have responded to the system's incentives.

B.4 THE UNITED STATES: WATER POLLUTION CONTROL POLICIES

B.4.1 Description

The goals of the Federal Water Pollution Control Act Amendments of 1972 and 1977[13] are very ambitious: i.e. fishable and swimmable rivers throughout the United

12 Brown, Gardner M. Jr, Johnson, Ralph W., Pollution Control by Effluent Charges: It Works in the Federal Republic of Germany, Why Not in the US., in: Natural Resources Journal, Vol. 24, No. 4, 1984, pp929-966.

13 Hereafter referred to as 'Act'.

States and zero discharge of pollutants into US waters. The EPA was required by Congress to meet the following deadlines:

1. By 1973, to issue effluent guidelines for major industrial categories of water pollution.
2. By 1974, to grant permits to all water pollution sources.
3. By 1977, all sources were to install the "best practicable technology" (BPT) for abatement of pollutants emitted.
4. By 1981, all major US waterways were to be fishable and swimmable.
5. By 1983, all sources were to install the "best available technology" (BAT) to abate pollution,
6. By 1985, all discharges to waterways were to be eliminated.

The political and legal battle that surrounded the introduction and the requirements of the Act, display very clearly the inefficiency of an Act, which was essentially based on a command-and-control approach. Within one year i.e. by 1973 the EPA was required to issue effluent guidelines for over 200,000 industrial polluters emitting 30 major categories of pollution (plus 250 sub-categorise). Neither this first nor the following deadlines set out in the Act were met, and the EPA was faced with spiralling costs and lawsuits regarding the standard setting which was based on the assessments made in the first year. The regulatory procedures established by the Act did not work very well throughout the 1970s and into the 1980s. A further problem was that the Act did not provide for any economic incentives for industry to comply with the regulations. In addition the notion of uniform BPTs or BATs must be considered unreasonable, a point which will be discussed in more detail below. The methods required by this Act led to a high-cost form of control, which did not guarantee improved water quality.

The Clean Water Act (CWA) introduced in 1972 was met by industry with antagonism, both due to the philosophy and its specific provisions. However, polluters did not find the effluent-permit discharge system embodied in the Act excessively trying. This was helped by the fact that the federal government bore some of the costs for municipal waste-treatment plants that eased the compliance factor.

By conventional criteria, i.e. according to the set standards, water quality in the US was not found to be deteriorating in the 1980s and 1990s: most polluters had applied for and received their discharge permits. This does not mean, however, that water quality standards were set at their economically optimal level[14]. It became evident that in order to improve water quality, targets had to be changed and new approaches had to be developed.

In 1992 the EPA sponsored initiatives that use tradable permits to improve national efficiency in attaining air and water quality goals. Under a tradable or marketable permit system, the EPA issued firms with permits for allowable pollutant emissions. Firms may then choose a compliance strategy that is the most appropriate and cost-effective for their operation. If a firm with relatively low compliance costs can reduce its pollutant emissions below the allowable level, it can sell or trade its extra pollution allowance to others. In short, the system achieves an overall national pollution reduction goal while creating an economic incentive for firms to reduce pollution emissions using more efficient and cost-effective approaches. The success of this market-based trading will in-time depend on the ability of polluters to reduce their emissions efficiently, engage in trading, and meet the overall environmental goal.

14 For a further discussion in general terms, see chapter 5 of this report.

APPPENDIX C

ECONOMIC INSTRUMENTS FOR NON-POINT SOURCE POLLUTION

CONTENTS

C. ECONOMIC INSTRUMENTS FOR NON-POINT SOURCE POLLUTION

C.1 TAXES AND FEES

The idea behind taxes and fees has been discussed in Appendix B in terms of their use for controlling point-source pollution.

The general idea is here, as in point source pollution, to increase the costs associated with generating nonpoint pollution and thereby prompting the polluter to take ameliorative action.

C.2 TARGETING

One of the methods to control nonpoint pollution in the United States has been the use of targeting. 'Targeting' "describes the selective application of abatement measures to key resources and to actual damages rather than emissions or ambient conditions."[1] Braden et al. (1989) consider the use of targeting for the control of

1 Braden, John B., Herricks, Edwin E., Larson, Robert S., Economic Targeting of Nonpoint Pollution Abatement for Fish Habitat Protection, in: Water Resources Research, Vol, 25, No. 12, December 1989, pp. 2399-2405.

agricultural nonpoint source pollution which impacts on fish habitats. They developed a model which indicated where and how to alter farming practices so that costs are minimised for attaining a given fisheries impact goal. This model combined farm economics and stochastic simulations of fisheries degradation due to agricultural pesticides and sediment in surface runoff.

They found that for agricultural pollution management to move beyond narrowly focused programmes, linkages between on-land processes and instream effects must be made. There have to be linkages between the economic optimisation of agricultural practices and a quantitative analysis of the risk that agricultural pollutants pose to fish populations. These attributes permit the targeting of pollution sources and their ultimate impacts, as opposed to pollutant loads or discharges.

C.3 TRADABLE PERMITS AND BUBBLES

Tying nonpoint and point source pollution in a so-called 'bubble' is an innovative and potentially cost-effective policy. In such bubbles total effluent loading from all sources is targeted at some level. By issuing each polluter in the bubble with a "tradable permit" specifying the amount of pollution loading to which they are entitled, total pollution levels in the bubble are controlled at minimum overall cost to the local economy. The same rationale for using tradable permits to control point-source pollution applies here.[2]

C.3.1 Point-Nonpoint Source Trading

In the United States, the idea of trading between point and nonpoint sources of water pollution has taken on a more explicit form in 1992. The EPA continued to study the potential of such trading. Under most scenarios that were considered, regulated point sources could defer water treatment system upgrades, if they would pay for, or arrange for, equivalent or greater reductions in nonpoint source pollution within the same watershed. EPA has approved the use of point-nonpoint source trading involving nutrient pollutants in water bodies that have water quality problems. Programmes have been developed for Cherry Creek Reservoir and Dillon

2 For a detailed discussion, refer to WRC 1993.

Reservoir in Colorado and for Tar-Palmico River Basin in North Carolina. The EPA and other agencies are evaluating the results of these programmes.[3]

C.4 UNITED STATES: NONPOINT POLLUTION CONTROL TRENDS

In the following section, the more recent status of water pollution legislation in the US and its potential for controlling nonpoint sources of pollution will be considered. Emphasis will be placed on implementation pitfalls and cost-effectiveness considerations of the Federal Water Pollution Control Act and the Clean Water Act.

The Federal Water Pollution Control Act, for instance, identifies the fact that water quality is affected both by point and nonpoint sources of waste discharges and makes provisions for controlling pollution from both sources.

In order to aid in the development of water pollution control strategies, the federal government requires the assessment of the quality of the nation's water resources. Despite decades of research, however, only about a third of the US water resources have been assessed. Of these, about two-thirds met the federal water quality standards in 1990[4]. "The major remaining impairment to water quality was found to be polluted runoff from such sources as farmlands, city storm sewers, construction sites, and mines."[5]

Control of agricultural nonpoint pollution is essential for the restoration and protection of acceptable levels of water quality in streams and lakes. The need to alleviate agricultural and other nonpoint pollution problems was recognised with the amendment of the Clean Water Act in 1987. In contrast to the control of point sources, initially the EPA was not given any specific authority to regulate nonpoint sources. In February 1987 $400 million was authorised for a new programme to help states control runoff, but it still left the chief responsibility for controlling nonpoint sources to the individual states.

Under section 208 of the Act control of diffuse pollution was envisaged to be achieved by applying 'BMPs' to specified areas of forest, agriculture and urban land

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3 The Council on Environmental Quality, <u>23rd Annual Report</u>, Washington, January 1993, p. 55.

4 EPA National Water Quality Inventory, report 305(b), Washington 1990.

5 The Council on Environmental Quality, 1993, p. 225.

within a catchment. These practices were devised for the reduction of sediment, nutrients and chemicals carried to streams and lakes by storm runoff. BMPs were required to be designated by the state authorities. To assist the states in developing nonpoint source pollution management programmes, the EPA awarded a further US$ 52.5 m in 1992. One of the key elements of the BMPs is the minimisation of the economic burden placed on agriculture, thus making cost-effectiveness an important consideration in the designation of BMPs as well as that of the development and evaluation of farm plans for meeting water quality goals.

A survey by the National Association of State Foresters in 1991 showed that 32 states had implemented BMPs to prevent nonpoint source pollution. BMP compliance surveys were conducted in 18 states and it was found that compliance ranged from 79% for streamside management to 98% for forest-site preparation. The report, however, does not provide any information as to the impact of such BMPs on water quality and as to their economic efficiency.

C.4.1 Costs of control

As has been indicated, more emphasis is placed in the United States on controlling point-source pollution than nonpoint source pollution. If nonpoint source pollution is considered to be the largest contributor to water quality degradation, the question remains why such little emphasis has been placed on the control of such an important cause of water quality decline. Such neglect could only be justified, if the marginal damages caused by nonpoint pollution are significantly smaller than those of point sources, which makes it justifiable to support a lower level of control of nonpoint pollution.

Another argument for neglecting nonpoint pollution control is that the perceived costs of controlling diffuse pollution are very high relative to the known costs of controlling point sources. If this is the case, then the neglect may be economically justifiable.

Palmini's study (1984)[6] illustrates some of the issues surrounding the cost factor of different measures used to control nonpoint pollution. He examined the effects of agricultural nonpoint policies on two small rural communities in Illinois. The policies he examined were designed to control nitrogen, sediment (soil erosion) and

6 Dennis J. Palmini, The Secondary Impact of Nonpoint Pollution Controls: A Linear Programming-Input/Output Analysis, in: Journal of Environmental Economics and Management, No. 9, September 1984, pp. 263-278.

pesticides. He related the policies to the choice of farming practices, the effects on costs, and the net financial return to farmers.

In order to control nitrogen, input quantity restrictions (i.e. ceilings on the amount used per acre) and nitrogen taxes were introduced. Quantity restrictions were found to lead to a substantial reduction in farm income. Since the demand for nitrogen is inelastic, it was found that there was a need for very high rates of taxation, which resulted in high income losses for the farmers. The main problem was that cost recovery could only be achieved through increasing the price of agricultural products. Policies that are state- or region-based and which introduce a comparative disadvantage for farmers in the state/region subjected to such policies, compared to those elsewhere, are difficult to introduce and maintain.

On the other hand, however, Palmini also found that soil erosion could be reduced by 74% at a cost of less than 1% of net farm earnings. Also a ban on toxic pesticides, causing farmers to switch to other less damaging pest control means, only resulted in a reduction of the net return to farmers of 0.7%.

Palmini's study suggests that some nonpoint source control can be undertaken at reasonable cost but not necessarily across board. It is apparent that the form and intensity of government intervention has to be adapted to specific problems in order to introduce the most cost-effective and most beneficial control methods. In other words, 'balanced' programmes for controlling both point and nonpoint sources are called for.

C.4.2 Cost-effectiveness of nonpoint source control

The cost-effectiveness of pollution control is usually based on the general rule that an improvement in efficiency is brought about by reallocating abatement efforts from sources with high marginal abatement costs to sources with low marginal costs. Cost-effectiveness is measured by using average abatement costs.

The fundamental problem with this approach, however, is that it is only really applicable to emissions of a non-stochastic nature. Nonpoint source emissions invariably possess stochastic characteristics. Properly defined, pollution control of stochastic emissions involves the improvement of the distribution of emissions rather than reducing them to a scalar value. Despite these difficulties, most analyses of cost-effectiveness measure pollution control on the basis of estimating long-term average expected discharges, and associated control costs. McSweeney and

Shortle (1990)[7] looked at probabilistic, rather than average cost-effectiveness and focused on methods for whole-farm pollution rather than individual practices. Most importantly they found, that, excluding transaction costs, broad prescriptions of appropriate technology in form of BMPs might perform poorly with respect to cost-effectiveness. They recommended a number of alternative instruments by which to arrive at cost-effectiveness for stochastic emissions. These included firstly the imposition of standards on means and weighted variances from which farmers could then decide on the least-cost plans for meeting such standards, and secondly, economic incentives could be offered for promoting cost effective planning at farm level.

Shortle and Dunn (1986)[8] also examined the relative expected efficiency (net benefits) of four general strategies, referring to the flow of pollutants from farms as run-off, incorporating stochastic considerations. These strategies were:

a) economic incentives applied to the estimated run-off, e.g. tax on estimated soil loss
b) estimated run-off standards, e.g. estimated soil-loss standards
c) economic incentives applied to farm management practices, e.g. taxes on nutrient application
d) farm management practice standards, e.g. required use of no-till.

They found that an agency choosing an efficient policy for promoting water pollution abatement for a single farm[9], although unable to observe runoff from a farm at reasonable cost, could form expectations as to the runoff, using observations from farm management practices and other data. The general form of the agency's runoff model is:

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7 William T. McSweeney, James S. Shortle, Probabilistic Cost Effectiveness in Agricultural Nonpoint Pollution Control, in: Southern Journal of Agricultural Economics, 22(1), July 1990, pp 95-104.

8 James S. Shortle, James W. Dunn, The Relative Efficiency of Agricultural Source Water Pollution Control Policies, in: American Journal of Agricultural Economics, Vol. 68, August 1986, pp 668-677.

9 The model only considers a single farm, recognising however that situations of practical interest involve numerous polluters. The authors hold, however, that the outcome of nonpoint policies depends upon the responses they elicit at the individual farm level.

$r = f(X, w, \lambda)$

where **r** is the true, but unobservable flow of runoff from the farm, **X** is a vector of farm management decision, **w** is an index for weather conditions such as rainfall etc., which plays an important role in nonpoint source pollution and λ is a random variable representing the agency's imperfect knowledge of the runoff function. The model essentially represents a stochastic specification after Griffin and Bromley's (1982)[10] 'nonpoint production function', with imperfect information and unobservability (represented by λ) and uncertainty regarding stochastic issues (represented by w).

The modelling of the four policy strategies revealed that, policy transaction costs aside, all four policies yielded the same efficient outcome, under the restrictive assumptions of there only being a single polluter and that the polluting farmer is an expected profit maximiser. If these two assumptions are relaxed and multiple sources of pollution and risk aversion are introduced, bringing the scenario a lot closer to a real world situation, the outcome is quite different.

For example:

1. Considering multiple sources of pollution it was found that *management practice incentives* display a distinct advantage over other policies. This is because management practice incentives allow farmers to utilise fully their specialised knowledge of their farm operations. Furthermore, incentives can give farmers at least as much, and even more, information about the expected external costs of their management decisions than quantity control schemes and estimated run-off incentives. An appropriately specified management practice incentive is expected to yield greater expected net benefits than any of the other policy options.

2. It was also found that none of the policies under discussion could be defined as a first-best strategy where farmers avert risk. It is still important to note that it was found that a management practice incentive fares preferentially over the other strategies. Although it must be stated that a tax (or subsidy) for a management practice incentive depends upon the agency's perfect knowledge of a given farmer's risk preference and specialised knowledge of the farm operations, such an incentive reveals to the farmer the agency's evaluation of the expected external cost of his

10 Ronald Griffin and Daniel Bromley, Agricultural Runoff as a Nonpoint Externality, in: American Journal of Agricultural Economics, Vol. 62, 1982, pp 547-552.

decision - to a greater degree than the other policies. At the same time the farmer is still able to fully utilise his comparative informational advantage as to the returns from other management practices in order to maximise his welfare.

APPENDIX D

WITBANK DAM: COMPARATIVE COSTS OF WATER QUALITY MANAGEMENT OPTIONS

CONTENTS

D. WITBANK DAM: COMPARATIVE COSTS OF WATER QUALITY MANAGEMENT OPTIONS

D.1 INTRODUCTION

The Witbank dam is located at the headwaters of the Olifants River. The land use practices in the catchment include agriculture, electric power generation, coal mining and urban settlements. All power generation is by means of coal fired power stations.

Various streams, all of them tributaries of the Olifants River in which the Witbank dam is located, drain the catchment. All the land use practices have some effect on the water quality of the streams draining the catchment.

Concerns regarding the water quality of the Witbank dam have been raised and the Department of Water Affairs and Forestry (DWA&F) is presently considering various water quality management options. Wates Meiring & Barnard (WMB) produced a report titled *Olifants River Basin, Technical Support Document for Witbank Dam Water Quality Management Plan, report no 1505/611/1/W* for the Water Research Commission as part of the initiatives to improve water quality in the catchment.

An economic analysis of the water management options has been requested and the comparative cost analysis, which is the subject of this report, forms part of the wider economic analysis.

Pollution is caused by point sources and diffuse sources. In a point source the pollution occurs at a point and the quantity of impurities in the water can therefore be measured at the source. In a diffuse source the pollution occurs over a large area and affects surface water run-off and is found to seep into ground water. The quantity of pollution from a diffuse source of pollution can not be measured at the source. An example of a point source is the outflow of a municipal sewerage treatment plant while an example of a diffuse source is a coal mine waste dump. It would be possible to convert a diffuse source of pollution into a point source by, for instance, digging a trench around the diffuse source to drain all run-off and seepage water into a channel. This is however not a simple exercise and therefore expensive.

The Witbank Dam Water Quality Management Plan makes it clear that to achieve the water quality management objectives it is imperative that adequate information be available. The plan also specifies compliance monitoring points (CMPs) and control points (CPs) that need to be in place. What it cannot specify at this stage is the exact location of the compliance monitoring points. The difficulty is that much of the pollution in the streams is generated by diffuse sources that cannot be monitored at source. It is therefore proposed that diffuse sources of pollution be monitored on the water course that is affected by discharges of impurities, downstream of the source but upstream of any neighbouring sources of pollution. The placing of the monitoring points is therefore critical, because if the monitoring point is placed too high upstream, not all pollution will be measured, while if it is placed too far downstream, pollution from the next source will be included. The role players and the water authority will therefore have to agree on the exact position of all compliance monitoring points.

D.2 SCOPE OF THIS RESEARCH

This analysis needs to compare the costs of the following approaches to water quality management in the Witbank Dam catchment:

- The conventional command and control approach (CAC) i.e. total control by the water authority

- A joint venture approach as proposed by WMB i.e. joint responsibility (and costs) between the water authority and the polluters
- An economic based approach using 'green taxes' to provide an incentive to polluters to participate in discharge permit trading for effluents i.e. the authority's role is mainly to set goals and monitor their achievement

(See Section 3 for a more detailed description of the approaches.)

The cost analysis will focus on the **financial costs** of **establishing** and **operating** the various systems and will involve the following broad cost areas:

- Capital expenditure to provide monitoring stations
- Capital expenditure for instrumentation
- Operational expenses for data collection and analysis; manpower and associated expenses
- Operational expenses for analysis of water samples
- Management, administrative and support expenses associated with the above
- Permit trading expenses
- Office equipment and office space

D.3 DESCRIPTION OF THE MANAGEMENT APPROACHES

D.3.1 3.1 COMMAND AND CONTROL APPROACH

In the command and control approach the authority takes total responsibility to set maximum emission standards for each polluter, to monitor the levels of emissions by each polluter and to set an appropriate penalty if maximum emission standards are exceeded. The magnitude of the penalty will depend on how far an emission standard is exceeded. No credit is given to polluters who emit less than the maximum standard.

D.3.2 ECONOMIC BASED APPROACH

In the economic based approach, rather than set a maximum emission standard for each polluter, the authority would set a water quality standard for a catchment or sub-catchment. Each polluter in the catchment would then be allocated a permit that would allow a certain amount of emissions. A penalty would still be imposed on polluters who exceed the emission quantity specified in their permit. These permits are however tradable on the open market and will have a market value that will be determined by the cost of emission abatement and the magnitude of the penalty that is imposed if the permit emission quantity is exceeded. In this way polluters that produce more "clean up" than required, can sell their excess "clean up" to polluters who have difficulty in achieving their quotas.

D.3.3 SIMILARITIES AND DIFFERENCES BETWEEN THE APPROACHES

The best way to gain a better understanding of the two approaches is to look at the similarities and differences between them.

D.3.3.1 Similarities

- Each polluter is assigned a level of pollution or quota that may not be exceeded.
- Measurements will be taken to determine the amount of pollution from each source.
- Some form of penalty is imposed on polluters that exceed their quota.
- The quotas assigned to each polluter will aggregate to the amount of pollution that has been decided on for a particular body of water in a catchment, i.e. the water quality of the body of water will be acceptable for a defined use. Note that some quotas may be kept in reserve by the authority for assignment to future entrants into the area.

D.3.3.2 Differences

- In the CAC approach no credit is given to polluters that pollute less than their assigned quota while the economic approach encourages polluters who can achieve a better water quality than their quota requires, to sell this excess "clean up" to polluters that have difficulty in achieving their quotas. How much "clean up" is bought and sold will depend on the cost of achieving units of "clean up".

- Presently the larger sources of pollution are diffuse sources and it will not be possible to determine exactly which polluters are responsible for the level of pollution measured within a sub-catchment area. This means that a set of polluters in a sub-catchment will all receive a proportion, calculated by a pre-set formula, of the penalty that is imposed when the combined quota for the sub-catchment is exceeded. The economic approach sets a penalty in the form of a tax that reduces to zero when the quota is not exceeded while the CAC approach sets a fine which increases the further the quota is exceeded. The economic approach will encourage polluters to change their diffuse sources that cannot be measured and managed properly to point sources that are easier to manage and measure, even though they do not exceed their quotas, so that they can sell any excess "clean up" to polluters that have difficulty in achieving their quota. This implies that polluters in one sub-catchment could trade with polluters in another sub-catchment.

- Each catchment will have a saturation point i.e. a point where no further polluters can be accommodated in a particular catchment. The CAC approach will result in this saturation point being reached much sooner than the Economic approach i.e. the CAC approach will result in barriers to entry of new economic activities within a catchment sooner than necessary as there will be no incentive to produce excess "clean up".

- The CAC approach will place an onerous regulatory responsibility, which will be paid for by the tax payer in general, on the water authorities while the economic approach will place a self regulatory responsibility on the polluters, resulting in the polluters themselves paying most of the costs associated with managing the system.

D.4 DETERMINATION OF COSTS

D.4.1 ASSUMPTIONS

- The valuation for the different management approaches is based on the data needs as described in the report *Olifants River Basin, Technical Support Document for Witbank Dam Water Quality Management Plan, report no 1505/611/1/W* by Wates Meiring & Barnard.
- The data needs will not differ for the various management approaches.
- Existing infrastructure will be used as far as possible.
- The costs determined in this research do not include existing monitoring that has to be done as part of other initiatives. These costs include the following:
  - ⇒ monitoring for atmospheric depositions.
  - ⇒ background water quality monitoring.
  - ⇒ biomonitoring.
  - ⇒ special studies to determine eutrophication and heavy metal deposition.

D.4.2 Philosophical discussion of the valuations

If it is accepted that the data requirements for the various management approaches is the same, it follows that the costs for establishing infrastructure and operation of the systems will also be the same. The allocation of the costs will however differ. In the CAC approach all costs will be allocated to the Water Authority, in this case DWA&F. In the approach proposed by WMB, costs for establishing and operating the control points will be allocated to DWA&F while costs for the compliance monitoring points could be allocated to the various role players. The exact proportions of the allocation will however depend on negotiation between DWA&F and the role players. What will need to be negotiated are the type of instrumentation, who will pay for auditing and calibration of instruments, and the frequency of reports. This situation will also exist for the economic approach if it is implemented.

The only difference between the CAC approach, the joint venture approach and the economic based approach will be the costs associated with permit trading. Permit trading will involve the following:

- negotiations between role players for trading of permits, possibly assisted by a broker or agent who will receive a commission.
- registration of the trade, similar to a share transfer; such a transfer would be open for public inspection and be recorded by DWA&F or a mutually agreed agent appointed by DWA&F.

These costs would however be reflected in the permit trading price and will have no influence on the costs to establish and operate the system and need not be included in this analysis.

It could be argued that the total costs for establishing and operating the economic based system could be reflected in the permit trading prices. At this stage there is however not enough empirical evidence available from economic based systems world wide, to warrant this point of view. Issues that could influence the free trading of permits and which will affect permit trading prices are:

- size of the market; there are a total of 30 role players in this sub-catchment and this may be a too small number to ensure free trade.
- the trading of permits may stabilise after a period, i.e. all emissions are balanced in line with permits owned and there is no need for trading to take place.
- role players may hoard permits for future use in expanding their own operations or because they fear that selling a permit will result in a competitive advantage to their competition.

The above issues do not militate against implementing an economic based system however. There are still many advantages that may be gained at no risk, as the costs of permit trading will be included in permit prices.

All manpower expenses were based on the salary scales of DWA&F as it was considered that these scales would best reflect the going market rate for such expertise.

D.4.3 Valuations

D.4.3.1 Compliance Monitoring Points (CMP)

A total of 30 compliance-monitoring points will be required. A weir will have to be constructed for each CMP. As the exact positions of the CMPs are not known at this stage, an average length of 22 m was taken for each weir. The cost of a weir is R8 000 per running metre. (Pers. com. DWA&F)

The cost of the weirs is therefore R 8 000 x 22 x 30 = R 5 280 000

D.4.3.2 Control Points (CP)

There are 9 control points specified by WMB, 8 of which will be at existing weirs or dam walls. The exception is the CP on the Steenkoolspruit, which will be where the Tavistock abstraction takes place and will require a weir.

The cost of the weir is R 8 000 x 22 x 1 = R 176 000

D.4.3.3 Capital Expenditure for Instrumentation

Instrumentation to continuously measure flow quantity, salinity and acidity will have to be installed at each CMP and CP, a total of 39 instruments. Because of the potential financial implications (it is expected that penalties for non-compliance will be high) the instrumentation used for the compliance measurements must be of a high standard. The costs for instrumentation were therefore based on the Grant Environmental System.

The cost of instrumentation is R 28 000 x 39 = R 1 092 000

It is expected that, due to normal wear and tear and the development of more sophisticated systems, the instrumentation will have to be replaced periodically. A replacement period of 10 years was taken for the purpose of this analysis. The discount rate used was 8%, which is the standard rate for DWA&F projects.

NPV of Capital Expenditure @ 8% over 45 years = R 1 990 880

D.4.3.4 Operational Expenses

These costs include data collection, analysis, travelling, office space and are made up of manpower and associated expenses. As these expenses will be incurred over the life cycle of the project a net present value (NPV) was calculated over a 45-year period at 8%.

Some of the operational expenses for CMPs may coincide with expenses that are already incurred for the Environmental Management Progress Reports (EMPR) that mines have to carry out in terms of the Minerals Act. It is however not possible to determine to what extent the expenses will coincide at this stage. A conservative view has therefore been taken and all expenses associated with compliance monitoring have been included in this analysis. Table 4.1 below summarises the operational expenses.

Item	Quantity per Annum	Units	Rate per Unit	Total per Annum
Sample & Data Collection	260	man days	R300.00	R78,000
Sample Analysis	1506	samples	R240.00	R361,440
Traveling	75300	km	R0.395	R29,744
Processing & Analysis	52	man days	R525.00	R27,300
Independent Auditing	480	man hours	R200.00	R96,000
Audit Sample Analysis	125	samples	R240.00	R30,000
Calibration of Instruments	16	calibrations	R1,500.00	R24,000
Maintenance Costs	8	man days	R1,500.00	R12,000
Admin. Support	52	man days	R140.00	R7,280
Office Space	13.2	square m	R300.00	R3,960
TOTAL ANNUAL OPERATIONAL COSTS				**R669,724**
Net Present Value @ 8% over 45 Years				**R8,109,281**

TABLE 4.1: SUMMARY OF OPERATIONAL COSTS

D.4.3.5 Explanatory Notes on Values for Calculation Purposes

Manpower costs

DWA&F salary scale for Assistant Water Pollution Control Officer

R 37 170 x R 1 875 - R 46 454: Median Value	R 41 812
Add 13 th Cheque	R 3 484
Annual Total	R 45 296
Add Fringe Benefits 70% (includes car allowance)	R 31 707
Total Package	R 77 003
Daily Rate (to nearest R 5)	R 300

DWA&F Salary Scale for Principal Water Pollution Control Officer

R 69 510 x R 2 901 - R 78 213: Median Value	R 73 861
Add 13 th Cheque	R 6 155
Annual Total	R 80 016
Add Fringe Benefits 70% (includes car allowance)	R 56 011
Total Package	R136 027
Daily Rate (to nearest R 5)	R 525

Administrative Assistant

Median Value	R 24 000
Add 13 th Cheque	R 2 000
Annual Total	R 26 000
Add Fringe Benefits 40% (excludes car allowance)	R 10 400
Total Package	R 36 400
Daily Rate (to nearest R 5)	R 140

Sampling

As specified by WMB on the Control Points	336 per annum
30 Compliance Monitoring Points (every week in summer)	780 per annum
30 Compliance Monitoring Points (every 2 weeks in winter)	390 per annum
Total	1 506 per annum

Cost to analyse 1 sample = R 240

Travelling Expenses

Taking of 1506 samples @ 50 km per sample = 75 300 km

AA rate per kilometre (2 litre vehicle) = R 0,395 for fuel and maintenance; capital expenditure is included in fringe benefits

Manpower Requirements

Taking of samples and recording data: 1 Assistant Water Pollution Control Officer full time = 260 man days per annum

Data processing and analysis: 1 Principal Water Pollution Control Officer, 1 man day per week = 52 man days per annum

Admin. support: 1 Data Processor/Administrative Assistant, 1 man day per week = 52 man days per annum

Calibration of Instruments

39 Instruments calibrated once every two months = 78 calibrations per annum

78 calibrations @ 5 calibrations per day = 16 man days (to nearest day)

Calibration contract, including instruments, travelling and manpower: R 1 500 per day

Maintenance of Instruments

39 Instruments serviced once every two months = 78 services per annum

78 services @ 10 services per day = 8 man days (to nearest day)

Service contract, including equipment, spares and travelling: R 1 500 per day

Office Space

1 Office for full time Assistant Water Pollution Control Officer: $9m^2$

1 Office part time (20%) for Principal Water Pollution Control Officer: $2,4m^2$

1 Office part time (20%) for admin. support: $1,8m^2$

Cost of office space @ R $25/m^2$ per month = R $300/m^2$ per annum

Independent Audits

39 Stations audited on a monthly basis @ 1 week per audit = 480 man hours

Consulting rate per hour = R 200

D.4.3.6 Total Expenses

Table 4.2 gives a summary of the total expenses for capital expenditure and operational management of the water quality in the Witbank Dam.

Item	Cost R Million
Building of Weirs	R 5,456
Cost of Instrumentation *	R 1,991
Operational Expenses	R 8,109
Total (1994 Rand)	**R 15,556**

* Includes replacement costs

TABLE 4.2: TOTAL COST OF WATER QUALITY MANAGEMENT FOR THE WITBANK DAM

D.4.3.7 4.3.7 ALLOCATION OF COSTS

If the allocation of costs is negotiated along the lines proposed by WMB the proportions can be calculated as follows:

Building of weirs

1 weir for DWA&F = R 0,176 million
30 weirs for the role players = R 5,280

Instrumentation

9 Control Points to DWA&F

30 Compliance Monitoring Points to the Role Players

which gives a ratio of 23% to DWA&F and 77% to the role players for instrument costs i.e.

R 0,458 million to DWA&F and R 1,533 million to the role players

Operational Costs

9 Control Points to DWA&F

30 Compliance Monitoring Points to the Role Players

which gives a ratio of 23% to DWA&F and 77% to the role players for operational costs i.e.

R 1,865 million to DWA&F and R 6,244 million to the role players

Table A1.3 summarises the cost breakdown.

Item	Cost R million DWA&F	Cost R million Role Players	Total Costs
Building of Weirs	R 0,176	R 5,280	R 5,456
Cost of Instrumentation *	R 0,458	R 1,533	R 1,991
Operational Expenses	R 1,865	R 6,244	R 8,109
Total (1994 Rand)	**R 2,499**	**R 13,057**	**R 15,566**

* Includes Replacement Costs

TABLE A1.3: ALLOCATION OF WATER QUALITY MANAGEMENT COSTS

APPENDIX E

MODEL OUTPUT DATA

E. MODEL OUTPUT DATA

Additional data from both the Simulation model and the Marginal Cost model are here provided for the reader to analyse for himself along the lines indicated in Chapter 5. The data sheets are arranged in pairs, such that the output for both models for any given input will appear together to facilitate comparison.

Data is provided for the following pollution abatement scenarios:

Pollution abatement required: 200 units
225 units
250 units
275 units
300 units
325 units
350 units
375 units
400 units
425 units
450 units

It should be noted that the abatement of 186 units represents the sum of the abatements occurring at the dips in the abatement curves of the individual mines. Since the green tax will drive abatement efforts down to this level without the need for trading, no interest in trading will be evidenced by the players, and below this level the model produces spurious results.

500 units of abatement represents 100% abatement by all players (this is the theoretical maximum pollution which can be emitted), and this input produces the trivial result where all mines abate to the maximum, and no trading occurs and no benefits accrue. This scenario is therefore not included.

MARGINAL COST MODEL OUTPUT

200 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 12 024.29	**R 14 024.29**	**R 16 024.29**	**R 18 024.29**	**R 20 024.29**	**R 80 121.44**	Cost of legislative approach
R 12 391.41	R 14 226.41	R 15 950.13	R 17 552.49	R 19 070.47	R 79 190.90	Cost of abatement instituted
4.12	1.52	(0.38)	(1.98)	(3.28)	0.00	Number of permits sold (bought)
R 725.12	R 267.52	R (66.88)	R (348.48)	R (577.28)	R 0.00	Cost of permits sold (bought)
R 11 666.29	**R13 958.89**	**R 16 017.01**	**R 17 900.97**	**R 19 647.75**	**R 79 190.90**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 358.00	**R 65.40**	**R 7.28**	**R 123.32**	**R 376.54**	**R 930.54**	Potential savings (cost of legislative approach less actual abatement costs)
60.02	60.02	60.02	60.02	60.02	300.10	Permits issued to cover allowable emissions
55.90	58.50	60.40	62.00	63.30	300.10	Actual emissions (based on marginal costs)
44.10	41.50	39.60	38.00	36.70	199.90	Actual implemented (based on marginal costs)
4.12	1.52	(0.38)	(1.98)	(3.28)	0.00	Excess (deficit) of permits

Abatement desired	**200**
Permits issued	**300**
Market price of permits	**176**

SIMULATION MODEL OUTPUT 200 UNITS OF ABATEMENT DESIRED

COSTS												EXPLANATIONS
MINE A		MINE B		MINE C		MINE D		MINE E		TOTAL		
R	**12 024**	**R**	**14 024**	**R**	**16 024**	**R**	**18 024**	**R**	**20 024**	**R**	**80 120**	Cost of legislative approach
R	12 374	R	14 146	R	16 024	R	17 553	R	19 126	R	79 223	Cost of abatement instituted
	4		1		0		(2)		(3)		0	Number of permits sold (bought)
R	684	R	171	R	-	R	(342)	R	(513)	R	-	Cost of permits sold (bought)
R	**11 690**	**R**	**13 975**	**R**	**16 024**	**R**	**17 895**	**R**	**19 639**	**R**	**79 223**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R	**334**	**R**	**49**	**R**	**-**	**R**	**129**	**R**	**385**	**R**	**897**	Potential savings (cost of legislative approach less actual abatement costs)

60	60	60	60	60	300	Permits issued to cover allowable emissions
56	59	60	62	63	300	Actual emissions (based on simulation)
44	41	40	38	37	200	Actual implemented (based on simulation)
4	1	0	(2)	(3)	0	Excess (deficit) of permits

Abatement desired	**200**
Permits issued	**300**
Market price of permits	**171**

MARGINAL COST MODEL OUTPUT 225 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 12 561.92	**R 15 093.17**	**R 17 624.42**	**R 20 155.67**	**R 22 686.92**	**R 88 122.10**	Cost of legislative approach
R 14 645.85	R 15 877.70	R 17 253.43	R 18 648.07	R 19 984.93	R 86 409.98	Cost of abatement instituted
6.84	2.24	(0.86)	(3.16)	(5.06)	0.00	Number of permits sold (bought)
R 2 708.64	R 887.04	R (340.56)	R (1 251.36)	R (2 003.76)	R 0.00	Cost of permits sold (bought)
R 11 937.21	**R14 990.66**	**R 17 593.99**	**R 19 899.43**	**R 21 988.69**	**R 86 409.98**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 624.71	**R 102.51**	**R 30.43**	**R 256.24**	**R 698.23**	**R 1 712.11**	Potential savings (cost of legislative approach less actual abatement costs)
55.04	55.04	55.04	55.04	55.04	275.20	Permits issued to cover allowable emissions
48.20	52.80	55.90	58.20	60.10	275.20	Actual emissions (based on marginal costs)
51.80	47.20	44.10	41.80	39.90	224.80	Actual implemented (based on marginal costs)
6.84	2.24	(0.86)	(3.16)	(5.06)	0.00	Excess (deficit) of permits

Abatement desired	**225**
Permits issued	**275**
Market price of permits	**396**

SIMULATION MODEL OUTPUT 225 UNITS OF ABATEMENT DESIRED

COSTS												EXPLANATIONS
MINE A		MINE B		MINE C		MINE D		MINE E		TOTAL		
R	**12 562**	**R**	**15 093**	**R**	**17 625**	**R**	**20 156**	**R**	**22 687**	**R**	**88 123**	Cost of legislative approach
R	14 725	R	15 799	R	17 214	R	18 728	R	20 024	R	86 490	Cost of abatement instituted
	7		2		(1)		(3)		(5)		0	Number of permits sold (bought)
R	2 772	R	792	R	(396)	R	(1 188)	R	(1 980)	R	-	Cost of permits sold (bought)
R	**11 953**	**R**	**15 007**	**R**	**17 610**	**R**	**19 916**	**R**	**22 004**	**R**	**86 490**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R	**609**	**R**	**86**	**R**	**15**	**R**	**240**	**R**	**683**	**R**	**1 633**	Potential savings (cost of legislative approach less actual abatement costs)

55	55	55	55	55	275	Permits issued to cover allowable emissions
48	53	56	58	60	275	Actual emissions (based on simulation)
52	47	44	42	40	225	Actual implemented (based on simulation)
7	2	(1)	(3)	(5)	0	Excess (deficit) of permits

Abatement desired	**225**
Permits issued	**275**
Market price of permits	**396**

MARGINAL COST MODEL OUTPUT 250 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 13 974.13	**R17 099.13**	**R 20 224.13**	**R 23 349.13**	**R 26 474.13**	**R 101 120.66**	Cost of legislative approach
R 18 810.60	R18 645.72	R 19 300.84	R 20 265.07	R 21 357.45	R 98 379.69	Cost of abatement instituted
10.52	3.02	(1.58)	(4.78)	(7.18)	(0.00)	Number of permits sold (bought)
R 5 828.08	R 1 673.08	R (875.32)	R (2 648.12)	R (3 977.72)	R (0.00)	Cost of permits sold (bought)
R 12 982.52	**R16 972.64**	**R 20 176.16**	**R 22 913.19**	**R 25 335.17**	**R 98 379.69**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 991.61	**R 126.49**	**R 47.97**	**R 435.94**	**R 1 138.96**	**R 2 740.97**	Potential savings (cost of legislative approach less actual abatement costs)
50.02	50.02	50.02	50.02	50.02	250.10	Permits issued to cover allowable emissions
39.50	47.00	51.60	54.80	57.20	250.10	Actual emissions (based on marginal costs)
60.50	53.00	48.40	45.20	42.80	249.90	Actual implemented (based on marginal costs)
10.52	3.02	(1.58)	(4.78)	(7.18)	(0.00)	Excess (deficit) of permits

Abatement desired	**250**
Permits issued	**250**
Market price of permits	**554**

SIMULATION MODEL OUTPUT 250 UNITS OF ABATEMENT DESIRED

COSTS												EXPLANATIONS
MINE A		MINE B		MINE C		MINE D		MINE E		TOTAL		
R	**13 974**	**R**	**17 099**	**R**	**20 224**	**R**	**23 349**	**R**	**26 474**	**R**	**101 120**	Cost of legislative approach
R	19 089	R	18 645	R	19 083	R	20 156	R	21 469	R	98 442	Cost of abatement instituted
	11		3		(2)		(5)		(7)		0	Number of permits sold (bought)
R	6 094	R	1 662	R	(1 108)	R	(2 770)	R	(3 878)	R	-	Cost of permits sold (bought)
R	**12 995**	**R**	**16 983**	**R**	**20 191**	**R**	**22 926**	**R**	**25 347**	**R**	**98 442**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R	**979**	**R**	**116**	**R**	**33**	**R**	**423**	**R**	**1 127**	**R**	**2 678**	Potential savings (cost of legislative approach less actual abatement costs)

50	50	50	50	50	250	Permits issued to cover allowable emissions
39	47	52	55	57	250	Actual emissions (based on simulation)
61	53	48	45	43	250	Actual implemented (based on simulation)
11	3	(2)	(5)	(7)	0	Excess (deficit) of permits

Abatement desired	**250**
Permits issued	**250**
Market price of permits	**554**

MARGINAL COST MODEL OUTPUT 275 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 16 015.17	**R 19 796.42**	**R 23 577.67**	**R 27 358.92**	**R 31 140.17**	**R 117 888.36**	Cost of legislative approach
R 24 419.85	R 22 282.03	R 21 885.04	R 22 229.04	R 22 952.57	R 113 768.54	Cost of abatement instituted
14.62	3.92	(2.38)	(6.58)	(9.58)	0.00	Number of permits sold (bought)
R 9 883.12	R 2 649.92	R (1 608.88)	R (4 448.08)	R (6 476.08)	R -	Cost of permits sold (bought)
R 14 536.73	**R19 632.11**	**R 23 493.92**	**R 26 677.12**	**R 29 428.65**	**R 113 768.54**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 1 478.44	**R 164.31**	**R 83.75**	**R 681.80**	**R 1 711.52**	**R 4 119.81**	*Potential savings (cost of legislative approach less actual abatement costs)*
45.02	45.02	45.02	45.02	45.02	225.10	Permits issued to cover allowable emissions
30.40	41.10	47.40	51.60	54.60	225.10	Actual emissions (based on marginal costs)
69.60	58.90	52.60	48.40	45.40	274.90	Actual implemented (based on marginal costs)
14.62	3.92	(2.38)	(6.58)	(9.58)	0.00	Excess (deficit) of permits

Abatement desired	**275**
Permits issued	**225**
Market price of permits	**676**

SIMULATION MODEL OUTPUT 275 UNITS OF ABATEMENT DESIRED

COSTS												EXPLANATIONS
MINE A		MINE B		MINE C		MINE D		MINE E		TOTAL		
R	**16 015**	R	**19 796**	R	**23 578**	R	**27 359**	R	**31 140**	R	**117 888**	Cost of legislative approach
R	24 691	R	22 349	R	22 157	R	21 963	R	22 687	R	113 847	Cost of abatement instituted
	15		4		(2)		(7)		(10)		0	Number of permits sold (bought)
R	10 140	R	2 704	R	(1 352)	R	(4 732)	R	(6 760)	R	-	Cost of permits sold (bought)
R	**14 551**	R	**19 645**	R	**23 509**	R	**26 695**	R	**29 447**	R	**113 847**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R	**1 464**	R	**151**	R	**69**	R	**664**	R	**1 693**	R	**4 041**	Potential savings (cost of legislative approach less actual abatement costs)

45	45	45	45	45	225	Permits issued to cover allowable emissions
30	41	47	52	55	225	Actual emissions (based on simulation)
70	59	53	48	45	275	Actual implemented (based on simulation)
15	4	(2)	(7)	(10)	0	Excess (deficit) of permits

Abatement desired	**275**
Permits issued	**225**
Market price of permits	**676**

MARGINAL COST MODEL OUTPUT 300 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 18 535.98	**R23 035.98**	**R 27 535.98**	**R 32 035.98**	**R 36 535.98**	**R 137 679.91**	Cost of legislative approach
R 30 964.79	R26 649.55	R 24 938.69	R 24 552.09	R 24 765.04	R 131 870.16	Cost of abatement instituted
18.64	4.94	(3.16)	(8.36)	(12.06)	0.00	Number of permits sold (bought)
R 14 501.92	R 3 843.32	R (2 458.48)	R (6 504.08)	R (9 382.68)	R -	Cost of permits sold (bought)
R 16 462.87	**R22 806.23**	**R 27 397.17**	**R 31 056.17**	**R 34 147.72**	**R 131 870.16**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 2 073.11	**R 229.76**	**R 138.82**	**R 979.81**	**R 2 388.26**	**R 5 809.75**	Potential savings (cost of legislative approach less actual abatement costs)
40.04	40.04	40.04	40.04	40.04	200.20	Permits issued to cover allowable emissions
21.40	35.10	43.20	48.40	52.10	200.20	Actual emissions (based on marginal costs)
78.60	64.90	56.80	51.60	47.90	299.80	Actual implemented (based on marginal costs)
18.64	4.94	(3.16)	(8.36)	(12.06)	0.00	Excess (deficit) of permits

Abatement desired	**300**
Permits issued	**200**
Market price of permits	**778**

SIMULATION MODEL OUTPUT 300 UNITS OF ABATEMENT DESIRED

COSTS												EXPLANATIONS
MINE A		MINE B		MINE C		MINE D		MINE E		TOTAL		
R	**18 536**	R	**23 036**	R	**27 536**	R	**32 036**	R	**36 536**	R	**137 680**	Cost of legislative approach
R	30 500	R	26 727	R	25 095	R	24 865	R	24 843	R	132 030	Cost of abatement instituted
	18		5		(3)		(8)		(12)		0	Number of permits sold (bought)
R	13 968	R	3 880	R	(2 328)	R	(6 208)	R	(9 312)	R	-	Cost of permits sold (bought)
R	**16 532**	**R**	**22 847**	**R**	**27 423**	**R**	**31 073**	**R**	**34 155**	**R**	**132 030**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R	**2 004**	**R**	**189**	**R**	**113**	**R**	**963**	**R**	**2 381**	**R**	**5 650**	Potential savings (cost of legislative approach less actual abatement costs)

40	40	40	40	40	200	Permits issued to cover allowable emissions
22	35	43	48	52	200	Actual emissions (based on simulation)
78	65	57	52	48	300	Actual implemented (based on simulation)
18	5	(3)	(8)	(12)	0	Excess (deficit) of permits

Abatement desired	**300**
Permits issued	**200**
Market price of permits	**776**

MARGINAL COST MODEL OUTPUT 325 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 21 446.15	**R 26 727.40**	**R 32 008.65**	**R 37 289.90**	**R 42 571.15**	**R 160 043.27**	Cost of legislative approach
R 38 132.06	R 31 677.99	R 28 565.04	R 27 271.81	R 26 904.25	R 152 551.15	Cost of abatement instituted
22.32	6.02	(3.78)	(10.08)	(14.48)	0.00	Number of permits sold (bought)
R 19 418.40	R 5 237.40	R (3 288.60)	R (8 769.60)	R (12 597.60)	R 0.00	Cost of permits sold (bought)
R 18 713.66	**R 26 440.59**	**R 31 853.64**	**R 36 041.41**	**R 39 501.85**	**R 152 551.15**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 2 732.50	**R 286.81**	**R 155.01**	**R 1 248.50**	**R 3 069.30**	**R 7 492.13**	Potential savings (cost of legislative approach less actual abatement costs)
35.02	35.02	35.02	35.02	35.02	175.10	Permits issued to cover allowable emissions
12.70	29.00	38.80	45.10	49.50	175.10	Actual emissions (based on marginal costs)
87.30	71.00	61.20	54.90	50.50	324.90	Actual implemented (based on marginal costs)
22.32	6.02	(3.78)	(10.08)	(14.48)	0.00	Excess (deficit) of permits

Abatement desired	**325**
Permits issued	**175**
Market price of permits	**870**

SIMULATION MODEL OUTPUT 325 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 21 446	**R 26 727**	**R 32 009**	**R 37 290**	**R 42 571**	**R 160 043**	Cost of legislative approach
R 37 872	R 31 678	R 28 392	R 27 359	R 27 343	R 152 644	Cost of abatement instituted
22	6	(4)	(10)	(14)	0	Number of permits sold (bought)
R 19 140	R 5 220	R (3 480)	R (8 700)	R (12 180)	R -	Cost of permits sold (bought)
R 18 732	**R 26 458**	**R 31 872**	**R 36 059**	**R 39 523**	**R 152 644**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 2 714	**R 269**	**R 137**	**R 1 231**	**R 3 048**	**R 7 399**	Potential savings (cost of legislative approach less actual abatement costs)

35	35	35	35	35	175	Permits issued to cover allowable emissions
13	29	39	45	49	175	Actual emissions (based on simulation)
87	71	61	55	51	325	Actual implemented (based on simulation)
22	6	(4)	(10)	(14)	0	Excess (deficit) of permits

Abatement desired	**325**
Permits issued	**175**
Market price of permits	**870**

MARGINAL COST MODEL OUTPUT 350 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 24 690.86	**R30 815.86**	**R 36 940.86**	**R 43 065.86**	**R 49 190.86**	**R 184 704.28**	Cost of legislative approach
R 45 702.33	R37 241.31	R 32 672.44	R 30 282.01	R 29 274.63	R 175 172.72	Cost of abatement instituted
25.66	7.16	(4.24)	(11.74)	(16.84)	0.00	Number of permits sold (bought)
R 24 505.30	R 6 837.80	R (4 049.20)	R (11 211.70)	R (16 082.20)	R (0.00)	Cost of permits sold (bought)
R 21 197.03	**R30 403.51**	**R 36 721.64**	**R 41 493.71**	**R 45 356.83**	**R 175 172.72**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 3 493.83	**R 412.34**	**R 219.21**	**R 1 572.15**	**R 3 834.02**	**R 9 531.56**	Potential savings (cost of legislative approach less actual abatement costs)
30.06	30.06	30.06	30.06	30.06	150.30	Permits issued to cover allowable emissions
4.40	22.90	34.30	41.80	46.90	150.30	Actual emissions (based on marginal costs)
95.60	77.10	65.70	58.20	53.10	349.70	Actual implemented (based on marginal costs)
25.66	7.16	(4.24)	(11.74)	(16.84)	0.00	Excess (deficit) of permits

Abatement desired	**350**
Permits issued	**150**
Market price of permits	**955**

SIMULATION MODEL OUTPUT 350 UNITS OF ABATEMENT DESIRED

COSTS												EXPLANATIONS
MINE A		MINE B		MINE C		MINE D		MINE E		TOTAL		
R	**24 691**	**R**	**30 816**	**R**	**36 941**	**R**	**43 066**	**R**	**49 191**	**R**	**184 705**	Cost of legislative approach
R	46 085	R	37 146	R	32 960	R	30 092	R	29 179	R	175 462	Cost of abatement instituted
	26		7		(4)		(12)		(17)		0	Number of permits sold (bought)
R	24 830	R	6 685	R	(3 820)	R	(11 460)	R	(16 235)	R	-	Cost of permits sold (bought)
R	**21 255**	**R**	**30 461**	**R**	**36 780**	**R**	**41 552**	**R**	**45 414**	**R**	**175 462**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R	**3 436**	**R**	**355**	**R**	**161**	**R**	**1 514**	**R**	**3 777**	**R**	**9 243**	Potential savings (cost of legislative approach less actual abatement costs)

30	30	30	30	30	150	*Permits issued to cover allowable emissions*
4	23	34	42	47	150	Actual emissions (based on simulation)
96	77	66	58	53	350	Actual implemented (based on simulation)
26	7	(4)	(12)	(17)	0	Excess (deficit) of permits

Abatement desired	**350**
Permits issued	**150**
Market price of permits	**955**

MARGINAL COST MODEL OUTPUT 375 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 28 236.82	**R 35 268.07**	**R 42 299.32**	**R 49 330.57**	**R 56 361.82**	**R 211 496.62**	Cost of legislative approach
R 50 000.00	R 44 768.90	R 38 294.05	R 34 594.90	R 32 687.28	R 200 345.12	Cost of abatement instituted
25.02	9.62	(3.68)	(12.48)	(18.48)	0.00	Number of permits sold (bought)
R 26 346.06	R 10 129.86	R (3 875.04)	R (13 141.44)	R (19 459.44)	R 0.00	Cost of permits sold (bought)
R 23 653.94	**R34 639.04**	**R 42 169.09**	**R 47 736.34**	**R 52 146.72**	**R 200 345.12**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 4 582.88	**R 629.04**	**R 130.24**	**R 1 594.24**	**R 4 215.10**	**R 11 151.50**	Potential savings (cost of legislative approach less actual abatement costs)
25.02	25.02	25.02	25.02	25.02	125.10	Permits issued to cover allowable emissions
0.00	15.40	28.70	37.50	43.50	125.10	Actual emissions (based on marginal costs)
100.00	84.60	71.30	62.50	56.50	374.90	Actual implemented (based on marginal costs)
25.02	9.62	(3.68)	(12.48)	(18.48)	0.00	Excess (deficit) of permits

Abatement desired	**375**
Permits issued	**125**
Market price of permits	**1 053**

SIMULATION MODEL OUTPUT 375 UNITS OF ABATEMENT DESIRED

COSTS												EXPLANATIONS
MINE A		MINE B		MINE C		MINE D		MINE E		TOTAL		
R	**28 237**	**R**	**35 268**	**R**	**42 299**	**R**	**49 331**	**R**	**56 362**	**R**	**211 497**	Cost of legislative approach
R	50 000	R	45 191	R	37 980	R	35 123	R	33 217	R	201 511	Cost of abatement instituted
	25		10		(4)		(12)		(18)		1	Number of permits sold (bought)
R	26 325	R	10 530	R	(4 212)	R	(12 636)	R	(18 954)	R	1 053	Cost of permits sold (bought)
R	**23 675**	**R**	**34 661**	**R**	**42 192**	**R**	**47 759**	**R**	**52 171**	**R**	**200 458**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R	**4 562**	**R**	**607**	**R**	**107**	**R**	**1 572**	**R**	**4 191**	**R**	**11 039**	Potential savings (cost of legislative approach less actual abatement costs)

25	25	25	25	25	125	Permits issued to cover allowable emissions
0	15	29	37	43	124	Actual emissions (based on simulation)
100	85	71	63	57	376	Actual implemented (based on simulation)
25	10	(4)	(12)	(18)	1	Excess (deficit) of permits

Abatement desired	**375**
Permits issued	**125**
Market price of permits	**1 053**

MARGINAL COST MODEL OUTPUT 400 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 32 063.89	**R40 063.89**	**R 48 063.89**	**R 56 063.89**	**R 64 063.89**	**R 240 319.45**	Cost of legislative approach
R 50 000.00	R54 298.74	R 45 826.43	R 40 578.88	R 37 343.97	R 228 048.01	Cost of abatement instituted
20.02	13.22	(1.88)	(12.08)	(19.28)	(0.00)	Number of permits sold (bought)
R 23 303.28	R15 388.08	R (2 188.32)	R (14 061.12)	R (22 441.92)	R (0.00)	Cost of permits sold (bought)
R 26 696.72	**R38 910.66**	**R 48 014.75**	**R 54 640.00**	**R 59 785.89**	**R 228 048.01**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 5 367.17	**R 1 153.23**	**R 49.14**	**R 1 423.89**	**R 4 278.00**	**R 12 271.44**	Potential savings (cost of legislative approach less actual abatement costs)
20.02	20.02	20.02	20.02	20.02	100.10	Permits issued to cover allowable emissions
0.00	6.80	21.90	32.10	39.30	100.10	Actual emissions (based on marginal costs)
100.00	93.20	78.10	67.90	60.70	399.90	Actual implemented (based on marginal costs)
20.02	13.22	(1.88)	(12.08)	(19.28)	(0.00)	Excess (deficit) of permits

Abatement desired	**400**
Permits issued	**100**
Market price of permits	**1 164**

SIMULATION MODEL OUTPUT 400 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 32 064	**R 40 064**	**R 48 064**	**R 56 064**	**R 64 064**	**R 240 320**	Cost of legislative approach
R 50 000	R 54 066	R 45 710	R 40 695	R 37 694	R 228 165	Cost of abatement instituted
20	13	(2)	(12)	(19)	0	Number of permits sold (bought)
R 23 260	R 15 119	R (2 326)	R (13 956)	R (22 097)	R -	Cost of permits sold (bought)
R 26 740	**R 38 947**	**R 48 036**	**R 54 651**	**R 59 791**	**R 228 165**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 5 324	**R 1 117**	**R 28**	**R 1 413**	**R 4 273**	**R 12 155**	Potential savings (cost of legislative approach less actual abatement costs)

20	20	20	20	20	100	Permits issued to cover allowable emissions
0	7	22	32	39	100	Actual emissions (based on simulation)
100	93	78	68	61	400	Actual implemented (based on simulation)
20	13	(2)	(12)	(19)	0	Excess (deficit) of permits

Abatement desired	**400**
Permits issued	**100**
Market price of permits	**1 163**

MARGINAL COST MODEL OUTPUT 425 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 36 159.82	**R45 191.07**	**R 54 222.32**	**R 63 253.57**	**R 72 284.82**	**R 271 111.58**	Cost of legislative approach
R 50 000.00	R62 500.00	R 54 987.41	R 47 911.58	R 43 207.50	R 258 606.49	Cost of abatement instituted
15.00	15.00	0.60	(11.10)	(19.50)	(0.00)	Number of permits sold (bought)
R 19 200.00	R19 200.00	R 768.00	R (14 208.00)	R (24 960.00)	R (0.00)	Cost of permits sold (bought)
R 30 800.00	**R43 300.00**	**R 54 219.41**	**R 62 119.58**	**R 68 167.50**	**R 258 606.49**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 5 359.82	**R 1 891.07**	**R 2.91**	**R 1 133.99**	**R 4 117.31**	**R 12 505.10**	Potential savings (cost of legislative approach less actual abatement costs)
15.00	15.00	15.00	15.00	15.00	75.00	Permits issued to cover allowable emissions
0.00	0.00	14.40	26.10	34.50	75.00	Actual emissions (based on marginal costs)
100.00	100.00	85.60	73.90	65.50	425.00	Actual implemented (based on marginal costs)
15.00	15.00	0.60	(11.10)	(19.50)	(0.00)	Excess (deficit) of permits

Abatement desired	**425**
Permits issued	**75**
Market price of permits	**1 280**

SIMULATION MODEL OUTPUT 425 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 36 160	R 45 191	R 54 223	R 63 254	R 72 285	R 271 113	Cost of legislative approach
R 50 000	R 62 500	R 55 501	R 48 040	R 43 850	R 259 891	Cost of abatement instituted
15	15	1	(11)	(19)	1	Number of permits sold (bought)
R 19 185	R 19 185	R 1 279	R (14 069)	R (24 301)	R 1 279	Cost of permits sold (bought)
R 30 815	R 43 315	R 54 222	R 62 109	R 68 151	R 258 612	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 5 345	R 1 876	R 1	R 1 145	R 4 134	R 12 501	Potential savings (cost of legislative approach less actual abatement costs)

15	15	15	15	15	75	Permits issued to cover allowable emissions
0	0	14	26	34	74	Actual emissions (based on simulation)
100	100	86	74	66	426	Actual implemented (based on simulation)
15	15	1	(11)	(19)	1	Excess (deficit) of permits

Abatement desired	425
Permits issued	75
Market price of permits	1 279

MARGINAL COST MODEL OUTPUT 450 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 40 517.18	**R 50 642.18**	**R 60 767.18**	**R 70 892.18**	**R 81 017.18**	**R 303 835.91**	Cost of legislative approach
R 50 000.00	R 62 500.00	R 68 407.56	R 59 028.48	R 52 422.49	R 292 358.53	Cost of abatement instituted
10.02	10.02	5.52	(7.88)	(17.68)	0.00	Number of permits sold (bought)
R 14 348.64	R 14 348.64	R 7 904.64	R (11 284.16)	R (25 317.76)	R -	Cost of permits sold (bought)
R 35 651.36	**R48 151.36**	**R 60 502.92**	**R 70 312.64**	**R 77 740.25**	**R 292 358.53**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 4 865.82	**R 2 490.82**	**R 264.26**	**R 579.54**	**R 3 276.94**	**R 11 477.39**	Potential savings (cost of legislative approach less actual abatement costs)
10.02	10.02	10.02	10.02	10.02	50.10	Permits issued to cover allowable emissions
0.00	0.00	4.50	17.90	27.70	50.10	Actual emissions (based on marginal costs)
100.00	100.00	95.50	82.10	72.30	449.90	Actual implemented (based on marginal costs)
10.02	10.02	5.52	(7.88)	(17.68)	0.00	Excess (deficit) of permits

Abatement desired	**450**
Permits issued	**50**
Market price of permits	**1 432**

SIMULATION MODEL OUTPUT 450 UNITS OF ABATEMENT DESIRED

COSTS												EXPLANATIONS
MINE A		MINE B		MINE C		MINE D		MINE E		TOTAL		
R	**40 517**	**R**	**50 642**	**R**	**60 767**	**R**	**70 892**	**R**	**81 017**	**R**	**303 835**	Cost of legislative approach
R	50 000	R	62 500	R	69 125	R	58 886	R	51 994	R	292 505	Cost of abatement instituted
	10		10		6		(8)		(18)		0	Number of permits sold (bought)
R	14 320	R	14 320	R	8 592	R	(11 456)	R	(25 776)	R	-	Cost of permits sold (bought)
R	**35 680**	**R**	**48 180**	**R**	**60 533**	**R**	**70 342**	**R**	**77 770**	**R**	**292 505**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R	**4 837**	**R**	**2 462**	**R**	**234**	**R**	**550**	**R**	**3 247**	**R**	**11 330**	Potential savings (cost of legislative approach less actual abatement costs)

10	10	10	10	10	50	Permits issued to cover allowable emissions
0	0	4	18	28	50	Actual emissions (based on simulation)
100	100	96	82	72	450	Actual implemented (based on simulation)
10	10	6	(8)	(18)	0	Excess (deficit) of permits

Abatement desired	**450**
Permits issued	**50**
Market price of permits	**1 432**

GLOSSARY

GLOSSARY

Average Costs: These are simply total costs per unit of output.

Command and Control: This is the term usually applied to legislative or regulatory approaches to resource management.

Consumer Surplus: The price which a person pays for a thing can never exceed, and seldom comes up to, that which he would be willing to pay rather than go without it so that the satisfaction which he gets from its purchase generally exceeds that which he gives up in paying for it. He thus derives from the purchase a surplus of satisfaction. This surplus can be measured and can be used as a proxy for social welfare.

Cost Benefit Analysis: This approach attempts primarily to compare the relative economic merits of alternative projects. All of the relative benefits and costs of a particular project are determined and, to the extent possible, these benefits and costs are quantified and valued in monetary terms. In turn, projects may be compared with each other on the basis of their relative economic merits.

Cost Effectiveness Analysis: Where project benefits cannot be quantified in monetary terms the focus of analysis changes to goal setting and goal realisation. The process is then referred to as Cost Effectiveness Analysis.

Demand Side Management: A management style which permits the consumer to dictate the supply of any given commodity. In other words, if demand for a commodity rises, then supply of the commodity will automatically follow. This is in contrast to supply side management, which holds that demand will automatically rise to meet any level of supply introduced to the market.

Direct controls: In general direct controls involve the regulation of the behaviour of polluters by the issue of permits, the specification of detailed standards for the construction and operation of industrial plant, and the setting of emission standards.

Economic Efficiency: The state of an economy in which no-one can be made better off without someone else being made worse off.

Economic Equity: The conflict that is traditionally held to arise between maximising average consumption and making that consumption equal across the population.

Externalities: are essentially activities whose full cost or benefit is not incorporated into an economic decision; hence they lead to sub-optimal social allocation. **Internalisation of externalities** thus involves fully incorporating these costs and benefits into the decision process. (See also the inset "Defining externalities" on page 1.)

Fiscal instruments: These are basically charges levied on a product, or the inputs used to make it, which raise the cost at which the product is sold, thus reducing the quantity of it which will be demanded and hence produced. Taxes of this nature are often imposed on products which are undesirable socially, such as tobacco and alcohol, and they can be extended to various forms of pollution or other sources of environmental degradation.

Green Tax: This tax is levied on pollution emissions and it is directly related to the quantity of emissions discharged. It is traditionally used as a behaviour modifying, rather than a revenue generating, instrument, since as the desired levels of pollution abatement are achieved, the tax falls away.

Income Elasticity of Demand: This is the percentage change in the quantity of a commodity demanded divided by the percentage change in the purchaser's income at that that level of demand.

Marginal Costs: (Long and short run)A marginal cost is the increase in the total costs of a firm caused by increasing its output by one extra unit.

Market economy: The essence of the market economy is that individual agents make economic decisions on the basis of costs and benefits associated with activity. They will always choose activities with the highest marginal benefit. This, assuming costs and benefits have been appraised correctly, will always lead to a socially efficient use of resources.

Pareto Optimum:

Pigovian Taxes: A Pigovian tax ideally takes the form of a levy per unit of pollution emitted into the natural environment, not as a tax per unit of the firm's outputs or inputs.

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.

Shadow Price:

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.

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THE POTENTIAL FOR THE USE OF ECONOMIC INSTRUMENTS TO PROTECT THE QUALITY OF WATER RESOURCES IN SOUTH AFRICA

FINAL REPORT

Submitted to

WATER RESEARCH COMMISSION

by

ECONOMIC PROJECT EVALUATION (PTY) LTD

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EXECUTIVE SUMMARY

BACKGROUND

It is generally accepted that the traditional legislative, or command-and-control, approach to managing water quality faces many difficulties. The need to prescribe standards and procedures individually suited to the circumstances of various polluters presents daunting administrative problems. The policing of direct controls is often difficult and costly, and can be inequitable, with widely differing consequences for those subjected to them. They may also have dubious incentive effects, failing to achieve additional pollution abatement even when this could be done at minimal additional cost.

These difficulties led environmental economists world-wide to develop an alternative approach, based on the use of economic incentives. Theory suggests that the greater flexibility that these offer could lead to significant cost savings, and a series of empirical studies has born this out. These results were documented in the Water Research Commission (WRC) project report entitled "The Application of Economic Principles to Water Management Decision-making in South Africa", which was published in 1994, and which concluded by saying, *inter alia*, that economics could make a significant potential contribution by providing an alternative to the traditional command-and-control macro management approach to deal with water quality problems.

Thus the economic approach to water quality control may offer significant benefits by way of enhanced effectiveness and reduced costs in South Africa, although to date there had been little attempt to examine the pros and cons of the approach empirically. It is the purpose of this report to make such an empirical examination, and to build upon it in a practical situation in South Africa.

DETAILED STATEMENT OF OBJECTIVES

The aims of this research project as set out in the contractual brief are as follows:

- To investigate the practicality of employing economic measures to protect water quality in South Africa;
- to determine the benefits by way of cost savings to either the public or private sectors, that could result from adopting an economic approach to water quality management as a complement to the more traditional approach embodied in current water quality management plans;

- to analyse in detail criteria for successful implementation of the economic approach; and
- to compile a detailed economic strategy for a selected catchment to serve as a demonstration project.

During the execution of the project the four aims set out above were interpreted to comprise the following tasks:

Task 1: Provide a literature survey (focusing on practice rather than theory) from which a toolbox of economic instruments for water pollution control relevant to South African catchments could be assembled.

Task 2: Postulate economic instruments suitable for controlling sulphate pollution in the upper Olifants catchment, and to test their feasibility by simulation. For the simulation to be meaningful, it would need to use a data set that was truly representative of the activities taking place in the catchment. (In the event the data collection task proved to be unmanageable, and recourse was made to a dummy data set, where some data was be simulated. It was felt that this would not detract from the value of the exercise, as it would provide an opportunity for the principles of the chosen economic instruments to be observed in action.)

Task 3: Exercise two models designed and implemented to demonstrate the efficacy of the chosen economic instruments in the relevant catchment.

Task 4: Combine the conclusions from the literature survey and the outcome of the simulation exercise.

ECONOMIC INSTRUMENTS AND WATER QUALITY MANAGEMENT

South Africa's total exploitable water resources, both surface and ground water, are estimated to be 38 000 million cubic metres per annum. The current demand for water is 18 500 million cubic metres per annum. Whilst this suggests a situation of surplus, it must be remembered that this water is poorly distributed relative to areas experiencing economic growth. Only a comparatively narrow region along the eastern and southern coastline is moderately well watered, while the greater part of the interior is semi-arid.

Water is used as an essential input into most production processes. Its excessive use and abuse can lead to increased pollution run off. Water pollution can be point source (easily monitored and measured) or non-point source (not so easily monitored or measured). Controlling point-source pollution from industry and agriculture has been widely discussed in the literature. In recent years market-based instruments have proved to be the most cost-effective and beneficial tools for the implementation of point-source pollution control.

Non-point sources of pollution cannot be monitored on a continuous and widespread basis with reasonable accuracy or at reasonable cost. This makes the application of economic-based policy instruments, which are used for point source pollution control and which rely upon relatively accurate and broadly accepted information, difficult.

None of the policies reported in the literature were found to use pure market mechanisms to control non-point pollution, although policies are often assessed to determine their economic efficiency.

Methods of controlling water demand in order to control pollution are simple and basic; for example, correct pricing and recycling water.

The earlier mentioned WRC project emphasises the importance of water pricing and has said in this regard that it is widely recognised that one of the best ways to improve water use efficiency, and thus control demand, is to increase the price of water.

Apart from the use of water pricing, one of the more innovative economic instruments that has the potential for controlling water pollution, from both point- and non-point sources, is water marketing.

The arguments for water marketing as a means to control pollution are similar to those for restrictive water allocations. The opportunity to market water merely acts as an incentive to ensure that those who have more water than they really require are encouraged to determine their real needs and then sell the remainder for a market related price, thereby increasing and diversifying their income.

In the literature, it is however, pointed out that unrestricted water markets can impose significant costs on other water users, such as rural communities and the environment. An analysis of the impact of water marketing on water availability and environmental quality found that water marketing can lead to a reduction in water use by agriculture.

Property rights are also important so far as water marketing is concerned: they define and limit the rights of members of society with respect to water resources and allow the right holders to form secure expectations regarding benefits stemming from their rights.

The literature on water rights is to a large extent concerned with the efficiency of allocations of water where there are legal and institutional constraints on the trading of water rights.

From a legal perspective, water in South Africa is regarded as being either public or private. Private individuals and organisations, however, cannot sell public water. The private sale of water rights is permitted in South Africa. Unfortunately, as agricultural land without water rights is only worth a fraction of land with rights, the purchasing of water rights invariably means purchasing the land to which such rights pertain. This latter option is referred to in the USA literature as water farming, and is often practised by municipalities and industries in South Africa which are situated in water scarce areas.

Water allocation, water pricing and water marketing are all demand management strategies that can add value to water, thereby ensuring its more considered utilisation. A crucial question is to what extent these strategies can be used to control water pollution in South Africa.

Water pricing increases can encourage better water use efficiencies by placing pressure on input production costs. In First-World South Africa it is the policy of the Department of Water Affairs and Forestry (DWA&F) that water supplies to urban consumers be priced such that the full cost of providing the service is recovered. Existing urban water supplies are therefore probably under-priced. Although water tariffs are used widely they are usually viewed as a means of cost recovery rather than as a way of managing demand.

In forecasting the way the demand for water varies with price the price elasticity of demand is an important parameter. There is, however, a dearth of information on water use and price elasticities of demand among agricultural and urban consumers in South Africa which severely hampers using this parameter in water pricing analysis.

The traditional view that water is price inelastic is based on a legacy of low prices being paid for water in most countries, particularly for agricultural use. Where water prices have been raised they have shown considerable price elasticity of demand.

Generally price increases will only be effective in conserving water and controlling pollution if the price exceeds the marginal value of the water to the user. Theoretically economic efficiency in the pricing process for a commodity will be achieved when the necessary assumptions underlying the formation of a competitive market are met.

Achieving efficient pricing which internalises economic externalities requires a certain amount of effort on the part of both government and the private sector. It involves some study of the costs of the specific economic activities and social goals at stake, which enables the trade-offs involved to be identified and valued in monetary terms.

Two important market-based instruments that can be used to manage water pollution are taxes and subsidies and it has long been recognised by economist that a subsidy per unit of pollution emission abatement provides the same incentive as a tax to entrepreneurs to internalise pollution externalities.

There are however, some subtle and important economic differences between these two policy instruments. In the first instance subsidies increase profits whilst taxes decrease them. Consequently the instruments provide opposite signals to firms regarding entry and exit to a particular market.

Pollution taxes or charges are command and control instruments that come in many forms and could be introduced into the water economy of South Africa in several different ways.

Before the likely impact of a pollution tax can be estimated, however, the objective and level of tax must first be determined.

Pollution taxes can have a number of objectives some of which may have nothing to do with pollution control. For example they may be used to raise revenue, prevent pollution from increasing any further and reduce pollution to a predetermined level.

So far as the level of the tax is concerned, experience from countries that have used pollution taxes for several years has shown that it is not so difficult to introduce a tax for revenue generating purposes, - one simply begins with a low level tax and periodically increases it until pollutant discharges start to fall.

Another economic instrument, which has a place in South African pollution control activities, is emission charges. So far as point source pollution is concerned, charges should be levied on the volume of water discharged and the pollutant concentration. Thus it requires good monitoring facilities at the point of discharge.

So far as non-point source pollution is concerned, it is possible to introduce and indirect emission charge for more insidious types of pollution by levying charges or taxes on the activities which give rise to this type of pollution. For example, a charge could be levied on fertiliser used by farmers.

In 1991, the DWA&F introduced a new approach to water pollution control. This stated that, in certain catchments, effluents should be discharged to the surface drainage system without the quality specifications of the receiving water (based on the needs of downstream users) being exceeded. These specifications are more commonly known as Receiving Water Quality Objectives (RWQOs) and are described in more detail in the Department of Water Affairs and Forestry publication, *Water quality management policies and strategies in the RSA*, (1991).

The RWQO approach was intended to overcome deficiencies in the existing water pollution control policy, i.e. returning effluents to the channel of origin, and the polluter pays principle.

Pollution control and environmental protection are costly: the selection of environmental quality standards to do this can illustrate some of the issues involved in using cost-benefit analysis for environmental policy making.

An environmental (or water) quality standard is either a legally established minimum level of cleanliness or a maximum level of pollution in some part of the environment. Cost-benefit analysis provides a basis for determining at what level an environmental quality standard should be set.

The research undertaken in this study also examined the use of economic instruments for water quality management in the Olifants River Catchment

The geographical extent of the upper-Olifants river, upstream and including Loskop dam incorporates several drainage basins, including the Olifants River catchment, the Klein-Olifants River catchment, the Wilge River catchment and the Klipspruit catchment, giving a mean annual run-off of some 469 millions of cubic metres per annum.

An investigation by Wates, Meiring and Barnard (WMB) confirms that the Olifants river catchment upstream of Witbank Dam is the single largest source of sulphate pollution. The sources of this pollution have been analysed by the Department of

Water Affairs and Forestry and Eskom, and the findings are that agriculture, power generation and coal-mining activities are responsible for the major sulphate pollution in the Witbank dam.

However, WMB conclude that non-point sources of pollution associated with coal mining activity constitute the single largest sulphate load contribution to Witbank Dam. The total impact of power station effluents was judged to be small. Furthermore, diffuse source pollution control on coal mining complexes was identified as the most attractive approach to salinity management.

Tradable permits are particularly powerful economic instruments for water quality management and they allow a polluter to discharge a certain amount of pollution over a given period of time into the water system. For permit trading to be considered, it is necessary to have a geographic collection of emission points whose total emissions are regulated. Such areas are referred to as bubbles. Permits can then be traded by players within bubbles to alter individual source emissions whilst keeping the overall emission from the bubble constant. The upper Olifants catchment is an ideal candidate for the establishment of a bubble.

As there is only one type of pollutant that is being targeted in this study, the trading of permits is probably a feasible option, despite the possibility of a "thin" market. The reason for this is that the various polluters are all known, as are their respective contributions to sulphate pollution. Thus information about trading partners, which is one of the requirements for a market to function effectively, can be obtained fairly quickly.

Effluent charges must be imposed on all monitored effluent discharges for which permits are not held. These must eventually be set at a level that discourages all but the most accidental and unforeseen discharges.

An economic instrument or mix of instruments that could best meet the needs of water quality management requirements in the Upper Olifants catchment should be able to offer:

- Effective management of non-point source pollution discharge;
- Ease and cost-effectiveness of administration;
- A measure of autonomy for each individual player in determining his pollution management strategy in order to minimise his costs;
- A revenue neutral system;

Whilst tradable permits as management instruments will fulfil most of the needs mentioned above, it is felt that the addition of a green tax to add urgency to the requirements of rationalising diffuse source pollution would be an advantage.

The theory of using green taxes and tradable permits was explored and their operation in conjunction with each other was demonstrated by using a pair of models. The object of the exercise was to illustrate that these two instruments are viable in a simulated situation, and that economic benefits do in fact accrue.

Crucial to an understanding of market clearing prices in the case of tradable permits is the concept of marginal costs. Ideally marginal cost is a measure of the value to society of the extra resources required to produce another unit of output in a particular time period. In terms of economic efficiency the general presumption is that if the price which a consumer is willing to pay for another unit exceeds the value of the extra resources required to make it, then the allocation of resources will be improved if that unit is produced and vice versa.

Exactly the same logic applies when we consider using tradable permits for water quality management. When the marginal costs of abatement for any particular player are greater than the prevailing costs of permits, he will choose to buy permits rather than institute the required abatement measures himself, and a demand for permits is thereby created.

If his marginal costs of abatement are less than permit costs, then he will rather choose to carry out abatement measures and sell his excess permits. A supply is thus created.

In this way permits will be traded until no player perceives an advantage in acquiring more permits, or indulging in additional abatement in order to be able to sell permits.

It will be demonstrated when the trading model is exercised that the actual costs of abatement will tend to fall in individual cases (or the outcome may be neutral) and any savings from instituting abatement measures obviously translate into additional profits. In addition, the control of the abatement initiatives remains in the hands of the individual players insofar as the decision as to whether to abate or go the permit route is theirs alone, and depends upon their individual production functions.

A green tax would operate on a sliding scale and work in the opposite sense from abatement costs. At zero abatement levels, the green tax is pitched at an extremely high level to obviate the possibility that players may choose simply to pay the tax rather than to implement abatement measures. In practice each player will play off the rise in his abatement costs against the fall in green tax until some equilibrium level is demonstrated.

Two models were developed to demonstrate the action of economic instruments. The first, a Marginal Cost Model (MC model) is effective in demonstrating graphically in a spreadsheet environment the mathematical and economic principles involved in the application of green taxes, and creating a market for emission permits. However, this model gives no intuitive feeling for what is happening during the trading process, and it is also somewhat restricted as to the number of players it can accommodate.

For this reason, the second model, a Simulation Model was developed in parallel. This model, which takes the trading process from the point where the first permit changes hands through to where market equilibrium is achieved, also serves to validate the results generated by the spread-sheet model. In addition, it is able to accept more wide-ranging and sophisticated data sets and it should be able to be used effectively should on-the-ground problem solving be required.

The following goals were desired from running the models:

- to demonstrate a market for tradable permits in action;
- to determine whether there are circumstances under which the market fails;
- to determine whether, or under what circumstances, costs of abatement measures are minimised;
- to explore the implications of the green tax, and to establish appropriate values for it; and
- to investigate to what extent the system can suffer perturbations and still remain stable.

It was found that the market price of permits calculated by both models over a range of abatement levels agreed consistently. The actual amount of abatement implemented by each mine also agreed for the two models when rounding and truncation errors were taken into account.

The final critical issue is to determine whether the trading of permits has resulted in any benefits to the players, vis-à-vis what would have occurred under a command and control approach. These benefits are calculated by taking the difference between the cost of the legislative approach (where abatement requirements are equally spread) and the outcome after trading has taken place. It was shown that a benefit does accrue, both to the bubble as a whole, and to the individual players.

Admittedly, the benefit to individual mines is sometimes minimal, and the outcome from their point of view could be regarded as neutral. However, a non-trivial potential saving to the complete bubble was consistently demonstrated.

Having outlined the original brief and the brief as modified by the steering committee, and having discussed the essential features of the research carried out, it is now appropriate to consider how effectively the research has met the modified brief.

It will be recalled that the first task was to undertake a literature survey of the subject. A significant amount of international literature was found on the use of economic instruments, and this was able to provide appropriate guidance in setting up a toolbox of instruments for water quality control relevant to the South African situation. No mention of any instruments currently in place in South Africa was found, although the Department of Environment Affairs and Tourism is currently conducting a research project on the use of economic instruments for environmental management. The international survey was thus used as the basis for our toolbox.

The next task of the study was to postulate economic instruments suitable for controlling sulphate pollution of the upper Olifants catchment. From the toolbox mentioned above, green taxes and tradable emission permits were identified as being the two most appropriate instruments.

The next phase of the project involved simulating the use of these instruments using actual data relevant to the upper Olifants catchment. In practice it proved impossible to compile a data set which could be regarded as truly representative of the area chosen. A reason for this was that much of the data required had to come from the mines operating in the catchment, and this data was commercially sensitive and not readily available to the researchers. However, at this stage of the project it had become clear to both the researchers and the steering committee that the operation of economic instruments was generally not understood. The aim of the modelling exercise therefore focused on facilitating an understanding of these two instruments, and making them accessible to a wider audience.

The outcome of the modelling exercise satisfactorily illustrated the underlying theory of tradable permits used as water quality control instruments, and also demonstrated that their use can bring economic benefits to the trading partners. This exercise was supported by a workshop, attended by representatives of various sectors of the economy, which was aimed at widening understanding of the operation of tradable permits. It was generally agreed that this workshop achieved its objectives.

RECOMMENDATIONS FOR FUTURE RESEARCH

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

- Taxes can have a detrimental effect on some industries if indiscriminately applied. Particular cases in point are older industries, and mining industries where prices are set internationally. An in-depth investigation into the effects of a green tax on these industries is recommended. However, a study such as this would have to get very close to potentially sensitive financial information in the relative industries, and the full co-operation of the industries concerned would be a pre-requisite. Without this co-operation such a study would not be of great value.

- A knowledge of both income and price elasticities of demand enables more effective forecasting to be done for water management purposes. Countries such as the USA (Howe and Linaweaver, 1967) and the OECD Countries (Bhatia, 1992) have carried out studies to determine these parameters from the '60s to the present. These studies have included the determination of elasticities of both industrial and household (municipal) water demand. A similar study in South Africa should be undertaken, and might commence by looking at municipal elasticities of demand.

- Reliable and extensive time-series data is an important pre-requisite for any forecasting exercise, and indeed for establishing elasticities of demand. A database extending for at least five years and containing information on water usage, water price, and pollution control activities and their costs in all sectors of the economy could be considered to be a minimum requirement. It is recommended that existing data of this nature should be gathered together in a database form which would make it useful to economists, and that a programme should be established to continue accumulation of similar data over the forthcoming five years.

- Whilst accepting that the research carried out in this report had as its aim to educate rather than to solve specific problems, it is nevertheless felt that a pilot study using tradable permits and green taxes and incorporating real data should be carried out before any recommendation to implement these instruments on a widespread basis could be made. Such a pilot study should investigate the effects of these instruments on a specific community or "bubble" and should report on the effects of levying taxes at different levels. This study would however also involve the use of sensitive financial data and its success would be heavily dependent upon the total co-operation of the players in the chosen bubble.

- Water pricing and tariff-setting, and demand-side management are issues, which ought to be receiving urgent attention in South Africa. Appropriate pricing of water would have direct effects on both its allocation and the management of its quality. As mentioned this report, this is a wide field of research, but it is clear from feedback from the Steering Committee that it is a subject that needs urgent investigation.

RECOMMENDATIONS FOR FURTHER TECHNOLOGY TRANSFER

It has been found that a more accessible précis of research such as that just described has proved to be popular. Cases in point are "Economics and Water Management" Prepared by the Institute of Natural Resources, which stemmed from the Water Research Commission Report No 415/1/94 "The Application of Economics to Water Management in South Africa", and "Managing SA's Environmental Resources: A Possible New Approach" which was written in response to the Department of Environment Affairs report "General guidelines for a policy on the use of fiscal instruments in environmental management".

This "popular" document was well received, and won an EPPIC Award in for the best South African Environmental publication in 1994. It is recommended that a similar brief document aimed at a wider audience be prepared, based on this research report.

It is also recommended that further workshops, similar to the one mentioned above, could materially assist in the technology transfer effort. These workshops could be of an educational nature, or of a problem solving nature. In the latter case, co-operation would be required from the relevant sectors of the economy in providing robust and appropriate data to be run through the models.

PREFACE

Prior to this study there has been little attention paid to analysing water management issues from an economic perspective. Also it is known that a considerable body of work linking water management and economics has been undertaken internationally from about 1980. It seems logical, therefore, to consider whether lessons can be learned from this work that are appropriate to South Africa.

Three basic aims guided the research. The first was the quest for useful and generally applicable international experience and methodologies. The second aim was to identify appropriate instruments for use in the South African context. The final aim was to test the applicability of the chosen .instruments in a South African environment by means of mathematical modelling.

In the course of the project, a great many problems associated with the availability of robust data were encountered, and these were instrumental in shaping the course of this study and the final product.

After extensive research, it was concluded that the most promising contribution to be made by economic instruments to water quality management in South African lay in an alternative to the traditional command-and-control macro management approach to deal with water quality problems by means of market based economic instruments. As such the content and structure of this report and its appendices reflect this conclusion.

This document is not aimed specifically at economists. The methodologies it contains will likely prove somewhat conventional to practitioners of this discipline. It is primarily intended for water managers and decision-makers, particularly those who have had limited exposure to economic concepts. Moreover, this report is not a comprehensive manual on the economics of water quality management or water project planning. Although these may be worthwhile products for future consideration, the purpose of this project is to introduce, in broad terms, the potential application of market based economic instruments to water quality management in South Africa.

ACKNOWLEDGEMENTS

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  - ◊ Alan Veck.......................... Economic Project Evaluation (Pty) Ltd
  - ◊ Chris Williams.................. Economic Project Evaluation (Pty) Ltd
  - ◊ Arthur Kamp...................... Eskom
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PART ONE

INTRODUCTION

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1. INTRODUCTION

1.1 BACKGROUND TO STUDY

At the time that this research project was mooted, Economic Project Evaluation (Pty) Ltd (EPE) had just concluded a project for the Water Research Commission (WRC) entitled "The Application of Economics to Water Management in South Africa" (henceforth referred to as WRC 1993). The brief for WRC1 provided the researchers with the opportunity to develop statements of broad economic principle, which after further investigation and debate, could lead to their adoption in finding solutions to water management problems. WRC1 concluded that economics' most significant potential contribution lay in providing:

1. An alternative (to the traditional supply-fix) macro management approach to deal with water quantity (allocation) problems;
2. An alternative (to the traditional command-and-control) macro management approach to deal with water quality (pollution) problems; and
3. Methods to assist in the piecemeal implementation of macro-economic approaches, whether these were the ones advocated, or the more traditional ones.

The object of the present project is to augment contribution number 2 mentioned above. In this regard four aims are postulated, these being:

1. To investigate the practicality of employing economic measures to protect water quality in South Africa;

2. To compile a detailed economic strategy for a selected catchment to serve as a demonstration project;

3. To determine the benefits, by way of cost-savings to either the public or private sectors, that could result from adopting an economic approach to water quality management as a complement to the more traditional approach embodied in current water quality management plans; and

4. To analyse in detail criteria for successfully implementing the economic approach.

1.2 THE DEVELOPING BRIEF

Under the guidance of the project steering committee the four aims were interpreted to comprise the following tasks:

Task 1: Provide a literature survey (focusing on practice rather than theory) from which a toolbox of economic instruments for water pollution control relevant to South African catchments would be assembled.

Task 2: Postulate economic instruments suitable for controlling sulphate pollution in the upper Olifants catchment, and to test their feasibility by simulation. For the simulation to be meaningful, it would need to use a data set that was truly representative of the activities taking place in the catchment.

Task 3: Exercise two models designed and implemented to demonstrate the efficacy of the chosen economic instruments in the relevant catchment. (In the event the data collection task proved to be unmanageable, and recourse was made to a dummy data set, where some data was simulated. It was felt that this would not detract from the value of the exercise, as it would provide an opportunity for the principles of the chosen economic instruments to be observed in action.)

Aim 4: Combine the conclusions from the literature survey and the outcome of the simulation exercise.

It is clear that Aims 2 and 3 overlap to the extent that it is not practical to regard them as separate issues. This report therefore combines them, and it is structured to focus upon three principal aims only.

1.3 SCHEMA OF THE REPORT

The report is divided into four parts. The first part comprises this introduction.

Part two discusses water quantity/quality relationships, point and non-point source pollution, water quality standards and the selection of the most appropriate economic instruments for dealing with these issues in the South African context.

Part three looks at the selection of apprOpriate economic instruments for South Africa.

Part four is a practical application of the use of economic instruments in the Olifants River catchment.

Part five discusses and analyses the issues raised, draws conclusions and points to future possible areas of research.

PART TWO

WATER, POLLUTION AND ECONOMIC INSTRUMENTS

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2. WATER QUANTITY - WATER QUALITY RELATIONSHIPS

2.1 INTRODUCTION

This chapter offers a general introduction to water quality and quantity management. The main topics of importance are identified, and these are developed further later in this report.

2.2 WATER DEMAND

South Africa's total exploitable water resources, both surface and ground water, are estimated to be 38 000 million cubic metres per annum (m^3/a). The current demand for water is 18 500 million m^3/a, of which 9 300 million m^3/a, or 50 per cent, comes from irrigators. Demands from other sectors include 3700 million m^3/a (20%) from urban industrial users, 470 million m^3/a (2%) from mining, 440 million m^3/a (2%) from Eskom power-stations, 1400 million m^3/a (8%) from forestry, and 3000 million m^3/a (16%) from nature conservation. Whilst these figures suggest a situation of surplus it must be remembered that this water is poorly distributed relative to areas experiencing economic growth. Only a comparatively narrow region along the eastern and southern coastline is moderately well watered, while the greater part of the interior is arid or semi-arid. Furthermore, Gauteng, the nation's economic 'power house' developed around mineral reserves and not water sources as is the case for most other large metropolitan centres in the World. Additionally, the supply of water from many catchments in South Africa is becoming insufficient to meet demand.

Water is used as an essential input into most production processes. Its excessive use and abuse can lead to increased pollution run off. Methods of controlling water demand in order to control pollution are simple and basic, for example:

1. The imposition of restrictions on water extraction from a river system, through correct pricing and/or stricter withdrawal permits, has the potential to induce users to utilise water more conservatively, thus increasing the availability of dilution water in the system.

2. Such restrictions may induce a given user to consider recycling water. Although the overall consumptive use might not necessarily be reduced by other measures, extractions, return flows and pollutant loads can be curtailed. Reducing wastewater volumes can also facilitate improved pre-discharge storage and treatment.

Economic instruments that may lead to the control of water demand will be identified in sections 2.3 and 2.4 below.

The following criteria have to be considered when evaluating the cost-effectiveness of using water demand control mechanisms:

- a given user's specific *water demand function*,
- the price elasticity of demand for water, and
- the nature of the use of water in different sectors of the economy, e.g., domestic and industrial.

Discussing aggregate demand for water across a region is not really practical, since each user displays very different water demand characteristics, and water utilisation systems are highly disaggregate.

Price elasticity of demand for any commodity (including water) is, however, an important economic indicator that can be used for the planning of future water demand. It is appropriate therefore to briefly discuss this subject. Figure 2.1 depicts the elasticity of water demand in relation to its price.

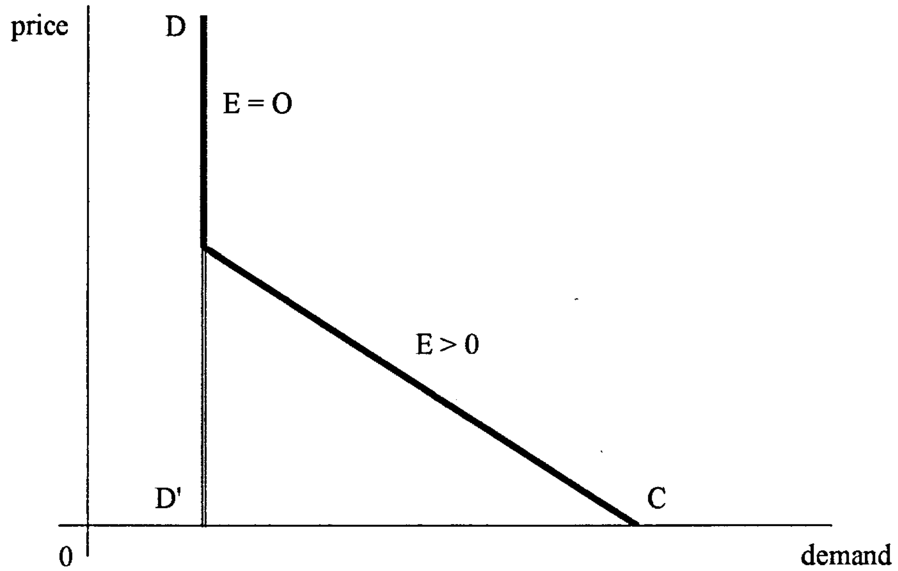

FIGURE 2.1: ELASTICITY OF DEMAND

The elasticity of demand for a commodity depends mainly on the range of available substitutes. The better the substitutes available, the more elastic will be the demand for the commodity. Water is one of the commodities that have few substitutes and demand for water is therefore perfectly inelastic up to a certain amount. Consider Figure 2.1: up to a certain point D' on the demand axis, water demand is perfectly inelastic: E = 0, which means that no matter how high the price, the user is willing to pay for it, as water has no substitutes and is a necessary input into production and life support processes. Beyond D', however, the demand for water becomes elastic, E>0, which means that the demand for water becomes a function of its price, i.e. Q = fD (P). Beyond D' consumers begin to respond to price changes for water: i.e. the higher the price per unit of water beyond D', the less consumers will be demanding the commodity. To sum up, it is suffice to recognise that water demand is determined by its price elasticity of demand and its marginal utility[1].

[1] **Marginal Utility** is defined as the extent to which a consumer's satisfaction would be increased or decreased if he had one more or one less unit of a commodity.

2.3 THE ROLE OF WATER PRICING IN WATER QUALITY MANAGEMENT

The importance of water pricing has been emphasised previously in Water Research Commission report "The application of Economic Principles to water management decision-making in Southern Africa"[2]:

> "The pricing of water is possibly one of the most under-used, but potentially most effective, demand management tools available to the water manager. Apart from providing the necessary revenue from which water schemes can be financed, it has the potential to (1) ensure the maximum beneficial use of water, (2) accurately control demand such that the timing of new schemes can be postponed until they are absolutely necessary, (3) curb demand during periods of shortages, and (4) raise revenue (possibly for the subsidisation of water services to the very poor). In South Africa pricing is used primarily to recover scheme costs and, in some instances, to penalise excessive use during droughts. In view of the economic and physical limitations on further water resource development in South Africa, there would seem to be merit in considering the application of demand management strategies such as water pricing more seriously: it could have advantages in terms of reconciling supply and demand and the production of revenue.
>
> More specifically, given the State's urgent need for new revenue sources, pricing could be considered in water-scarce regions where continued supply augmentation is extremely expensive. It could be very useful to evaluate the revenue yield, and demand reduction, that could result over the long term from, say, introducing water pricing at modest rates (which would prevent a disruption of the economy over the short term) but with the clearly stated intention of escalating those rates annually. In this respect it should be noted that by using the accepted equivalent basket of goods and services approach as a basis for comparison, South Africa's municipal water tariffs are far cheaper than those of many well-watered European nations are. In practice, though, pricing water such that the price reflects its correct economic value is rare."

2 Hereinafter referred to as WRC 1993.

Numerous studies on aspects of water quality have shown that the issue of the unit price of water is of considerable importance. If the price for water does not reflect its scarcity, water use becomes indiscriminate, wasteful and leads to increased wastewater discharge. The optimal pricing of water has been dealt with in detail in WRC 1993. The following section discusses how water has been priced through the market place in other countries and how this pricing has been used as a means to conserve water and to improve water quality. Water pricing issues will be discussed further in Chapter 4 of this report.

2.4 WATER MARKETING

One of the more innovative economic instruments that has the potential for controlling water pollution, from both point and non-point sources, is water marketing.

In the Western part of the United States, where water marketing has been practised for some years to price and allocate water more efficiently, a number of water resources have been involved in transactions. These include groundwater, native and imported surface water, artificially recharged and recovered water and effluent and conserved water.

The potential use of such water markets to control water pollution will be considered briefly. At present the 'beneficial use doctrine' in American water law, for instance, contains the 'use it or lose it'[3] component which can promote extravagant use of water and discourage conservation, since water saved by conservation is typically forfeited. What is needed therefore, is to allow users to realise the value of water saved, by permitting them to sell excess and conserved water. This would stimulate water conservation, encourage higher valued uses and raise revenue for improved utilisation methods.

Unrestricted water markets, however, may pose a problem of third-party costs. As Colby (1988)[4] points out, unrestricted water markets can impose significant costs on other water users, such as rural communities and the environment.

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3 Tietenberg, Tom, Environmental and Natural Resource Economics, Harper Collins Publishers Inc., New York 1992 (3), p 236.

4 Colby, Bonnie G., Economic Impacts of Water Law - State Law and Water Market Development in the Southwest, in: Natural Resources Journal, Vol. 28, No. 4, fall 1988, October 1988, pp 721-749.

Finally, Dinar and Letey (1991)[5] analysed the impact of water marketing on water availability and environmental quality. They found that water marketing could lead to a reduction in water use by agriculture. Through water marketing farmers are encouraged to use only water necessary to satisfy crop requirements and to make part of their quota (allotment) available for sale in the market. Thus excess irrigation could be discouraged, the drainage volume could be reduced and environmental pollution and social costs associated with drainage could be diminished. If the farmer's profit increases, he is more likely to invest in improved irrigation systems, for instance lined canals, thereby contributing to water conservation.

Furthermore, a positive effect on water quality can be expected: reduced water input would lead to reduced drainage water and reduced dissolution and mobilisation of problematic salts from the drainage pathways. Also water marketing can serve as a further source of income for farmers.

The net outcome, under perfect conditions (i.e. no political, legal and implementation barriers), would be that the farmer is faced with increased net returns, water consumption would be reduced and water quality improved.

Water marketing is discussed further in Chapter 4.

2.4.1 Property rights

One of the most basic functions of water law regarding markets is the definition of property rights. They define and limit the rights of members of society with respect to water resources and allow the right holders to form secure expectations regarding benefits stemming from their rights. Property rights thus provide an essential base for market exchanges. In the western parts of the United States five basic types of water rights exist:

- riparian rights
- appropriative rights
- permits
- allotments
- mutual stock.

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5 Dinar, Ariel, Letey, J., Agricultural Water Marketing, Allocative Efficiency, and Drainage Reduction, in: Journal of Environmental Economics and Management, Vol. 20, Issue 3, May 1991, pp 210-233.

The literature on water rights is to a large extent concerned with the efficiency of allocations of water where there are legal and institutional constraints on the trading of water rights. Economists argue that it is exactly these constraints that prevent water from moving to its socially highest valued uses and that under these conditions the allocation of water is economically inefficient. It is further argued that if water were sold separately from land in a perfectly competitive market, then the allocation of water would be efficient.

2.4.1.1 Experiences in the United States

Miltz et al mention that:

> "A further incentive to the relinquishing of generous water rights, would be to permit them to be traded. This approach is now used extensively in the USA where irrigation water rights have been purchased at very high prices by municipal authorities on behalf of urban consumers. (The system is also to great effect in Chile where it is supported extensively by legislative and self-funding institutional structures.) The outcome of this system has been a marked increase in water use efficiency as well as an overall shift towards the allocation of scarce water to more economically beneficial uses."

Shupe et al. (1989)[6] look at mechanisms through which water rights are reallocated in the Western part of the US and consider in particular voluntary transfers:

Leases for Fixed Term

The city of Albuquerque issues leases of surplus water, for instance, to vineyard owners in Southern New Mexico (1100 acre foot per year - af/y) at a charge of $40 af/y which is roughly equal to the payment of the Bureau of Reclamation which provides the city with water surplus.

Dry-Year-Option

Negotiations of dry year options between some cities and farmers in the West led to the city of Utah paying $25 000 for an option to lease senior irrigation water rights.

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6 Shupe, Steven J., Weatherford, Gary D., Checchio, Elizabeth, Western Water Rights: The Era of Reallocation, in: Natural Resources Journal, Vol. 29, spring 1989, No. 2, pp. 413-434.

In return the city agreed to supply the farmers, the owners of the water rights, with 300 tons of hay and $1000 in any season that the city exercised this option. For the first 25 years that the scheme was in operation, the city used the option three times. The net results were that the farmers received a cash payment, hay without harvesting and some pasture production from non-irrigated farming. Other examples of such a scheme exist in California: with different payment schemes but based on the same idea

Subordination Agreements

Subordination agreements are based on the idea that the major attribute of an appropriated water right is its relative priority, which can be marketed separately from the right itself, which is similar to the dry-year-option.

A senior priority right, as opposed to a junior right, which is not deemed reliable enough, may be compromised for something other than money. The Navajo Indian Reservation, for instance, has senior priority claim on the San Juan River. The Reservation agreed in 1968 to share shortages during droughts in order to obtain federal authorisation for a Navajo Indian Irrigation Project. This allowed the construction of the San Juan-Chama Project delivering trans-basin water into the Rio Grande drainage basin to serve Central New Mexico.

Conservation Offsets

Conservation offsets are used as a reallocation strategy for junior municipal and industrial users who are in need of a more reliable supply by making water conservation investments in a senior use. By financing the modernisation of old irrigation systems by junior users, surplus water is made available to junior users while senior users irrigate the same amount of land with less water.

Exchanges

The exchange of water supplies (temporarily, seasonally or permanently) can prove advantageous if water rights of respective parties are, for some reason, not appropriate to their needs - for instance the need for water of different quality.

Blocks of Water District Shares

The purchase of shares of agricultural water district stock, independent of land, has been in effect in north-eastern Colorado since the 1960s. In Colorado-Big-Thompson (CBT) an active market for shares has been in operation. The scheme started in 1960 at an initial share price of $11/af, which rose to $3000/af in the late 1970s. After the prices had plummeted in 1981, the market was still existing in 1986, at prices of *circa* $1000/af.

Individual Sales

Costs of individual sales can be very high as the following example shows: water prices in the Park City area in the mountains above Salt Lake lie at and above $4000/af. In the mountain resort area in Colorado, the price per acre foot lies in some instances at almost $10 000.

2.5 POINT-SOURCE POLLUTION

Water that is clean and safe to use is essential to man's existence. So why, as man becomes wiser and wealthier, does he continue to degrade this basic element? There is a basic reason for this. The emissions which are discharged are seen as having no value, and the environment into which they are discharged is seen as being a free good, thus the economic impact of such discharges is perceived to be zero. These beliefs are obviously erroneous, yet they are reflected in the pricing mechanisms that form part of the current policy and legislation governing the use and protection of our natural resources.

If water is cheap, the tendency will be for users to discard used water and buy more clean water. Also, if there are no incentives to minimise the degree to which the discarded water is polluted then it is inevitable that our rivers will gradually become more degraded as water use increases.

One obvious way to place a tangible value on water resources is to levy a charge on activities that degrade them. In other words, charge for the privilege of using surface water for waste disposal.

Controlling point-source pollution from industry and agriculture has been widely discussed in the literature. The command-and-control and market-based instruments to achieve this have been used world-wide. In recent years market-based instruments have proved to be the most cost-effective and beneficial tools for the implementation of point-source pollution control. However, the effectiveness of economic instruments is, to some extent, dependent on legislation and standard setting. Appendix B discusses appropriate economic instruments and the legislation used in other countries that has not only formed the basis for pollution control, but in some instances has given rise to pollution control through the market.

2.6 NONPOINT-SOURCE POLLUTION

The control of nonpoint source pollution[7] is an important aspect in water quality management. Policy-makers have been faced with severe difficulties in determining the most appropriate and economically efficient policies for water pollution abatement from nonpoint sources.

Nonpoint sources of pollution cannot be monitored on a continuous and widespread basis with reasonable accuracy or at reasonable cost. This makes the application of economic-based policy instruments, which are used for point source pollution control and which rely upon relatively accurate and broadly accepted information, difficult. Agricultural nonpoint source pollution control has been the main focus of research in the literature and in the design of nonpoint water pollution control policies world-wide, since agriculture is considered to be the largest contributor to nonpoint source pollution. Consequently, policies will be considered here which have been used to abate water pollution from agricultural runoffs.

None of the policies reported in the literature were found to use pure market mechanisms to control nonpoint pollution, although policies are often assessed to determine their economic efficiency.

Appendix C discusses economic approaches for controlling non-point source pollution.

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7 Point sources are predominantly industrial and municipal pipe discharges. Nonpoint (or diffuse) sources are discharges carried by storm runoff.

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FIGURES

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3. ECONOMIC JUSTIFICATION OF WATER QUALITY STANDARDS

3.1 EXISTING SOUTH AFRICAN POLICIES, LEGISLATION AND REGULATIONS: RECEIVING WATER QUALITY OBJECTIVES

Effluent discharges are controlled by the DWAF in terms of the Water Act. Until recently, the DWAF applied the Uniform Effluent Standards (UES) approach to water pollution control by enforcing compliance with the General and Special Standard for Effluent Discharge. Two policy principles dominated this approach. The first was that, due to the arid nature of South Africa's climate, wastewater must be returned to the channel from which the water supply originated. The second principle was that the polluter must pay for the abatement of his own pollution. These principles are described in more detail in DWA (1986)[1].

In 1991, the DWAF introduced a new approach to water pollution control, which embodied a third fundamental principle. This stated that, in certain catchments, effluents should be discharged to the surface drainage system without the quality specifications of the receiving water (based on the needs of downstream users) being exceeded. These specifications are more commonly known as Receiving Water Quality Objectives (RWQOs) and are described in more detail in DWA (1991)[2].

The RWQO approach was intended to overcome deficiencies in the existing water pollution control policy. These deficiencies can be considered in terms of the two original policy principles, i.e. returning effluents to the channel of origin, and the polluter pays.

Returning effluents to the channel of origin

The increased utilisation of surface water resources meant that there was insufficient dilution water present in many of South Africa's rivers to ameliorate the water quality impact of the returned effluent, even if the effluent met the required quality standard. Thus, while striving to conserve as much water as possible for reuse, this policy was actually promoting the quality deterioration of the country's water resources.

The 'polluter pays' principle

The problem with the 'polluter pays' principle is that it becomes difficult to justify forcing the effluent producer to treat his waste water to a specified standard if there are no downstream users disadvantaged by the discharge of the effluent, or if the quality of the receiving water is similar or worse than the effluent. Such justification becomes even more difficult to establish when it threatens the viability and employment capabilities of certain industries.

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1 Department of Water Affairs, Management of the water resources of the Republic of South Africa, Department of Water Affairs and Forestry, Pretoria 1986.

2 Department of Water Affairs and Forestry, Water quality management policies and strategies in the RSA, Department of Water Affairs and Forestry, Pretoria 1991.

The RWQO approach allows DWAF officials to modify these two principles on a catchment basis so that the quality of the receiving water does not deteriorate beyond the water quality requirements of downstream users, and so that the costs incurred by the effluent producer can be justified in terms of meeting such requirements. This approach also permits officials to deviate from the General Standard for Effluent Discharge, which has been criticised for its limited scope in accommodating water supply and demand variations from one catchment to another.

3.1.1 Application of the RWQO approach[3]

Whilst the RWQO approach is a major policy advancement, its operationalisation is proving to be more difficult than was originally anticipated. Its application currently focuses on the determination of the water quality requirements for each and every downstream user, followed by the selection of the most suitably stringent requirements to calculate, by means of a waste load allocation (WLA), the quality and volume of the effluent that can be discharged upstream.

The problem with this approach is that most downstream users do not know what their water quality requirements are, and when urged to adopt a specification they tend to play safe and opt for overly stringent values. As the long term low level impacts of marginally unsuitable water quality are largely unknown for many uses, it is difficult to challenge such values. This problem is compounded by the fact that there is no incentive for downstream water users to be more precise about their water quality requirements. Nor is there any incentive for them to quantify the impact of a less than ideal water quality, or to even consider some form of compensation from upstream polluters for agreeing to an inferior RWQO.

Another uncertainty surrounding the RWQO approach relates to the allocation of waste discharge permits in a multi-polluter system. As yet no official policy has been tabled to guide the allocation of waste permits in systems where the present or likely future amount of effluent exceeds the total WLA. Some of the important questions that have to be answered in this regard are: Should allocations be made on the basis of priority in time, or the economic importance of an effluent producing industry, or should they perhaps be auctioned off to the highest bidder? Can WLA permits be traded amongst effluent producers, and if not, what alternative incentive

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3 Refer to: "Use of Economic Instruments to Control the Discharge of Effluent from Sappi's Ngodwana Paper Mill to the Elands River: A Case Study", in preparation for Department of Environment Affairs by Economic Project Evaluation (Pty) Ltd., 1993.

mechanisms need to be introduced to encourage the consideration and possible adoption of new waste management technology by industry? Will effluent producers be eligible for compensation if downstream RWQOs become more stringent and existing allocations have to be adjusted? Finally, should the agency administering the permit system retain some permits for future economic development, assuming that it may not be possible to purchase these from existing permit holders?

In addition to the issues raised above, a major problem with the RWQO approach is the determination of the minimum flow regime on which to base the WLAs. RWQOs and WLAs are water quality management tools that were developed in the temperate climates of Europe and North America on large rivers with substantial dry-weather flows. South Africa has a predominantly semi-arid climate and the dry-weather flow for many rivers is often zero. The logical way to overcome this problem would be to adopt a probabilistic approach to selecting a minimum flow, whereby the risk of a flow occurring, which is less than the minimum, is acceptable to downstream users who will have to bear the consequences of transient exceedences of the RWQO. By using stochastic hydrology to select minimum flow regimes for WLAs, it would be possible to estimate the frequency, duration and severity of RWQO exceedences over a given period of time. However, for such risks to remain constant, upstream abstractions from the river must also remain constant. For this to occur the relevant authorities would need to implement diligent abstraction control, thereby placing additional pressure on overstretched resources. This aspect also emphasises the inseparability of pollution control and abstraction control functions for the maintenance of water quality in riverine systems.

Overseas experience indicates that these problems are not insurmountable. However, while they remain unresolved in South Africa, the RWQO approach risks becoming an over-simplified 'top-down' regulatory mechanism. Actions based on the approach are likely to possess debatable justification and may therefore command variable support from effluent producers and water users alike.

Clearly, the success of the RWQO approach to pollution control is dependent upon the introduction of appropriate incentives which encourage the joint development of more optimal, self-regulatory solutions by both effluent producers and water users. As such solutions will invariably be the product of some form of economic optimisation, it follows that the incentives to participate in such an activity should be of an economic nature and not based on command and control.

3.1.2 Economic aspects of the RWQO approach

In certain circumstances, RWQOs may be more successfully implemented using economic approaches applied in a deregulated environment, as opposed to a technically based implementation using CAC approaches. For example, if one were to view an insufficient amount of effluent discharge permits (relative to the quantity of effluent to be discharged) as a scarce resource, then the efficient allocation of that resource can only be achieved by the market. To allocate permits in any other way will introduce bias, inefficiency and controversy into the process. It should be noted however, that the comments made in Chapter 4 about satisfactory operation of markets would also be relevant here.

Figure 5.1 demonstrates the economic relationship between an upstream effluent producer and a downstream water user. The benefits curve for the water user is characterised by significant increases associated with more stringent RWQOs at the lower levels. These benefits gradually taper off as the RWQO resulting in maximised benefits is reached. The costs curve for the effluent producer is characterised by steeply rising costs, as the RWQO becomes more stringent. Q_2 represents the RWQO at which the net social welfare is maximised. Although neither the polluter nor the receiver may appear to have optimised his situation, the *net benefit to the economy* occurs when the difference between the benefits and costs is greatest, and positive. This occurs where the vertical distance between the benefit curve and the cost curve is greatest[4].

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4 It can be shown by considering the first derivatives of the benefit and cost curves that this is also where the marginal benefits (or willingness-to-pay) equal the marginal costs.

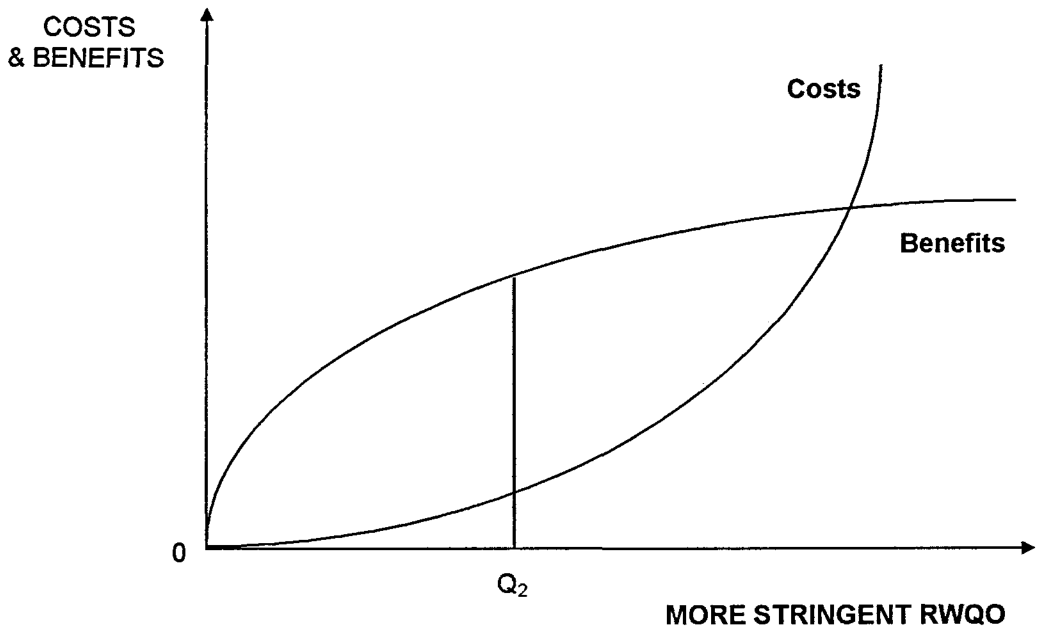

FIGURE 3.1: ECONOMIC IMPLICATIONS OF THE RWQO APPROACH

Determining the benefit curve of the receiver will place a financial burden on the taxpayer for the funding of the relevant investigations. An alternative approach would be to allow the effluent producer and the downstream water user to determine the optimal position of Q by means of negotiations conducted in a free market environment. Such an arrangement would automatically lead to a measure of independent monitoring/policing by the producer and the receiver, thereby reducing the pollution control cost burden on the State.

Figure 3.1 presents a simplified situation that would be complicated in the real world by multiple user and multiple polluter circumstances. However, if appropriate local institutional arrangements existed in which polluters and water users could reach agreements, then the same economic principles would apply.

3.2 THE USE OF COST-BENEFIT ANALYSIS IN STANDARD SETTING

Pollution control and environmental protection are costly. To maximise social welfare in this regard policy decisions should be underpinned by economic theory. This is true in two senses:

1. Resources devoted to pollution control and environmental protection have to be compared with depriving these resources from other uses. Pollution control activities should only be undertaken, if the results are worth more than the resources applied. This is essentially the purpose of cost-benefit analysis (CBA).

2. No matter what pollution targets are chosen, the means selected to achieve these targets should be chosen on the basis of cost-minimisation. Many environmental protection and pollution control policies adopted throughout the world are wasteful, since they use more resources than are necessary. One of the major contributions of economic analysis to environmental policy is that it reveals when and how these policies can be made more cost-effective.

CBA is a set of analytical tools designed to measure the costs and benefits, hence the net contribution that any public policy makes to the economic well being of society. The analysis seeks to determine whether the aggregate of the gains to those made better off is greater than the aggregate of losses to those made worse off. The gains and losses are to be measured in terms of each individual's 'willingness to pay' to receive the gain or to prevent the policy-imposed losses. The selection of environmental quality standards can illustrate some of the issues involved in using cost-benefit analysis for environmental policy making.

An environmental (or water) quality standard is either a legally established minimum level of cleanliness or a maximum level of pollution in some part of the environment[5]. Cost-benefit analysis provides a basis for determining at what level an environmental quality standard should be set. In general, economic principles require that each good be provided at the level for which the marginal willingness to pay equals the good's marginal cost, i.e. the cost of providing one more unit of the good.

An environmental standard set by this rule will almost never call for complete elimination of pollution. As the worst of the pollution is cleaned up, the willingness to pay for additional improvement will decrease, while the extra cost of further cleanups will increase. Seldom will it be worth it in terms of willingness to pay or in terms of environmental benefits.

3.2.1 Experience

United States

The US Environmental Protection Agency is required by law to establish maximum allowable levels (ambient air quality standards) for major air pollutants such as sulphur dioxide and ozone. A standard, once established, can be the basis for

5 Refer to the discussion on the optimal level of pollution in chapter 3.2.1.1 of this document.

enforcement actions against a polluter whose discharges cause the standard to be violated.

In a 1987 report[6] EPA's experiences with cost-benefit analysis are recounted. CBA has influenced the development of regulations at EPA in a number of ways:

- to guide the regulation's development,
- to add new alternatives,
- to eliminate non-cost-effective alternatives,
- to adjust alternatives to account for differences between industries and segments, and
- to support decisions.

In some instances the use of CBA has resulted in more efficient regulations, since analyses had shown that stricter alternatives could lead to greater reduction in pollution without a proportional cost increase. Table 3.1 gives some indication of the potential increases in total net benefits of regulations:

Applying cost-benefit analysis to lead in fuel, for instance, led to introducing regulations that were more stringent than initially proposed. On the other hand CBA also showed that the costs of stricter regulations would be higher than the expected benefits. The relaxation of standards for used oil and premanufacture review, for instance, led to reduced regulatory burdens without significantly reducing environmental improvements.

6 United States Environmental Protection Agency, EPA's Use of Benefit-Cost Analysis, US EPA, Washington DC, August 1987.

Environmental Impact Assessment	**Change in regulation**	**Potential increase in total net benefits of regulations**
Lead in fuels	more stringent standard, greater health and welfare benefits	\$6.7 billion
Used oil	reduced regulatory cost, greater reduction risk	\$3.6 billion
Premanufacture preview	reduced regulatory costs, no significant reduction in effectiveness	\$ 40 million

TABLE 3.1: POTENTIAL INCREASES IN TOTAL NET BENEFITS OF REGULATIONS THROUGH APPLYING CBA.[7]

Although the use of cost-benefit analysis was not the only factor bringing about such cost savings, it is fair to assume that the analyses played major roles in improving regulation.

As a result of a series of Presidential Executive Orders, the formal requirements to support regulation through cost, economic impact and benefit analyses have increased steadily. Executive Order 12291, issued by President Reagan in 1981, for instance, requires the preparation of a Regulatory Impact Analysis (RIA) for every major rule. Section 2 of the Order provides that "Regulatory objectives shall be chosen to maximise the net benefits to society" and that "Regulatory action shall not be undertaken unless the potential benefits to society for the regulation outweigh the potential costs to society."[8]

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7 Source: Pearce, David, Markandya Anil, Barbier, Edward B., Blueprint for a Green Economy, Earthscan Publications Ltd, London 1989, p 123.

8 United States, Presidential Executive Order 12291, Washington D.C. 1981.

There is therefore little doubt that CBA has an important role to play in the setting of standards for water pollution and control. Despite certain problems, which will always exist with data collation and the choice of the discount rate to use in a particular analysis, the technique is a powerful aid in economic decision-making. It is recommended that in future regulators should be guided by full CBA analyses before revising standards and regulations.

PART THREE

SELECTION OF ECONOMIC INSTRUMENTS FOR SOUTH AFRICA

CONTENTS

TABLES

4. SELECTION OF APPROPRIATE ECONOMIC INSTRUMENTS FOR SOUTH AFRICA:

Having discussed economic instruments for water quality management in an international context in the previous chapter, this chapter will focus on the appropriateness of some of these instruments in South Africa.

Specifically, the chapter will consider water pricing, taxes and subsidies, tradable discharge permits, and emission charges.

4.1 WATER DEMAND MANAGEMENT

4.1.1 General

Water allocation, water pricing and water marketing are all demand management strategies that can add value to water, thereby ensuring its more considered utilisation. South Africa is a semi-arid country, in which water is a scarce resource and unevenly distributed relative to areas of development. Despite this situation, water in South Africa is generally considered to be undervalued. This is supported by the fact that it is readily available in many areas (due to extensive storage and infrastructure), it is far cheaper in South Africa than in many well-watered countries (partly because of State subsidies), it is often used in a wasteful manner, and is invariably disposed of in a polluted condition with little thought given to its potential in-situ or downstream reuse. Consequently, there is clearly scope for the control of pollution by increasing the inherent value of water. The question now arises as to what extent, if any, can these strategies be used to control water pollution in South Africa.

4.1.2 Restrictive water allocation

Interestingly, the impact of restrictive allocations on water quality has already been demonstrated in South Africa. The 1960s and 1970s saw a rapid increase in the area of land under irrigation as a result of the development of a number of large water storage and transfer projects, e.g. Fish-Sundays, Greater Brandvlei, Vaalhaarts etc. During this period there was a concomitant increase in the salinity of the rivers draining these newly irrigated areas. The rate of increase in river salinity was a major cause for concern, and resulted in the funding of numerous projects to investigate the causes of the increase and develop ameliorating strategies.

However, towards the mid-1980s and early 1990s the increase in river salinity tapered off, despite the continued increase in irrigated areas.

Several theories have been advanced as to the reason for this, including the belief that the availability of soluble salts in the newly irrigated lands had been greatly reduced due to the leaching action of percolating irrigation water, and that the reduced availability of water meant that if a farmer wanted to continue to expand his irrigated lands, he had to do so without increasing his water requirement.

This reduced availability of water was brought about in some instances by the full allocation of the safe yield of dams, while on other schemes the cost of purchasing further water rights was deemed by farmers to be expensive. In addition, water restrictions brought about by droughts during this period also forced many irrigators to produce crops with far less water than they were normally used to. These circumstances demonstrated to farmers the benefits of improving water use efficiency and subsequently resulted in a rapid shift away from inefficient application methods such as flood irrigation and overhead sprinklers to the more efficient drip and under canopy microjets. Not only was the application of water per unit area of land greatly reduced, but the volume of soil (containing soluble salts) which came in contact with percolating irrigation water was also curtailed. As the salinity of irrigation drainage water is a function of both the volume of the wetted soil and the quantity of water flowing through it, the increased efficiency in irrigation water use offset the expected increase in the salinity of those rivers draining areas where irrigation expansion continued.

On the basis of the above experience and from similar overseas examples, some general guidelines can be developed when considering the use of restrictive water allocations to control water pollution. These are as follows:

(i) The best results will be achieved with users who

- require large quantities of water,
- use it in an inefficient manner,
- use it in such a way that the quality is impaired, and who
- discharge a significant portion of the intake volume as waste.

(ii) In order to avoid a negative economic impact on a water user, the technical and financial scope for improving water use efficiency in a cost-effective manner should be predetermined. (It should be noted that the irrigators in the above example were all cultivating high value crops.)

(iii) There will be no water quality benefits in instances where improved water use efficiency does not alter the pollution load.

(iv) Additional incentives/penalties may need to be introduced in situations where existing water allocations are protected by water rights. It may be necessary in such circumstances to couple allocation restrictions with water use levies, emission charges or permits, or surplus water marketing systems.

(v) The impact on receiving waters of reduced effluent discharges with possibly higher pollutant concentrations should be investigated. (It should be noted that the dry weather flow of many rivers is dependent upon return flows).

(vi) It is important to be able to justify targeting a specific water user/polluter for allocation restriction, especially where problems of perceived bias arise in the selection process. Such justification should be based the estimated water quality improvements and possibly the increased availability of water.

4.1.3 Water pricing

4.1.3.1 General

Water pricing increases can encourage better water use efficiencies by placing pressure on input production costs. In the case of wastewater price hikes not only increase the value of the intake water but also the value of the effluents. If the value of the effluent is increased to the point where it is too valuable to discharge it into a drain or a river (i.e. higher than the cost of treating it to a condition where it can be reused), then reuse becomes financially viable and significant water quality benefits can be expected.

In First-World South Africa it is the policy of the Department of Water Affairs and Forestry (DWAF) that water supplies to urban consumers be priced such that the full cost of providing the service is recovered[1]. A problem arises when the time-value of money, in an inflationary economy, reduces the cost (in real terms) of water supplied

1 Department of Water Affairs, 1986.

by the older schemes to a level well below one that reflects any significant value of the resource.

When introducing financial penalties to curb household water consumption during droughts, some municipalities found that in order to have any discernible restriction effect, severe penalties were necessary. It has since been speculated that most First-World consumers may only start considering permanent water saving measures when the price reaches about R2.50 per cubic meter, well in excess of the current R1.20 to R1.60 paid by most domestic and industrial consumers. If correct, this would mean that existing urban water supplies are probably underpriced. This in turn suggests that a significant price increase (>50 per cent) may be required before industrial users would consider the cost effectiveness of wastewater treatment and reuse.

It should also be noted that the issue of water pricing is a sensitive one among farming and developing communities, and that any attempt to increase water prices to encourage effluent recycling could be met with resistance. There is also the problem of how to dispose of the additional funds generated by such price increases. Should they be used to subsidise (and artificially devalue) supplies to other user sectors, should it be used for intensified pollution control activities or should it go to Treasury?

Although water tariffs are used widely they are usually viewed as a means of cost recovery rather than as a way of managing demand. Even then, the water supplier does not always successfully cover, costs, since the long-run marginal costs of supply (LRMC) is typically higher than average current costs charged for water. Metering is essential in calculating LRMC and where metering is not available pricing according to LRMC principles cannot be applied

For reason of public health and equity there is a strong case for supplying a minimum amount of water at a nominal low unit rate. Higher consumption of water should attract higher charges to reflect the higher costs involved in providing more water and of course to encourage consumers to use less water for non essential purposes. The water-pricing regimen can of course be fine-tuned and involve deferent tariff structures to encourage off-peak consumption. Where households share a single water connection such as exist in many rural areas of South Africa differentiated tariffs will not work, however. In forecasting the way the demand for water varies with price the price elasticity of demand is an important parameter. There is, however, a dearth of information on water use and price elasticities of demand among urban consumers in South Africa which severely hampers using this parameter in water pricing analysis.

Where it is assumed that charging higher prices for water is effective this means that the price elasticity of demand for water must be significant. There is evidence to suggest that this is the case (Gibbons (1984)). In Australia, Canada and the UK it has been shown that the price elasticity of demand for household water consumption falls within the range -0,3 to 0,7 Bhatia et al., (1993). This means that demand will fall by between 3 and 7 per cent in response to a price increase of 10 per cent.

There is then a growing empirical body of evidence that demand for water will respond to high unit prices in metropolitan areas of developing countries. Industrial users also have a potential to respond to water price increase by reducing demand. Further, where effluent restriction and pollution charges are imposed, which effectively increase the price of water, there is evidence of reduced consumption. Some studies in this respect have forecast that in many OECD countries average industrial water use is expected in the year 2000 to be 50 per cent of what it was on 1975: and in the USA it may be only 33 per cent Bhatia et al., (1993).

The traditional view that water is price inelastic is based on a legacy of low prices being paid for water in most countries. Where water prices have been raised they have shown considerable price elasticity of demand. One factor determining the price elasticity of demand of household consumers is the margin for cutting back water consumption in outdoor use. Industrial use of water is less able to observe such discretionary behaviour and the price elasticity of demand is dependent on the scope for recycling water.

Generally price increases will only be effective in conserving water if the price exceeds the marginal value of the water to the user. In irrigation schemes, for example, price increases are an uncertain way of ensuring conservation practices, where prices have an exceedingly low base to begin with. In such cases the marginal value of the water simply remains above its marginal cost to the user. Here the price of water should be raised to its shadow price, at a maximum and clearly this depends on many factors such as types of crop, location of schemes etc.

It is important to acknowledge that active pricing requires political involvement otherwise water utilities will not readily overcome consumer resistance to price increases for a commodity that is generally considered to be a basic right.

Theoretically economic efficiency in the pricing process for a commodity will be achieved when the necessary assumptions underlying the formation of a competitive market are met.

To establish such a market the rate of water substitution in production must equal the rate of water substitution in consumption and each is equal to a common price. When this equilibrium position is reached a further reallocation of water would make some consumers worse off than they are at the equilibrium price and such a reallocation is therefore inefficient in economic terms.

The important point arising from this result is that both competitive equilibrium and an equality between the marginal costs of supplying water and corresponding prices for water satisfy the commonly held definition of economic efficiency.

There is, however, no market for water in South Africa and therefore these conditions cannot come about unaided. To overcome this restriction a simulated market has to be established. This would require ensuring conditions (a) and (b) above would be met and could be achieved if the supplier of water priced the commodity at its marginal cost of supply. This price would clearly equal the last unit of water purchased and used by each consumer in the South African water economy. Condition (b) above would then be fulfilled. With regard to condition (a) Samuelson (1980) showed that competitive equilibrium in a simulated market would come about between prices and commodity allocations between economic sectors when the sum of the social payoffs throughout the economy minus the transport costs involved in moving the commodity between different sectors was maximised.[2]

4.1.3.2 Pricing goods and services having a polluting effect

Government can affect consumer behaviour and also producer behaviour by fixing the prices of goods or services at levels other than the market-clearing price. Low prices encourage consumption but will discourage investment in productive processes by entrepreneurs if they are set low enough to jeopardise profits. Conversely, prices that are set at too high a level will discourage consumption but encourage production and investment particularly if they result in excess profits.

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2 For details of a water pricing and allocation model based upon these principles, cf., *The Application Economics to Water Management in South Africa*, WRC Report No 415/1/94, pp. A3.16-A3.36.

Price setting schemes therefore invariably affect supply and demand and can result in imbalances. The effect of pricing schemes although not specifically initiated for environmental reasons may be found in energy industries. The pricing of natural gas is an example. In the USA it was set below the market-clearing price until 1980's and in Japan prices for kerosene have been kept low. Conversely oil prices have usually been set above the marginal costs of production which has resulted in supply/ demand discrepancies.

The market also sets prices, and to this end the government can deliberately foster market driven pricing regimens. Such market pricing can internalise economic externalities arising from pollution. For example where market intervention has effectively set a price or created a market for otherwise freely available goods. An example would be tradable emission permits.

Efficient pricing can then include market values or at least proxy prices for the use and depletion of the environment. Using proxy prices for scarce and costly "clean" environmental resources can encourage the use of freely available common resources under the discipline of market forces e.g., the "correct" pricing of water. Effluent charges, permit fees, and tradable permits are examples of proxy pricing techniques for controlling the allocation of goods and services that have a polluting effect. Proxy prices can also be based on expressions of "willingness-to-pay" to preserve or to pollute, or as some notion of acceptable avoidance costing.

As mentioned above achieving efficient pricing which internalises economic externalities requires a certain amount of effort on the part of both government and the private sector. It involves some study of the costs of the specific economic activities and social goals at stake, which enables the trade-offs involved to be identified and valued in monetary terms.

Capturing economic externalities in pricing systems is an iterative process because externalities usually lie outside the producer-pricing scheme but have to be brought into the pricing process - usually by government intervention. The process is seldom accurate or complete and this is perhaps the prime reason for utilising standards and regulations which can create or reinforce the market approach to the pricing of goods and services which have a polluting effect.

4.1.4 Water marketing

The arguments for water marketing as a means to control pollution are similar to those for restrictive water allocations. The opportunity to market water merely acts as an incentive to ensure that those who have more water than they really require are encouraged to determine their real needs and then sell the remainder for a market related price, thereby increasing and diversifying their income.

In order for water marketing to be efficient economically, a number of legal and political requirements are also necessary. Theoretically, for the economically efficient functioning of water transfers via markets, the following requirements are necessary:

1. The value of water must be recognised as being distinct from the value of land. Water should be bought and sold for its own sake, not merely as an incidental part of a land transfer.

2. Buyers and sellers must voluntarily agree to the reallocation of water, both parties believing it to be in their own best interest.

3. Price (and other terms of water transfer) are negotiable by the buyer and seller and are not constrained to 'non profit' or 'at cost' considerations.

4. As in any other theoretical market, water markets are required to display 'perfect' attributes, which include the existence of a large number of agents, the availability of complete information and minimal transaction costs.

Transactions may include the sale or lease of fee titles, water use permits, conservancy district shares and project contract rights. Further transactions can be in the form of conditional water leases for drought year uses, the exchange of water rights with varying priority dates and arrangements to use conserved water.

From a legal perspective, water in South Africa is regarded as being either public or private. Public water is that which flows in a public stream, whereas private water includes most ground water and the water flowing in private streams, i.e. streams which rise on, and flow across a single property. Private water can be sold for industrial, urban and agricultural purposes, providing a permit is first obtained from the Department of Water Affairs and Forestry. Private individuals and organisations cannot sell public water[3]. When an individual is granted or purchases a water right permitting the abstraction of public water from a public stream, that person does not own the water and is therefore not at liberty to sell it. The owner of a water right merely has the right to use public water for the purpose specified in the right. If he

3 Water Boards, Irrigation Boards and Municipalities are deemed to be public bodies.

chooses not to use it for that purpose it must remain in the public stream whereupon it becomes available to the holders of downstream water rights.

This does not mean that consideration should not be given to the marketing of some or all of the water that forms part of a water right. As this water cannot be taken back and used by the State, unless the right is revoked (something that very seldom happens), it may as well be considered as private property. Therefore any mechanism which discourages the misuse and abuse of this water and which promotes its better utilisation, should be considered. Clearly the purchase of water from farmers by municipalities at urban water prices, has been shown in the USA to be a highly successful way to increase agricultural water use efficiency, reduce pollution from farmlands, and improve farmer incomes, whilst at the same time averting the need to construct new urban water supply schemes.

The private sale of water rights is permitted in South Africa. Unfortunately, as agricultural land without water rights is only worth a fraction of land with rights, the purchasing of water rights invariably means purchasing the land to which such rights pertain. This latter option is referred to in the USA literature as water farming, and is often practised by municipalities and industries in South Africa that are situated in water scarce areas. Because water users get land with their newly acquired water rights, which they neither want nor need, the risk of non-beneficial land use is very real. The primary difference between the sale of water and the sale of water rights is that the latter is a single payment for a right that may be exercised in perpetuity, whereas the former is a series of payments for the sale of a given volume of water. The main attraction of purchasing a water right is that it has a greater measure of supply security than is provided by an agreement to purchase water from an individual who may one day increase the price, sell to someone else or even resume irrigating.

As the term implies, market based control mechanisms require a viable market in which to function properly. Thus, for water marketing to have any beneficial effect on water quality and water use efficiency, there must be a regular demand for water from a number of independent buyers, and an adequate number of independent water sellers prepared to meet that demand. Only in such a market can security of supply be established.

4.2 TAXES AND SUBSIDIES

4.2.1 Policy Implications of Taxes and Subsidies

The policy implications of taxes can be expressed as a "price" that polluting agents are confronted with to induce them to internalise at the margin the full social costs of their activities and to modify their polluting behaviour. This price can take the form of a tax equal in magnitude to the marginal social damage. Such a tax, commonly called a "Pigovian" tax, should be attached directly to the polluting activity and not to some other related activity.

The Pigovian tax should ideally take the form of a levy per unit of pollution emitted into the natural environment not as a tax per unit of the firm's outputs or inputs. An example of such inputs would be coal bought by Eskom for power generation.

It is important to note that the Pigovian tax solution to externality generation has been the subject of critical analysis by Coase (1960). Coase maintains that the government should not become embroiled in the externalities debate and the economic distribution created by externalities can be overcome by private sector negotiation or bargaining.

It is difficult to see this approach being totally successful, however, since problems associated with identifying the polluting agents and the costs involved in the bargaining process are too difficult to overcome to permit a practical solution to the problem of pollution externalities along Coasian lines.

Now it has long been recognised by economist that a subsidy per unit of pollution emission abatement provides the same incentive as a tax to entrepreneurs to internalise pollution externalities: this is because a subsidy of 50 cents per kg of sulphur emission reduction, for example, creates the same opportunity costs for sulphur emission as a tax of 50 cents per kg.

There are however, some subtle and important economic differences between these two policy instruments. In the first instance subsidies increase profits whilst taxes decrease them. Consequently the instruments provide opposite signals to firms regarding entry and exit to a particular market.

Subsidies have the effect of shifting the industry supply curve to the right since a firm will try and increase its output to collect greater subsidies and increase their profit. Taxes on the other hand shifts the supply curve to the left since firms will try to limit their output to the optimal level and reduce their tax burden as much as possible.

These supply curve shifts clearly have an effect on the numbers of firms wishing to enter or leave the market. Subsidies would tend to expand the number of players whilst taxes would tend to reduce the number of players a priori. A problem may now develop since as the number of firms in a particular market increases, pollution emissions may also increase and the possible benefits of subsidy so far as pollution abatement is concerned may be undone.

It seems from the above argument that to obtain the optimally current number of firms in a particular market it is essential that each firm should be forced to pay the total costs of the marginal damages caused by their pollutants and also the total costs of their waste emissions in the form of a tax since only if the total cost of the externality to society is charged will the profitability of each firm reflect the correct benefits of entering or leaving a particular market.

Taxation schemes can change the relative cost of consumption or corporate behaviour by raising costs, which will induce less production of the taxed product. Prices will be raised by taxation schemes hence there will be less consumption of the taxed product. Because of these price and income effects taxes can induce more efficient use of resources.

Taxes on business, including taxes levied to combat pollution, simply raise the cost of doing business and a portion of the tax will invariably be passed on to consumers in the form of higher priced goods or services. Who ultimately bears the burden of the tax depends on the price elasticity of supply and demand in the market for the affected product.

Tax differentiation can lead to relatively lower prices for less environmentally damaging products. Differential taxes tend to bring about substitution among goods consumed rather than reductions in overall consumption levels. Differential taxes for different fuels tend to encourage substitution effects rather than an overall reduction in energy use. Whilst tax differentials directly affect only consumption at first, the shift in effective demand will ultimately affect investment decision-making in production processes.

The other aspect of tax differentiation policy is “forgiveness”. This is essentially a reward or incentive to encourage certain behaviour. This mechanism means absolving one group of taxpayers from all or some of their obligation to provide a share of the government's revenue. The remaining revenue is made up by other taxpayers. This allows enterprises to have more money available for investment but it does not necessarily mean that it is the most efficient method of allocating resources.

4.2.2 Types of pollution tax

Pollution taxes or charges are command and control instruments that could be introduced into the water economy of South Africa.

Pollution taxes and effluent charges come in many forms, and are often tailored to specific circumstances. They include:

- Volume of effluent related charges.
- Charges levied on the pollutant concentration, usually based on the amount by which an effluent exceeds some predetermined threshold concentration limit.
- Pollutant load related charges.
- Sliding scale charges, i.e. the more you discharge the more you pay.
- Flat rate charges for certain sizes or categories of industry.
- Annual fixed fee for being permitted to discharge an effluent.

In this chapter a simple tax on the per-unit pollutant load that is discharged to streams and rivers, will be considered. The pollutants considered are the total dissolved salt content (or salinity) of an effluent and the quantity of oxygen demanding waste. The tax will be levied on the tonnage of salt and oxygen demanding waste discharged at a known and measurable point. It is assumed that tonnages will be calculated by means of periodic volumetric flow and pollutant concentration measurements.

The first criticism of such a tax that may be raised is - 'how does that help control pollutant concentrations in effluents, after all it is the concentration that results in an impact on down-stream water users and not necessarily the pollutant load? This is why the General Standard for Effluent Discharge specifies permissible pollutant concentrations.' The response to this is that:

- So long as water remains under-priced and is not considered a major cost factor in industrial processes (even wet processes), the manipulation of effluent concentrations will always be a possible way of complying with effluent concentration standards, especially if a pollution tax incentive is introduced.

- Pollutant loads are an important consideration in the maintenance of environmental quality, particularly in river systems that are heavily impounded and where pollutant accumulation can take place.
- Pollutant load taxes are more equitable in that they are volume independent; thus they penalise polluters rather than industries with a high water consumption. They also do not interfere with water pricing strategies or consumption control mechanisms.
- The discouragement of pollution loading to the environment encourages the treatment of pollution at source. Because of the assimilative limitations of the environment (which are rapidly being reached), this approach is recognised internationally as the direction in which pollution control strategies should develop.
- Pollution taxes can still be imposed in conjunction with Receiving Water Quality Criteria in order to control pollutant concentrations in those flowing rivers into which effluents are discharged.

An additional query that may be raised is why not tax the volume of effluent, as this would create a water conservation incentive? As indicated above, multi-objective taxes may lose their original focus, i.e. a volumetric-based pollution control tax may interfere with the achievement of water pricing objectives. Also, in a hot, semi-arid country such as South Africa, there is considerable potential for effluent volume reduction through evaporation and irrigation, thereby reducing the volume of water in the system without reducing the pollution loading. Volumetric taxes may encourage the use of volume reducing methods.

Another issue that is often raised, - is who should the tax be targeted at? There are instances in other countries where certain industries, which are causing major environmental problems, are taxed whereas other industries which produce the same pollutant but in much smaller quantities, escape tax. This situation often has more to do with the cost of tax collection and effluent discharge monitoring than the respective impacts of the effluent discharges. It is generally more cost-effective (but sometimes inequitable) to collect taxes from a few major polluters than from a large number of very small polluters, particularly in developing economies which possess a sizeable informal and entrepreneurial sector. Hence volumetric sliding scales or threshold volume levels are sometimes found in pollution tax systems. This is an option that might be employed if South Africa were to adopt a system of pollution taxes, although it should only be considered after detailed sectoral analysis of the socio-economic impact of the tax. Pollution tax impacts are discussed in the next section.

4.2.3 Impact of Pollution Taxes

Pollution taxes can impact enterprises and South Africa's economy in the following ways:

- Company profits and enterprise viability;
- Sector competitiveness;
- Employment levels;
- Pollution emission levels and subsequent tax revenue;
- Likely environmental benefits.
- Opportunities for new enterprises.
- New marketing opportunities.

To undertake a quantitative assessment of anticipated impacts requires a very different type of study to this research project. Extensive interviews would need to be conducted with politicians, business, organised labour, and environmentalists to determine the likely responses to a policy of pollution taxation. Furthermore, as such a survey will at best encounter a sceptical response, and at worst, predictions of disaster, (few people are positive at the prospect of new taxes) the results may not be encouraging. Consequently, it was deemed necessary in this section to include a brief discussion on the nature of both the positive and negative impacts often associated with pollution taxes.

Before the likely impact of a pollution tax can be estimated, however, the objective and level of tax must first be determined, the latter being entirely dependent on the former. The next section will discuss these issues.

4.2.3.1 Taxation Objectives

Pollution taxes can have a number of objectives, some of which may have nothing to do with pollution control. For example they may be used to:

1. Raise revenue to:

    - Increase income for the general fiscus.

- Fund pollution control administrative and technical services.
- Establish a fund from which subsidies could be awarded to industry to install pollution control equipment.
- Establish a fund with which to assist poor communities to properly treat and dispose of their waste.
- Establish an insurance fund from which downstream water users who are impacted by upstream effluent discharges can be compensated.

2. Prevent pollution from increasing any further; i.e. maintain the status quo.

3. Reduce pollution to a predetermined level.

4.2.3.2 Selecting tax levels

Whilst these three objectives are all achievable with pollution taxes, the policy-maker has no way of knowing at what level to set the tax in order to achieve any given objective.

Experience from countries that have used pollution taxes for several years has shown that it is not so difficult to introduce a tax for revenue generating purposes, - one simply begins with a low level tax and periodically increases it until pollutant discharges start to fall. Just prior to this is the point where tax revenue is maximised without any pollution control benefits. In other words the revenue base is not threatened by pollution reductions. This does not mean that the revenue per se is maximised. The tax level that yields the maximum revenue may well be associated with significant reductions in discharge; i.e. the remaining polluters are prepared to pay a high tax without altering their discharge. In such circumstances, maximum revenue would only be attainable with a pollution reduction objective and not with a revenue generating objective. This debate will be briefly discussed next.

4.2.3.3 Revenue generation versus pollution control

Problems may be experienced with multi-purpose pollution tax systems. However, this does not seem to discourage policy-makers for opting for the so-called 'double-dividend' in pollution taxes whereby the level of the tax reduces pollution emissions and the revenue generated is used to further reduce pollution by means of pollution control subsidies for industry, waste management assistance for poor communities, and intensified pollution monitoring.

The problem arises when self-funding pollution control agencies start to depend on the revenue from a tax which was introduced to reduce pollution. Such a revenue base is vulnerable to one of two developments.

- Abatement costs fall due to new technology, resulting in some industries preferring to treat effluent rather than discharge it and pay tax. This occurrence is often prevalent in situations where industrialists anticipate regularly increasing tax levels and invest in treatment technology either early or at the point where it becomes cost-effective.
- The pollution control benefits of the tax prove insufficient thereby forcing an increase in tax levels to a point where the discharge deterrent is sufficient to reduce total revenue.

The problems described above have occurred in Europe and have led to some interesting consequences.

In one instance in the Artois-Picardie River Basin in France the tax level was set quite high resulting in an effluent discharge reduction of 45% between 1975 and 1984. However, this was associated with a reduction in industrial and municipal water abstractions from 560m^3 per year in 1970 to 479m^3 per year in 1989 due to greater water use efficiency and wastewater recycling[4].

In the Netherlands[5], an industrial wastewater discharge levy was introduced in 1970 with the intention of raising revenue to help fund the administration of a wastewater licensing and monitoring system. However, the levy was set too high and industries started treating their effluent in-house to avoid paying the tax. Between 1970 and 1976 industrial water consumption fell 30% while industrial productivity grew. As wastewater discharges fell the tax was increased to preserve the revenue for water pollution control administration. Since 1980, the levy has increased 100% and has

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4 Tuddenham, M (1994) The System of Water Charges. In - *The Greening of Government Taxes and Subsidies: An International Casebook on Leading Practices.* IISD.

5 OECD (1987) Pricing Water Services, OECD, Paris.

resulted in a 65% reduction in the discharge of oxygen demanding waste. Between 1971 and 1993 the Dutch water authorities have collected effluent taxes totalling Df 11.4 billion or R25.88 billion.

Whilst a well-considered, gradual 'trial and error' approach to the setting of pollution taxes appears to be called for, determining an introductory level of tax is still a problem. Studies similar to this one can be undertaken to estimate sector by sector revenue from a specific pollution tax. This revenue can then be compared with the declared profit margin of each sector to see if the impact is likely to be significant or not. Alternatively, the marginal cost of abatement could be calculated for each individual discharger, however this is likely to be a major task and may not represent the real response of industrialists.

4.2.3.4 Likely Impacts of Pollution Taxes

Pre-pollution tax investigations conducted in other countries have often predicted a wide variety of negative consequences, most of which were intended to discourage government from introducing pollution taxes in the first place. Predictions of the collapse of entire industrial sectors and the subsequent swelling of the ranks of the unemployed, were not, and are not, uncommon. However, most of these types of studies are generally too narrow and demonstrated too superficial a knowledge of the workings of the economy, to be of any real value. One of the commonest oversights is the employment opportunities that are created by changes in government policy on pollution, particularly when greater responsibility is placed on the polluter to either clean up or pay up. Such policy changes have led to the creation of entirely new industrial sectors offering advice, products and services relating to waste management.

Another common omission is the adaptability of the private manufacturing sector to a changing production environment whilst maintaining competitiveness. There are a growing number case studies which demonstrate that being forced to consider the level of emissions also forces a company to consider its consumption of raw materials, the associated wastage and inefficient use of materials, the streamlining of production processes, and the actual value of what was originally considered waste substances. By undertaking life cycle analyses and internal environmental audits, and by implementing the recommendations of these studies, companies not only become more efficient, but their products may also become more acceptable to markets with high environmental production criteria.

Another spurious objection to pollution taxes is the argument that industrial development will be suppressed in an area where such taxes are imposed, leading to industries migrating to neighbouring countries where pollution control is more lenient and less expensive. An investigation into the primary facets of industrial location analysis will reveal that the cost of complying with pollution control requirements is often a minor consideration compared with the cost of site development, electrical energy and distances to and from markets. In any case, new industries can generally meet high levels of effluent treatment at a fraction of the cost of established industries.

However, the impacts of the introduction of pollution taxes may not always be positive and the anti-pollution tax lobby may well possess good arguments as to why the imposition of such taxes should be reconsidered. Whilst appearing to be fair and adhering to such sound principles as the 'polluter must pay', pollution taxes are quite capable of exerting an inequitable impact on certain industrial sectors and on certain sectors of society.

Pollution taxes, like most environmental regulations, hit older industries the hardest. Indeed. Given the age and low resource use efficiency of older manufacturing plants, taxes which are based on pollutant loads, as opposed to concentrations, are likely to have a greater negative impact because of the higher throughput of raw materials and waste generation per unit of production. Moreover, both volumetric and pollutant load sliding-scale taxes (i.e. the more you discharge the more you pay), are going to penalise old industries even further. Old industrial plant is also difficult, expensive and sometimes non-cost-effective to upgrade.

But it is the labour issue that discourages governments the most from imposing potentially harmful pollution taxes on old industries. Old industries are generally more labour intensive than their newer, automated and more efficient counterparts. Thus factory closure, due to the imposition of pollution taxes and resulting non-viability, can exact a high social cost. Even factory modernisation, prompted by environmental policy changes, can result in job losses due to the introduction of more labour-efficient production systems. The theory is frequently advance by environmental policy-makers that old industry welcomes the introduction of new and more stringent environmental regulations as it presents an opportunity to refurbish manufacturing plant, reduce the labour force, and place the blame for redundancies firmly on the shoulders of the government.

Another negative aspect of pollution taxes is their potential for stimulating price increases, and thus inflation, when applied to monopolistic industries. If pollution taxes are imposed on monopolies, the pollution deterrent effects are likely to be zero and the cost of the tax could well be passed directly onto the consumer, often with an explanation as to why the price is being increased. Therefore, unless government can control price increases in monopolies, very careful thought should be given to the imposition of pollution taxes. Pollution taxes actually work best in highly competitive systems where manufacturers have to internalise as much of the tax as possible in order to maximise their competitiveness.

Clearly, while there may be winners in the introduction of pollution taxes, there may also be genuine losers. It is the task of government to decide whether it will accept the losers as a victim of economic progress, compensate them, or tolerate old polluting and inefficient industries. One frequently adopted option for ameliorating the negative impacts of pollution taxes is to use the tax revenue to issue subsidies to older industries to help them install pollution control equipment. Whilst this can be, and is in many countries, a highly successful strategy, and one that is still permitted under the recently signed GATT treaty, it also has numerous pitfalls many of which pertain to the limited thought that governments often give to the targeting and administering of subsidies. Inappropriately handled pollution control subsidies can quickly erode any existing incentive mechanisms for effluent discharge reduction and result in increased levels of pollution. It can also lead to a demand for subsidies which exceeds the available revenue base resulting in one group of effluent dischargers paying increasing taxes to subsidise a growing number of less profitable polluting industries.

Government must always be careful to restrict pollution control subsidies to a narrow category of worthy industrialists. It is far easier to broaden the range of subsidy beneficiaries than it is to restrict it. Whilst employment criteria can be useful in targeting pollution control subsidies, governments must be careful not to fall into the trap of supporting so called 'lame duck' industries, i.e. those that are in decline and will eventually close with or without subsidies.

4.2.4 Estimated Revenues from the Introduction of Liquid Effluent Taxes in South Africa

The following is the approach adopted in estimating the possible revenue from the imposition of a liquid effluent tax.

- The tax is imposed on all liquid effluents discharged by the manufacturing sector at a measurable point into rivers and streams.
- Discharges to sewers, solid waste sites, irrigation sites and the marine environment are not considered.
- Discharges by other sectors of the economy (e.g. mining, agriculture and municipal) are not considered.
- The tax is imposed on the pollutant load, (i.e. the volume of effluent multiplied by the pollutant concentration.
- A tax of R10 per ton is imposed on both total dissolved salt loads and oxygen demanding waste loads.
- The revenue is calculated for the level of production achieved in the 1992/93 financial year.

The manufacturing industries included in this analysis are those contained in Major Division 3 of the Central Statistical Service's (CSS) Standard Industrial Classification of Economic Activities (Fifth edition). The effluent discharge data was obtained mainly from the Water Research Commission's (WRC) Natsurv Project and other WRC sectoral studies on industrial effluents such as leather tanning and textiles. The effluent discharge data was converted to discharge per unit of production and then used in conjunction with the CSS's sectoral production data for the 1992/93 financial year to calculate annual effluent volumes and qualities. This calculation, which involved the processing of considerable quantities of economic data, was performed using the Development Bank of Southern Africa's (DBSA) SANEEP Model. This model permits the imposition of pollution taxes in order to estimate revenues and to determine the distribution of revenues among the different types of polluting industries.

The results of the effluent tax revenue simulation are presented in Table 4.1 (total dissolved salts) and Table 4.2 (oxygen demanding waste). The contributions of the various industrial sectors to the total revenue are ranked in order of magnitude.

It will be immediately noticed from Tables 4.1 and 4.2 that the tax burden is not evenly distributed. Indeed, it is highly skewed with 94% and 91% of the revenue respectively coming from the same four industries, i.e. textiles, leather and tanning, metals and petro-chemicals. There is also considerable skewness within these four sectors. For example, in the case of total dissolved salts, the textile industry would be responsible for over 60% of the national revenue from this pollutant. While for oxygen demanding wastes, the petro-chemical industry would be responsible for almost 49% of revenues.

The other point that may be noticed is that the top four sectors are all quite old South African industries. They most likely possess ageing plant that is probably inefficient in terms of resource use, outmoded in terms of cost-effective pollution control, and expensive to upgrade. Furthermore, with the exception of petro-chemicals, they are all labour intensive. Indeed, in the case of the textile industry, major policy issues have recently been raised concerning the Government's future support for this sector, particularly in view of the need to remove all the protection it enjoys within 15 years to comply with the conditions of the GATT treaty.

This raises the question of whether these industries would be able to pay pollution taxes of the amounts shown in Tables 4.1 and 4.2, bearing in mind that the amount of R10 per ton for TDS and oxygen demanding wastes is purely arbitrary.

The amount of R130 million for the textile industry represents approximately 7.8% of the sector's R1652 million turnover in 1992/93. However, as the sector's contribution to Gross Domestic Product (GDP) for that year was only R225 million, it is reasonable to assume that its profit margins were quite small in relation to its turnover. Hence, an additional tax burden of R130 million may be difficult for it to accommodate, particularly since the sector is striving for improved competitiveness.

The petro-chemical industry is of course far wealthier than the textile industry, although it is also confronting the possibility of deregulation and increased competition. It must be pointed out however, that the data used for the petro-chemical industry is of a very poor quality compared to that for the textile industry. Estimates of pollution discharge have been drawn from the international literature and could be highly unrepresentative of the South African situation. It does however raise the issue of how serious the pollution is from this sector given that it has been shrouded in secrecy for the duration of the sanctions era.

The R49 million the petro-chemical industry would have to pay if a R10 per ton tax were imposed on the discharge of oxygen demanding waste, represents 0.3% of the sectors annual turnover in 1992/93. As the sector contributed over R7289 million to

GDP in that year it is safe to assume that such a tax would be quite affordable and may not result in any further abatement measures by the industry.

SECTOR	REVENUE (R)	%
Textiles	130 171 400	60.29
Leather and Tanning	36 560 700	16.93
Metals	19 425 000	9.00
Petro-chemicals	16 840 500	7.80
Tiles, Bricks and Cement etc.	3 982 800	1.84
Sugar and Sugar products	3 523 500	1.63
Rubber products	1 783 000	0.83
Food processing	1 379 500	0.64
Wood, Pulp and Paper	1 223 700	0.57
Glass and Pottery	326 800	0.15
Beverages	189 000	0.09
Plastics	175 500	0.08
Grains, Starches and Feeds	168 500	0.08
Paints and Detergents	144 000	0.07
	215 893 900	100.00

NB: The secrecy surrounding the production and pollution levels in the petro-chemical industry has only recently been lifted. As such the availability of South African data is still very poor. Consequently, international data on pollutant emissions for this sector have been used.

TABLE 4.1: ESTIMATED SECTORALISED REVENUE FROM IMPOSING AN EFFLUENT TAX ON TOTAL DISSOLVED SALTS FOR THE YEAR 1992-93

SECTOR	REVENUE (R)	%
Petro-**chemicals**	105 252 800	48.79
Textiles	60 074 600	27.85
Leather and Tanning	18 093 800	8.39
Metals	12 723 600	5.90
Food processing	4 312 100	2.00
Tiles, Bricks and Cement etc.	3 982 800	1.85
Sugar and Sugar products	3 915 000	1.81
Rubber products	2 971 600	1.38
Wood, Pulp and Paper	1 748 100	0.81
Beverages	1 347 600	0.62
Glass and Pottery	454 500	0.21
Paints and Detergents	385 700	0.18
Plastics	292 500	0.14
Grains, Starches and Feeds	168 500	0.08
	215 723 200	100.00

NB: The secrecy surrounding the production and pollution levels in the petro-chemical industry has only recently been lifted. As such the availability of South African data is still very poor. Consequently, international data on pollutant emissions for this sector have been used.

TABLE 4.2: ESTIMATED SECTORALISED REVENUE FROM IMPOSING AN EFFLUENT TAX ON OXYGEN DEMANDING WASTE FOR THE YEAR 1992-93

The interesting feature of the exercise carried out and described in the last chapter was the way in which the pollution tax targeted old and weaker industries such as textiles and tanning. Both industries have a long history of polluting surface water resources in South Africa and the search for affordable pollution control strategies has been ongoing for well over a decade. It must be pointed out that much of the research that has gone into finding pollution control solutions for these industries has come from the Water Research Commission. Perhaps what is required now is an incentive system to encourage the widespread implementation of the wastewater treatment technology that has been developed for these industries.

The analysis documented in this report has shown that great care is required in taking successfully working economic-based pollution control systems from other countries and applying them to the South African situation. The possibility of a combined objection from industry and organised labour to the introduction of fiscal instruments for pollution control is very real. However, there is also little doubt that effluent taxes, used both as a discharge deterrent and as a means of raising revenue, do have an important role to play in the pollution control of our water resources. The key would seem to lie in structuring the tax package such that it includes subsidies that are targeted at those industries that are inequitably disadvantaged by the tax. Clearly, the selection, targeting, and level of introduction of pollution taxes must be preceded by the necessary socio-economic investigations to avoid unintentional negative impacts.

It should be noted that, should the introduction of a pollution tax result in failure and embarrassment for the implementing agency, it will be very difficult to re-introduce it at a later date. As such a useful water quality management tool will be lost.

4.3 TRADABLE DISCHARGE PERMITS

4.3.1 Conditions needed to support permit trading

The points made in the last paragraph of 4.1.4 offer an appropriate introduction to a discussion on the application of tradable effluent discharge permits in South Africa. Tradable permits are, in principle, an equivalent alternative to taxes. Hence instead of setting the optimal (Pigovian) tax and reaping an economically efficient level of pollution discharge, the environmental authority could issue the efficient number of tradable permits and allow firms to compete for them. This would generate a market clearing price for the permits, an outcome that satisfies the economic argument for pollution abatement activities in the short run, and equally important, for the entry and exit conditions of firms into the market in the long-run. Further, the regulator has the option of setting either price or quantity constraints for the permits to achieve the desired result.

There is, as in all things economic, a caveat to this suggestion: it is based upon the tenuous assumption of perfect knowledge. Considering the imperfect information usually attached to firms' costs functions, and societies' damage functions, this is of course difficult to justify as being extant.

Any investigation on the workability of a tradable permit system for waste water discharges within catchment-based bubbles[6] must focus on one single issue: - is there a viable market for permits to be traded efficiently and effectively to the ultimate benefit of society? By analysing the examples of permit trading as reported in the literature, one starts to suspect that tradable permits are best suited to air pollution control strategies rather than those for water pollution control. This seems to contradict the widely held belief that good accurate information (such as that collected for point source effluent discharges to rivers) is an important prerequisite for permit trading. But, as indicated previously, the existence of a viable market populated by an adequate number of active and independent players is more important than the availability of accurate information.

The problem with many South African situations where permit trading may prove beneficial, is that catchment based bubbles are too small, in terms of the number of emission point sources of a particular pollutant, to support a viable market. By contrast, air pollution bubbles are, by virtue of the nature of the pollutants, much larger and can thus include a greater number of independent players. In theory, one could conceivably establish a global air pollution bubble for managing greenhouse gas emissions. There would certainly be sufficient players to create an active market.

4.3.2 Possible application of permit trading in South Africa

Two categories of water pollutants may be suitable for permit trading in South Africa. These are nutrients and oxygen demanding wastes. Unfortunately, the primary

6 Bubbles are geographic collections of emission points whose total emissions are regulated. Permits can be traded by firms and plants within bubbles to alter individual source emissions whilst keeping the overall emission from the bubble constant.

dischargers of these types of wastes are municipalities, particularly those serving the poorer communities, who do not have the capital resources to afford adequate oxidation and maturation treatment facilities. It is unlikely that these dischargers will be in a position to compete in a free market for permits. If they fail to acquire permits they will merely continue to discharge effluent illegally. Should the State intervene to assist such communities by either buying or reserving permits for them, then the incentive for minimising pollution will be destroyed.

The scope for applying either CAC (command-and-control) or economic based pollution control instruments to poor communities is limited. If such communities were to be prosecuted for contravening pollution 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 pollution problem.

There are other categories of pollutant such as saline wastes in Gauteng, and sulphate waste in the Upper Olifants catchment (which will be discussed in more detail in this chapter). However, both have a significant non-point source component, thus a tradable permit system may not achieve the water quality goal that was intended, a factor which may tempt point source dischargers to disguise their effluent emissions as non-point source pollutants (e.g. effluent irrigation and dust suppression) in preference to having to buy additional permits.

4.4 Emission Charges

4.4.1 Merits and suitability

The main criticism of emission charges used to be that the cost of determining, imposing and collecting the charge was so great that the income it generated was hardly worth the effort. Then administrators increased the efficiency of emission charge systems by targeting them more specifically at those polluting activities which were widespread and on which charges could be levied with relative ease and at low cost. Hence, as has been shown earlier, the situation exists in many countries where emission charge systems are used largely to generate revenue for funding other public sector environmental control responsibilities. Few such systems have a pollution deterrent purpose, as the charges are usually set too low. Whether this is a result of political lobbying by polluters or concern that revenues may fall if charges are increased to the point where polluters reduce discharges to avoid levies, is probably a complex issue. Given such a dubious history, do charges have a place in South African pollution control activities?

The answer is undoubtedly yes? Indeed, charges are probably more suited to South Africa, with its mix of First and Third World economies, than they are to the USA and Europe. It has been demonstrated over the last eight years that environmental management is far down the South African Government's list of priorities when it comes to the allocation of State funds. There are just too many other important issues that require scarce financial resources, and this situation is likely to continue for some years. Therefore any system which generates revenue for pollution control activities, either at a national or local level, must surely be worth considering, regardless whether or not there are pollution control spin-offs.

Charges can be levied on both point and nonpoint sources; however the nature of the charge is different for each type of pollution.

4.4.2 Point source pollution

Water pollution control charges should be levied on the volume of water discharged and the pollutant concentration. Thus it requires good monitoring facilities at the point of discharge. This limits the range of South African polluters to the wealthier municipalities and wet-industries (e.g. textiles, tanning, food and beverages, power generation etc.). Unfortunately, these are also the industries that have made good pollution control advances in recent years, and it could be argued that the authorities, in introducing charges on emissions from these industries, are merely aiming for a 'soft' target from which it is easy to collect revenue. In other words, these industries would be penalised for having well-managed and well-monitored effluent systems. In addition, those activities which carry a heavy responsibility for water quality deterioration in South Africa (e.g. farming, abandoned and some working mines, informal settlements etc.) would probably be exempt from charges because of the difficulty and expense in determining and collecting the amounts payable.

Therefore care must be taken when imposing charges on point source pollution to ensure that the system is equitable and justified. For this reason point source effluent charges are probably best implemented at a local level for specific pollutants or groups of pollutants (e.g. nutrients, oxygen demanding wastes etc.). The system should also be applied to pollutants that result in a low-level impact on downstream water users, as it is probably inevitable that administrators will set charges to generate revenue rather than discourage discharges. Like many economic instruments for environmental management, emission charges alone are not a solution but are best used in conjunction with other instruments (both economic and CAC).

4.4.3 Nonpoint source pollution

As indicated in the last section, emission charges are best suited to well-monitored point sources of pollution. However, it is possible to introduce an indirect emission charge for more insidious types of pollution by levying charges or taxes on the activities that give rise to this type of pollution. As shown previously, these taxes (sometimes referred to as 'Green Taxes') have and are being applied to air pollution by means of a levy on the carbon, lead, and sulphur content of various fuels. Can these approaches be applied with any significant benefit to water pollution in South Africa?

A charge could be levied on the use of fertilisers by farmers in those areas where the eutrophication of rivers and dams is an expensive problem for water treatment plants. Such a charge would have to be combined with a charge on point sources of nutrients. Levying charges on activities that merely exacerbate natural levels of contamination may prove problematic in that it is the activity and not a polluting substance used by the activity that must be taxed. For example, irrigation releases more inorganic salts into the drainage system than would otherwise have been released by natural rainfall. Thus a tax would have to be levied on processes which mobilise excessive quantities of salts (e.g. over-irrigation, the irrigation of soil which does not contribute to crop growth etc.). Such a levy may be imposed in the form of a tax on flood irrigation, the salt content of certain soils, the quantity of water used per unit area of irrigation or, on certain well-organised irrigation schemes, the quality and quantity of return flows.

An alternative and lower cost approach to the taxing of specific practices which give rise to nonpoint pollution would be to introduce a flat rate tax for the activity in question, regardless of what practices are employed, and then offer pro-rata rebates on those practices which reduce nonpoint pollution or convert it to point source pollution. In other words, by using the above example, a tax would be levied on irrigation per se and rebates offered for that portion of the irrigation that employs efficient water application techniques.

The use of charges in controlling nonpoint pollution from mining operations will be discussed in the following section.

4.5 Concluding Remarks

This chapter has looked at the strengths and weaknesses of a range of economic instruments. It is clear from the discussions that water pricing emerges as a formidable management tool. However, this topic has been covered in greater or lesser detail in other reports referred to, and it was desired to focus more strongly on other instruments which have as yet not had significant exposure. Furthermore the subject of water pricing remains a vast one, and it would not be feasible to do it greater justice within the confines of this report.

The remaining instruments considered fall into two categories; market and non-market related instruments. Market related instruments (such as tradable permits) have demonstrated their ability to allocate scarce natural resources in an economically efficient manner, provided that the market is not too thin and they are traded regularly. They therefore show promise as potential instruments for managing water quality.

Non-market related instruments are essentially charges, subsidies and taxes. These are command-and-control instruments and they have both strengths and weaknesses. Amongst their weaknesses is their inability to control players' entry to and exit from the market, and the fact that they do not intrinsically engender entrepreneurial activity. On the other hand, one of their main strengths is their ability to redistribute income, and they are therefore powerful instruments for dealing with issues of economic equity. A tax which is proportional to pollution discharge would be effective in motivating pollution abatement measures since reduced pollution discharge would lead to lower tax rates. If the onus were on the polluter to demonstrate this reduction in pollution discharge, then the administrative burden would also be lessened.

Economists generally favour market-related instruments over command-and-control instruments because they are considered to be cheaper to put in place and to administer. However, even given a market-friendly environment, tradable permits will not necessarily emerge as suitable instruments for water quality management, unless their performance can be properly monitored. In other words, it has to be demonstrated that the holders of permits are not exceeding the discharges allowed them in terms of their permits.

At this stage it cannot be categorically recommended that any one instrument, or in fact a mix of instruments, be used. Each proposed application would need to be considered individually. The next chapter examines a specific area and investigates a suitable mix of instruments for that specific application.

PART FOUR

A PRACTICAL APPLICATION

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FIGURES

TABLES

5. ECONOMIC INSTRUMENTS AND THE OLIFANTS RIVER CATCHMENT

5.1 INTRODUCTION

The primary thrust of this chapter of the report is to examine the Olifants River Catchment, its water quality problems and to postulate and test an appropriate set of economic instruments.

The overview of the study area establishes that sulphate emissions (both point source and non-point source) from mining activities in the catchment play a determining part in the water quality of the Witbank Dam, so economic instruments which can assist with management of this problem have been focused upon. Appropriate instruments are selected, and these are tested using two models that simulate market forces in operation in conjunction with these instruments.

A representative simulation exercise presupposes two main data sets, one relating to emission levels into Witbank Dam, and the other relating to emission abatement costs on the part of the mines. The first data-set uses information assembled by Wates, Meiring and Barnard (WMB)[1] and posed no particular problems. Data relating to individual mines' abatement costs, however, proved less tractable, despite efforts made by the researchers and members of the steering committee. As a result it was decided that the simulation should be used as an educative device aimed at increasing understanding among interested parties of the operation of economic instruments, rather than as a definitive problem solving exercise. Consequently a dummy data-set was postulated which enabled the integrity of the simulation models to be tested, as well as to clearly demonstrate the action of the instruments in practice. This having been done, the models are ready to accept real data sets (which would need to be assembled together with interested parties in a workshop-like environment) and they could then be used in an interactive, problem-solving mode.

5.2 OVERVIEW OF THE STUDY AREA

WMB have summarised the regional context as follows:

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1 Water Quality Management of Water Resources in South Africa, Department of Water Affairs and Forestry Report No. 1505/611/1/W, September 1993.

"The geographical extent of the upper-Olifants river, upstream and including Loskop dam is shown in Figure [5.1]. Several drainage basins, including Olifants River catchment, Klein-Olifants River catchment, Wilge River catchment and Klipspruit catchment are located upstream of Loskop Dam.

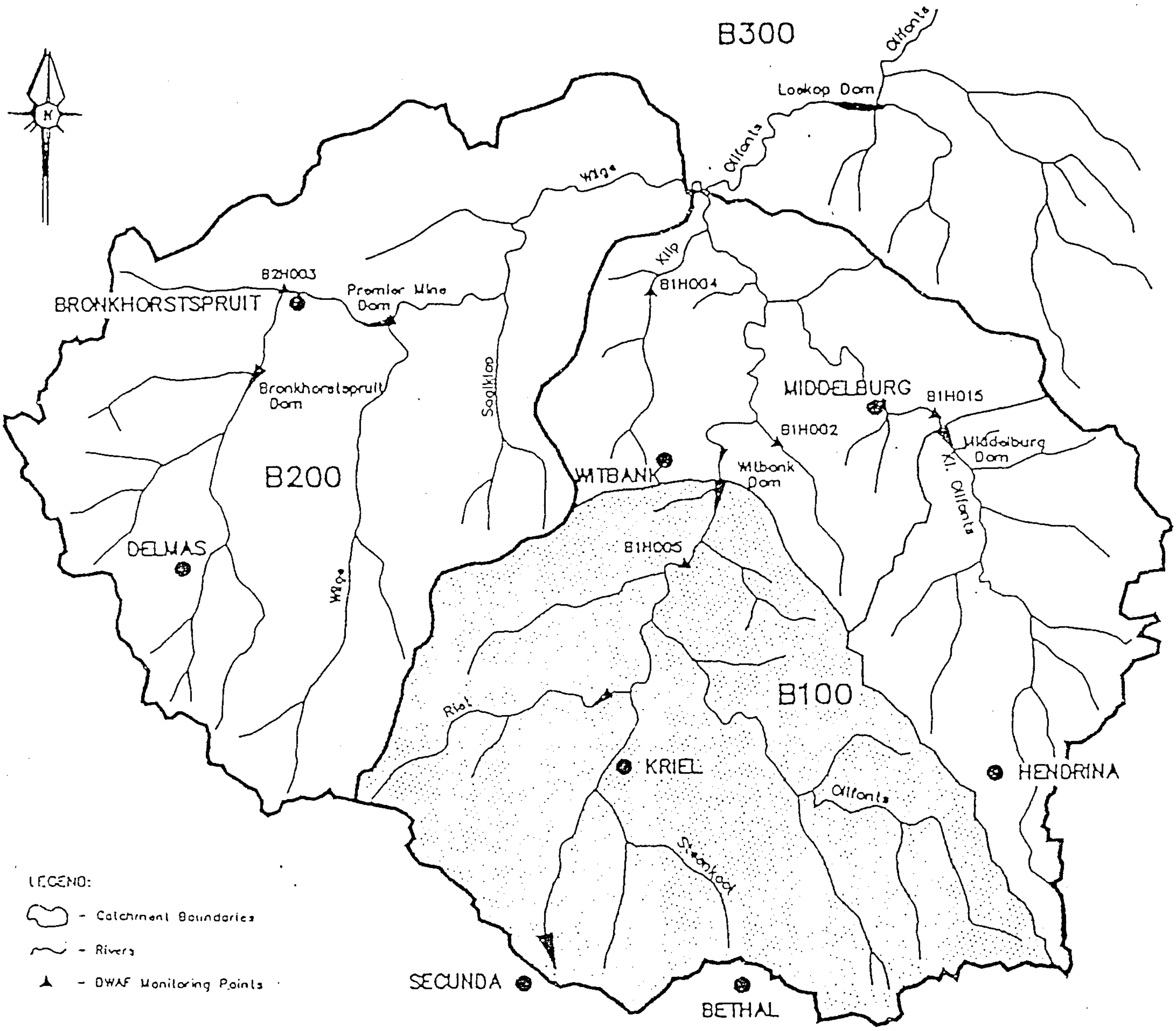

FIGURE 5.1: THE UPPER OLIFANTS CATCHMENT

An investigation into the sources of salinity and of specifically chloride and sulphate was conducted in the Olifants River upstream of Loskop Dam (WMB Report - Historical Water Quality Status and Trends in

Middelburg Dam dated November 1992). The investigation confirmed that the Olifants river catchment upstream of Witbank Dam is the single largest source of sulphate and chloride pollution; it is estimated that the Witbank Dam catchment contributes 41% of the chloride load exported to Loskop Dam."

In addition to the WMB report, the sources of sulphate[2] that are located in the catchment, and which result in the high sulphate levels of the Witbank Dam, are analysed in a Department of Water Affairs/ and Forestry/Eskom report dated 1989[3].

The findings are that agriculture, power generation and coal mining activities are responsible for the major sulphate pollution in the Witbank dam: their various contributions are discussed below.

Agriculture is believed to have the least impact, because agricultural activities are limited mainly to dryland farming and grazing. It must, however, be stated, that some irrigated agriculture can be found in the northern part of the catchment, downstream of Witbank Dam. It can be assumed that in this particular region the impact of polluted water on agriculture will be larger than the impact on water by agriculture itself.

Coal fired power stations emit sulphates in four ways:

1. particulate matter from smokestacks forms a minor source since the electrostatic precipitators are 95-99% effective.
2. discharge of excess blowdown to the streams
3. seepage from ash dams and coal stock piles
4. dust blowing from ash dumps and stockpiles onto the surrounding land

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2 It is estimated that the sulphate contribution form the Witbank Dam Catchment amounts to 44% of the total load exported from the Upper Olifants River to Loskop Dam. (Personal communication with Mr AM van Niekerk of Wates, Meiring and Barnard, 25/1/96).

3 Department of Water Affairs/Eskom, Investigation into water quality problems at Duvha, Arnot and Hendrina power-stations, Confidential report of the Joint Working Group on Water Supply Quality to the Transvaal Power-Stations, Report. No. E B100/00/0189, 1989.

Coal Mining contributes sulphates through:

1. mining operations such as excavation and blasting, which introduce sulphate rich dust into the atmosphere
2. point sources such as leachate and runoff from both active and abandoned spoils dumps and stockpiles, as well as pumped discharges from active open cast and underground mines.
3. non-point sources which essentially consist of runoff from areas immediately surrounding the active mining area.

WMB conclude that:

> "Non-point sources of pollution associated with coal mining activity constitute the single largest sulphate load contribution to Witbank Dam. Technology exists to reduce this source of pollution in the form of stormwater control, rehabilitation of waste dumps, collection and re-use of seepage and of polluted drainage. Diffuse source pollution control on coal mining complexes was identified as the most attractive approach to salinity management."

In total, the impact of power station effluents is judged to be small, estimated at 6.5% of the sulphate load entering Witbank Dam, while approximately 70.6% of the sulphate load entering Witbank Dam does so by way of drainage from areas influenced by mining activities. A large portion of this mining activity is concentrated in five zones, covering approximately 6% of the total catchment area. In the subcatchments affected by these zones, sulphate concentrations ranging from 200 to 2000 mg/l were measured during a 1987/88 survey, whereas in the subcatchments devoid of mining they ranged from 10 to 55 mg/l.

The increase of the sulphate content in Witbank Dam brings about considerable costs. One area in which increased cost can be attributed directly to the increasing sulphate content of the catchment is that of electricity generation.

Duvha power station, one of the important elements of Eskom's supply capability because of its ability to provide large quantities (3600 MW) of baseload power that is amongst the cheapest in the grid, was designed to draw a substantial quantity of its water requirements from Witbank Dam. In really severe drought conditions, Duvha would draw 100% of its water from the Witbank Dam.

However, Duvha was designed to accept water of the quality that pertained at the time construction of the station commenced in 1977, namely approximately 25 mg/l of sulphate concentration. This quality has subsequently declined to sulphate concentrations in excess of 100 mg/l, as a result of increased open cast coal mining, power generation and other land uses in the catchment, and there are fears that the quality could fall further as the expansion of coal mining continues.

This presents Eskom with three options: either to infringe the zero effluent standards to which the station was designed, to upgrade the station to deal with the reduced quality of intake water, or to bring in Komati System Water.

The first of these options is unacceptable to the Department of Water Affairs and Forestry (DWA&F), because any effluent discharged from Duvha would cause further deterioration in the quality of the water in Loskop Dam, which is used for the irrigation of salt sensitive crops. Consequently, in practice the increased sulphate loading confronts Eskom with whatever costs will be associated with the technical remedies that may exist.

5.3 SELECTION OF ECONOMIC INSTRUMENTS FOR CONTROLLING SULPHATE POLLUTION IN THE UPPER OLIFANTS CATCHMENT

5.3.1 Administrative options

In Chapter 4 and Appendix B the concept of a bubble, and the application of various economic instruments within bubbles, are discussed. Although the Water Quality Management Plan for the Witbank Dam identifies a number of Management Units, The catchment is still an attractive candidate for such a bubble, for the following reasons:

- the bubble outlet may be clearly demarcated by the Witbank Dam, or the inflows thereto, and monitoring facilities exist for pollution sources;
- the upstream polluters are essentially private sector organisations such as coal mines and possibly certain Eskom power stations; and
- the users affected by the sulphate pollution are limited to Eskom's Duvha Power Station, Highveld Steel and Vanadium and the Municipality of Witbank, both of whom abstract water from the Witbank Dam.

In other words, it is a system in which the main players are all capable of competing in a market-based system for pollution control.

Two possible administrative options exist for controlling sulphate pollution within the Upper Olifants bubble:

1. Control by a public sector authority using a combination of command-and-control and economic instruments to ensure the attainment of water quality goals, achieve a measure of cost-recovery and the establishment of incentives for self-regulation;
2. Autonomous control by a private sector body created by the polluters to manage emissions and achieve water quality goals on their behalf in an equitable manner.

The economic instruments that may be used by either the public sector authority or the private sector body are discussed in the following sections.

5.3.2 Operational costs of Economic Instruments Vs Command and Control

An important issue in considering the impact of using economic instruments, is the impact which the use of economic instruments may have on administrative cost structures vis-à-vis the impact of the existing control-and-command approach.

This section analyses the costs of the following approaches to water quality management in the Witbank Dam catchment:

- The conventional command-and-control approach i.e. total control by the water authority
- A joint venture between the water authority and the polluters as proposed by WMB
- An economic based approach using 'green taxes' and tradable emission permits

The cost analysis focuses on the financial costs of establishing and operating the various systems and takes into account issues such as cost of monitoring and administration expenses.[4]

In the CAC approach the authority takes total responsibility for setting maximum emission standards for each polluter, monitoring the levels of emissions by each polluter, and setting an appropriate penalty if maximum emission standards are exceeded.

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4 Full details of the scope and calculations involved in this analysis can be found in Appendix A of this document.

In the economic based approach rather than set a maximum emission standard for each polluter, the authority would set a water quality standard for the catchment. Each polluter in the catchment would then be allocated a tradable permit that would allow a certain amount of emissions, with a penalty being imposed for exceeding this limit.

The analysis assumes data as presented in WMB, that data needs will not differ for the various management approaches, and that existing infrastructures will be used as far as possible.

If it is accepted that the data requirements for the various management approaches are the same, it follows that the costs for establishing infrastructure and operation of the systems will also be the same. The allocation of the costs will however differ.

The only difference between the CAC approach, the joint venture approach and the economic based approach will be the costs associated with permit trading, and these would in any case be reflected in the permit trading price, and would not influence institutional administration costs.

The total costs incurred[5] were calculated and distributed between the players. The results are summarised in Table 5.1 below.

Item	Cost R million DWA&F	Cost R million Role Players	Total Costs
Building of Weirs	R 0,176	R 5,280	R 5,456
Cost of Instrumentation *	R 0,458	R 1,533	R 1,991
Operational Expenses	R 1,865	R 6,244	R 8,109
Total (1994 Rand)	**R 2,499**	**R 13,057**	**R 15,566**

* Includes Replacement Costs

TABLE 5.1: ALLOCATION OF WATER QUALITY MANAGEMENT COSTS

5.3.3 Water demand management instruments

Pricing as a water quality management instrument has been discussed in section 6 in general terms, but brief mention needs to be made here in the context of the mining community in the Olifants River catchment. Since water only constitutes a

5 These operational expenses are the capitalised costs discounted over 45 years.

small proportion of the production cost, the mining industry may be able to absorb substantial price increases without significantly increasing production costs. In 1986 the Directorate of Planning of the then Department of Water Affairs commented "The cost of water to the mining industry is 0.7% of the total cost of stores purchased. The Chamber of Mines has stated that the cost of water as an input to the mining industry is minimal in comparison to other inputs and even a doubling of tariffs would be acceptable." [6] Thus appropriate pricing levels for water could help to reduce pollution by promoting it to the status of a valuable resource which it is not economic to pollute and discard, whilst still not increasing production costs significantly.

A viable water market is often seen to go hand-in-hand with pricing reforms. Reference has been made to the water quality benefits of water marketing in Chapter 2 section 2.4. This possibility can now be examined for the Upper Olifants catchment. In mining, wastewater is either discharged to the stream of origin or recycled. Also contaminated water drains from the surface of the mine into natural watercourses. Assuming a theoretically 'perfect' market, i.e. a deregulated market with many players, no monopolies, and complete information availability, the control of pollution by water marketing could be a useful option for the Upper Olifants catchment. By selling a limited amount of surface and ground water abstraction quotas at a market price, an incentive would be created to maximise water utility and thus reduce mine drainage. It is worthy of note that it is not advisable to create a water market in areas where the market is "thin" (i.e. too few completely independent players). This may indeed be the case in the upper Olifants river basin.

5.3.4 Water quality management instruments

Before embarking on a discussion of water quality management instruments, it is well to bear in mind that for any system of management to be effective, it is necessary to be able to measure the results of any activities or results in order to be able to assess the effectiveness of the management system, and to provide the feedback signals to keep the system on track. This is equally true when using economic instruments as management tools. Unfortunately, non-point (or diffuse) source pollution features greatly in the discussions to follow, and this is notoriously

6 Department of Water Affairs, Directorate of Planning, BE Hollingworth, Vaal River System Analysis, Review of User Economics, prepared by BLS in association with SS&O, Johannesburg May 1986, report 4161/20.

difficult to measure and accurately apportion. Whilst not militating against the use of economic instruments, this measurement problem needs to be borne in mind at all times, and will be revisited from time to time as the discussion evolves.

5.3.4.1 Water quality standard setting

The first step in the establishment of a bubble is the determination of the "optimal level" of pollution that must emanate from it. The optimal level of pollution in a bubble can be equated with the optimal aggregate discharge level, which considers all dischargers of a specific pollutant, in this case the sulphate emitters of the Upper Olifants catchment. However, it must be borne in mind that "hot-spots" or areas of high pollution concentration may occur within the bubble, as the individual emission levels are not prescribed, but only the total emission from the bubble. Each proposed bubble needs to be analysed individually to ensure that unacceptable hot-spots are not likely to occur in practice.

5.3.4.2 Tradable permits

In order to disaggregate the total pollutant load, discharge permits have to be allocated to the various point sources of sulphate pollution. These permits allow a polluter to discharge a certain amount of pollutants over a given period of time into the water system. It is envisaged that these permits should be marketable instruments and that trading of them should be able to take place. It is a debatable issue whether these permits should in the first instance be sold, auctioned or issued free of charge to the respective polluters in the bubble[7]. Following the arguments of pollution permit trading, polluters with a comparative advantage with respect to effluent reduction could gain from selling permits - or parts thereof - to polluters with a comparative disadvantage within the bubble.

As there is only one type of pollutant that is being targeted in this study, the trading of permits is probably a feasible option, despite the possibility of a "thin" market. The reason for this is that the various players are all known, and their respective contributions to sulphate pollution should be capable of being determined. Thus information about trading partners, which is one of the requirements for a market to function effectively, ought to be accessible. In order to avoid monopolisation of and covert lobbying for permits in a "thin" market, the permit trading controlling body

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7 For a discussion of benefits and disadvantages of different methods of issuing pollution permits, see WRC 1993.

should either be completely neutral or should represent the interests of all the polluters.

Any effluents discharged without a permit allowance should become subject to charges imposed by the body controlling pollution within the bubble. These are discussed in the next section.

5.3.4.3 Effluent charges

Effluent charges must be imposed on all monitored effluent discharges for which permits are not held. These must eventually be set at a level that discourages all but the most accidental and unforeseen discharges.

However, to ease the burden on polluters in the initial stages of a charge system, (i.e. when they are least prepared for the likely costs) a transition period is envisaged. For example, charges could be introduced in three phases:

- **Period A:** set a very high standard for unpermitted effluent discharges but adopt a relatively low pollution unit price;
- **Period B:** lower the standard set in Period A but increase the pollution unit price; and
- **Period C:** impose target standard and unit price.

This periodic phasing-in of charges has the advantage that the cost burden on polluters is phased in gradually. The costs during the first period will be relatively low, giving industry time to adjust to the additional responsibility and potential costs, whilst giving emphasis to the control of point-source effluents.

As indicated in the preceding sections, the enforcement of effluent charge systems, is a major concern and has led to a number of pollution charge policies becoming unviable. As the only way to enforce a charge system cost-effectively is to require the polluter to declare any unpermitted discharges on a regular basis, some sort of penalty/incentive mechanism needs to be in place. A combination of the following two penalties have been used to great effect in Germany:

1. If companies fail to comply with the requirements of the system, a high financial penalty will be imposed on them;
2. The regulatory authority is given powers to estimate the unpermitted effluent discharge level for non-complying firms and to set charges retrospectively.

To support the authenticity of the effluent discharge declarations, environmental audits, carried out either at random or when the need arises, by an independent organisation, would serve as a good monitoring instrument. Such audits could be commissioned by the bubble controlling authority, but financed by the polluter.

5.3.4.4 Taxing polluting activities (Green Taxes)

Controlling non-point source pollution in the Upper Olifants catchment is an important aspect of water quality management, since the pollution from the mining activities can be, to a significant extent, of a non-point nature.

If the findings of Chapter 4 on use of economic incentives to control non-point source pollution from agriculture are transferred to the upper Olifants catchment, a set of strategies can be developed which may prove cost-effective.

Since authorities find it difficult and expensive to monitor non-point pollution, the introduction of a 'Green Tax' on the extent and severity of the polluting activity is a viable idea. This can and is achieved in a number of ways: the tonnage of coal mined, the sulphate content of the coal mined, or the spatial extent of the mining activity (i.e. area of sulphate rich material exposed to rainfall). However, it should be understood that green taxes represent a 'stick and carrot' approach to non-point source pollution control. Thus, while taxes are levied on activities which result in non-point source pollution, tax rebates must be given for those activities which reduce non-point source pollution or convert it to point source pollution to be controlled by permits and charges, i.e., the tax applied is related to the pollution abatement activities implemented. These activities could include mine management practices such as drainage works, overflow basins, interception of runoff from spoil dumps or their rehabilitation etc. Mines that can demonstrate that they are applying sound management practices to counter sources of non-point pollution would thus be taxed at a lower level, thereby giving them a comparative advantage over mines that have poorer management practices so far as pollution control is concerned. A similar result would be achieved by coupling non-point and point source pollution and allowing offsets between the two (e.g. permit for one free unit of point source discharge for every two units of non-point source pollution halted or converted.

The important issue is that it is the mines themselves that have the technical expertise to know which practices will be most cost-effective in achieving a given standard. Of course standards have to be set so as to offer guidelines for mine-based pollution abatement policies. Consequently, the controlling agency should determine the estimated pollution run-off from mines including the relative contribution of non-point and point sources to deteriorating water quality. Based on this assessment target levels for point source and non-point source pollution can be set.

5.3.5 An Economic Instrument Mix

It is now sought to seek an economic instrument, or mix of instruments which could best meet the needs of water quality management requirements in the Upper Olifants catchment. The main characteristics of the area for the purpose of this exercise are:

- Only one type of emission (sulphates) is being considered;
- The pollution dischargers are engaged in similar activities, using similar production processes;
- The area can feasibly be regarded as a bubble; and
- There is a high percentage of non-point source pollution.

The chief benefits sought from a water quality management system in the catchment would include:

- Effective management of non-point source pollution discharge;
- Ease and cost-effectiveness of administration;
- A measure of autonomy for each individual player in determining his pollution management strategy in order to minimise his costs;
- A revenue neutral system;

Careful examination of the economic instruments described reveals that a judicious choice of a mix of instruments could well go a long way to satisfying these requirements.

One of the chief difficulties in managing pollution in the catchment is the fact that so much pollution is of a non-point source type. This means that measurement of discharges cannot by done directly, and without measurement, it is not possible to exercise any control over discharges. Indirect measurement of non-point source discharge can be made, for example, by taking the difference between up-stream and down-stream pollution measurements. However, it is not necessarily simple to apportion this burden to any specific players, since by the time the run-off reaches the dam, there may have been several contributors. There is thus a compelling need either to encourage conversion of non-point source pollution into point source, or to develop methodologies which would allow these non-point source emissions to be allocated amongst the players so that when changes in emissions occur, those responsible can be clearly identified. A "green" tax which is related to abatement practices would encourage this aim, since reduction in emissions would have to be demonstrated to gain any relief from the tax.

However, as will be demonstrated later in this section, these green taxes will interact with individual players' abatement costs, and will only stimulate abatement to a certain level, beyond which there is no motivation to go. Any changes in the level of abatement desired by the authorities would have to be accompanied by a change in the tax structure - not leading to very easy or efficient administration.

An instrument is required which will result in greater motivation amongst individual players to meet (or even exceed) the emission standards set, whilst also providing a measure of individual autonomy to the players, is required. Tradable permits fit these requirements well. Provided that a bubble with sufficient players can be established, and that overall emission standards are met, permits can be bought and sold, thus leaving the decision as to whether to institute abatement or purchase permits up to the individual players. Market forces govern these exchanges, so additional administration is not required. An additional advantage, which is not intuitively obvious, is that efficient trading of permits will also yield a financial advantage to players vis-à-vis the command-and-control system.

Tradable permits may be used on their own, or used in conjunction with other instruments. Whilst tradable permits as management instruments will fulfil most of the needs mentioned above, it is felt that the addition of a green tax to add urgency to the requirements of rationalising diffuse source pollution would be an advantage.

It is thus intended in the ensuing discussion to explore the theory of using "green" taxes and tradable permits, and to demonstrate their operation in conjunction by using a pair of models. The object of the exercise is to convince the reader that these two instruments are viable in a simulated situation, and that the economic benefits mentioned above do in fact accrue.

5.4 ECONOMIC INSTRUMENTS IN ACTION

5.4.1 Philosophy

Later in this section two mathematical models which demonstrate the action of "green" taxes and tradable permits operating together in an area such as the Upper Olifants catchment will be presented. The purpose of this discussion is to provide a basic understanding of the principles that underlie these models.

5.4.1.1 Marginal Costs

Crucial to an understanding of market clearing prices in the case of tradable permits is the concept of marginal costs. Ideally marginal cost is a measure of the value to society of the extra resources required to produce another unit of output in a particular time period. It is a money measure of the value of the output sacrificed elsewhere by producing another unit of the good. In terms of economic efficiency the general presumption is that if the price which a consumer is willing to pay for another unit exceeds the value of the extra resources required to make it, then the allocation of resources will be improved if that unit is produced and vice versa. In other words, in any production process, a manufacturer will make a component in-house if his marginal production costs are less than the market price of that component, if not he will buy it in.

5.4.1.2 Tradable Permits

Exactly the same logic applies when we consider using tradable permits for water quality management. All that is needed is to be able to imagine a market in "clean-ups" and how it might work[8]. In this instance a "clean-up" is nothing less than a unit of pollution abatement, and it is analogous with any component produced in-house in any production process.

In explaining this concept in further detail, reference is made to Fig 5.2, which is an idealised curve relating the price of clean-p to the quantity of emission abatement. The underlying assumption is that cost will in an exponential fashion as emission abatement increases.

Consider "clean-up" units in conjunction with pollution permits. If a mine has, for example, permits which allow 10 units of pollution to be discharged and it is currently producing 10 units of pollution, it does not necessarily need to discharge all of those units. If it has the ability, and this were economically viable, it could instead control 6 units of pollution by way of abatement measures. This means that there are now permits for 4 units of emission which are not being used. These could be sold at an appropriate price to another player who was not able to implement sufficient abatement measures. In so doing 4 units of clean up would effectively be changing hands.

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8 This description is deliberately kept qualitative. A quantitative description with a numerical example is included in Appendix A.

When the marginal costs of abatement for any particular player are greater than the prevailing costs of permits (i.e., point D on the marginal cost curve in Fig 5.2), he will choose to buy permits rather than institute the required abatement measures himself (his saving will be DE), and a demand for permits is thereby created.

If his marginal costs of abatement are greater than permit costs (i.e., point B on the marginal cost curve in Fig 5.2), then he will rather choose to carry out abatement measures and sell his excess permits (his profit will be AB). A supply is thus created.

In this way permits will be traded until no player perceives an advantage in acquiring more permits, or indulging in additional abatement in order to be able to sell permits.

It will be demonstrated when the trading model is exercised that the actual costs of abatement will tend to fall in individual cases (or the outcome may be neutral) and any savings from instituting abatement measures obviously translate into additional profits. In addition, the control of the abatement initiatives remains in the hands of the individual players insofar as the decision as to whether to abate or go the permit route is theirs alone, and depends upon their individual production functions.

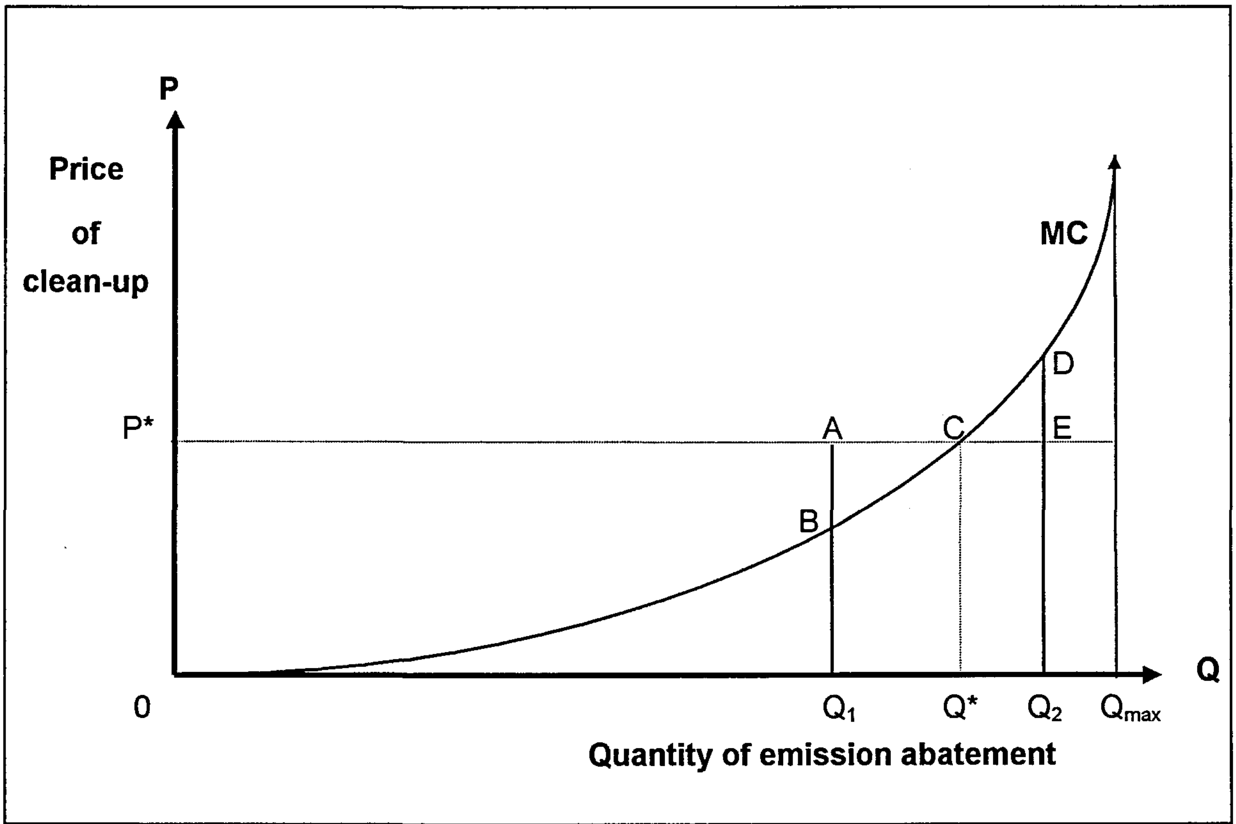

FIGURE 5.2: MARGINAL COSTS OF EMISSION ABATEMENT

Any would-be new entrants to the market in a bubble would have to draw on the same stock of permits available at the time to meet their pollution discharge needs. It is not envisioned that the authority would issue more permits to allow for additional players; this would in fact be sanctioning increased pollution activities when the drive should be for reduced activities. New players would therefore increase the demand in the market place for permits, thus driving their price up. The increased price should spur existing players to seek new abatement techniques in order to release permits for sale at this increased price. Thus new players are not excluded, as they might well be under a control and command system where allowable pollution discharge is fully subscribed. What happens instead is that market forces stimulate more efficient abatement techniques by driving permit prices up, thus creating "space" for more players.

It is possible that there will be a temptation for some players to buy and hoard permits, either as a speculative activity, or to attempt to keep new players out of the market. Anyone wishing to do this would of course have to take into account the costs associated with holding unused permits. One form of hoarding which could occur, and which would be difficult to combat, would be the buying-up of permits by green movements with the express intention of keeping them out of circulation, and thereby forcing a reduction of pollution levels in the dam. Whether or not such movements would be capable of raising the necessary funds to undertake such a venture is problematic, but in theory the system gives them the opportunity to "put their money where their mouths are".

5.4.1.3 "Green" Taxes, and Abatement Costs

A green tax would be of the form shown in Fig 5.3. It will be seen that the green tax operates on a sliding scale and works in the opposite sense from the abatement cost curve. At zero abatement levels, the green tax is pitched at an extremely high (punitive) level to obviate the possibility that players may choose simply to pay the tax rather than to implement abatement measures. As increasing levels of abatement are introduced and their effectiveness demonstrated, the green tax falls off.

The effect of an additional (green) tax on industries whose prices are set internationally, rather than by local markets (for example gold mines) requires serious consideration by authorities. Such industries are not able to adjust their selling prices to accommodate the extra drain imposed by additional taxes. They can only offset the effect by means of increased efficiency or reduced profits. Should there come a time when these courses of action are no longer possible, then the only way open may be to cease production.

In practice each player will play off the rise in his abatement costs against the fall in green tax until some equilibrium level is demonstrated. If the green tax and the cost of implementing abatement measures are both regarded as costs of discharging pollution, then a composite cost curve emerges, as shown in Fig 5.4, with the equilibrium position being the lowest point on the curve. Such a composite cost curve will form the basis of the tradable permit model.

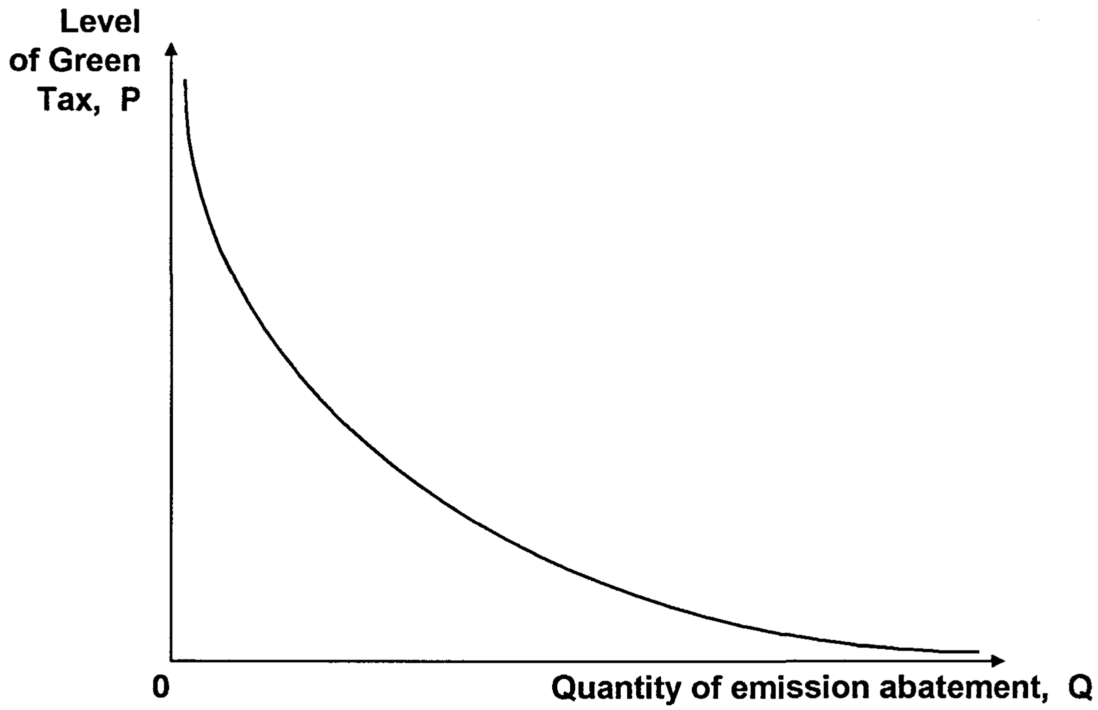

FIGURE 5.3: TYPICAL GREEN TAX CURVE

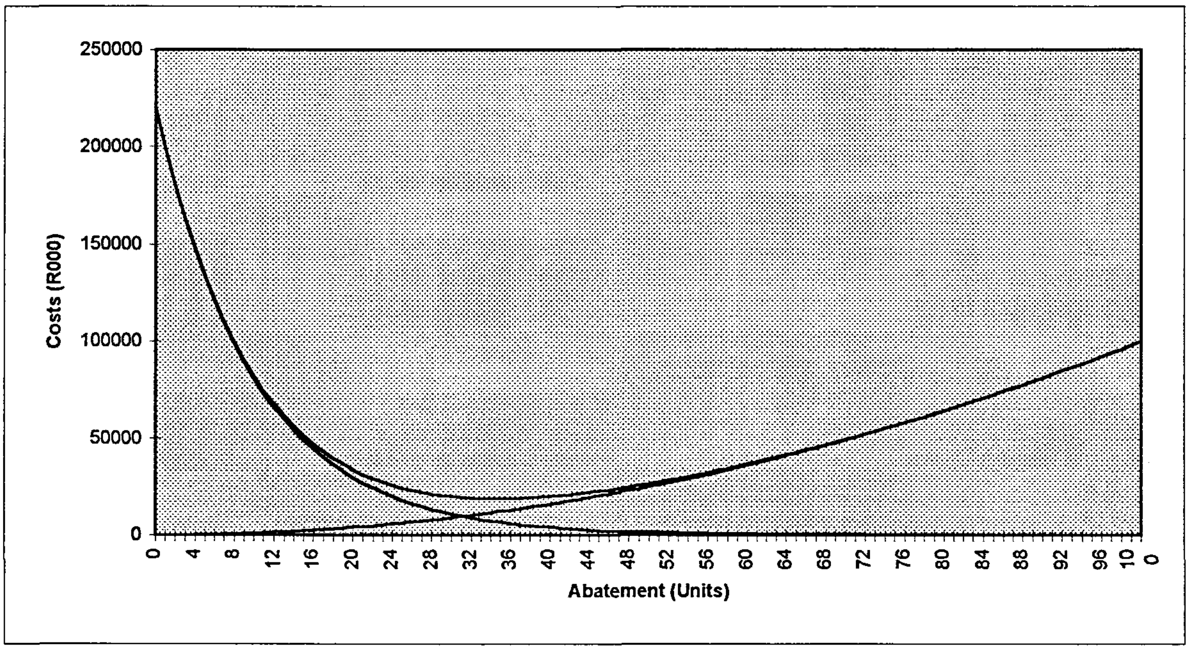

FIGURE 5.4: COMPOSITE GREEN TAX - ABATEMENT COST CURVE

5.4.2 The Players and the arena

5.4.2.1 The Pollution scene

5.4.2.1.1 The environment

Wherever economic activity is taking place, there is likely to be some adverse effects on the environment. Consequently, there is ongoing conflict between those who seek to preserve the environment, and those whose aim is to promote economic growth. Resource economics seeks to mediate in this conflict by looking for trade-offs between these two apparently incompatible goals. The very word trade-off implies some compromise, so clearly the aims of neither party can be completely met.

From an economic viewpoint, therefore, a total absence of pollution is not the primary objective: it involves no trade-off. The environment generally has the ability to absorb a certain amount of pollution without necessarily setting it on an irreversible downhill journey to destruction. This pollution burden, which we will refer to as the maximum sustainable pollution load (or MSPL) should be what we strive to maintain. If acceptable economic growth can take place without exceeding the MSPL then the environment will not sustain irreversible damage; i.e., the situation will be sustainable.

5.4.2.1.2 The polluters

The mining of coal entails the release of sulphate rich material that tends to be transported into natural waters. Where these waters empty into dams that are used by a community for various purposes, great attention must be paid to the control of such pollution.

To preserve the ecology of the dam environment, and maintain the quality of the water drawn off from the dam, the pollution discharge must never be allowed to exceed the MSPL. Excessive pollution of the dam can result in irreparable damage to water using activities and the economy of the region.

To control this pollution, however, presupposes some knowledge of the actual discharges from various sources. Since pollution is normally of two types, point source and diffuse source, this is not always the case. Point source pollution emanates from a known point and is therefore capable of being monitored. Diffuse source pollution, which is created by leaching through soil or dispersion through the air does not lend itself to easy measurement. Clearly, the more pollution that can be of the point source type, the easier it is to assess whether the MSPL is being exceeded.

5.4.2.1.3 Sustainability

Where there are several mines operating in the same area, the MSPL must be divided between them in some equitable fashion if sustainability is to be achieved. Each mine should be assessed for its pollution potential. This potential could be based on the area of the mine, the average sulphate concentration of the soil and the natural slope of the land towards the water, amongst other things. (Pollution potential here means the expected tonnage of sulphate to be released during mine operation).

This activity, however, only sets the limits that are necessary for sustainability. Unless pollution can be monitored, as indicated earlier, it is not possible to ensure that these limits will be observed.

5.4.2.2 The Environmental Management Problem

5.4.2.2.1 The Authority

The message that emerges from these discussions is that there is a need to monitor pollution discharge if there is to be any control of water quality by the authorities. A key issue for them is to try to convert as much diffuse source pollution into point sources, so that effective monitoring can be carried out, or to implement methodologies for tracing diffuse source pollution back to its originators. The focus can then shift to the introduction of abatement measures to reduce the actual discharge from these point sources.

5.4.2.2.2 The Players

The mines, whilst they may be sympathetic to environmental sustainability desires, have rather different goals. They want to maximise profits. Seen in the light of environmental sustainability, this means that they want to minimise the costs of pollution abatement measures.

The mines also desire to maintain their autonomy in the matter of environmental management. That is they wish to minimise interference by authority on how they manage their abatement practices. They also want to able to use any competitive edge they may have in their individual abilities to implement abatement strategies to their own advantage (and profit).

5.4.2.2.3 Modus Operandi: interaction between players and authority

These sometimes-conflicting requirements can be satisfactorily addressed through the medium of fiscal instruments. The choice of appropriate instruments can:

- permit individual autonomy of individual mines in planning their approach to pollution abatement;
- encourage pollution abatement using profit motives; and
- minimise administration by authority.

The key to success in the use of fiscal instruments is to select the most appropriate instrument in each case for the job in hand. Previous sections of this project identified a combination of two instruments as being the most suited to this situation, and these are:

- *green taxes* for the control of *diffuse source pollution*; and
- *tradable permits* for the control of *point source pollution*.

5.4.3 The Models

5.4.3.1 Introduction

Two models have been developed to demonstrate the action of economic instruments. The first, a Marginal Cost Model (MC model) is effective in demonstrating graphically in a spreadsheet environment the mathematical and economic principles involved in the application of green taxes, and creating a market for emission permits. However, this model gives no intuitive feeling for what is happening during the trading process, and it is also somewhat restricted as to the number of players it can accommodate.

For this reason, the second model, a Simulation Model was developed in parallel. This model, which will take the trading process from the point where the first permit changes hands through to where market equilibrium is achieved, will also serve to validate the results generated by the spread-sheet model. In addition, it will be able to accept more wide-ranging and sophisticated data sets and it should be able to be used effectively should on-the-ground problem solving be required.

5.4.3.2 Principles

The following broad principles apply to both models as presently implemented.

Each player will have a maximum pollution emission level that he may not exceed.

In the absence of point source (measurable) discharge, total pollution load will be taxed at green tax rates. These rates will be pitched sufficiently high to encourage conversion from diffuse source to point source pollution.

As abatement takes place and reduction in pollution discharge is demonstrated, the green tax is reduced. Green tax will thus be the first motivation for mines to institute demonstrable abatement measures. Balance sheet bottom-line considerations will automatically drive all players to this abatement level, as can be seen from Fig 7.4 above. Pollution permits become effective at this point, and from there on, any player may only discharge effluent *provided* that he has sufficient permits to cover the discharge.

Permits will be then be traded according to the economic precepts laid down above. The motivation to trade will be the decrease in abatement costs and consequent increase in profitability.

In order for trading to be possible, there must be differences in the abatement costs of each player, and these are simulated in the models.

5.4.3.3 The models in action

The models will accordingly be run as follows:

- Permits are distributed according to the criteria mentioned above.
- The model trades permits until equilibrium amongst the players is achieved.
- Perturbations are introduced (new players, players falling out, authority moving the goalposts, etc.).

The goals that can be achieved are:

- to demonstrate a market for tradable permits in action;
- to determine whether there are circumstances under which the market fails;
- to determine whether, or under what circumstances, costs of abatement measures are minimised;
- to explore the implications of the green tax, and to establish appropriate values for it; and
- to investigate to what extent the system can suffer perturbations and still remain stable.

5.4.3.4 Assumptions

- The game will be played strictly according to market principles: There will be no hoarding or speculation.
- All mines will be assumed to be equal except with regard to their abatement costs, surface area and sulphate richness.
- Production functions (i.e. abatement costs) will be quadratic, and green tax curves will be exponential.
- The field will be restricted to five players.
- Initial distribution of permits will be free.

5.4.4 Operation of the models

5.4.4.1 The Marginal Cost Model

The philosophy underlying the operation of the Marginal Cost Model is described in some detail in Appendix A. In summary, the system of equations presented in Figure A2 of Appendix A is augmented to incorporate a green tax, and to allow for five rather than two players. The green tax curve is common to all mines, but abatement costs differ for the individual mines. This difference in abatement costs between mines is necessary to allow permit trading is to take place.

In order to demonstrate the principals of permit trading, the curves chosen have been given rigorous mathematical forms, but it should be noted that in practice abatement curves are likely to be non-linear and probably discontinuous. However, the spreadsheet approach can accommodate itself readily to virtually any data set, since solution is dependent upon look-up tables and not mathematical solutions. Thus data which would arise in practice can be readily incorporated into the model when they become available.

The procedure adopted in the MC model is to use spreadsheel lookup tables to parallel the graphical procedure which was detailed in section A.3 of Appendix A. To accomplish this, the curves shown graphically in Figure A4 are converted into tables that are accessible to, and can be manipulated by, macros embedded in the spreadsheet model. However, whereas graphical curves are continuous, look-up tables comprise a finite number of discrete points. The fact that the tables thus represent non-continuous curves introduces truncation errors into the look-up process. The severity of these errors can be lessened by making the intervals between individual entries in the tables as small as possible. Additionally, in order to reduce these errors, it is necessary to allow the model to deal in fractions of a permit. This would not occur in real life, but the problem is readily overcome by issuing, say, 100 permits instead of only one for a given amount of pollution emission. Nevertheless, this truncation error, combined with rounding errors introduced in getting back to whole numbers of permits, accounts for differences in results between this model and the Simulation model described below.

5.4.4.2 The Simulation Model

The Simulation model uses the same data-set and curves as described above for the MC model. However, solution is found not by table look-up, but by simulating successive rounds of trading between the players. There are two main reasons for setting up this parallel model in support of the Marginal Cost model:

- To provide a demonstration of the trading process which is intuitive in its operation, and divorces itself from the principles of marginal costs; and
- To provide an alternative calculation of the clearing price of permits, which can be used to verify the results obtained from the Marginal Cost model.

Having established the desired level of abatement desired, the model operates by postulating the presence of an Auctioneer who proposes a market price for permits and calls for offers to buy and sell at that price. The individual mines then calculate their abatement costs at the given level of abatement and determine whether it is cheaper for them to implement the abatement required, or not to abate and to buy additional permits to cover excess discharges.

If there is an excess of potential buyers over sellers, then the price set by the Auctioneer is too low, and he proceeds to set a higher price and vice versa. The calculation to determine potential buyers and sellers proceeds again based on the new permit price, and the ratio of buyers to sellers is once again observed. This process proceeds, with a change of permit price at each round, until there is an equal number of potential buyers or sellers at the given permit price. In economic terms this is now the situation where supply equals demand, and the price arrived is in fact the equilibrium price, or the market clearing price.

5.4.5 Comparison of Output from Models

The workings of the models are described in greater detail in Appendices A and F, but to expose the reader to their implications and to compare their output, one case of pollution abatement will be examined in detail here.

The following input data was run through both models:

- Maximum potential pollution from each mine .....100 units
- Abatement desired per mine ....70 units
- Number of permits issued to each mine 30
- Number of mines 5
- Total abatement required for bubble ....350 units
- Total number of permits issued to bubble 150

The amount of abatement desired was entered, and the models then calculated the market price of permits. Additional calculations included the number of permits changing hands, and the potential savings brought about by trading permits as opposed to being subject to a CAC regime are detailed[9].

The output data as obtained by exercising both models is presented in Tables 5.2 and 5.3. An identical format has been chosen for the presentation of the output from both models so that inconsistencies in the output can be more readily detected and discussed.

It will be seen from the summary block at the bottom of Tables 5.2 and 5.3 that the market price of permits calculated by both models for an overall abatement level of 350 units is the same, viz. R955. The actual amount of abatement implemented by each mine also agrees for the two models, if the results for the MC model are rounded to the nearest permit.

The output from the two models which is set out in the upper block of tables 5.2 and 5.3 will be seen to contain some discrepancies. In the case of the MC model, calculations are based on the trading of fractions of permits as described above. This approach is unfortunately necessary in order to contain the truncation errors as much as possible, but this, together with the discontinuous nature of the look-up tables inherent in the MC model, does contribute to discrepancies between the two models. However, it can be seen that the total difference in potential savings between the two models is R887, which is less than the cost of a single permit. The overall resolution cannot be expected to be better than ±1 permit, so this deviation is to be expected. Furthermore, this represents an error of only 3% of the total number of permits traded.

The final critical issue is to determine whether the trading of permits has resulted in any benefits to the players, vis-à-vis what would have occurred under a command and control approach. This information is encapsulated in the last line of the first block of Tables 5.2 and 5.3, where the potential savings are detailed. These savings are calculated by taking the difference between the cost of the legislative approach (where abatement requirements are equally spread) and the outcome after trading has taken place. It will be seen that a benefit does accrue, both to the

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9 The cost of the legislative (command-and-control) approach assumes that the abatement requirement (350 units) is divided equally between all players, giving 70 units per mine.

bubble as a whole, and to the individual players. Admittedly, the benefit to mines B and C is minimal (less than the cost of a single permit), and the outcome from their point of view could be regarded as neutral. However, the potential savings to the complete bubble is of the order of the cost of 10 permits, and therefore not trivial.

More data from various runs of both models are contained in Appendix E, should the reader wish to carry out similar analysis to that described above on a more diverse range of output[10].

10 If this data is examined, it will be observed In general that in all cases there is a saving to the economy as a result of trading, and a saving (or a neutral outcome) to the individual players. The instances where a small loss is shown to accrue to some players (notably mine C) can be attributed to truncation errors in the look-up procedure employed in the MC Model.

TABLE 5.2: OUTPUT FROM THE MARGINAL COST MODEL

MARGINAL COST MODEL OUTPUT 350 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 24 690.86	**R 30 815.86**	**R 36 940.86**	**R 43 065.86**	**R 49 190.86**	**R 184 704.28**	Cost of legislative approach
R 45 702.33	R 37 241.31	R 32 672.44	R 30 282.01	R 29 274.63	R 175 172.72	Cost of abatement instituted
25.66	7.16	(4.24)	(11.74)	(16.84)	0.00	Number of permits sold (bought)
R 24 505.30	R 6 837.80	R (4 049.20)	R (11 211.70)	R (16 082.20)	R (0.00)	Cost of permits sold (bought)
R 21 197.03	**R30 403.51**	**R 36 721.64**	**R 41 493.71**	**R 45 356.83**	**R 175 172.72**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 3 493.83	**R 412.34**	**R 219.21**	**R 1 572.15**	**R 3 834.02**	**R 9 531.56**	Potential savings (cost of legislative approach less actual abatement costs)
30.06	30.06	30.06	30.06	30.06	150.30	Permits issued to cover allowable emissions
4.40	22.90	34.30	41.80	46.90	150.30	Actual emissions (based on marginal costs)
95.60	77.10	65.70	58.20	53.10	349.70	Actual implemented (based on marginal costs)
25.66	7.16	(4.24)	(11.74)	(16.84)	0.00	*Excess (deficit) of permits*

Abatement desired	**350**
Permits issued	**150**
Market price of permits	**955**

TABLE 5.3: OUTPUT FROM THE SIMULATION MODEL

SIMULATION MODEL OUTPUT 350 UNITS OF ABATEMENT DESIRED

COSTS												EXPLANATIONS
MINE A		MINE B		MINE C		MINE D		MINE E		TOTAL		
R	**24 691**	R	**30 816**	R	**36 941**	R	**43 066**	R	**49 191**	R	**184 705**	Cost of legislative approach
R	46 085	R	37 146	R	32 960	R	30 092	R	29 179	R	175 462	Cost of abatement instituted
	26		7		(4)		(12)		(17)		0	Number of permits sold (bought)
R	24 830	R	6 685	R	(3 820)	R	(11 460)	R	(16 235)	R	-	Cost of permits sold (bought)
R	**21 255**	R	**30 461**	R	**36 780**	R	**41 552**	R	**45 414**	R	175 462	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R	**3 436**	R	**355**	R	**161**	R	**1 514**	R	**3 777**	R	9 243	Potential savings (cost of legislative approach less actual abatement costs)

30	30	30	30	30	150	Permits issued to cover allowable emissions
4	23	34	42	47	150	Actual emissions (based on marginal costs)
96	77	66	58	53	350	Actual implemented (based on marginal costs)
26	7	(4)	(12)	(17)	0	Excess (deficit) of permits

Abatement desired	**350**
Permits issued	**150**
Market price of permits	**955**

PART FIVE

CONCLUSIONS AND FUTURE DIRECTIONS

CONTENTS

6. CONCLUSIONS AND FUTURE DIRECTIONS

6.1 CONCLUSIONS

This report has examined current literature on water pollution and economic instruments that can be used to control it. Of the instruments reviewed, water pricing, green taxes and tradable pollution permits were recognised as being appropriate for use in the South African context.

Water tends to be seen by the public in general as a "free good". It is seen as having been placed on earth for the use of its inhabitants, and therefore no price should be associated with it. As a result of this perception, water users are not motivated to conserve water (there is no price signal to assist them) and there is a tendency to use water, pollute it, and return it to source. Once again there is no price signal to indicate that it is a scarce resource, or that there might be economic benefit in recycling it.

Water pricing strategies can be used to redress this situation by adding value to the resource. This of course makes for more considered water usage and introduces economic efficiency into the water management process. It is important to note that water-pricing strategies can be very sensitive, particularly amongst farming and developing communities. In the case of the former this is because traditionally the price of water for irrigation has been kept at a very low level and an ethic has developed that farmers have a right to low-cost water. In a similar way, developing communities view water as a free good and any attempt to price it at its real economic value would meet with considerable resistance.

In South Africa, water pricing has been based on cost-recovery principles, and has not been viewed as a potential water management tool. There is evidence in the international literature, however, to show that water pricing is a powerful method of controlling demand, and both industrial and municipal users have been shown to respond appropriately to its use. Studies in this respect have been carried out both in the OECD countries and the USA. It must however be pointed out that price elasticities of demand underpin all studies of the demand for water and its related price. Studies to determine the price elasticity of demand have been carried out, but unfortunately not in South Africa, so this is clearly a promising area for future research.

Any attempt to increase the price of water must include a political initiative, and it is imperative that the community and the industrial sectors be kept involved. This means that an educational programme would be necessary to inform them of the real economic value of the resource. The market mechanism is an ideal vehicle for arriving at the economically efficient price for a commodity, and water of course is no exception to this. Economists have therefore reworked economic theory to allow a market mechanism to be put in place for water. How economists have put this in place has been discussed in the text.

Pricing has the effect of changing user behaviour, low prices encouraging mis-use of water with high prices encouraging conservation. Thus price-setting invariably affects supply and demand and can therefore be used to implement governmental policies in the management of water.

Green taxes are a special form of tax insofar as the underlying rationale is that they should act as a behaviour modifier, and that they should ultimately be self-eradicating in nature. This means in practice that as the desired level of pollution abatement is approached, the level of taxation reduces until it disappears altogether. (At this stage economic efficiency, or Pareto optimality, has been achieved.) Thus the temptation to view a green tax as a permanent source of revenue for the fiscus after it has achieved its objectives should be avoided, as this will have the effect of diminishing economic efficiency.

From an economic point of view there would be great advantages if the market mechanism could be brought in to assist with water quality management. Tradable permits are powerful instruments for bringing this about. The market mechanism's power to allocate resources efficiently rests on the fact that all the trade-offs required to produce efficiency are taken account of when individuals make decisions to buy or sell commodities. Exactly the same logic applies when we consider using tradable permits for water quality management. All that is needed is to be able to envisage a market in pollution abatement units. To make a tradable permit viable, i.e., to introduce the market mechanism into the pollution control system there must be sufficient users of the permits and they must be traded on a regular basis. Traditionally tradable permits have been used for air pollution (where these requirements are properly met), but there is no reason why they could not be used equally effectively for water management.

Because of the inherent problems associated with water pricing in South Africa, and the need for more research into the subject, this report focused on the use of green taxes and tradable permits. These two instruments are able to be put into place relatively easily and do not place excessive burdens on the administration.

Two models were designed and implemented to demonstrate the efficacy of these instruments in the area of the Witbank Dam, an area that is heavily polluted by sulphates.

An important economic debate revolves around whether the public sector or the private sector should administer the economic instruments mentioned above. The answer to this question is dependent upon which of the approaches yields the greatest economic benefits. This issue was examined in some depth, and it was concluded that the outcome was neutral in the case of a green tax / tradable permit mix. However, it is important to remember that the indiscriminate levying of a tax (such as a green tax) may diminish social welfare by financially burdening older industries to the extent that they reduce their production capacity, or in the extreme case, cease to trade. The result of this is increased unemployment, hardship and poverty. As a consequence, great care must be taken in designing the tax structure that is to be used for pollution control. The models described in this report, whilst not used for designing a tax structure due to lack of robust data, could nevertheless be used as a scenario generator to examine the impact of green tax structures in the area.

The applicability of economic instruments in the South African context was only partially addressed in this report. The reason for this is that the South African economy is undergoing change as a result of the momentous political reform currently under way. This is demonstrated by the direction that is being provided by the RDP. It would therefore be inadvisable to be too prescriptive in this regard. It was however felt that the choice of instruments was not inappropriate to the situation, and that the analysis to which they were subjected would at least provide an enhanced understanding of their operation and usefulness in practice.

Because the environment into which polluted water is discharged is seen as a free good, and wastewater itself is seen as having no economic value, water pricing and water marketing are frequently neglected as water pollution management tools. We conclude, however, that they have great potential in this regard, but as they are not intrinsically economic instruments, the issue was not pursued in any depth.

Although the focus of this report has been on economic instruments, it is nonetheless true that command and control measures (such as regulation) do have a role to play. For example, control measures for pollution emissions that can cause grievous suffering (such as toxic waste) need to be prescriptive.

Tradable permits offer a wide range of benefits to both the private and public sectors. They are able to offer a high degree of autonomy to the private sector, whilst still remaining economically efficient. Despite their attractiveness, they have not been well tested internationally, so it is somewhat premature to comment on their effectiveness in South Africa. However, our modelling exercises have indeed demonstrated economic efficiency so we conclude that they are potentially powerful instruments for pollution emission control, and that their possible use should be pursued vigorously.

In summary, after extensive investigation of both the economic instrument toolbox and the study area and its problems, two economic instruments (green taxes and tradable permits) were selected for further study. This study was not as in-depth as could be desired, due to data gathering problems, but our simulations have indicated considerable promise for these instruments and it is recommended that every effort be made at this stage to bring them to the attention of both public and private sector decision-makers and policy formulators.

6.2 Recommendations

- This report has dealt with the operation of green taxes and tradable permits as instruments of water quality management, and has found them to be viable under ideal simulated conditions.

  It is recommended that serious consideration be given by decision-makers to using these instruments for this purpose in future. However, it is clear that considerable additional research will be necessary before this aspiration can be realised, and this issue is addressed more fully in the following section of this report.

- The issue of water pricing as an instrument of water quality control has also been touched upon in this report, but not dealt with in great depth. However, even from the fairly shallow discussions above, it is clear that pricing is a critical issue and deserves to have its place in a properly constituted toolbox of economic instruments for the management of water quality. Once again, a great deal more work needs to be done, and this is also addressed in the next section of this report.

- Additionally it is recommended that no new regulations should be promulgated without a comprehensive cost-benefit analysis having been carried out. Executive Order 12291 issued by President Reagan in 1981 requires the preparation of a Regulatory Impact Analysis (RIA) for every major rule. Section 2 of the Order provides that "Regulatory objectives shall be chosen to maximise the net benefits to society" and that "Regulatory action shall not be undertaken unless the potential benefits to society for the regulation outweigh the potential costs to society"

- The mines also desire to maintain their autonomy in the matter of environmental management, by minimising interference by authority on how they manage their abatement practices. This means that they would wish to be able to use any competitive edge they may have in their individual abilities to implement abatement strategies to their own advantage (and profit). It is therefore recommended that this be taken into account when implementing economic instruments for water quality management, in order to encourage mine "buy-in" to the scheme.

6.3 Future Directions

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:

- As pointed out above and in Chapter 5, taxes can have a detrimental effect on some industries if indiscriminately applied. Particular cases in point are older industries, and mining industries where prices are set internationally. An in-depth investigation into the effects of a green tax on these industries is recommended. However, a study such as this would have to get very close to potentially sensitive financial information in the relative industries, and the full co-operation of the industries concerned would be a pre-requisite. Without this co-operation such a study would not be of great value.

- A knowledge of both income and price elasticities of demand enables more effective forecasting to be done for water management purposes. Countries such as the USA and the OECD Countries have carried out studies to determine these parameters from the '60s to the present. These studies have included the determination of elasticities of both industrial and household (municipal) water demand. A similar study in South Africa might commence by looking at municipal elasticities of demand.

- Reliable and extensive time-series data is an important pre-requisite for any forecasting exercise, and indeed for establishing elasticities of demand. A database extending for at least five years and containing information on water usage, water price and pollution control activities in all sectors of the economy could be considered to be a minimum requirement. It is recommended that existing data of this nature should be gathered together in a database form that would make it useful to economists, and that a programme should be established to continue accumulation of similar data over the forthcoming five years.

- Whilst accepting that the research carried out in this report had as its aim to educate rather than to solve specific problems, it is nevertheless felt that a pilot study using tradable permits and green taxes and incorporating real data should be carried out before any recommendation to implement these instruments on a widespread basis could be made. Such a pilot study should investigate the effects of these instruments on a specific community or "bubble" and should report on the effects of levying taxes at different levels. This study would also involve the use of sensitive financial data and its success would be heavily dependent upon the total co-operation of the players in the chosen bubble.

- Water pricing and tariff-setting, and demand-side management are issues which ought to be receiving urgent attention in South Africa. Appropriate pricing of water would have direct effects on both its allocation and the management of its quality. As mentioned this report, this is a wide field of research, but it is clear from feedback from the Steering Committee that it is a subject worthy of investigation.

APPENDIX A

MARGINAL COSTS, TRADABLE PERMITS AND A MARGINAL COST TRADING MODEL

CONTENTS

FIGURES

TABLES

A. MARGINAL COSTS AND TRADABLE PERMITS

A.1 MARGINAL COSTS

The principles underlying the economic approach to the regulation of sulphate emissions can be explained quite simply. Figure 1 will be used to analyse a typical mine's behaviour.

The horizontal axis of this diagram shows the extent of emissions abatement undertaken by the mine and the vertical axis the cost of achieving that abatement. The abatement can be described as units of "clean-up" produced, and can be analysed much like any other market commodity. OQ_{max} indicates the total amount of clean-up that could be produced, equal to total current emissions. The MC curve represents marginal costs: the additional cost of producing successive units of clean-up.

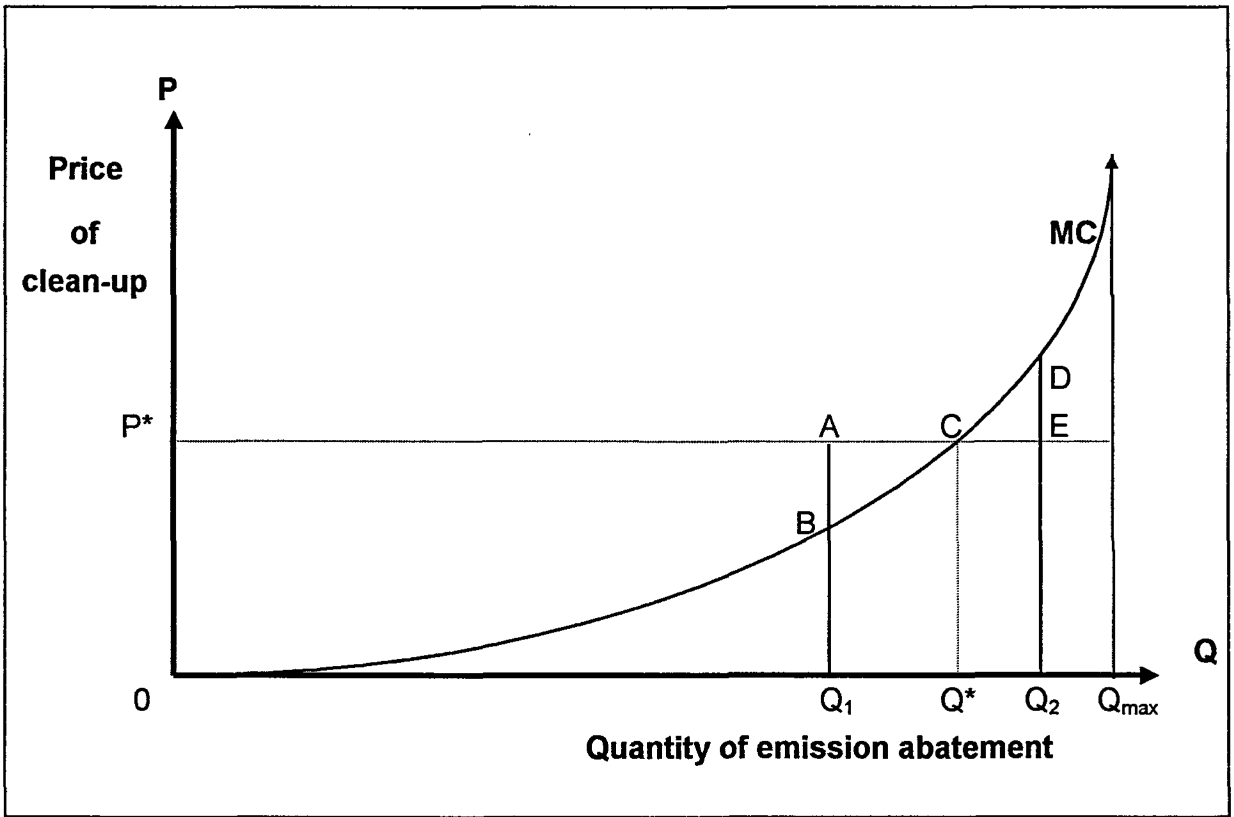


FIGURE A.1: ABATEMENT COST CURVE

As the amount of clean-up produced increases, it becomes more and more expensive to increase it further. In this diagram, the rate of increase in marginal costs is assumed to be exponential, hence the curved shape of MC.

Assume now that a market is created for clean-up, and that the mine can produce and sell units of clean-up on that market. Assume further that the prevailing price of clean-up is as shown by OP* in Figure 1. It is now possible to determine how much clean-up the mine will sell.

Consider an abatement level of OQ_1. The cost of producing the last unit of clean-up is Q_1B, and it can be sold on the market for a price Q_1A, thus producing a profit equal to AB.

If OQ_2 units of clean-up were to be produced, however, the cost Q_2D of the last unit produced would be higher than the market price of clean-up as indicated by Q_2E, and a loss of DE would be made.

In general, it can be said that profits can be made for all quantities of clean-up to the left of point C, or OQ*, but that losses are made for quantities of clean-up greater than OQ*.

Assuming that the mine wishes to maximise its profits, it will produce and sell OQ*, where the price is equal to the marginal cost. Generalising this conclusion, it can be said that production of clean-up by the mine will always be determined at the point where the prevailing market price is equal to its marginal cost of producing the clean-up. This means that the curve MC is also the mine's supply curve, showing how much clean-up it will produce at any given market price.

A.2 A MARKET IN PERMITS

Now assume that the mine is obliged by legislation to curtail its emissions, in other words, produce clean-up. If the target it is set equals OQ_2 units of clean-up, the mine would prefer not to produce all these units itself. Instead of producing the last unit required at a marginal cost of Q_2D, it could buy it on the market for the price OP*, thus saving DE. Similar savings could be made on all units of clean-up in excess of quantity OQ*.

By contrast, if the mine's target were OQ_1, it would be willing to produce a surplus of clean-up of Q_1Q^* in order to profit by selling it on the market for price OP*.

This opens the way for trade to occur on the market between mines wishing to produce surpluses or deficits relative to their legislated targets, as shown by OQ_1 and OQ_2 in Figure 1 respectively. Mines in both categories could benefit from trade, the former by increasing profits and the latter by minimising the costs of abatement. This can be illustrated by a numerical example.

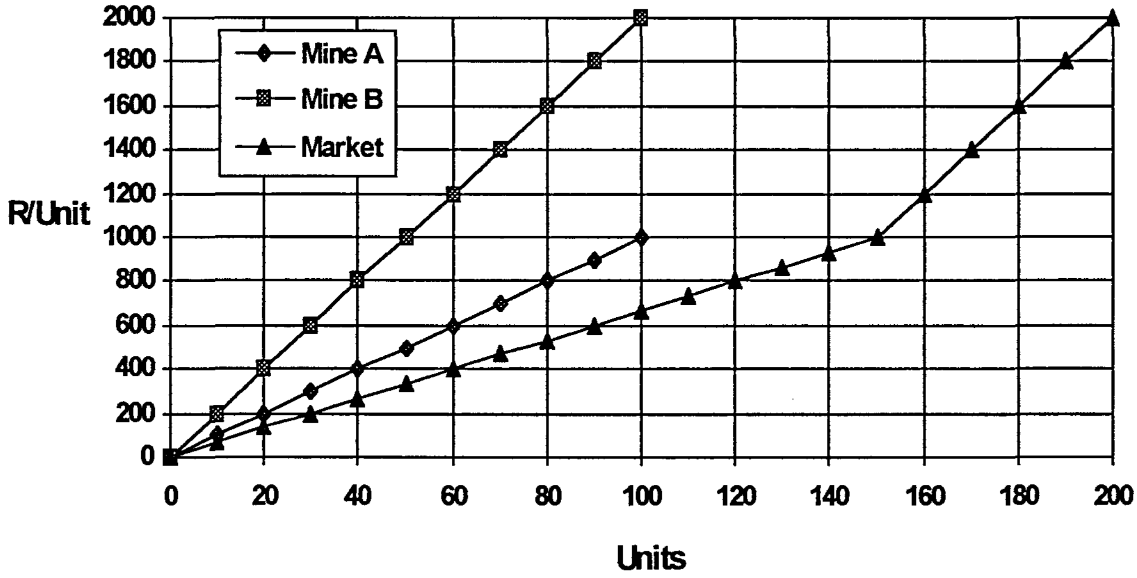


FIGURE A.2: EXAMPLE OF CLEAN-UP COSTS FOR TWO MINES

In Figure 2, two mines and the market for clean-up are shown. To simplify the example, the marginal cost, or supply, curves are now drawn as straight lines.

Mines A and B are assumed to be identical, except for the marginal costs they incur to produce clean-up, mine B finding clean-up to be twice as expensive. Their differences in this respect are shown in Schedule 1 as well as Figure 2. Each mine's current emissions equal 100 units of clean-up.

The market supply curve is by summing the mines' individual supplies; for example, at a price of R800, Mine A will supply 80 units and Mine B 40 units of clean-up, providing a total quantity on the market of 120 units.

Now suppose that the authorities require a reduction in emissions of sixty per cent. A legislative approach would impose a derived common clean-up target on each mine, probably - as the mines are identical in all respects but their marginal costs - of sixty percent or 60 units each.

Units of clean-up	MINE A		MINE B	
	Marginal cost	Cum. cost	Marginal cost	Cum. cost
10	R 100	R 500	R 200	R 1 000
20	200	2 000	400	4 000
30	300	4 500	600	9 000
40	400	8 000	800	16 000
50	500	12 500	1 000	25 000
60	600	18 000	1 200	36 000
70	700	24 500	1 400	49 000
80	800	32 000	1 600	64 000
90	900	40 500	1 800	81 000
100	1 000	50 000	2 000	100 000

TABLE A.1: SCHEDULE OF MARGINAL AND CUMULATIVE CLEAN-UP COSTS

Table 1 shows that to produce six units of clean-up would cost:

Mine A	R18 000
Mine B	R36 000
Total	R54 000

The required clean-up could be produced in another way, however. On the market, a total of 120 units of clean-up are needed to satisfy the authorities' requirement. The market supply curve shows that this would be forthcoming at a price of R800/unit. Assume now that this price is in fact set. Both mines would react by producing the quantities of clean-up where this price is equal to their marginal costs. In the case of Mine A, 80 units of clean-up would be produced, with 20 of those units being surplus to the mine's own requirements and available for sale. Mine B would produce only 40 units, and would have to buy 20 more units to make up its deficit.

The total cost of producing the clean-up has now fallen in comparison to the legislative approach. To produce the clean-up costs:

Mine A	R32 000	for 80 units
Mine B	R16 000	for 40 units
Total	R48 000	

The total saving produced by the economic approach is therefore R6 000. Of this, R2 000 accrues to Mine A as increased profit; it produces 20 surplus units of clean-up for (R32 000 - R18 000 = R14 000) and sells them to Mine B for (R800 x 20 = R16 000). Mine B saves R4 000; instead of having to produce them itself at a cost of (R36 000 - R16 000 = R20 000), it buys its deficit 20 units of clean-up from Mine A for R16 000.

As long as the mines' marginal cost curves for clean-up are different, it is generally true to say that savings can be obtained by moving from the "legislative" approach to the "economic" one, as shown by the above example.

This outline of how an "economic approach" might work in allocating pollution abatement efforts to meet some exogenously imposed target, overly simple as it might be, does point to both the major benefit and a significant difficulty of the approach. The major benefit is the savings that could be achieved by the industry as a whole. The difficulty is in inducing some mines to participate in trading when trade itself holds out no particular benefits for them, particularly when the beneficiaries may be their competitors.

A.3 A Marginal Costs Permit Trading Model

The Marginal Cost (or MC) model is essentially the incorporation of the concepts presented in Figure A.2 and Table A.1 into an extensive spreadsheet. The spreadsheet concept appeals for this purpose as the solution of the system of equations lends itself to look-up tables rather than to direct mathematical solution.

For the MC model, the system of equations presented in Figure A.2 is augmented to incorporate a green tax, and to allow for five rather than two players. The results of combining a green tax with representative cumulative abatement cost curves to provide composite abatement cost curves is illustrated in Figure A.3 at the end of this appendix. The green tax curve has been chosen to have an exponential shape in order that the tax may be extremely onerous under very low abatement regimes, but markedly less so as full abatement is approached. The green tax curve is common to all mines. The abatement cost curves for the individual mines were chosen to have a quadratic form. These curves will also rise rapidly as the level of abatement rises, but the effect is not as dramatic as with the green tax curve. As has been stated previously, it is necessary for abatement costs to differ between mines if permit trading is to take place, so different coefficients have been chosen for the five abatement curves. The curves are of the form $y=ax^2$, and the different *a*'s have been allocated in the range 5 to 10. It should be noted that in the absence of actual costs, these curves are arbitrarily chosen, but are nevertheless considered to be sufficiently representative of the real-life situation to enable some meaningful conclusions to be drawn. Furthermore, the curves are unlikely to be smooth mathematical functions as here presented. However, the spreadsheet approach can accommodate itself readily to virtually any data set, since solution is dependent upon look-up tables and not mathematical solutions. Thus the non-linear and probably discontinuous functions which would arise in practice can be readily incorporated into the model if they become available.

The operation of the model is encapsulated in the marginal cost curves as presented in Figure A.4. In order to ascertain what the market clearing price for permits will be at any given level of pollution abatement, and how much abatement will be implemented by each player, the following procedure is adopted:

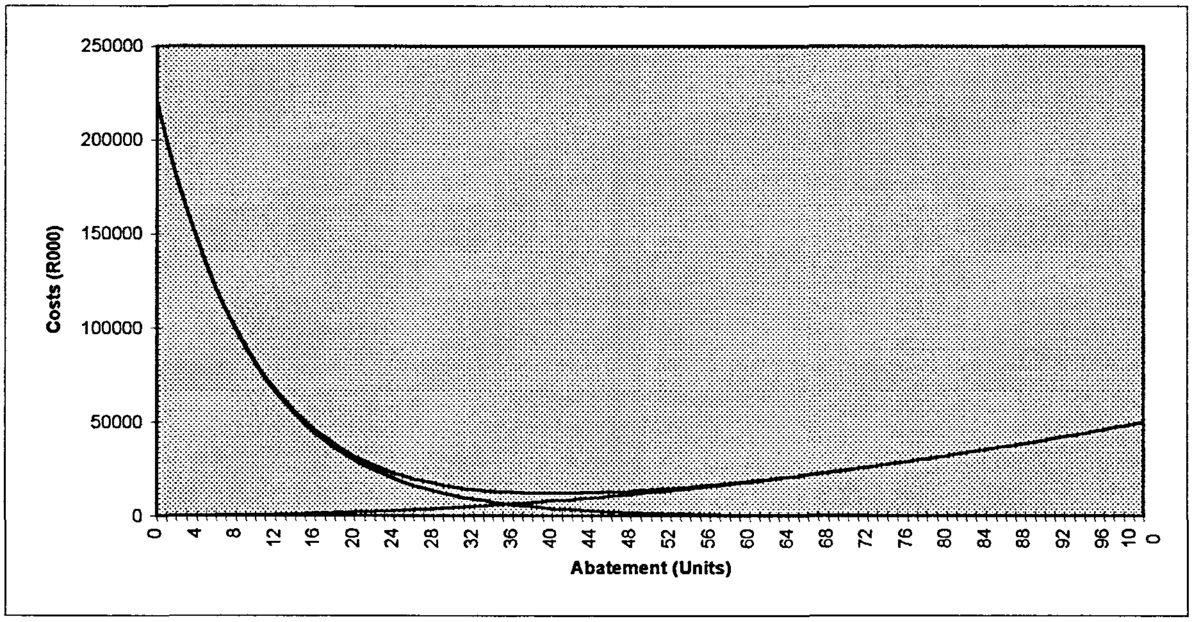
- Identify the total amount of abatement required on the Y-axis (Units of Abatement).
- Draw a line parallel to the X-axis (Marginal Abatement Costs) to cut the market curve.
- Drop a perpendicular from the point of intersection to the X-axis.
- This perpendicular indicates the market clearing price for permits, for the given level of abatement, on the X-axis.
- The point where the perpendicular cuts the individual mines' marginal abatement cost curves indicates the amount of abatement that each mine will implement, since the market curve simply represents the sum of the abatement activities of the individual mines.

In Figure A.4, an abatement level of 350 units was chosen to demonstrate this operation. It can be seen that the permit price is R955, and the abatement implemented by Mines A, B, C, D and E respectively is 95 units, 77 units, 66 units, 58 units and 53 units. The total (allowing for rounding error) is the 350 units that were required. Under a control and command system, each mine would have been required to implement 70 units (350/5) of abatement. The buying and selling of permits makes up the differences between this figure and the actual abatement figures. In practice, this procedure is carried out by the computer using look-up tables on a spreadsheet. In addition the model readily calculates other statistics at the same time. An output sheet provided by the model for the same data discussed above is given in Table A.2. The results discussed above can readily be confirmed from this table. In addition it can be seen that all players (last line of the upper box) demonstrate potential savings. This is as expected from the discussion of the philosophy above.

Further representative output from this model is provided in Appendix E, so that the reader may examine and verify further scenarios should it be so desired.

A notable drawback with the MC model is that a tremendous amount of data has to be available and entered if the table-lookup procedure is to produce without unacceptable truncation errors. This places a heavy recalculation load on the spreadsheet as new scenarios are investigated, and calculation times, even on fast PCs, can grow alarmingly[1].

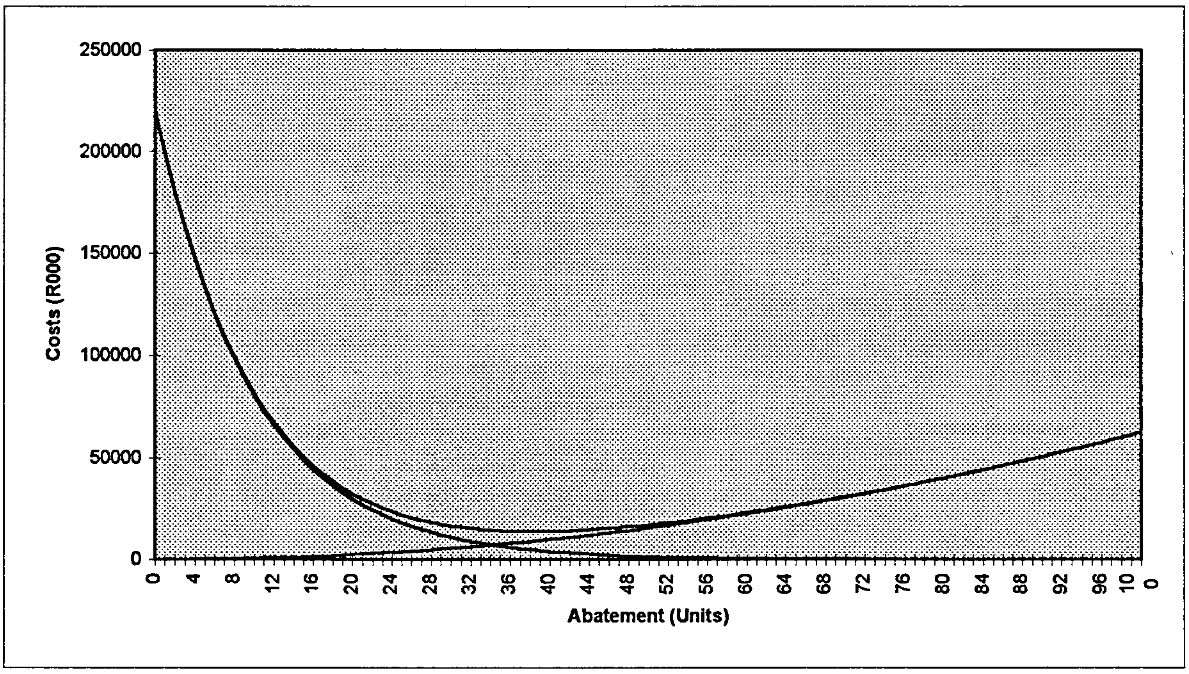
FIGURE A.3: COMPOSITE CUMULATIVE ABATEMENT COST CURVES



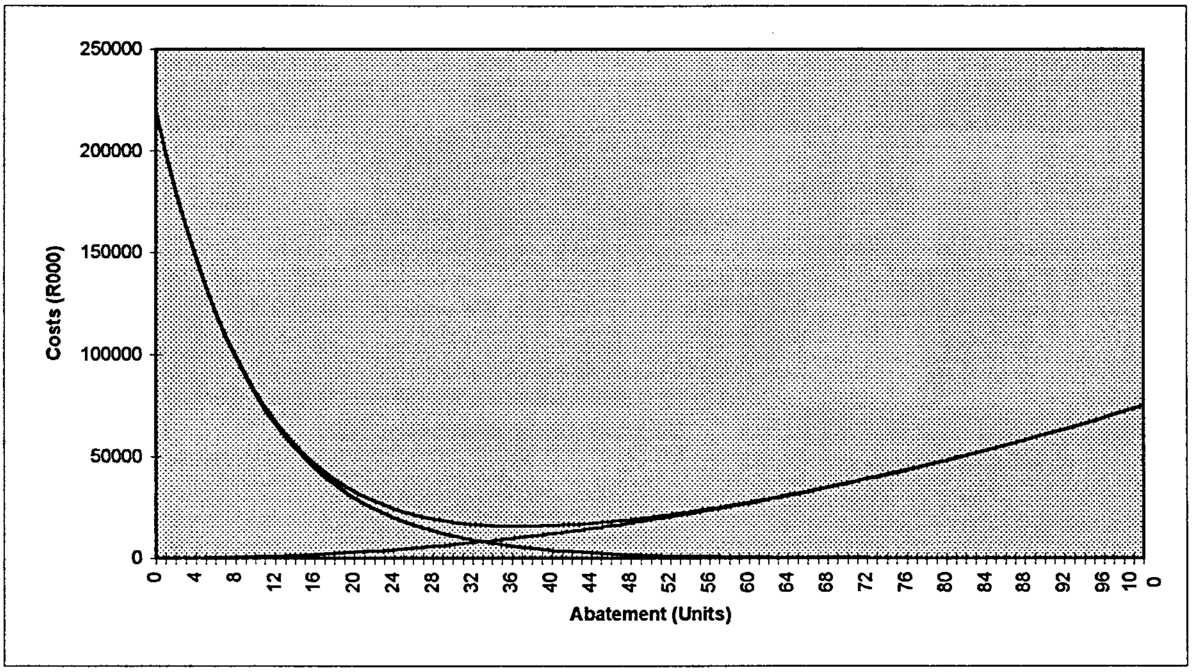
Coefficient of abatement cost curve: a = 5

1 The spreadsheet model used to generate the data presented here used two matrices, one of 1 000x11 elements and the other of 2 000x8 elements. Recalculation times using a 486DX2/66 PC were of the order of 90 seconds for each new scenario generated.

FIGURE A.3: COMPOSITE CUMULATIVE ABATEMENT COST CURVES (CONTINUED)

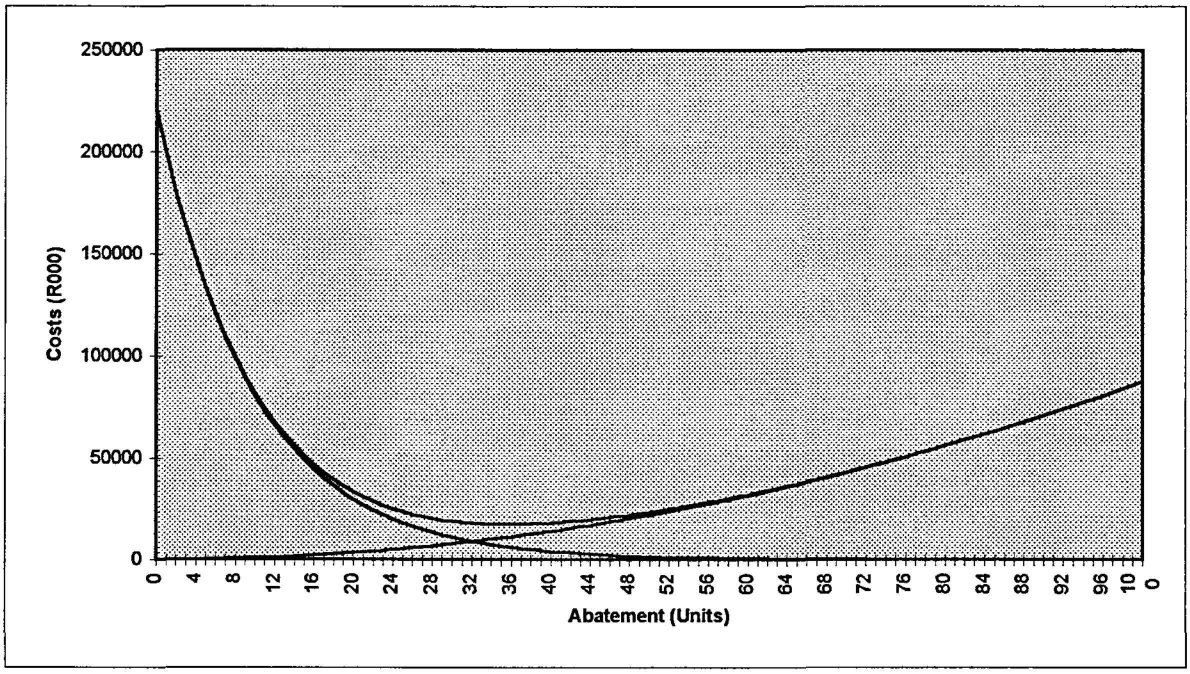


Coefficient of abatement cost curve: a = 6.25

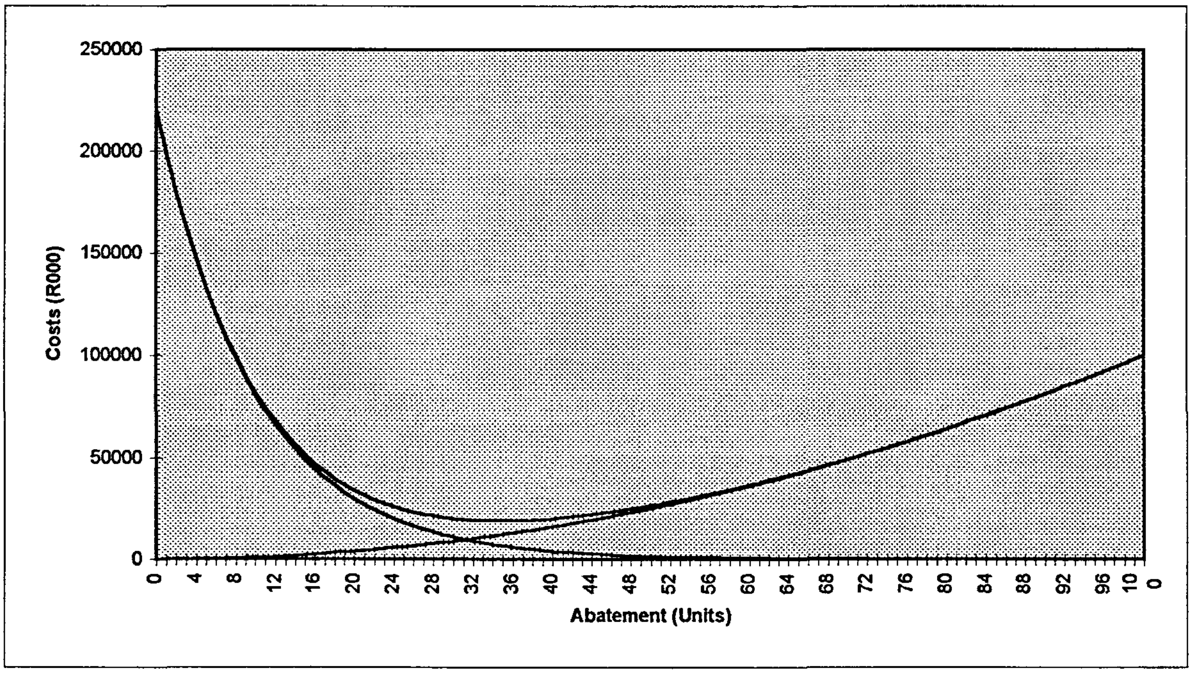


Coefficient of abatement cost curve: a = 7.5

FIGURE A.3: COMPOSITE CUMULATIVE ABATEMENT COST CURVES (CONTINUED)



Coefficient of abatement cost curve: a = 8.75



Coefficient of abatement cost curve: a = 10

FIGURE A.4: MARGINAL ABATEMENT COST CURVES FOR 5 PLAYERS

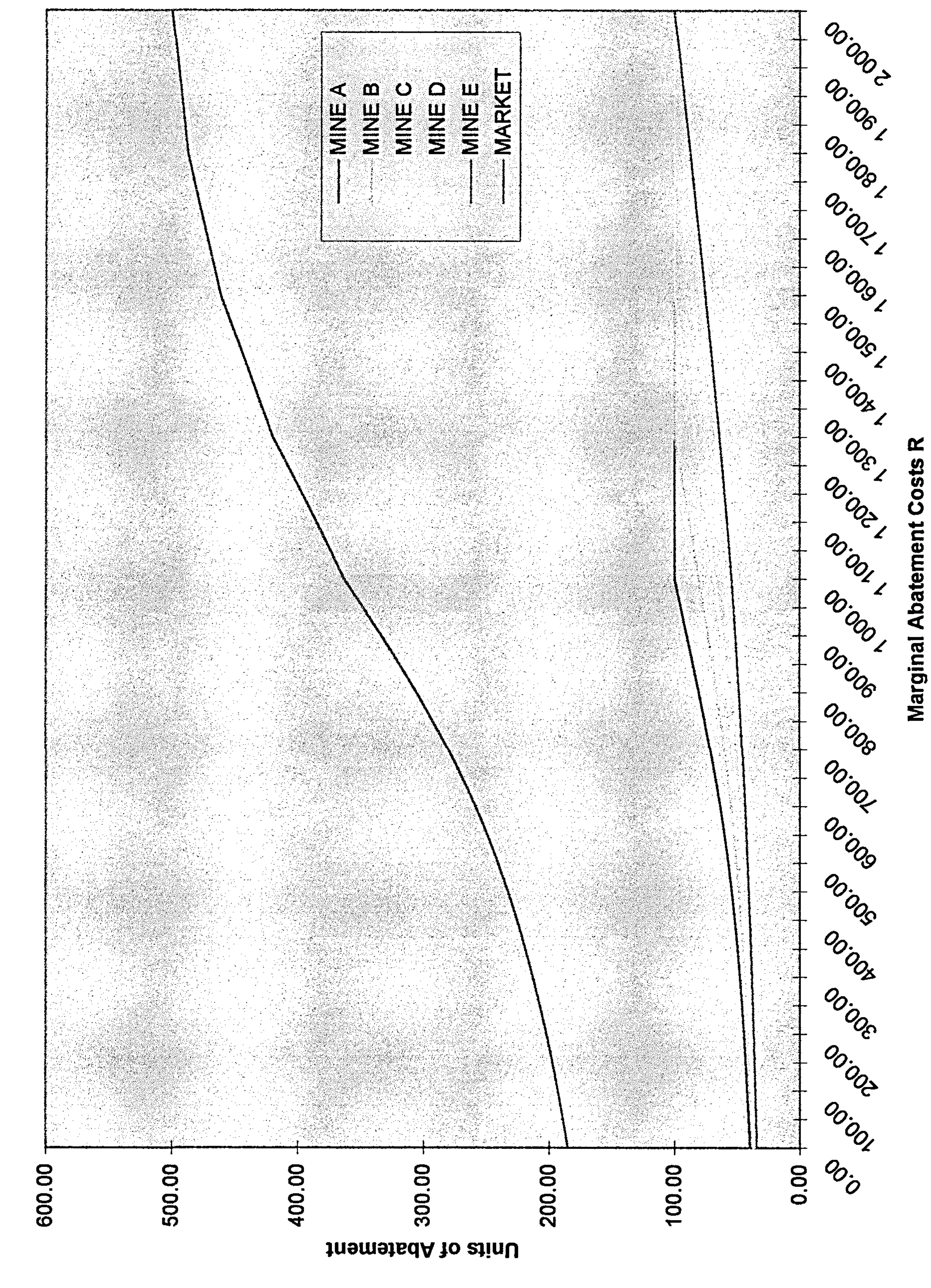


TABLE A.2: OUTPUT FROM THE MARGINAL COSTS MODEL

MARGINAL COST MODEL OUTPUT — 350 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 24 690.86	**R 30 815.86**	**R 36 940.86**	**R 43 065.86**	**R 49 190.86**	**R 184 704.28**	Cost of legislative approach
R 45 702.33	R 37 241.31	R 32 672.44	R 30 282.01	R 29 274.63	R 175 172.72	Cost of abatement instituted
25.66	7.16	(4.24)	(11.74)	(16.84)	0.00	Number of permits sold (bought)
R 24 505.30	R 6 837.80	R (4 049.20)	R (11 211.70)	R (16 082.20)	R (0.00)	Cost of permits sold (bought)
R 21 197.03	**R 30 403.51**	**R 36 721.64**	**R 41 493.71**	**R 45 356.83**	**R 175 172.72**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 3 493.83	**R 412.34**	**R 219.21**	**R 1 572.15**	**R 3 834.02**	**R 9 531.56**	Potential savings (cost of legislative approach less actual abatement costs)
30.06	30.06	30.06	30.06	30.06	150.30	Permits issued to cover allowable emissions
4.40	22.90	34.30	41.80	46.90	150.30	Actual emissions (based on marginal costs)
95.60	77.10	65.70	58.20	53.10	349.70	Actual implemented (based on marginal costs)
25.66	7.16	(4.24)	(11.74)	(16.84)	0.00	Excess (deficit) of permits

Abatement desired	350
Permits issued	150
Market price of permits	955

APPENDIX B

ECONOMIC INSTRUMENTS FOR POINT SOURCE POLLUTION

CONTENTS

B. ECONOMIC INSTRUMENTS FOR POINT SOURCE POLLUTION

This section will consider the theory and practical application of a number of economic instruments that have been used worldwide to abate pollution of point origin.

B.1 DISTRIBUTIVE CHARGES[1]

B.1.1 Theoretical Considerations

One means of controlling effluent is the use of charges. Under the Standard Polluter Pays Principle (Standard PPP), the polluter is required to pay for controlling effluent discharges to a given level, but not for environmental damage caused by the optimal

1 For a detailed discussion of the theory of distributive charges, refer to WRC 1993.

effluent load[2]. Effluent standards would have to be set such that the effluent discharged equalled the optimal pollution level. The optimal level of pollution is depicted in figure 3.1.[3]. At Q*Y the maximum allowable pollution would be set at the pollution level associated with output Q*. Hence, public regulators could induce firms to produce at the socially optimal output level.

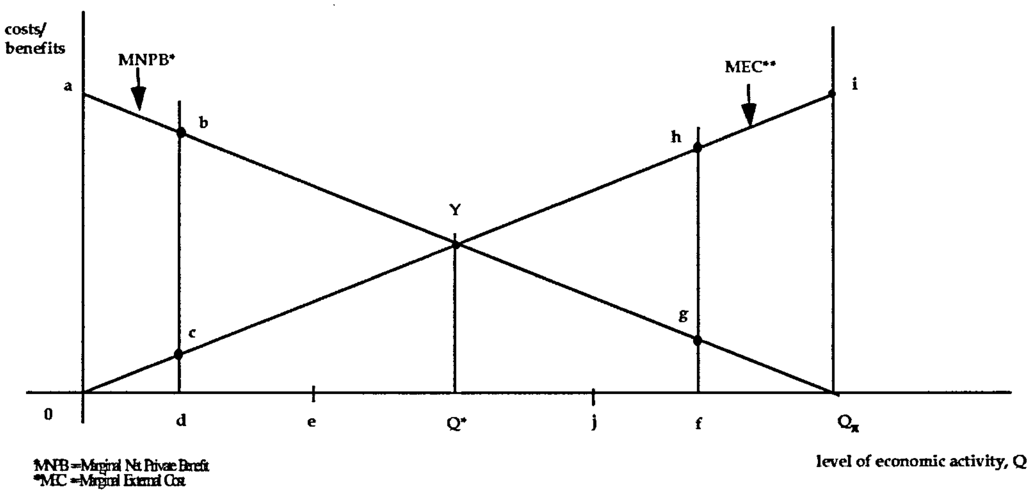


FIGURE B.1: OPTIMAL POLLUTION BY BARGAINING

Two policy choices are open: either a direct regulation of the total discharge to the optimal level or the imposition of a tax or charge on each unit of the polluter's discharge. This latter approach forms the basis of the distributive charge.

The effect of a tax or charge is to shift a firm's marginal net private benefit curve downward by the amount of the tax or charge. If the tax level or charge is selected appropriately, the polluter's behaviour will be modified in such a way that the effluent discharge will move to the optimal level.

There are several difficulties associated with the introduction of distributive charges, of which the most pertinent and immediate ones are:

- the difficulties to properly calculate the optimal level of tax/charge

- possible strong opposition from industry, and

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2 For a more detailed discussion of the 'polluter-pays-principle' see: WRC 1993.

3 Refer to WRC 1993 for a discussion of the optimal level of pollution.

- potentially high transaction costs.

Despite associated disadvantages relative to the theoretical optimum, various charge systems have been used worldwide to curtail water pollution from effluents. These experiences can serve to illustrate the practicability of the theoretical considerations discussed above.

B.1.2 Practical Implementation

So far, most governments trying to correct market failures have turned to regulations, dictating specifically what measures must be taken to meet environmental goals. This approach has improved the environment in many cases, and is especially important where there is little room for error, such as in disposing of high-level radioactive waste or safeguarding an endangered species. Taxes or charges would be a complement to regulations, not a substitute.

A survey by the OECD revealed more than 50 environmental charges among 14 of its members, including levies on air and water pollution, waste, and noise, as well as various product charges, such as fees on fertilisers and batteries. In most cases, however, these tariffs have been set too low to motivate major changes in behaviour, and have been used instead to raise a modest amount of revenue. A number of representative experiences with charges levied on water pollution will be discussed in the following sections.

(a) Bulawayo[4]

> "Bulawayo is a relatively affluent city with well established water supply and sewerage systems. Nearly all of the population is connected to piped water and sanitation services. Good housekeeping has been the policy of the local authority in reducing water losses. However, the authorities have always been aware of the scarcity of water, and as such all houses are metered for their water consumption and charged.
>
> Until recently, water charges were based on an estimated water ration regardless of the true use. Despite this, water charges were increased 7 times during the last decade. During the severe 1991 to 1992 droughts, charges on excessive water uses were increased 20 to 30

4 Miltz et al. Source?

times. This led water consumption to decline by 50%, showing how sensitive consumption is towards price.

In 1992, the government changed from the ration pricing to volumetric pricing. It is too early to make an estimate of the effect of this new pricing system. However, the new system will create important reductions in water use as well as raising substantial amounts of revenue. Excessive uses such as car washing are going to be hit hardest and hence will decline the most.

Industry is happy to pay more for the water provided that this means a more reliable supply. Thus, they support this new policy. In the residential sector, the change should not bring too much resistance since water expenditures consist of 1% of their spending. However the poor will be hardest hit since for them water expenditures form 3% of their budget. So, the protection of the poorer sections of the society is a crucial point. The government has responded to this concern by providing a free entitlement to a minimum amount of necessary water."

(b) Shanghai[5]

"The purpose of the Shanghai system is to promote conservation and minimise water use. A wastewater discharge fee of Y0.12/tonne is payable by all enterprises, public agencies and institutions. Households, schools, nurseries and old people's homes are excluded from the system. There are also fines if an enterprise does not comply with the system. For late payments, the fine increase 0.2% each day after the due date. If the authorities find out about an understatement regarding the amount of discharge, the enterprise becomes liable to pay three times the fee.

Revenue from discharge fees can be allocated for innovation and operation and maintenance of the sewer system. Thus, the fee system makes the polluter pay for the sewerage system and decreases the financial burden on the local government."

5 Miltz, et al, op. cit.

(c) *France*[6]

The French charge system consists of a two-tier system: pollution charges and consumption charges on surface and ground water supplies. Anyone who pollutes sea or fresh water incurs pollution charges. Household charges are calculated each year while other sources are charged on the basis of a flat rate estimate or by actual measurement. Rates vary by agency and are chosen on the basis of budget neutrality rather than on an environmental cost estimate.

The function of the French charge system, implemented in 1969, is purely revenue raising. Total revenues raised under the charge program in 1986 were US $274m. These are used to provide financial aid to local authorities and industry for constructing infrastructure projects, related to water supply and quality management.

There are, however, a number of disadvantages associated with the French charge system, which diminish its incentive effect.

- pollution charges are set too low to have much of an impact on firms,
- according to an OECD estimate in 1989[7] the investment aid provided to firms offsets the abatement costs by about 12%. In other words, the programme appears to have mainly a subsidy rather than a charge effect.

Since charges are set too low and industry is vehemently opposing a charge increase, it is doubtful that charges will reach a level where they have an incentive effect.

Partial positive effects on water quality have been recorded: Organic pollution has been significantly reduced while other substances require further attention.

This charge system is not found to be economically efficient, since it does not result in the lowest cost to society. Its simplicity and administrative efficiency is, however, appealing and there is some degree of adherence to the polluter pays principle.

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6 Further discussion can be found in Miltz, et al, Department of Environment Affairs, 1994.

7 OECD, Economic Instruments for Environmental Protection. OECD, Paris 1989.

(d) *Netherlands*

The Dutch charge system, in place since 1969, is considered to be the world's best administered system and is a mixture of user/effluent charges and direct regulations. Like the French system, the main purpose is to raise revenues for financing projects that will improve water quality. The level of charges is determined by the Dutch water boards who are responsible for maintaining balanced budgets.

Biodegradable matter, suspendable solids, toxic substances and heavy metals are liable to charges; households and small firms pay a standard charge, whilst medium firms are charged according to a table with unit rates for different industries. Large firms are monitored individually. If the pre-treatment of effluents takes place, a rate-reduction for all cases is possible.

Unlike in other charge systems, the effluent charges are relatively high. Thus the incentive factor is well over the intended revenue generating effect.

Between 1969 and 1975 water pollution decreased by 50% with a further 20% fall up to 1980. Another 10% reduction was estimated to 1986. The abatement was expected to be a direct result of increasing and anticipated increases in charge rates.

Furthermore, this system is found to be highly efficient in terms of the administrative costs as it runs on only 4-5% of the revenues collected.

In terms of economic efficiency, in the sense of reducing the overall cost of reaching pollution targets, it is only moderate however. This is because, with the exception of large firms, a dynamic relationships between charges and pollution discharge is absent in the system.

(e) *West Germany*

The West German charge system was announced in 1976 and implemented in 1981. The level of the charge is related to the degree of compliance with the standards. Firms failing to meet their required standards pay a charge on all actual emissions. The German charge system is discussed in detail in chapter 3.3 of this document.

(f) *Czechoslovakia*

Czechoslovakia - up until 31 December 1992 - used effluent charges to sustain water quality at predetermined levels since 1976. A basic charge was placed on

BOD (biological oxygen demand) and suspended solids. Depending on the contribution of the individual discharge to ambient pollutant concentrations, the charge was complemented by a surcharge ranging from 10 to 100%. To reflect the quality of the receiving waters, the basic rates could be adjusted. In its concept the system was very close to the US ambient emission charge system. It is also considered to be cost-effective. No further information on the present form of water pollution control in the new countries is available as of yet.

(g) *East Germany and Hungary*

Until 1990 East Germany and Hungary used a system which combined effluent charges with effluent standards. The charge was levied on discharges in excess of fixed effluent limits. In the Hungarian system the charge level was based, among other factors, on the condition of the receiving waters. At first the charges had little effect; however, when charge levels were raised waste-treatment activity increased.

Conclusions

Nowhere do charges operate alone. All existing systems have linked effluent charges to a regulatory permit standards system. In most cases the primary goal has been to raise revenue for abatement programmes and subsidies. One generally reported result has been that environmental quality has improved.

Some degree of economic success can also be attributed to the charge systems discussed. Incentive mechanisms have been observed, particularly in Germany and the Netherlands.

In addition, despite their differences in terms of application and success, the mere existence of such charge systems may suggest that there is scope for possible and practical implementation in South Africa. The German Council of Experts on Environmental Questions, for instance, estimated that the German effluent charge system is about one-third cheaper for the polluters as a group than an otherwise comparable uniform effluent treatment policy. Additionally, the system encourages firms to go beyond the uniform standards when such an effort can be justified on cost-grounds. Finally charge systems in general have gained wide acceptability as a means of environmental regulation.

B.2 TRADABLE PERMITS[8]

B.2.1 Theoretical Considerations[9]

"A number of economists have suggested the sale of pollution permits as an alternative to effluent taxes. This approach involves the sale of permits, which allow the owner a specified amount of effluent emission.

Both taxes and permits have essentially the same outcome in practice, and share many characteristics. They are both dependable in that they are relatively automatic and routine), they are permanent (they remain in force until explicitly repealed) and they are equitable in that they follow the polluter pays principle. Taxes tend, however, to be more politically acceptable than permits.

If one is prepared to consider the auctioning of permits (tradable permits) then several shortcomings inherent in both taxes and ordinary permits will fall away, as the following list will reveal:

- Tradable permits are not vulnerable to inflation. As they are marketable instruments, they may be bought and sold just as any other marketable securities, and their trading price will always be set by market forces provided that they are traded frequently.
- As economic activity increases, the demand for more permits will undoubtedly rise. In the absence of any new issues, all that will happen is that the price of existing permits will increase. The allowable levels of pollution remain the same in any area, and would-be polluters are faced with the alternative of paying the going price for a permit (if there are any on the market) or of avoiding pollution.
- The differences in the ability of the environment to absorb pollution in different regions are quite readily coped with using permits. Permits can be made region specific, and the number of permits sold for various pollutants can vary from region to region. Permits can also be made seasonal, so that during dry seasons when water

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8 For a detailed discussion of the theory of tradable permits, refer to WRC 1993.

9 Baumol, WJ and Oates, WE, *Economics, Environmental Policy and the Quality of Life*, Prentice Hall, 1979.

levels are low, an appropriate seasonal permit would be required in order to discharge any effluents.

- Effluent taxes tend to introduce uncertainty about the final levels of emission, as they are based on a per unit system. If the amount of tax is correctly set, then the right levels of emission will ultimately be achieved. This uncertainty is avoided with permits, as they are based on actual emission levels. This does assume, of course, that no illegal emission is taking place outside the amount sanctioned by the permits.

It has been noted that pollution permits put an upper limit on the amount of pollution permitted. This does, of course, have its downside, in that there is no limit put on the costs that may be incurred in staying within that limit. Although it may be argued that the polluter himself is paying for his own pollution, it must be recognised that money spent on pollution abatement is money withdrawn from the economy as a whole, and is therefore unavailable for other investments. Effluent taxes tend to operate in the opposite sense, by directly controlling the amount of money spent on abatement.

Two possibilities exist for the initial issuing of emission permits. They may either be sold or auctioned to polluters, with the resulting revenue entering the general treasury. Alternatively consent s can be issued free of charge to polluters. The latter is the method generally used, and the permits are known as granted tradable consents.

A number of problems are associated with tradable consents, the most relevant being that:

- there may be a danger of unrestricted permit trade between polluters, which may result in localised undesirable increases in emissions;
- imperfect competition in a market may prevent pollutant levels being achieved in the moist efficient manner; and
- thin markets may undermine the system, (i.e., trade in discharge permits may occur so rarely that there is no opportunity for a proper competitive price to be established)."

For this type of economic instrument to be effective in assisting South Africa's water pollution abatement, it has to be borne in mind that many of our water pollution problems are:

- non-point source in origin and therefore unsuited to tradable permits;
- stem from polluters who are not driven by the profit margin and would thus be unable to compete for permits;
- occur in small catchments where there are too few independent polluters to constitute a viable market.

The rationale behind tradable permits is, as in the case of distributive charges, to restrict the total effluent discharge to the optimal level of economic activity. This requires each polluter to possess a permit allowing the discharge of a maximum quantity of effluent. The total effluent permitted under all consents will amount to the economically optimal pollution level.

As the term indicates, such permits may be tradable. Firms that can abate pollution relatively cheaply are thus enabled to sell their excess "pollution right" to another firm that may find the purchase of a consent cheaper than abatement. This would achieve the reduction of pollution to the optimal level in the most efficient manner.

Although the use of tradable permits has been discussed world-wide, only the United States have so far implemented a workable pollution permit trading system. This will be discussed in chapter 3.4.

With regards to tradable permits, Tietenberg (1992)[10] holds:

> "In the absence of a marketable permit program, a control authority would not only have to keep abreast of all technological developments so emission standards could be adjusted accordingly, but it would also have to ensure an overall balance between effluent increases and decreases so as to preserve water quality. This tough assignment is handled completely by the market in a marketable permit system, thereby facilitating the evolution of the economy by responding flexibly and predictably to change. Marketable permits encourage, as well as facilitate, this evolution. Since permits have value, in order to minimise costs firms must continually be looking for new opportunities to control

10 Tietenberg, Environmental and Natural Resource Economics, 1992, p.505-6

emissions at lower cost. This search eventually results in the adoption of new technologies and in the initiation of changes in the product-mix, which result in lower amounts of emissions. The pressure on sources to continually search for better ways to control pollution is a distinct advantage that economic incentive systems have over bureaucratically defined standards."

B.2.2 Enforcement and Implementation

Although it is still too early to assess permit trading under the Clean Water Act, some enforcement procedures have already been reported: In 1992 the EPA enforcement under the Clean Water Act focused on cases of major non-compliance. In addition, EPA regional offices developed geographic enforcement initiatives, such as the Grand Calument River initiative, to improve water quality of the Great Lakes.

In one major case, *United States v. City of Beaumont, Texas* (E.D. Tex), which is representative of recent enforcement procedures under the Clean Water Act, the district court awarded a penalty of $400,000 against the city. The penalty represented the savings to the city of non-compliance with the CWA ($316,000) and a gravity component ($84,000). The court found that the city had failed to complete key pre-treatment tasks on time. These included sampling and analysis of industrial users, issuing permits requiring industrial self-monitoring, taking enforcement actions, and not publishing a list of significant violators in the newspaper.

Trading of Water Pollution Rights, Fox River, Wisconsin: a failed approach ***(Hahn et al, 1989)***

This case study of a failed trading scheme, shows that as restrictions on trading activity increase, the more trading activity decreases.

Since 1981, Wisconsin's permit programme has allowed point sources of water pollution to trade rights to discharge into the Fox River. The permit system relies on the existing regulatory programmes, and standards such as the Clean Water Act. The main sources of pollution into the river are paper mills and municipal wastewater plants.

However the scheme has proved an outright failure. It has fallen far short of the expected high savings in abatement costs and low monitoring costs. Indeed potential annual cost savings from marketable permits were estimated at $7 million, based on the industry abatement costs estimated by EPA in 1979. Monitoring of trade and discharges was expected to be relatively easy and cheap due to the fact that most pollutants were point sources, i.e. mills and plants.

There are, however, three restrictions on trading. Firstly, the buyer firm has to be a new or an expanding firm, otherwise the trading is not allowed. Secondly, the firm has to prove the need for additional permits and authorities have to approve the trade. This process can take up to 6 months. It is both costly for firms to comply with the regulations and may force them to reveal commercial information that they would prefer to keep confidential. Finally, permits are allocated to their initial owners only for a five-year period, and a bought permit has to be in use at least for a year. Thus, short term trading which is very essential, is not allowed.

With this over-regulated framework, it is not surprising that by 1989, seven years after the start of the scheme, only one trade had taken place. It was between a paper mill that was closing its treatment plant and a municipal plant that was taking on this treatment.

B.2.3 EPA Emissions Trading Program

Although the emissions trading programme has its foundations in US Clean Air Act of 1955 it will be discussed briefly, since it provides some further insights into pollution permit trading in the United States.[11]

The EPA emissions trading program, introduced in 1974, has four distinct policies: netting, offset, bubble and emission banking policies, which all apply to emissions of single pollutants. The four policies are linked by a common element: the emission reduction credit (ERC), which is essentially a currency, used in trading among emission points. Does a polluter decide to control any emission point to a higher degree than necessary to fulfil its legal obligation, he can apply to the control authority for certification of the excess control as an emission reduction credit.

1. Netting or internal trading allows single firms to create new emissions at a plant by reducing emissions from another source at the plant.
2. Offsets are emission reduction commitments by existing firms which must be obtained before major new or expanding sources can begin emissions in "non-attainment" areas, which are regions where the ambient air quality is less than that required by the standards.

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11 For a detailed description of the EPA Emissions Trading Program and its evaluation, refer to WRC 1993.

3. Bubbles are geographic collections of emission points whose total emissions are regulated. ERCs can be traded by firms and plants within bubbles to alter individual source emissions while maintaining the overall bubble emission constant.
4. Banking allows firms to store unused ERCs for future use or sale in the netting, offsets or bubble programmes.

B.3 THE GERMAN EFFLUENT CHARGE LAW

B.3.1 Description

The German effluent charge system (Abwasserabgabengesetz) is unique in a way, as it is the only known charge system with a clearly stated incentive purpose. It was introduced by law in 1976 and implemented in 1981. At first the law was met with strong opposition by industry, which later shifted to discussions over implementation issues, such as criteria for setting charges, the level of charges and dates when the system would go into effect.

It is interesting that the system was actually supported by some industries, notably the newer plants with new waste-saving production processes and the latest pollution control equipment and older plants with recently installed new pollution control equipment. Their support was founded on the belief that their charges would be relatively smaller and would thus give them a competitive edge over industrial facilities with less up-to-date equipment. It was the proactive companies that eventually derived more relative benefit from the effluent charge system. Although based on a command-and-control strategy, this particular system was one, in which market forces began to play a role at a very early stage of implementation.

The 1976 German Federal Water Act - FWA (Wasserhaushaltsgesetz) was a continuation of the operation of a permit system that had been in effect in the Länder since 1957. The FWA empowers the federal government to establish uniform discharge standards for certain major pollutants and to determine the level of technology that must be achieved by municipalities and industries. Furthermore the FWA grants the federal government the authority to establish a minimum national water quality goal for receiving waters. This was set at the 'quality level II' (Gütezustand II) which meant moderately polluted water with good oxygen supply, capable of supporting a large variety of shell-fish, insect larvae and fish.

The effluent discharge law was introduced in September 1976 and enacted in 1981 and empowered the Länder to levy charges on direct dischargers for specified effluents into public waters. Firms and households discharging into municipal sewerage facilities, however, are not charged directly. The system is essentially based on the extended polluter-pays-principle, where charges are levied on the basis of the amount that firms will pollute if they adhere to federal minimum emission standards.

The law consists of two parts:

1. The first part establishes a *discharge right*, containing all physical, chemical and biological data and monitoring procedures pertaining to waste and water quality. It legislates the maximum discharge of wastewater in specified time periods for which the quality must be better or equal in quality to the minimum requirements of the federal administrative regulation.
2. The second part provides all the data necessary to calculate the wastewater *discharge bill*. The charge is normally based on the expected rather than the actual level of discharge and contains an economic incentive for polluters to meet the federal minimum standard. Dischargers in compliance with the federal minimum standards will have the charge halved. If the Länder impose stricter standards than the federal government, Länder requirements have to be met to qualify for the 50% discount. The charges are based on the toxicity of the effluent. The federal government has powers to adjust procedures of testing according to new scientific development.

B.3.2 Enforcement and Implementation

One of the problems associated with any pollution control instrument (economic or regulatory) is the problem of enforcement. The German effluent charge law provides some scope for rigorous enforcement, since the law states that producers must declare all effluents. Should polluters fail to declare such effluents, the regulatory authority has the powers to estimate the pollution units (§ 12(2)) and a fine can be imposed of up to DM 5000 (ca. R10 000) (§ 15(2)).

Implementation Pitfalls

Brown and Johnson (1984)[12] assessed the German charge law, before its amendments in 1987 and found that there were a number of problems associated with this law. These problems were not redressed in the 1987 amendment. They were as follows:

1. about 90% of all firms in West Germany discharged their effluent into sewerage systems of municipalities and were thus not directly liable for the effluent charge. Questions arising from this relate to finding ways of how to charge these firms and whether their costs should resemble the costs of direct dischargers.
2. There is limited recourse of appeal if a firm's economic viability is threatened by charges imposed by the municipality for the firm's discharge.
3. The law is enforced by the 'Länder' and refers to domestic, commercial, agricultural and other uses that change the quality of ground and surface water. However, the agricultural pollution of groundwater is exempt.
4. The system has proved to be quite inefficient with more than half the revenues being spent on administration costs.
5. Charges are set at levels well below the true cost of the environmental damage being wrought by the emissions.

Despite the above problems, experience has shown that the German effluent charge system has had a clear beneficial impact on the environment and that public and private enterprise have responded to the system's incentives.

B.4 THE UNITED STATES: WATER POLLUTION CONTROL POLICIES

B.4.1 Description

The goals of the Federal Water Pollution Control Act Amendments of 1972 and 1977[13] are very ambitious: i.e. fishable and swimmable rivers throughout the United

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[12] Brown, Gardner M. Jr, Johnson, Ralph W., Pollution Control by Effluent Charges: It Works in the Federal Republic of Germany, Why Not in the US., in: Natural Resources Journal, Vol. 24, No. 4, 1984, pp929-966.

[13] Hereafter referred to as 'Act'.

States and zero discharge of pollutants into US waters. The EPA was required by Congress to meet the following deadlines:

1. By 1973, to issue effluent guidelines for major industrial categories of water pollution.
2. By 1974, to grant permits to all water pollution sources.
3. By 1977, all sources were to install the "best practicable technology" (BPT) for abatement of pollutants emitted.
4. By 1981, all major US waterways were to be fishable and swimmable.
5. By 1983, all sources were to install the "best available technology" (BAT) to abate pollution,
6. By 1985, all discharges to waterways were to be eliminated.

The political and legal battle that surrounded the introduction and the requirements of the Act, display very clearly the inefficiency of an Act, which was essentially based on a command-and-control approach. Within one year i.e. by 1973 the EPA was required to issue effluent guidelines for over 200,000 industrial polluters emitting 30 major categories of pollution (plus 250 sub-categorise). Neither this first nor the following deadlines set out in the Act were met, and the EPA was faced with spiralling costs and lawsuits regarding the standard setting which was based on the assessments made in the first year. The regulatory procedures established by the Act did not work very well throughout the 1970s and into the 1980s. A further problem was that the Act did not provide for any economic incentives for industry to comply with the regulations. In addition the notion of uniform BPTs or BATs must be considered unreasonable, a point which will be discussed in more detail below. The methods required by this Act led to a high-cost form of control, which did not guarantee improved water quality.

The Clean Water Act (CWA) introduced in 1972 was met by industry with antagonism, both due to the philosophy and its specific provisions. However, polluters did not find the effluent-permit discharge system embodied in the Act excessively trying. This was helped by the fact that the federal government bore some of the costs for municipal waste-treatment plants that eased the compliance factor.

By conventional criteria, i.e. according to the set standards, water quality in the US was not found to be deteriorating in the 1980s and 1990s: most polluters had applied for and received their discharge permits. This does not mean, however, that water quality standards were set at their economically optimal level[14]. It became evident that in order to improve water quality, targets had to be changed and new approaches had to be developed.

In 1992 the EPA sponsored initiatives that use tradable permits to improve national efficiency in attaining air and water quality goals. Under a tradable or marketable permit system, the EPA issued firms with permits for allowable pollutant emissions. Firms may then choose a compliance strategy that is the most appropriate and cost-effective for their operation. If a firm with relatively low compliance costs can reduce its pollutant emissions below the allowable level, it can sell or trade its extra pollution allowance to others. In short, the system achieves an overall national pollution reduction goal while creating an economic incentive for firms to reduce pollution emissions using more efficient and cost-effective approaches. The success of this market-based trading will in-time depend on the ability of polluters to reduce their emissions efficiently, engage in trading, and meet the overall environmental goal.

14 For a further discussion in general terms, see chapter 5 of this report.

APPPENDIX C

ECONOMIC INSTRUMENTS FOR NON-POINT SOURCE POLLUTION

CONTENTS

C. ECONOMIC INSTRUMENTS FOR NON-POINT SOURCE POLLUTION

C.1 TAXES AND FEES

The idea behind taxes and fees has been discussed in Appendix B in terms of their use for controlling point-source pollution.

The general idea is here, as in point source pollution, to increase the costs associated with generating nonpoint pollution and thereby prompting the polluter to take ameliorative action.

C.2 TARGETING

One of the methods to control nonpoint pollution in the United States has been the use of targeting. 'Targeting' "describes the selective application of abatement measures to key resources and to actual damages rather than emissions or ambient conditions."[1] Braden et al. (1989) consider the use of targeting for the control of

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1 Braden, John B., Herricks, Edwin E., Larson, Robert S., Economic Targeting of Nonpoint Pollution Abatement for Fish Habitat Protection, in: Water Resources Research, Vol, 25, No. 12, December 1989, pp. 2399-2405.

agricultural nonpoint source pollution which impacts on fish habitats. They developed a model which indicated where and how to alter farming practices so that costs are minimised for attaining a given fisheries impact goal. This model combined farm economics and stochastic simulations of fisheries degradation due to agricultural pesticides and sediment in surface runoff.

They found that for agricultural pollution management to move beyond narrowly focused programmes, linkages between on-land processes and instream effects must be made. There have to be linkages between the economic optimisation of agricultural practices and a quantitative analysis of the risk that agricultural pollutants pose to fish populations. These attributes permit the targeting of pollution sources and their ultimate impacts, as opposed to pollutant loads or discharges.

C.3 TRADABLE PERMITS AND BUBBLES

Tying nonpoint and point source pollution in a so-called 'bubble' is an innovative and potentially cost-effective policy. In such bubbles total effluent loading from all sources is targeted at some level. By issuing each polluter in the bubble with a "tradable permit" specifying the amount of pollution loading to which they are entitled, total pollution levels in the bubble are controlled at minimum overall cost to the local economy. The same rationale for using tradable permits to control point-source pollution applies here.[2]

C.3.1 Point-Nonpoint Source Trading

In the United States, the idea of trading between point and nonpoint sources of water pollution has taken on a more explicit form in 1992. The EPA continued to study the potential of such trading. Under most scenarios that were considered, regulated point sources could defer water treatment system upgrades, if they would pay for, or arrange for, equivalent or greater reductions in nonpoint source pollution within the same watershed. EPA has approved the use of point-nonpoint source trading involving nutrient pollutants in water bodies that have water quality problems. Programmes have been developed for Cherry Creek Reservoir and Dillon

2 For a detailed discussion, refer to WRC 1993.

Reservoir in Colorado and for Tar-Palmico River Basin in North Carolina. The EPA and other agencies are evaluating the results of these programmes.[3]

C.4 UNITED STATES: NONPOINT POLLUTION CONTROL TRENDS

In the following section, the more recent status of water pollution legislation in the US and its potential for controlling nonpoint sources of pollution will be considered. Emphasis will be placed on implementation pitfalls and cost-effectiveness considerations of the Federal Water Pollution Control Act and the Clean Water Act.

The Federal Water Pollution Control Act, for instance, identifies the fact that water quality is affected both by point and nonpoint sources of waste discharges and makes provisions for controlling pollution from both sources.

In order to aid in the development of water pollution control strategies, the federal government requires the assessment of the quality of the nation's water resources. Despite decades of research, however, only about a third of the US water resources have been assessed. Of these, about two-thirds met the federal water quality standards in 1990[4]. "The major remaining impairment to water quality was found to be polluted runoff from such sources as farmlands, city storm sewers, construction sites, and mines."[5]

Control of agricultural nonpoint pollution is essential for the restoration and protection of acceptable levels of water quality in streams and lakes. The need to alleviate agricultural and other nonpoint pollution problems was recognised with the amendment of the Clean Water Act in 1987. In contrast to the control of point sources, initially the EPA was not given any specific authority to regulate nonpoint sources. In February 1987 $400 million was authorised for a new programme to help states control runoff, but it still left the chief responsibility for controlling nonpoint sources to the individual states.

Under section 208 of the Act control of diffuse pollution was envisaged to be achieved by applying 'BMPs' to specified areas of forest, agriculture and urban land

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3 The Council on Environmental Quality, 23rd Annual Report, Washington, January 1993, p. 55.

4 EPA National Water Quality Inventory, report 305(b), Washington 1990.

5 The Council on Environmental Quality, 1993, p. 225.

within a catchment. These practices were devised for the reduction of sediment, nutrients and chemicals carried to streams and lakes by storm runoff. BMPs were required to be designated by the state authorities. To assist the states in developing nonpoint source pollution management programmes, the EPA awarded a further US$ 52.5 m in 1992. One of the key elements of the BMPs is the minimisation of the economic burden placed on agriculture, thus making cost-effectiveness an important consideration in the designation of BMPs as well as that of the development and evaluation of farm plans for meeting water quality goals.

A survey by the National Association of State Foresters in 1991 showed that 32 states had implemented BMPs to prevent nonpoint source pollution. BMP compliance surveys were conducted in 18 states and it was found that compliance ranged from 79% for streamside management to 98% for forest-site preparation. The report, however, does not provide any information as to the impact of such BMPs on water quality and as to their economic efficiency.

C.4.1 Costs of control

As has been indicated, more emphasis is placed in the United States on controlling point-source pollution than nonpoint source pollution. If nonpoint source pollution is considered to be the largest contributor to water quality degradation, the question remains why such little emphasis has been placed on the control of such an important cause of water quality decline. Such neglect could only be justified, if the marginal damages caused by nonpoint pollution are significantly smaller than those of point sources, which makes it justifiable to support a lower level of control of nonpoint pollution.

Another argument for neglecting nonpoint pollution control is that the perceived costs of controlling diffuse pollution are very high relative to the known costs of controlling point sources. If this is the case, then the neglect may be economically justifiable.

Palmini's study (1984)[6] illustrates some of the issues surrounding the cost factor of different measures used to control nonpoint pollution. He examined the effects of agricultural nonpoint policies on two small rural communities in Illinois. The policies he examined were designed to control nitrogen, sediment (soil erosion) and

6 Dennis J. Palmini, The Secondary Impact of Nonpoint Pollution Controls: A Linear Programming-Input/Output Analysis, in: Journal of Environmental Economics and Management, No. 9, September 1984, pp. 263-278.

pesticides. He related the policies to the choice of farming practices, the effects on costs, and the net financial return to farmers.

In order to control nitrogen, input quantity restrictions (i.e. ceilings on the amount used per acre) and nitrogen taxes were introduced. Quantity restrictions were found to lead to a substantial reduction in farm income. Since the demand for nitrogen is inelastic, it was found that there was a need for very high rates of taxation, which resulted in high income losses for the farmers. The main problem was that cost recovery could only be achieved through increasing the price of agricultural products. Policies that are state- or region-based and which introduce a comparative disadvantage for farmers in the state/region subjected to such policies, compared to those elsewhere, are difficult to introduce and maintain.

On the other hand, however, Palmini also found that soil erosion could be reduced by 74% at a cost of less than 1% of net farm earnings. Also a ban on toxic pesticides, causing farmers to switch to other less damaging pest control means, only resulted in a reduction of the net return to farmers of 0.7%.

Palmini's study suggests that some nonpoint source control can be undertaken at reasonable cost but not necessarily across board. It is apparent that the form and intensity of government intervention has to be adapted to specific problems in order to introduce the most cost-effective and most beneficial control methods. In other words, 'balanced' programmes for controlling both point and nonpoint sources are called for.

C.4.2 Cost-effectiveness of nonpoint source control

The cost-effectiveness of pollution control is usually based on the general rule that an improvement in efficiency is brought about by reallocating abatement efforts from sources with high marginal abatement costs to sources with low marginal costs. Cost-effectiveness is measured by using average abatement costs.

The fundamental problem with this approach, however, is that it is only really applicable to emissions of a non-stochastic nature. Nonpoint source emissions invariably possess stochastic characteristics. Properly defined, pollution control of stochastic emissions involves the improvement of the distribution of emissions rather than reducing them to a scalar value. Despite these difficulties, most analyses of cost-effectiveness measure pollution control on the basis of estimating long-term average expected discharges, and associated control costs. McSweeney and

Shortle (1990)[7] looked at probabilistic, rather than average cost-effectiveness and focused on methods for whole-farm pollution rather than individual practices. Most importantly they found, that, excluding transaction costs, broad prescriptions of appropriate technology in form of BMPs might perform poorly with respect to cost-effectiveness. They recommended a number of alternative instruments by which to arrive at cost-effectiveness for stochastic emissions. These included firstly the imposition of standards on means and weighted variances from which farmers could then decide on the least-cost plans for meeting such standards, and secondly, economic incentives could be offered for promoting cost effective planning at farm level.

Shortle and Dunn (1986)[8] also examined the relative expected efficiency (net benefits) of four general strategies, referring to the flow of pollutants from farms as run-off, incorporating stochastic considerations. These strategies were:

a) economic incentives applied to the estimated run-off, e.g. tax on estimated soil loss
b) estimated run-off standards, e.g. estimated soil-loss standards
c) economic incentives applied to farm management practices, e.g. taxes on nutrient application
d) farm management practice standards, e.g. required use of no-till.

They found that an agency choosing an efficient policy for promoting water pollution abatement for a single farm[9], although unable to observe runoff from a farm at reasonable cost, could form expectations as to the runoff, using observations from farm management practices and other data. The general form of the agency's runoff model is:

7 William T. McSweeney, James S. Shortle, Probabilistic Cost Effectiveness in Agricultural Nonpoint Pollution Control, in: Southern Journal of Agricultural Economics, 22(1), July 1990, pp 95-104.

8 James S. Shortle, James W. Dunn, The Relative Efficiency of Agricultural Source Water Pollution Control Policies, in: American Journal of Agricultural Economics, Vol. 68, August 1986, pp 668-677.

9 The model only considers a single farm, recognising however that situations of practical interest involve numerous polluters. The authors hold, however, that the outcome of nonpoint policies depends upon the responses they elicit at the individual farm level.

$\mathbf{r = f(X, w, \lambda)}$

where **r** is the true, but unobservable flow of runoff from the farm, **X** is a vector of farm management decision, **w** is an index for weather conditions such as rainfall etc., which plays an important role in nonpoint source pollution and λ is a random variable representing the agency's imperfect knowledge of the runoff function. The model essentially represents a stochastic specification after Griffin and Bromley's (1982)[10] 'nonpoint production function', with imperfect information and unobservability (represented by λ) and uncertainty regarding stochastic issues (represented by **w**).

The modelling of the four policy strategies revealed that, policy transaction costs aside, all four policies yielded the same efficient outcome, under the restrictive assumptions of there only being a single polluter and that the polluting farmer is an expected profit maximiser. If these two assumptions are relaxed and multiple sources of pollution and risk aversion are introduced, bringing the scenario a lot closer to a real world situation, the outcome is quite different.

For example:

1. Considering multiple sources of pollution it was found that *management practice incentives* display a distinct advantage over other policies. This is because management practice incentives allow farmers to utilise fully their specialised knowledge of their farm operations. Furthermore, incentives can give farmers at least as much, and even more, information about the expected external costs of their management decisions than quantity control schemes and estimated run-off incentives. An appropriately specified management practice incentive is expected to yield greater expected net benefits than any of the other policy options.

2. It was also found that none of the policies under discussion could be defined as a first-best strategy where farmers avert risk. It is still important to note that it was found that a management practice incentive fares preferentially over the other strategies. Although it must be stated that a tax (or subsidy) for a management practice incentive depends upon the agency's perfect knowledge of a given farmer's risk preference and specialised knowledge of the farm operations, such an incentive reveals to the farmer the agency's evaluation of the expected external cost of his

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10 Ronald Griffin and Daniel Bromley, Agricultural Runoff as a Nonpoint Externality, in: American Journal of Agricultural Economics, Vol. 62, 1982, pp 547-552.

decision - to a greater degree than the other policies. At the same time the farmer is still able to fully utilise his comparative informational advantage as to the returns from other management practices in order to maximise his welfare.

APPENDIX D

WITBANK DAM: COMPARATIVE COSTS OF WATER QUALITY MANAGEMENT OPTIONS

CONTENTS

D. WITBANK DAM: COMPARATIVE COSTS OF WATER QUALITY MANAGEMENT OPTIONS

D.1 INTRODUCTION

The Witbank dam is located at the headwaters of the Olifants River. The land use practices in the catchment include agriculture, electric power generation, coal mining and urban settlements. All power generation is by means of coal fired power stations.

Various streams, all of them tributaries of the Olifants River in which the Witbank dam is located, drain the catchment. All the land use practices have some effect on the water quality of the streams draining the catchment.

Concerns regarding the water quality of the Witbank dam have been raised and the Department of Water Affairs and Forestry (DWA&F) is presently considering various water quality management options. Wates Meiring & Barnard (WMB) produced a report titled *Olifants River Basin, Technical Support Document for Witbank Dam Water Quality Management Plan, report no 1505/611/1/W* for the Water Research Commission as part of the initiatives to improve water quality in the catchment.

An economic analysis of the water management options has been requested and the comparative cost analysis, which is the subject of this report, forms part of the wider economic analysis.

Pollution is caused by point sources and diffuse sources. In a point source the pollution occurs at a point and the quantity of impurities in the water can therefore be measured at the source. In a diffuse source the pollution occurs over a large area and affects surface water run-off and is found to seep into ground water. The quantity of pollution from a diffuse source of pollution can not be measured at the source. An example of a point source is the outflow of a municipal sewerage treatment plant while an example of a diffuse source is a coal mine waste dump. It would be possible to convert a diffuse source of pollution into a point source by, for instance, digging a trench around the diffuse source to drain all run-off and seepage water into a channel. This is however not a simple exercise and therefore expensive.

The Witbank Dam Water Quality Management Plan makes it clear that to achieve the water quality management objectives it is imperative that adequate information be available. The plan also specifies compliance monitoring points (CMPs) and control points (CPs) that need to be in place. What it cannot specify at this stage is the exact location of the compliance monitoring points. The difficulty is that much of the pollution in the streams is generated by diffuse sources that cannot be monitored at source. It is therefore proposed that diffuse sources of pollution be monitored on the water course that is affected by discharges of impurities, downstream of the source but upstream of any neighbouring sources of pollution. The placing of the monitoring points is therefore critical, because if the monitoring point is placed too high upstream, not all pollution will be measured, while if it is placed too far downstream, pollution from the next source will be included. The role players and the water authority will therefore have to agree on the exact position of all compliance monitoring points.

D.2 SCOPE OF THIS RESEARCH

This analysis needs to compare the costs of the following approaches to water quality management in the Witbank Dam catchment:

- The conventional command and control approach (CAC) i.e. total control by the water authority

- A joint venture approach as proposed by WMB i.e. joint responsibility (and costs) between the water authority and the polluters

- An economic based approach using 'green taxes' to provide an incentive to polluters to participate in discharge permit trading for effluents i.e. the authority's role is mainly to set goals and monitor their achievement

(See Section 3 for a more detailed description of the approaches.)

The cost analysis will focus on the **financial costs** of **establishing** and **operating** the various systems and will involve the following broad cost areas:

- Capital expenditure to provide monitoring stations
- Capital expenditure for instrumentation
- Operational expenses for data collection and analysis; manpower and associated expenses
- Operational expenses for analysis of water samples
- Management, administrative and support expenses associated with the above
- Permit trading expenses
- Office equipment and office space

D.3 DESCRIPTION OF THE MANAGEMENT APPROACHES

D.3.1 3.1 COMMAND AND CONTROL APPROACH

In the command and control approach the authority takes total responsibility to set maximum emission standards for each polluter, to monitor the levels of emissions by each polluter and to set an appropriate penalty if maximum emission standards are exceeded. The magnitude of the penalty will depend on how far an emission standard is exceeded. No credit is given to polluters who emit less than the maximum standard.

D.3.2 ECONOMIC BASED APPROACH

In the economic based approach, rather than set a maximum emission standard for each polluter, the authority would set a water quality standard for a catchment or sub-catchment. Each polluter in the catchment would then be allocated a permit that would allow a certain amount of emissions. A penalty would still be imposed on polluters who exceed the emission quantity specified in their permit. These permits are however tradable on the open market and will have a market value that will be determined by the cost of emission abatement and the magnitude of the penalty that is imposed if the permit emission quantity is exceeded. In this way polluters that produce more "clean up" than required, can sell their excess "clean up" to polluters who have difficulty in achieving their quotas.

D.3.3 SIMILARITIES AND DIFFERENCES BETWEEN THE APPROACHES

The best way to gain a better understanding of the two approaches is to look at the similarities and differences between them.

D.3.3.1 Similarities

- Each polluter is assigned a level of pollution or quota that may not be exceeded.
- Measurements will be taken to determine the amount of pollution from each source.
- Some form of penalty is imposed on polluters that exceed their quota.
- The quotas assigned to each polluter will aggregate to the amount of pollution that has been decided on for a particular body of water in a catchment, i.e. the water quality of the body of water will be acceptable for a defined use. Note that some quotas may be kept in reserve by the authority for assignment to future entrants into the area.

D.3.3.2 Differences

- In the CAC approach no credit is given to polluters that pollute less than their assigned quota while the economic approach encourages polluters who can achieve a better water quality than their quota requires, to sell this excess "clean up" to polluters that have difficulty in achieving their quotas. How much "clean up" is bought and sold will depend on the cost of achieving units of "clean up".

- Presently the larger sources of pollution are diffuse sources and it will not be possible to determine exactly which polluters are responsible for the level of pollution measured within a sub-catchment area. This means that a set of polluters in a sub-catchment will all receive a proportion, calculated by a pre-set formula, of the penalty that is imposed when the combined quota for the sub-catchment is exceeded. The economic approach sets a penalty in the form of a tax that reduces to zero when the quota is not exceeded while the CAC approach sets a fine which increases the further the quota is exceeded. The economic approach will encourage polluters to change their diffuse sources that cannot be measured and managed properly to point sources that are easier to manage and measure, even though they do not exceed their quotas, so that they can sell any excess "clean up" to polluters that have difficulty in achieving their quota. This implies that polluters in one sub-catchment could trade with polluters in another sub-catchment.

- Each catchment will have a saturation point i.e. a point where no further polluters can be accommodated in a particular catchment. The CAC approach will result in this saturation point being reached much sooner than the Economic approach i.e. the CAC approach will result in barriers to entry of new economic activities within a catchment sooner than necessary as there will be no incentive to produce excess "clean up".

- The CAC approach will place an onerous regulatory responsibility, which will be paid for by the tax payer in general, on the water authorities while the economic approach will place a self regulatory responsibility on the polluters, resulting in the polluters themselves paying most of the costs associated with managing the system.

D.4 DETERMINATION OF COSTS

D.4.1 ASSUMPTIONS

- The valuation for the different management approaches is based on the data needs as described in the report *Olifants River Basin, Technical Support Document for Witbank Dam Water Quality Management Plan, report no 1505/611/1/W* by Wates Meiring & Barnard.
- The data needs will not differ for the various management approaches.
- Existing infrastructure will be used as far as possible.
- The costs determined in this research do not include existing monitoring that has to be done as part of other initiatives. These costs include the following:
  - ⇒ monitoring for atmospheric depositions.
  - ⇒ background water quality monitoring.
  - ⇒ biomonitoring.
  - ⇒ special studies to determine eutrophication and heavy metal deposition.

D.4.2 Philosophical discussion of the valuations

If it is accepted that the data requirements for the various management approaches is the same, it follows that the costs for establishing infrastructure and operation of the systems will also be the same. The allocation of the costs will however differ. In the CAC approach all costs will be allocated to the Water Authority, in this case DWA&F. In the approach proposed by WMB, costs for establishing and operating the control points will be allocated to DWA&F while costs for the compliance monitoring points could be allocated to the various role players. The exact proportions of the allocation will however depend on negotiation between DWA&F and the role players. What will need to be negotiated are the type of instrumentation, who will pay for auditing and calibration of instruments, and the frequency of reports. This situation will also exist for the economic approach if it is implemented.

The only difference between the CAC approach, the joint venture approach and the economic based approach will be the costs associated with permit trading. Permit trading will involve the following:

- negotiations between role players for trading of permits, possibly assisted by a broker or agent who will receive a commission.
- registration of the trade, similar to a share transfer; such a transfer would be open for public inspection and be recorded by DWA&F or a mutually agreed agent appointed by DWA&F.

These costs would however be reflected in the permit trading price and will have no influence on the costs to establish and operate the system and need not be included in this analysis.

It could be argued that the total costs for establishing and operating the economic based system could be reflected in the permit trading prices. At this stage there is however not enough empirical evidence available from economic based systems world wide, to warrant this point of view. Issues that could influence the free trading of permits and which will affect permit trading prices are:

- size of the market; there are a total of 30 role players in this sub-catchment and this may be a too small number to ensure free trade.
- the trading of permits may stabilise after a period, i.e. all emissions are balanced in line with permits owned and there is no need for trading to take place.
- role players may hoard permits for future use in expanding their own operations or because they fear that selling a permit will result in a competitive advantage to their competition.

The above issues do not militate against implementing an economic based system however. There are still many advantages that may be gained at no risk, as the costs of permit trading will be included in permit prices.

All manpower expenses were based on the salary scales of DWA&F as it was considered that these scales would best reflect the going market rate for such expertise.

D.4.3 Valuations

D.4.3.1 Compliance Monitoring Points (CMP)

A total of 30 compliance-monitoring points will be required. A weir will have to be constructed for each CMP. As the exact positions of the CMPs are not known at this stage, an average length of 22 m was taken for each weir. The cost of a weir is R8 000 per running metre. (Pers. com. DWA&F)

The cost of the weirs is therefore R 8 000 x 22 x 30 = R 5 280 000

D.4.3.2 Control Points (CP)

There are 9 control points specified by WMB, 8 of which will be at existing weirs or dam walls. The exception is the CP on the Steenkoolspruit, which will be where the Tavistock abstraction takes place and will require a weir.

The cost of the weir is R 8 000 x 22 x 1 = R 176 000

D.4.3.3 Capital Expenditure for Instrumentation

Instrumentation to continuously measure flow quantity, salinity and acidity will have to be installed at each CMP and CP, a total of 39 instruments. Because of the potential financial implications (it is expected that penalties for non-compliance will be high) the instrumentation used for the compliance measurements must be of a high standard. The costs for instrumentation were therefore based on the Grant Environmental System.

The cost of instrumentation is R 28 000 x 39 = R 1 092 000

It is expected that, due to normal wear and tear and the development of more sophisticated systems, the instrumentation will have to be replaced periodically. A replacement period of 10 years was taken for the purpose of this analysis. The discount rate used was 8%, which is the standard rate for DWA&F projects.

NPV of Capital Expenditure @ 8% over 45 years = R 1 990 880

D.4.3.4 Operational Expenses

These costs include data collection, analysis, travelling, office space and are made up of manpower and associated expenses. As these expenses will be incurred over the life cycle of the project a net present value (NPV) was calculated over a 45-year period at 8%.

Some of the operational expenses for CMPs may coincide with expenses that are already incurred for the Environmental Management Progress Reports (EMPR) that mines have to carry out in terms of the Minerals Act. It is however not possible to determine to what extent the expenses will coincide at this stage. A conservative view has therefore been taken and all expenses associated with compliance monitoring have been included in this analysis. Table 4.1 below summarises the operational expenses.

Item	Quantity per Annum	Units	Rate per Unit	Total per Annum
Sample & Data Collection	260	man days	R300.00	R78,000
Sample Analysis	1506	samples	R240.00	R361,440
Traveling	75300	km	R0.395	R29,744
Processing & Analysis	52	man days	R525.00	R27,300
Independent Auditing	480	man hours	R200.00	R96,000
Audit Sample Analysis	125	samples	R240.00	R30,000
Calibration of Instruments	16	calibrations	R1,500.00	R24,000
Maintenance Costs	8	man days	R1,500.00	R12,000
Admin. Support	52	man days	R140.00	R7,280
Office Space	13.2	square m	R300.00	R3,960
TOTAL ANNUAL OPERATIONAL COSTS				**R669,724**
Net Present Value @ 8% over 45 Years				**R8,109,281**

TABLE 4.1: SUMMARY OF OPERATIONAL COSTS

D.4.3.5 Explanatory Notes on Values for Calculation Purposes

Manpower costs

DWA&F salary scale for Assistant Water Pollution Control Officer

R 37 170 x R 1 875 - R 46 454: Median Value	R 41 812
Add 13 th Cheque	R 3 484
Annual Total	R 45 296
Add Fringe Benefits 70% (includes car allowance)	R 31 707
Total Package	R 77 003
Daily Rate (to nearest R 5)	R 300

DWA&F Salary Scale for Principal Water Pollution Control Officer

R 69 510 x R 2 901 - R 78 213: Median Value	R 73 861
Add 13 th Cheque	R 6 155
Annual Total	R 80 016
Add Fringe Benefits 70% (includes car allowance)	R 56 011
Total Package	R136 027
Daily Rate (to nearest R 5)	R 525

Administrative Assistant

Median Value	R 24 000
Add 13 th Cheque	R 2 000
Annual Total	R 26 000
Add Fringe Benefits 40% (excludes car allowance)	R 10 400
Total Package	R 36 400
Daily Rate (to nearest R 5)	R 140

Sampling

As specified by WMB on the Control Points	336 per annum
30 Compliance Monitoring Points (every week in summer)	780 per annum
30 Compliance Monitoring Points (every 2 weeks in winter)	390 per annum
Total	1 506 per annum

Cost to analyse 1 sample = R 240

Travelling Expenses

Taking of 1506 samples @ 50 km per sample = 75 300 km

AA rate per kilometre (2 litre vehicle) = R 0,395 for fuel and maintenance; capital expenditure is included in fringe benefits

Manpower Requirements

Taking of samples and recording data: 1 Assistant Water Pollution Control Officer full time = 260 man days per annum

Data processing and analysis: 1 Principal Water Pollution Control Officer, 1 man day per week = 52 man days per annum

Admin. support: 1 Data Processor/Administrative Assistant, 1 man day per week = 52 man days per annum

Calibration of Instruments

39 Instruments calibrated once every two months = 78 calibrations per annum

78 calibrations @ 5 calibrations per day = 16 man days (to nearest day)

Calibration contract, including instruments, travelling and manpower: R 1 500 per day

Maintenance of Instruments

39 Instruments serviced once every two months = 78 services per annum

78 services @ 10 services per day = 8 man days (to nearest day)

Service contract, including equipment, spares and travelling: R 1 500 per day

Office Space

1 Office for full time Assistant Water Pollution Control Officer: $9m^2$

1 Office part time (20%) for Principal Water Pollution Control Officer: $2,4m^2$

1 Office part time (20%) for admin. support: $1,8m^2$

Cost of office space @ R $25/m^2$ per month = R $300/m^2$ per annum

Independent Audits

39 Stations audited on a monthly basis @ 1 week per audit = 480 man hours

Consulting rate per hour = R 200

D.4.3.6 Total Expenses

Table 4.2 gives a summary of the total expenses for capital expenditure and operational management of the water quality in the Witbank Dam.

Item	Cost R Million
Building of Weirs	R 5,456
Cost of Instrumentation *	R 1,991
Operational Expenses	R 8,109
Total (1994 Rand)	**R 15,556**

* Includes replacement costs

TABLE 4.2: TOTAL COST OF WATER QUALITY MANAGEMENT FOR THE WITBANK DAM

D.4.3.7 4.3.7 ALLOCATION OF COSTS

If the allocation of costs is negotiated along the lines proposed by WMB the proportions can be calculated as follows:

Building of weirs

1 weir for DWA&F = R 0,176 million

30 weirs for the role players = R 5,280

Instrumentation

9 Control Points to DWA&F

30 Compliance Monitoring Points to the Role Players

which gives a ratio of 23% to DWA&F and 77% to the role players for instrument costs i.e.

R 0,458 million to DWA&F and

R 1,533 million to the role players

Operational Costs

9 Control Points to DWA&F

30 Compliance Monitoring Points to the Role Players

which gives a ratio of 23% to DWA&F and 77% to the role players for operational costs i.e.

R 1,865 million to DWA&F and

R 6,244 million to the role players

Table A1.3 summarises the cost breakdown.

Item	Cost R million DWA&F	Cost R million Role Players	Total Costs
Building of Weirs	R 0,176	R 5,280	R 5,456
Cost of Instrumentation *	R 0,458	R 1,533	R 1,991
Operational Expenses	R 1,865	R 6,244	R 8,109
Total (1994 Rand)	**R 2,499**	**R 13,057**	**R 15,566**

* Includes Replacement Costs

TABLE A1.3: ALLOCATION OF WATER QUALITY MANAGEMENT COSTS

APPENDIX E

MODEL OUTPUT DATA

E. MODEL OUTPUT DATA

Additional data from both the Simulation model and the Marginal Cost model are here provided for the reader to analyse for himself along the lines indicated in Chapter 5. The data sheets are arranged in pairs, such that the output for both models for any given input will appear together to facilitate comparison.

Data is provided for the following pollution abatement scenarios:

Pollution abatement required: 200 units
225 units
250 units
275 units
300 units
325 units
350 units
375 units
400 units
425 units
450 units

It should be noted that the abatement of 186 units represents the sum of the abatements occurring at the dips in the abatement curves of the individual mines. Since the green tax will drive abatement efforts down to this level without the need for trading, no interest in trading will be evidenced by the players, and below this level the model produces spurious results.

500 units of abatement represents 100% abatement by all players (this is the theoretical maximum pollution which can be emitted), and this input produces the trivial result where all mines abate to the maximum, and no trading occurs and no benefits accrue. This scenario is therefore not included.

MARGINAL COST MODEL OUTPUT — 200 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 12 024.29	**R 14 024.29**	**R 16 024.29**	**R 18 024.29**	**R 20 024.29**	**R 80 121.44**	Cost of legislative approach
R 12 391.41	R 14 226.41	R 15 950.13	R 17 552.49	R 19 070.47	R 79 190.90	Cost of abatement instituted
4.12	1.52	(0.38)	(1.98)	(3.28)	0.00	Number of permits sold (bought)
R 725.12	R 267.52	R (66.88)	R (348.48)	R (577.28)	R 0.00	Cost of permits sold (bought)
R 11 666.29	**R13 958.89**	**R 16 017.01**	**R 17 900.97**	**R 19 647.75**	**R 79 190.90**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 358.00	**R 65.40**	**R 7.28**	**R 123.32**	**R 376.54**	**R 930.54**	Potential savings (cost of legislative approach less actual abatement costs)
60.02	60.02	60.02	60.02	60.02	300.10	Permits issued to cover allowable emissions
55.90	58.50	60.40	62.00	63.30	300.10	Actual emissions (based on marginal costs)
44.10	41.50	39.60	38.00	36.70	199.90	Actual implemented (based on marginal costs)
4.12	1.52	(0.38)	(1.98)	(3.28)	0.00	Excess (deficit) of permits

Abatement desired	**200**
Permits issued	**300**
Market price of permits	**176**

SIMULATION MODEL OUTPUT 200 UNITS OF ABATEMENT DESIRED

COSTS												EXPLANATIONS
MINE A		MINE B		MINE C		MINE D		MINE E		TOTAL		
R	**12 024**	**R**	**14 024**	**R**	**16 024**	**R**	**18 024**	**R**	**20 024**	**R**	**80 120**	Cost of legislative approach
R	12 374	R	14 146	R	16 024	R	17 553	R	19 126	R	79 223	Cost of abatement instituted
	4		1		0		(2)		(3)		0	Number of permits sold (bought)
R	684	R	171	R	-	R	(342)	R	(513)	R	-	Cost of permits sold (bought)
R	**11 690**	**R**	**13 975**	**R**	**16 024**	**R**	**17 895**	**R**	**19 639**	**R**	**79 223**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R	**334**	**R**	**49**	**R**	**-**	**R**	**129**	**R**	**385**	**R**	**897**	Potential savings (cost of legislative approach less actual abatement costs)

60	60	60	60	60	300	Permits issued to cover allowable emissions
56	59	60	62	63	300	Actual emissions (based on simulation)
44	41	40	38	37	200	Actual implemented (based on simulation)
4	1	0	(2)	(3)	0	Excess (deficit) of permits

Abatement desired	**200**
Permits issued	**300**
Market price of permits	**171**

MARGINAL COST MODEL OUTPUT 225 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 12 561.92	**R 15 093.17**	**R 17 624.42**	**R 20 155.67**	**R 22 686.92**	**R 88 122.10**	Cost of legislative approach
R 14 645.85	R 15 877.70	R 17 253.43	R 18 648.07	R 19 984.93	R 86 409.98	Cost of abatement instituted
6.84	2.24	(0.86)	(3.16)	(5.06)	0.00	Number of permits sold (bought)
R 2 708.64	R 887.04	R (340.56)	R (1 251.36)	R (2 003.76)	R 0.00	Cost of permits sold (bought)
R 11 937.21	**R14 990.66**	**R 17 593.99**	**R 19 899.43**	**R 21 988.69**	**R 86 409.98**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 624.71	**R 102.51**	**R 30.43**	**R 256.24**	**R 698.23**	**R 1 712.11**	Potential savings (cost of legislative approach less actual abatement costs)
55.04	55.04	55.04	55.04	55.04	275.20	Permits issued to cover allowable emissions
48.20	52.80	55.90	58.20	60.10	275.20	Actual emissions (based on marginal costs)
51.80	47.20	44.10	41.80	39.90	224.80	Actual implemented (based on marginal costs)
6.84	2.24	(0.86)	(3.16)	(5.06)	0.00	Excess (deficit) of permits

Abatement desired	**225**
Permits issued	**275**
Market price of permits	**396**

SIMULATION MODEL OUTPUT   225 UNITS OF ABATEMENT DESIRED

COSTS												EXPLANATIONS
MINE A		MINE B		MINE C		MINE D		MINE E		TOTAL		
R	**12 562**	**R**	**15 093**	**R**	**17 625**	**R**	**20 156**	**R**	**22 687**	**R**	**88 123**	Cost of legislative approach
R	14 725	R	15 799	R	17 214	R	18 728	R	20 024	R	86 490	Cost of abatement instituted
	7		2		(1)		(3)		(5)		0	Number of permits sold (bought)
R	2 772	R	792	R	(396)	R	(1 188)	R	(1 980)	R	-	Cost of permits sold (bought)
R	**11 953**	**R**	**15 007**	**R**	**17 610**	**R**	**19 916**	**R**	**22 004**	**R**	**86 490**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R	**609**	**R**	**86**	**R**	**15**	**R**	**240**	**R**	**683**	**R**	**1 633**	Potential savings (cost of legislative approach less actual abatement costs)

55	55	55	55	55	275	Permits issued to cover allowable emissions
48	53	56	58	60	275	Actual emissions (based on simulation)
52	47	44	42	40	225	Actual implemented (based on simulation)
7	2	(1)	(3)	(5)	0	Excess (deficit) of permits

Abatement desired	**225**
Permits issued	**275**
Market price of permits	**396**

MARGINAL COST MODEL OUTPUT 250 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 13 974.13	**R 17 099.13**	**R 20 224.13**	**R 23 349.13**	**R 26 474.13**	**R 101 120.66**	Cost of legislative approach
R 18 810.60	R 18 645.72	R 19 300.84	R 20 265.07	R 21 357.45	R 98 379.69	Cost of abatement instituted
10.52	3.02	(1.58)	(4.78)	(7.18)	(0.00)	Number of permits sold (bought)
R 5 828.08	R 1 673.08	R (875.32)	R (2 648.12)	R (3 977.72)	R (0.00)	Cost of permits sold (bought)
R 12 982.52	**R16 972.64**	**R 20 176.16**	**R 22 913.19**	**R 25 335.17**	**R 98 379.69**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 991.61	**R 126.49**	**R 47.97**	**R 435.94**	**R 1 138.96**	**R 2 740.97**	Potential savings (cost of legislative approach less actual abatement costs)
50.02	50.02	50.02	50.02	50.02	250.10	Permits issued to cover allowable emissions
39.50	47.00	51.60	54.80	57.20	250.10	Actual emissions (based on marginal costs)
60.50	53.00	48.40	45.20	42.80	249.90	Actual implemented (based on marginal costs)
10.52	3.02	(1.58)	(4.78)	(7.18)	(0.00)	Excess (deficit) of permits

Abatement desired	**250**
Permits issued	**250**
Market price of permits	**554**

SIMULATION MODEL OUTPUT 250 UNITS OF ABATEMENT DESIRED

COSTS												EXPLANATIONS
MINE A		MINE B		MINE C		MINE D		MINE E		TOTAL		
R	**13 974**	**R**	**17 099**	**R**	**20 224**	**R**	**23 349**	**R**	**26 474**	**R**	**101 120**	Cost of legislative approach
R	19 089	R	18 645	R	19 083	R	20 156	R	21 469	R	98 442	Cost of abatement instituted
	11		3		(2)		(5)		(7)		0	Number of permits sold (bought)
R	6 094	R	1 662	R	(1 108)	R	(2 770)	R	(3 878)	R	-	Cost of permits sold (bought)
R	**12 995**	**R**	**16 983**	**R**	**20 191**	**R**	**22 926**	**R**	**25 347**	R	98 442	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R	**979**	**R**	**116**	**R**	**33**	**R**	**423**	**R**	**1 127**	**R**	**2 678**	Potential savings (cost of legislative approach less actual abatement costs)

50	50	50	50	50	250	Permits issued to cover allowable emissions
39	47	52	55	57	250	Actual emissions (based on simulation)
61	53	48	45	43	250	Actual implemented (based on simulation)
11	3	(2)	(5)	(7)	0	Excess (deficit) of permits

Abatement desired	**250**
Permits issued	**250**
Market price of permits	**554**

MARGINAL COST MODEL OUTPUT — 275 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 16 015.17	**R 19 796.42**	**R 23 577.67**	**R 27 358.92**	**R 31 140.17**	**R 117 888.36**	Cost of legislative approach
R 24 419.85	R 22 282.03	R 21 885.04	R 22 229.04	R 22 952.57	R 113 768.54	Cost of abatement instituted
14.62	3.92	(2.38)	(6.58)	(9.58)	0.00	Number of permits sold (bought)
R 9 883.12	R 2 649.92	R (1 608.88)	R (4 448.08)	R (6 476.08)	R -	Cost of permits sold (bought)
R 14 536.73	**R 19 632.11**	**R 23 493.92**	**R 26 677.12**	**R 29 428.65**	**R 113 768.54**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 1 478.44	**R 164.31**	**R 83.75**	**R 681.80**	**R 1 711.52**	**R 4 119.81**	Potential savings (cost of legislative approach less actual abatement costs)
45.02	45.02	45.02	45.02	45.02	225.10	Permits issued to cover allowable emissions
30.40	41.10	47.40	51.60	54.60	225.10	Actual emissions (based on marginal costs)
69.60	58.90	52.60	48.40	45.40	274.90	Actual implemented (based on marginal costs)
14.62	3.92	(2.38)	(6.58)	(9.58)	0.00	Excess (deficit) of permits

Abatement desired	**275**
Permits issued	**225**
Market price of permits	**676**

SIMULATION MODEL OUTPUT 275 UNITS OF ABATEMENT DESIRED

COSTS												EXPLANATIONS
MINE A		MINE B		MINE C		MINE D		MINE E		TOTAL		
R	**16 015**	**R**	**19 796**	**R**	**23 578**	**R**	**27 359**	**R**	**31 140**	**R**	**117 888**	Cost of legislative approach
R	24 691	R	22 349	R	22 157	R	21 963	R	22 687	R	113 847	Cost of abatement instituted
	15		4		(2)		(7)		(10)		0	Number of permits sold (bought)
R	10 140	R	2 704	R	(1 352)	R	(4 732)	R	(6 760)	R	-	Cost of permits sold (bought)
R	**14 551**	**R**	**19 645**	**R**	**23 509**	**R**	**26 695**	**R**	**29 447**	**R**	**113 847**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R	**1 464**	**R**	**151**	**R**	**69**	**R**	**664**	**R**	**1 693**	**R**	**4 041**	Potential savings (cost of legislative approach less actual abatement costs)

45	45	45	45	45	225	Permits issued to cover allowable emissions
30	41	47	52	55	225	Actual emissions (based on simulation)
70	59	53	48	45	275	Actual implemented (based on simulation)
15	4	(2)	(7)	(10)	0	Excess (deficit) of permits

Abatement desired	**275**
Permits issued	**225**
Market price of permits	**676**

MARGINAL COST MODEL OUTPUT 300 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 18 535.98	**R 23 035.98**	**R 27 535.98**	**R 32 035.98**	**R 36 535.98**	**R 137 679.91**	Cost of legislative approach
R 30 964.79	R 26 649.55	R 24 938.69	R 24 552.09	R 24 765.04	R 131 870.16	Cost of abatement instituted
18.64	4.94	(3.16)	(8.36)	(12.06)	0.00	Number of permits sold (bought)
R 14 501.92	R 3 843.32	R (2 458.48)	R (6 504.08)	R (9 382.68)	R -	Cost of permits sold (bought)
R 16 462.87	**R 22 806.23**	**R 27 397.17**	**R 31 056.17**	**R 34 147.72**	**R 131 870.16**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 2 073.11	**R 229.76**	**R 138.82**	**R 979.81**	**R 2 388.26**	**R 5 809.75**	Potential savings (cost of legislative approach less actual abatement costs)

40.04	40.04	40.04	40.04	40.04	200.20	Permits issued to cover allowable emissions
21.40	35.10	43.20	48.40	52.10	200.20	Actual emissions (based on marginal costs)
78.60	64.90	56.80	51.60	47.90	299.80	Actual implemented (based on marginal costs)
18.64	4.94	(3.16)	(8.36)	(12.06)	0.00	Excess (deficit) of permits

Abatement desired	**300**
Permits issued	**200**
Market price of permits	**778**

SIMULATION MODEL OUTPUT 300 UNITS OF ABATEMENT DESIRED

COSTS												EXPLANATIONS
MINE A		MINE B		MINE C		MINE D		MINE E		TOTAL		
R	**18 536**	**R**	**23 036**	**R**	**27 536**	**R**	**32 036**	**R**	**36 536**	**R**	**137 680**	Cost of legislative approach
R	30 500	R	26 727	R	25 095	R	24 865	R	24 843	R	132 030	Cost of abatement instituted
	18		5		(3)		(8)		(12)		0	Number of permits sold (bought)
R	13 968	R	3 880	R	(2 328)	R	(6 208)	R	(9 312)	R	-	Cost of permits sold (bought)
R	**16 532**	**R**	**22 847**	**R**	**27 423**	**R**	**31 073**	**R**	**34 155**	**R**	**132 030**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R	**2 004**	**R**	**189**	**R**	**113**	**R**	**963**	**R**	**2 381**	**R**	**5 650**	Potential savings (cost of legislative approach less actual abatement costs)

40	40	40	40	40	200	Permits issued to cover allowable emissions
22	35	43	48	52	200	Actual emissions (based on simulation)
78	65	57	52	48	300	Actual implemented (based on simulation)
18	5	(3)	(8)	(12)	0	Excess (deficit) of permits

Abatement desired	**300**
Permits issued	**200**
Market price of permits	**776**

MARGINAL COST MODEL OUTPUT — 325 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 21 446.15	**R 26 727.40**	**R 32 008.65**	**R 37 289.90**	**R 42 571.15**	**R 160 043.27**	Cost of legislative approach
R 38 132.06	R 31 677.99	R 28 565.04	R 27 271.81	R 26 904.25	R 152 551.15	Cost of abatement instituted
22.32	6.02	(3.78)	(10.08)	(14.48)	0.00	Number of permits sold (bought)
R 19 418.40	R 5 237.40	R (3 288.60)	R (8 769.60)	R (12 597.60)	R 0.00	Cost of permits sold (bought)
R 18 713.66	**R 26 440.59**	**R 31 853.64**	**R 36 041.41**	**R 39 501.85**	**R 152 551.15**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 2 732.50	**R 286.81**	**R 155.01**	**R 1 248.50**	**R 3 069.30**	**R 7 492.13**	Potential savings (cost of legislative approach less actual abatement costs)
35.02	35.02	35.02	35.02	35.02	175.10	Permits issued to cover allowable emissions
12.70	29.00	38.80	45.10	49.50	175.10	Actual emissions (based on marginal costs)
87.30	71.00	61.20	54.90	50.50	324.90	Actual implemented (based on marginal costs)
22.32	6.02	(3.78)	(10.08)	(14.48)	0.00	Excess (deficit) of permits

Abatement desired	**325**
Permits issued	**175**
Market price of permits	**870**

SIMULATION MODEL OUTPUT 325 UNITS OF ABATEMENT DESIRED

COSTS												EXPLANATIONS
MINE A		MINE B		MINE C		MINE D		MINE E		TOTAL		
R	**21 446**	**R**	**26 727**	**R**	**32 009**	**R**	**37 290**	**R**	**42 571**	**R**	**160 043**	Cost of legislative approach
R	37 872	R	31 678	R	28 392	R	27 359	R	27 343	R	152 644	Cost of abatement instituted
	22		6		(4)		(10)		(14)		0	Number of permits sold (bought)
R	19 140	R	5 220	R	(3 480)	R	(8 700)	R	(12 180)	R	-	Cost of permits sold (bought)
R	**18 732**	**R**	**26 458**	**R**	**31 872**	**R**	**36 059**	**R**	**39 523**	**R**	**152 644**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R	**2 714**	**R**	**269**	**R**	**137**	**R**	**1 231**	**R**	**3 048**	**R**	**7 399**	Potential savings (cost of legislative approach less actual abatement costs)

35	35	35	35	35	175	Permits issued to cover allowable emissions
13	29	39	45	49	175	Actual emissions (based on simulation)
87	71	61	55	51	325	Actual implemented (based on simulation)
22	6	(4)	(10)	(14)	0	Excess (deficit) of permits

Abatement desired	**325**
Permits issued	**175**
Market price of permits	**870**

MARGINAL COST MODEL OUTPUT — 350 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 24 690.86	**R30 815.86**	**R 36 940.86**	**R 43 065.86**	**R 49 190.86**	**R 184 704.28**	Cost of legislative approach
R 45 702.33	R37 241.31	R 32 672.44	R 30 282.01	R 29 274.63	R 175 172.72	Cost of abatement instituted
25.66	7.16	(4.24)	(11.74)	(16.84)	0.00	Number of permits sold (bought)
R 24 505.30	R 6 837.80	R (4 049.20)	R (11 211.70)	R (16 082.20)	R (0.00)	Cost of permits sold (bought)
R 21 197.03	**R30 403.51**	**R 36 721.64**	**R 41 493.71**	**R 45 356.83**	**R 175 172.72**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 3 493.83	**R 412.34**	**R 219.21**	**R 1 572.15**	**R 3 834.02**	**R 9 531.56**	Potential savings (cost of legislative approach less actual abatement costs)
30.06	30.06	30.06	30.06	30.06	150.30	Permits issued to cover allowable emissions
4.40	22.90	34.30	41.80	46.90	150.30	Actual emissions (based on marginal costs)
95.60	77.10	65.70	58.20	53.10	349.70	Actual implemented (based on marginal costs)
25.66	7.16	(4.24)	(11.74)	(16.84)	0.00	Excess (deficit) of permits

Abatement desired	**350**
Permits issued	**150**
Market price of permits	**955**

SIMULATION MODEL OUTPUT 350 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 24 691	**R 30 816**	**R 36 941**	**R 43 066**	**R 49 191**	**R 184 705**	Cost of legislative approach
R 46 085	R 37 146	R 32 960	R 30 092	R 29 179	R 175 462	Cost of abatement instituted
26	7	(4)	(12)	(17)	0	Number of permits sold (bought)
R 24 830	R 6 685	R (3 820)	R (11 460)	R (16 235)	R -	Cost of permits sold (bought)
R 21 255	**R 30 461**	**R 36 780**	**R 41 552**	**R 45 414**	**R 175 462**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 3 436	**R 355**	**R 161**	**R 1 514**	**R 3 777**	**R 9 243**	Potential savings (cost of legislative approach less actual abatement costs)

30	30	30	30	30	150	Permits issued to cover allowable emissions
4	23	34	42	47	150	Actual emissions (based on simulation)
96	77	66	58	53	350	Actual implemented (based on simulation)
26	7	(4)	(12)	(17)	0	Excess (deficit) of permits

Abatement desired	**350**
Permits issued	**150**
Market price of permits	**955**

MARGINAL COST MODEL OUTPUT 375 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 28 236.82	**R 35 268.07**	**R 42 299.32**	**R 49 330.57**	**R 56 361.82**	**R 211 496.62**	Cost of legislative approach
R 50 000.00	R 44 768.90	R 38 294.05	R 34 594.90	R 32 687.28	R 200 345.12	Cost of abatement instituted
25.02	9.62	(3.68)	(12.48)	(18.48)	0.00	Number of permits sold (bought)
R 26 346.06	R 10 129.86	R (3 875.04)	R (13 141.44)	R (19 459.44)	R 0.00	Cost of permits sold (bought)
R 23 653.94	**R34 639.04**	**R 42 169.09**	**R 47 736.34**	**R 52 146.72**	**R 200 345.12**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 4 582.88	**R 629.04**	**R 130.24**	**R 1 594.24**	**R 4 215.10**	**R 11 151.50**	Potential savings (cost of legislative approach less actual abatement costs)
25.02	25.02	25.02	25.02	25.02	125.10	Permits issued to cover allowable emissions
0.00	15.40	28.70	37.50	43.50	125.10	Actual emissions (based on marginal costs)
100.00	84.60	71.30	62.50	56.50	374.90	Actual implemented (based on marginal costs)
25.02	9.62	(3.68)	(12.48)	(18.48)	0.00	Excess (deficit) of permits

Abatement desired	**375**
Permits issued	**125**
Market price of permits	**1 053**

SIMULATION MODEL OUTPUT 375 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 28 237	**R 35 268**	**R 42 299**	**R 49 331**	**R 56 362**	**R 211 497**	Cost of legislative approach
R 50 000	R 45 191	R 37 980	R 35 123	R 33 217	R 201 511	Cost of abatement instituted
25	10	(4)	(12)	(18)	1	Number of permits sold (bought)
R 26 325	R 10 530	R (4 212)	R (12 636)	R (18 954)	R 1 053	Cost of permits sold (bought)
R 23 675	**R 34 661**	**R 42 192**	**R 47 759**	**R 52 171**	**R 200 458**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 4 562	**R 607**	**R 107**	**R 1 572**	**R 4 191**	**R 11 039**	Potential savings (cost of legislative approach less actual abatement costs)

25	25	25	25	25	125	Permits issued to cover allowable emissions
0	15	29	37	43	124	Actual emissions (based on simulation)
100	85	71	63	57	376	Actual implemented (based on simulation)
25	10	(4)	(12)	(18)	1	Excess (deficit) of permits

Abatement desired	**375**
Permits issued	**125**
Market price of permits	**1 053**

MARGINAL COST MODEL OUTPUT 400 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 32 063.89	**R 40 063.89**	**R 48 063.89**	**R 56 063.89**	**R 64 063.89**	**R 240 319.45**	Cost of legislative approach
R 50 000.00	R 54 298.74	R 45 826.43	R 40 578.88	R 37 343.97	R 228 048.01	Cost of abatement instituted
20.02	13.22	(1.88)	(12.08)	(19.28)	(0.00)	Number of permits sold (bought)
R 23 303.28	R 15 388.08	R (2 188.32)	R (14 061.12)	R (22 441.92)	R (0.00)	Cost of permits sold (bought)
R 26 696.72	**R38 910.66**	**R 48 014.75**	**R 54 640.00**	**R 59 785.89**	**R 228 048.01**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 5 367.17	**R 1 153.23**	**R 49.14**	**R 1 423.89**	**R 4 278.00**	**R 12 271.44**	Potential savings (cost of legislative approach less actual abatement costs)
20.02	20.02	20.02	20.02	20.02	100.10	Permits issued to cover allowable emissions
0.00	6.80	21.90	32.10	39.30	100.10	Actual emissions (based on marginal costs)
100.00	93.20	78.10	67.90	60.70	399.90	Actual implemented (based on marginal costs)
20.02	13.22	(1.88)	(12.08)	(19.28)	(0.00)	Excess (deficit) of permits

Abatement desired	**400**
Permits issued	**100**
Market price of permits	**1 164**

SIMULATION MODEL OUTPUT 400 UNITS OF ABATEMENT DESIRED

COSTS												EXPLANATIONS
MINE A		MINE B		MINE C		MINE D		MINE E		TOTAL		
R	**32 064**	R	**40 064**	R	**48 064**	R	**56 064**	R	**64 064**	R	**240 320**	Cost of legislative approach
R	50 000	R	54 066	R	45 710	R	40 695	R	37 694	R	228 165	Cost of *abatement instituted*
	20		13		(2)		(12)		(19)		0	Number of permits sold (bought)
R	23 260	R	15 119	R	(2 326)	R	(13 956)	R	(22 097)	R	-	Cost of permits sold (bought)
R	**26 740**	R	**38 947**	R	**48 036**	R	**54 651**	R	**59 791**	R	**228 165**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R	**5 324**	R	**1 117**	R	**28**	R	**1 413**	R	**4 273**	R	**12 155**	Potential savings (cost of legislative approach less actual abatement costs)

20	20	20	20	20	100	Permits issued to cover allowable emissions
0	7	22	32	39	100	Actual emissions (based on simulation)
100	93	78	68	61	400	Actual implemented (based on simulation)
20	13	(2)	(12)	(19)	0	Excess (deficit) of permits

Abatement desired	**400**
Permits issued	**100**
Market price of permits	**1 163**

MARGINAL COST MODEL OUTPUT 425 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 36 159.82	**R 45 191.07**	**R 54 222.32**	**R 63 253.57**	**R 72 284.82**	**R 271 111.58**	Cost of legislative approach
R 50 000.00	R 62 500.00	R 54 987.41	R 47 911.58	R 43 207.50	R 258 606.49	Cost of abatement instituted
15.00	15.00	0.60	(11.10)	(19.50)	(0.00)	Number of permits sold (bought)
R 19 200.00	R 19 200.00	R 768.00	R (14 208.00)	R (24 960.00)	R (0.00)	Cost of permits sold (bought)
R 30 800.00	**R43 300.00**	**R 54 219.41**	**R 62 119.58**	**R 68 167.50**	**R 258 606.49**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 5 359.82	**R 1 891.07**	**R 2.91**	**R 1 133.99**	**R 4 117.31**	**R 12 505.10**	Potential savings (cost of legislative approach less actual abatement costs)
15.00	15.00	15.00	15.00	15.00	75.00	Permits issued to cover allowable emissions
0.00	0.00	14.40	26.10	34.50	75.00	Actual emissions (based on marginal costs)
100.00	*100.00*	85.60	73.90	65.50	425.00	Actual implemented (based on marginal costs)
15.00	15.00	0.60	(11.10)	(19.50)	(0.00)	Excess (deficit) of permits

Abatement desired	**425**
Permits issued	**75**
Market price of permits	**1 280**

SIMULATION MODEL OUTPUT 425 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 36 160	**R 45 191**	**R 54 223**	**R 63 254**	**R 72 285**	**R 271 113**	Cost of legislative approach
R 50 000	R 62 500	R 55 501	R 48 040	R 43 850	R 259 891	Cost of abatement instituted
15	15	1	(11)	(19)	1	Number of permits sold (bought)
R 19 185	R 19 185	R 1 279	R (14 069)	R (24 301)	R 1 279	Cost of permits sold (bought)
R 30 815	**R 43 315**	**R 54 222**	**R 62 109**	**R 68 151**	**R 258 612**	*Actual cost of abatement (cost of abatement instituted* less (plus) permits sold (bought))
R 5 345	**R 1 876**	**R 1**	**R 1 145**	**R 4 134**	**R 12 501**	Potential savings (cost of legislative approach less actual abatement costs)

15	15	15	15	15	75	Permits issued to cover allowable emissions
0	0	14	26	34	74	Actual emissions (based on simulation)
100	100	86	74	66	426	Actual implemented (based on simulation)
15	15	1	(11)	(19)	1	Excess (deficit) of permits

Abatement desired	**425**
Permits issued	**75**
Market price of permits	**1 279**

MARGINAL COST MODEL OUTPUT 450 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 40 517.18	**R 50 642.18**	**R 60 767.18**	**R 70 892.18**	**R 81 017.18**	**R 303 835.91**	Cost of legislative approach
R 50 000.00	R 62 500.00	R 68 407.56	R 59 028.48	R 52 422.49	R 292 358.53	Cost of abatement instituted
10.02	10.02	5.52	(7.88)	(17.68)	0.00	Number of permits sold (bought)
R 14 348.64	R 14 348.64	R 7 904.64	R (11 284.16)	R (25 317.76)	R -	Cost of permits sold (bought)
R 35 651.36	**R48 151.36**	**R 60 502.92**	**R 70 312.64**	**R 77 740.25**	**R 292 358.53**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 4 865.82	**R 2 490.82**	**R 264.26**	**R 579.54**	**R 3 276.94**	**R 11 477.39**	Potential savings (cost of legislative approach less actual abatement costs)
10.02	10.02	10.02	10.02	10.02	50.10	Permits issued to cover allowable emissions
0.00	0.00	4.50	17.90	27.70	50.10	Actual emissions (based on marginal costs)
100.00	100.00	95.50	82.10	72.30	449.90	Actual implemented (based on marginal costs)
10.02	10.02	5.52	(7.88)	(17.68)	0.00	Excess (deficit) of permits

Abatement desired	**450**
Permits issued	**50**
Market price of permits	**1 432**

SIMULATION MODEL OUTPUT 450 UNITS OF ABATEMENT DESIRED

COSTS						EXPLANATIONS
MINE A	MINE B	MINE C	MINE D	MINE E	TOTAL	
R 40 517	**R 50 642**	**R 60 767**	**R 70 892**	**R 81 017**	**R 303 835**	Cost of legislative approach
R 50 000	R 62 500	R 69 125	R 58 886	R 51 994	R 292 505	Cost of abatement instituted
10	10	6	(8)	(18)	0	Number of permits sold (bought)
R 14 320	R 14 320	R 8 592	R (11 456)	R (25 776)	R -	Cost of permits sold (bought)
R 35 680	**R 48 180**	**R 60 533**	**R 70 342**	**R 77 770**	**R 292 505**	Actual cost of abatement (cost of abatement instituted less (plus) permits sold (bought))
R 4 837	**R 2 462**	**R 234**	**R 550**	**R 3 247**	**R 11 330**	Potential savings (cost of legislative approach less actual abatement costs)

10	10	10	10	10	50	Permits issued to cover allowable emissions
0	0	4	18	28	50	Actual emissions (based on simulation)
100	100	96	82	72	450	Actual implemented (based on simulation)
10	10	6	(8)	(18)	0	Excess (deficit) of permits

Abatement desired	**450**
Permits issued	**50**
Market price of permits	**1 432**

GLOSSARY

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Average Costs: These are simply total costs per unit of output.

Command and Control: This is the term usually applied to legislative or regulatory approaches to resource management.

Consumer Surplus: The price which a person pays for a thing can never exceed, and seldom comes up to, that which he would be willing to pay rather than go without it so that the satisfaction which he gets from its purchase generally exceeds that which he gives up in paying for it. He thus derives from the purchase a surplus of satisfaction. This surplus can be measured and can be used as a proxy for social welfare.

Cost Benefit Analysis: This approach attempts primarily to compare the relative economic merits of alternative projects. All of the relative benefits and costs of a particular project are determined and, to the extent possible, these benefits and costs are quantified and valued in monetary terms. In turn, projects may be compared with each other on the basis of their relative economic merits.

Cost Effectiveness Analysis: Where project benefits cannot be quantified in monetary terms the focus of analysis changes to goal setting and goal realisation. The process is then referred to as Cost Effectiveness Analysis.

Demand Side Management: A management style which permits the consumer to dictate the supply of any given commodity. In other words, if demand for a commodity rises, then supply of the commodity will automatically follow. This is in contrast to supply side management, which holds that demand will automatically rise to meet any level of supply introduced to the market.

Direct controls: In general direct controls involve the regulation of the behaviour of polluters by the issue of permits, the specification of detailed standards for the construction and operation of industrial plant, and the setting of emission standards.

Economic Efficiency: The state of an economy in which no-one can be made better off without someone else being made worse off.

Economic Equity: The conflict that is traditionally held to arise between maximising average consumption and making that consumption equal across the population.

Externalities: are essentially activities whose full cost or benefit is not incorporated into an economic decision; hence they lead to sub-optimal social allocation. **Internalisation of externalities** thus involves fully incorporating these costs and benefits into the decision process. (See also the inset "Defining externalities" on page 1.)

Fiscal instruments: These are basically charges levied on a product, or the inputs used to make it, which raise the cost at which the product is sold, thus reducing the quantity of it which will be demanded and hence produced. Taxes of this nature are often imposed on products which are undesirable socially, such as tobacco and alcohol, and they can be extended to various forms of pollution or other sources of environmental degradation.

Green Tax: This tax is levied on pollution emissions and it is directly related to the quantity of emissions discharged. It is traditionally used as a behaviour modifying, rather than a revenue generating, instrument, since as the desired levels of pollution abatement are achieved, the tax falls away.

Income Elasticity of Demand: This is the percentage change in the quantity of a commodity demanded divided by the percentage change in the purchaser's income at that that level of demand.

Marginal Costs: (Long and short run)A marginal cost is the increase in the total costs of a firm caused by increasing its output by one extra unit.

Market economy: The essence of the market economy is that individual agents make economic decisions on the basis of costs and benefits associated with activity. They will always choose activities with the highest marginal benefit. This, assuming costs and benefits have been appraised correctly, will always lead to a socially efficient use of resources.

Pareto Optimum:

Pigovian Taxes: A Pigovian tax ideally takes the form of a levy per unit of pollution emitted into the natural environment, not as a tax per unit of the firm's outputs or inputs.

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.

Shadow Price:

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.

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