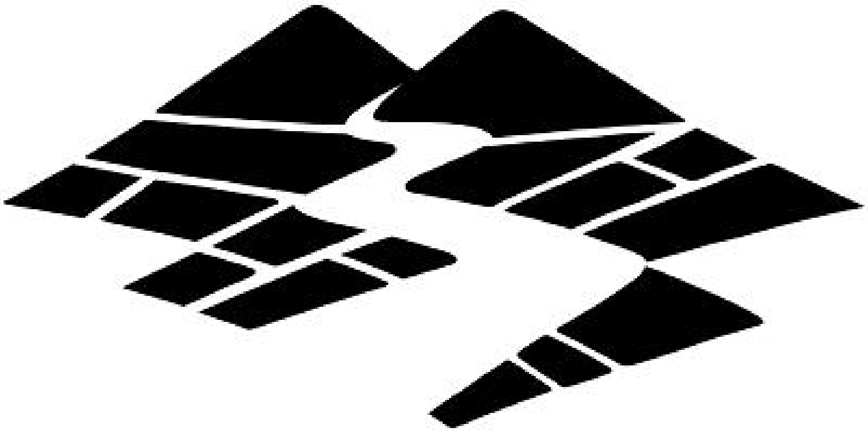
A framework for decision-making using a cost-effectiveness approach: a case study of the Ga-Selati River



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November 2006

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Citation:
Wise, R. M. and J.K. Musango (2006) *A framework for decision-making using a cost-effectiveness approach: a case study of the Ga-Selati River.* CSIR, Stellenbosch, RSA and International Institute for Environment and Development, London, UK.

Developing markets for watershed protection services and improved livelihoods

Based on evidence from a range of field sites the IIED project, ‘Developing markets for watershed services and improved livelihoods’ is generating debate on the potential role of markets for watershed services. Under this subset of markets for environmental services, downstream users of water compensate upstream land managers for activities that influence the quantity and quality of downstream water. The project purpose is to increase understanding of the potential role of market mechanisms in promoting the provision of watershed services for improving livelihoods in developing countries.

The project is funded by the UK Department for International Development (DFID).

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[1] The authors are grateful to Fritz Bekker of CleanStream Consultants for his valuable help. We also thank Dr Christo Marais, Dr Arthur Chapman, Dr David Le Maitre, and Jacob Mojapelo for their valuable assistance and for being available whenever help was required. A special note of thanks goes to Dr Pete Ashton for his extremely useful comments and suggestions during the review process. Acknowledgment also goes to Nicola King and Dr James Blignaut for their input in developing the framework adopted here. Final thanks and acknowledgement goes to the IIED for funding this research.

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Acronyms and abbreviations

CBA	Cost-benefit analysis
CEA	Cost-effectiveness analysis
CMA	Catchment Management Authority or Agency
CSIR	Council for Scientific and Industrial Research
DFID	Department for International Development
DWAF	Department of Water Affairs and Forestry
IAL	Invasive alien plants
IIED	International Institute for Environment and Development
KNP	Kruger National Park
LWB	Lepelle Water Board
NWA	*National Water Act*
PES	Payments for ecosystem services
SANParks	South African National Parks
WfW	The Working for Water Programme

Executive summary

As part of an IIED-funded study to determine the feasibility of payments for ecosystem services (PES) as a mechanism to help conserve and protect river catchments and the services they provide in South Africa, two small-scale catchments were identified as pilot sites for further investigation. The two sites selected were the Sand River catchment and the Ga-Selati River catchment. These sites were selected because: they provided potential opportunities for payments to be made to local communities that would improve livelihoods; potential buyers and sellers were easily identifiable; water demands greatly exceed the available water supplies; and distinct catchment-protection activities exist which could provide the services of improved water quality and quantity.

If a market-based mechanism such as PES is to be successfully implemented and sustainable, well-functioning institutions and infrastructure must be present. For example, there must be reasonable access to credit; property rights and water-use regulations must be enforced; and water-monitoring capabilities must exist. It is also essential that potential buyers and sellers of catchment services participate willingly in the market – this requires that the opportunities to trade are mutually beneficial. The focus of this study was to evaluate the economic feasibility of trade options between potential buyers and sellers of catchment services along the Ga-Selati River. Specifically, a cost-effectiveness analysis was undertaken to determine the least-cost way for upstream water users to increase the quantity of water flowing downstream. This involved estimating the costs of land-use and technology options available to upstream users to increase stream flows, and comparing them with the costs of developing alternative water sources downstream. Noteworthy findings from the results are:

A. The criterion used to prioritise the catchment-protection activities significantly influences their rank. Two cost criteria were used to rank alternatives: the time-averaged total cost and the cost per cubic metre of water saved. The former criterion ranks the activities involved in the control (attempted eradication) of invasive alien plants higher than activities where water-use efficiency is improved, whereas the opposite is found when using the latter criterion. This outcome is explained by the fact that the quantity of water released by eradicating invasive plants is substantially less than the water likely to be saved from improved water-use efficiency. Such a finding is important to potential investors as it helps them decide where and how to invest their funds. Investors with severe budget constraints are more likely to use the time-averaged total cost criterion as a guide to investment, whereas for investors with larger budgets, who want to maximise the quantity of water at minimum cost, the cost per cubic metre is more useful.

B. The estimated costs per cubic metre of water released from implementing the catchment-protection activities ranged between R0.17 and R1.94 m^{-3} yr^{-1}. This cost is likely to be substantially less than the expected use and non-use benefits (which were not quantified in this study, but are likely to be large because water is the limiting resource constraining productivity) from using the freed water. This indicates that, if the *status quo* is maintained, society will incur a greater cost in terms of the benefits forgone, (by not maintaining ecosystem integrity and thus increasing economic productivity), than through actually implementing the catchment-protection activities.

C. Two alternatives PES were identified for downstream water users to meet their water demands, namely: drilling boreholes and recycling wastewater. The cost per cubic metre of each of these was estimated and compared with the eight available catchment-protection activities. All eight catchment-protection activities were found to be more cost-effective than drilling boreholes when borehole yields are low (0.5 l/s) and only four were more cost-effective when borehole yields are high (2 l/s). Four of the eight PES options were found to be cheaper than recycling wastewater.

D. The maximum amount of water released if all eight catchment-protection activities are implemented is about 6.5 million m^3 yr^{-1}, which is small relative to the annual combined water demand of 25 million m^3 from just two of the many downstream water users. It is therefore expected that the alternative water sources will need to be developed anyway, but PES will ensure that the total cost of meeting the shortfall in supply is minimised and will also provide additional benefits in the form of biodiversity and ecosystem conservation.

E. The main beneficiaries of additional water flows in the river, and those most willing to pay for catchment-protection services, are the large mining companies far downstream from the implementation sites of the catchment-protection activities. The implication of this is that the transaction costs involved in monitoring and ensuring service delivery will be significant, and are a major impediment to the implementation of PES in this catchment.

F. An important downstream beneficiary of improved stream flows and water quality is the Kruger National Park (KNP), which currently receives less than is required to maintain the ecological integrity of the Olifants River. The KNP, however, is not a potential buyer of catchment-protection services as it is ‘guaranteed’ by law a minimum “Ecological Reserve” and there is little chance of convincing management that they should pay for what they are due by legislated right. The environmental costs, however, if stream flows to the KNP are not improved are likely to be large, which makes a compelling case for government to support and/or participate in innovative mechanisms such as PES. A further benefit to government from supporting PES is that the additional water flowing down the Olifants River will contribute to meeting its international obligations with Mozambique.

The virtual absence of reliable data on the costs of implementing catchment-protection activities and the quantities of water released by such activities, proved to be a significant limitation to this study. The estimates calculated in this study are therefore approximations of the values and should be used with caution. It is recommended that more detailed scoping and feasibility studies are conducted so reliable values for these costs and water quantities can be used.

The focus of this study was to determine the economic feasibility of implementing PES in the Ga-Selati River catchment. The practicalities of implementing such a system were not considered – such as the need to monitor and verify that the services are delivered – and it was also assumed that the necessary institutions and infrastructure to underpin such a market exist. The implication of these simplifying assumptions is that the transaction costs of trading are small. This is unlikely to be the case in the Ga-Selati River catchment (and other catchments across SA) where the infrastructure to measure and monitor water flows is lacking, illegal water harvesting is widespread, water regulations are not enforced, and property rights are insecure and in a continual state of flux. It is therefore recommended that:

- Many of these issues are resolved prior to attempting to implement a catchment-wide system of PES.
- Simple, relatively unsophisticated payment mechanisms should be attempted first (e.g., direct payments or intermediary-based payments are made between a single buyer and a single seller).
- Additional innovative economic and legal mechanisms be researched and developed to facilitate improvements in water allocation and efficiency in catchments throughout SA.
- Further research is funded into the transaction costs and how these can be minimised to make PES attractive to private and government investment.

1. Introduction

South Africa's climate ranges from semi-arid to hyper-arid and very few parts of the country are considered to be relatively humid, where rainfall exceeds 500 mm annually (Davies and Day 1998). This, together with the growing demands for water by a rapidly increasing population and the related increase in demand for freshwater driven by industrialisation, agriculture and urbanisation, has resulted in the country being classified by the International Water Management Institute as a water-stressed country (Claasen et al. 2004). The South African government has estimated that the developmental needs required to provide an adequate quality of life for all its citizens will mean that the country's total demand for economically usable, land-based fresh water will exceed the supply by the middle of the century[2] (DWAF 2004a), although this situation is already characteristic of many of the catchments today. Despite the country's extensive infrastructure developments and technological efforts, it is becoming increasingly costly and less viable to access exploitable water resources – this has stimulated the search for new and more 'creative' approaches to meeting water demands, including market-based instruments (King and Hattingh 2005).

In many areas, these demand-side problems are compounded by the inappropriate land-use and management practices adopted by many of the stakeholders (landowners, managers and government agencies) in the upper reaches of river catchments throughout South Africa. These activities have significant detrimental effects on the hydrological functioning of the catchments and their ability to provide reliable supplies of freshwater. Some of main practices that have been identified as having negative impacts on catchment-service provision include:

- Intensive land-use practices such as overgrazing, continuous cropping, and over-application of fertilisers.
- The uncontrolled spread of invasive alien plant species.
- Inadequate access to appropriate sanitation facilities.

Consequently, catchment management authorities, government departments at all levels, and community groups are focusing much of their efforts on eradicating, controlling and modifying these practices. A key concern in this regard is the continued high cost associated with existing efforts, which is driving authorities and governments to consider other more cost-effective and sustainable ways of procuring catchment services. Market-based approaches (including water trading, taxes, subsidies, and payments for ecosystem services) are increasingly being considered by the South African government as options to improve supply to meet the increasing water demands in South Africa. Market-based approaches are looked upon favourably because they use market forces to pass on incentives, which often ensure conservation objectives are achieved more cheaply than other approaches. Market-based approaches also offer the advantage of complementing traditional regulatory measures, for example by generating revenue to fund public conservation management (Brauer et al. 2006). Finally, market-based approaches to water management are in line with South Africa's 1998 *National Water Act* (Republic of South Africa 1998), which promotes "decentralised management and emphasises the use of market-based instruments in water management".

Payments for environmental services (PES)[3] are mechanisms that are used to facilitate reward by a demander of a particular service to a provider for supplying the service. These

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[2] DWAF (2004b) estimated that a surplus of 631 million $m^3 yr^{-1}$ of total economically usable water existed in SA in 2000, and predicted that this would reduce to a deficit of 1,788 million $m^3 yr^{-1}$ by 2025 if the base-case projections of the increase in demand were slightly higher than expected.

[3] The term 'payments for environmental (or ecosystem) services' is a generic one that encompasses the more specific 'payments for catchment services' or 'payments for catchment-protection services'. In this report, all of these terms are used interchangeably.

payments may be made directly between demander and supplier, or they may be made indirectly through an intermediary. Typical environmental services include: carbon sequestration, maintenance of biodiversity, fresh water provision, and flood control. The latter two are important services provided by catchment protection through reduced sedimentation and hydrological protection. In the case of catchment services, payments are typically made by downstream users to upstream users for improved land management or technology use that increases downstream water supplies. Such payments, if implemented and managed appropriately and sustainably, also have the potential to alleviate poverty and improve livelihoods. There is, however, an important complication in cases where the service(s) may be provided by more than one supplier (often at different levels of efficiency and cost). In such cases, identifying to whom payments should be made is extremely complicated and, where inefficient providers are present, PES could perpetuate inefficiencies. Many of these issues could be overcome through well-directed research, negotiations, and contract design, but these complexities are outside the scope of this report.

It needs to be acknowledged that payments for catchment services can be both an opportunity and a threat to the livelihoods of people living in catchments. Opportunities exist where participation by both buyers and sellers is voluntary and where the trade is mutually beneficial. In order to ensure that these two criteria are met, considerable stakeholder consultation must occur prior to PES implementation and there must be guarantees that payments will reach the poor and improve their livelihoods. An important threat that exists is where payments lead to changes in land management that worsen existing conditions or marginalise the poorest inhabitants in a catchment. It is therefore essential that all potential PES participants have equal access to the market. In their review of existing markets for ecosystem services around the world, Landell-Mills and Porras (2002) noted the existence of inequities in accessing and participating in such markets and gave the following main reasons for this inequity:

- Insecure land tenure.
- Inadequate and inappropriate regulatory frameworks.
- Inadequate skills and education.
- Insufficient access to finance.
- Inappropriate commodity design.
- High costs of participation.

This paper contributes to the work already carried out by the CSIR in the IIED-funded project: ‘How can payments help manage watersheds sustainably and fairly?’, whose goal is “to promote the maintenance of catchment services for improving livelihoods in developing countries.” In order to achieve this goal, the project set out to increase the understanding of the potential role of market mechanisms, in particular financial and/or non-financial payments and rewards, as a way to promote the provision of catchment services for improving livelihoods in South Africa. The study adopted an ‘action-learning’ approach, which required that all partner organisations and stakeholders would have to buy in to the problem and facilitate payments for catchment services in selected pilot sites across South Africa. In this regard, the economic analysis undertaken here contributes to this understanding by investigating the economic feasibility of potential trade options between buyers and sellers of catchment services in the Ga-Selati River catchment in the Limpopo Province of South Africa. Finally, it must be emphasised that this study does not attempt to engage with the political, cultural and social complexities that are involved, particularly the current lack of the institutions (e.g., access to information and finances, and property rights) that are necessary for such a market to function reliably and effectively.

2. Background

Two catchments in South Africa, the Olifants catchment and the Sabie-Sand catchment, were selected from a shortlist of six catchments across South Africa by the CSIR, local experts, and stakeholders as having many of the characteristics considered necessary for the development of payments for catchment services (King et al. 2003). Within each of these catchments, a pilot site was defined to provide case studies of appropriate scale that could be investigated and researched in order to determine how best to facilitate and develop PES in South Africa. The Ga-Selati River, within the lower Olifants catchment, was chosen as one of the pilot sites for a case study of the cost-effectiveness analysis reported here.

3. Study area – the Olifants catchment

The Olifants catchment forms part of the greater Limpopo basin, which is significant for water-resource management reasons because it is shared between South Africa, Botswana, Zimbabwe and Mozambique. The catchment has been divided into four sub-areas by the Department of Water Affairs and Forestry (DWAF): the Upper Olifants, Middle Olifants, Steelpoort, and Lower Olifants. The Olifants River is the major river in the catchment and it flows in a north-easterly direction across parts of the Gauteng and Limpopo Provinces of South Africa before flowing into Mozambique. The Olifants River catchment covers a relatively wide area and contains numerous and diverse landscape units, vegetation types, soils, climatic characteristics, and stakeholders. Because of this diversity, it was essential to select a smaller pilot site that represented a coherent sub-component of the Olifants catchment. The Ga-Selati River catchment was chosen as the pilot site and this component falls within the Lower Olifants sub-area (Figure 1).

Both water quality and water supply are critical issues in the Olifants catchment, especially during periods of low flow. The main factors that have negative effects on water quality are high sediment loads due to inappropriate land-use practices (intensive agriculture and removal of riparian vegetation along river banks), and high levels of effluent and pollution discharges from mining, agriculture, and inadequate domestic sanitation facilities in communal lands along the river. The main factors that have negative effects on water quantity are the illegal harvesting of excessive quantities of water by upstream users and inefficient (wasteful) water use. The severity of these water supply problems is highlighted by the recent proposals for the lower section of the Olifants River to be reclassified from a perennial to a seasonal river!

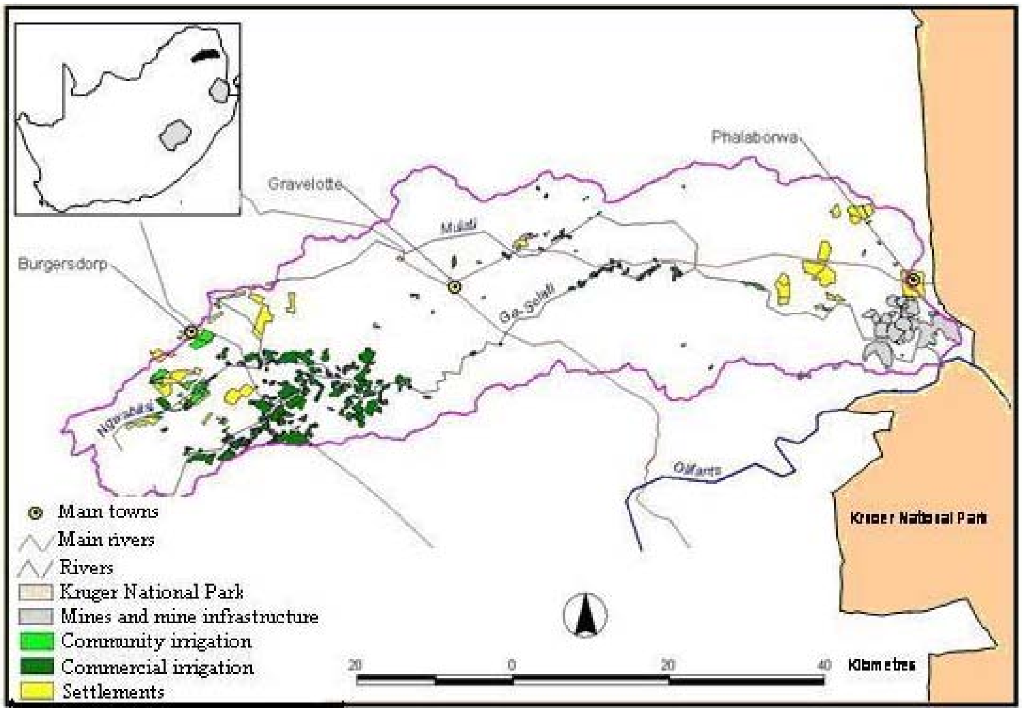

Figure 1: The Ga-Selati River catchment, showing community settlements and major land uses in the upper catchment. (Insert shows its location in South Africa)

3.1 The pilot site for payments for catchment services

The Lower Olifants catchment was identified by the main partners of the IIED project as an appropriate site to investigate the feasibility of implementing payments for catchment services because:

- It is characterised by very high and increasing upstream and downstream demands for water, and is faced with a continually decreasing and unreliable supply due to inefficient water use and inappropriate land management, particularly along the upstream reaches.
- There exist clearly defined alternative technologies and land-use options for upstream landowners (potential sellers) to adopt that could alleviate much of the water quality and water flow problems for downstream users (discussed in section 5.1).
- There are downstream water users (potential buyers) who could benefit from the additional water runoff. For example, an enhanced flow in the Ga-Selati River is expected to increase the volume and quality of water available to the downstream irrigators, game farmers, and communities and thus improve local livelihoods.

The Lower Olifants catchment, and all potential buyers and sellers of catchment services, are presented schematically in Figure 2.

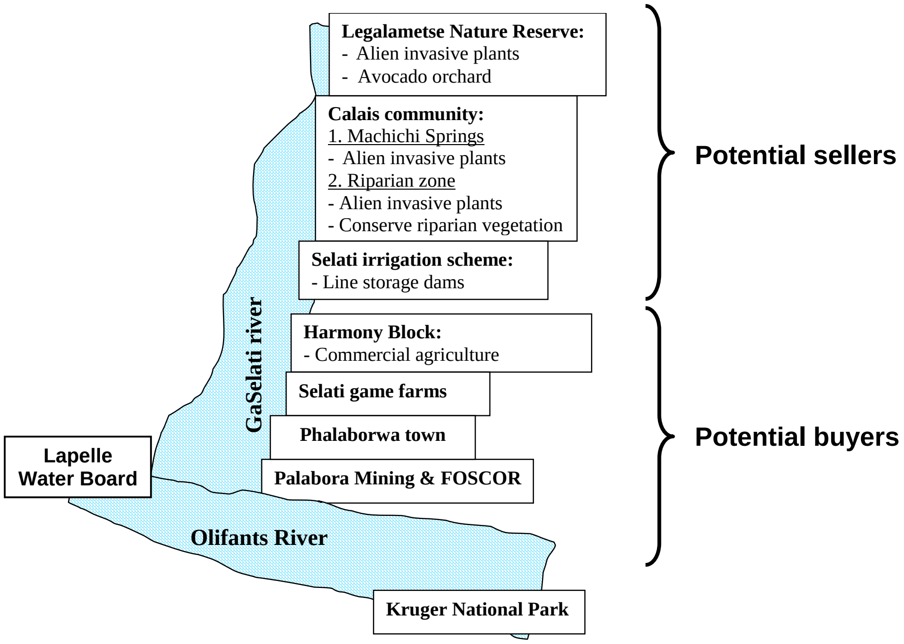

Figure 2: Schematic representation of the upstream and downstream agents (potential buyers and sellers) located along the Ga-Selati River in the Lower Olifants catchment

With these characteristics, the site offers clear opportunities for payments to be made by downstream beneficiaries to upstream landholders (which include communities, farmers, and nature reserves) for them to adopt improved catchment conservation and management activities that would decrease sediment loads and improve stream flows. These payments are envisaged to be in the form of:

1. ‘Directly negotiated payments between buyers and sellers’;
2. ‘Intermediary-based transactions’, where a government agency or NGO plays the role of the intermediary; or
3. ‘Pooled-buyer transactions’, where the potential buyers pool resources to pay for catchment services, as this minimises risk.

The more sophisticated exchange mechanisms such as ‘auction-based trades’, ‘retail-based trades’ or ‘exchange-based trades’ are not considered appropriate in this case as they require well-developed and functioning property-rights arrangements and financial institutions – many of which are lacking in this area.

Such a scheme, if successfully implemented and managed, could then be scaled up at a later stage to improve the functioning of other rivers in the remainder of the Olifants catchment.

4. Theoretical framework

Environmental resource economics has a suite of tools available to value and evaluate resource use and assist decision- and policy-makers to allocate scarce resources efficiently and equitably between competing demands. The two main economic decision-support tools available that are particularly suited to assessing the benefits and/or costs of alternative resource-use options are the cost-benefit analysis (CBA) and the cost-effectiveness analysis (CEA) techniques.

CBA is an economic decision-support tool that is designed to show whether or not the total benefits of a project or programme, measured in economic terms, outweigh the costs of implementing that project or programme. It is the most widely accepted technique for determining and comparing the economic viability of projects. Most commonly, CEA is used as an economic decision-support tool to determine the least-cost way of achieving a predetermined physical or environmental goal. It can also be used to identify and evaluate a means of maximising an environmental or physical benefit for a given economic cost.

In this case study, many alternative catchment-management and water-use practices (involving technology switching or land-use change) needed to be economically evaluated and compared to determine the most cost-effective way of improving the allocation and efficiency with which water is used, so that the water flow and quality reaching the many downstream users is improved. In addition to these supply options, there are other ways for downstream water users to meet their own water demands through improving water-use efficiency, wastewater recycling and reuse, or sinking boreholes; each of these also needs to be evaluated economically and compared in terms of their efficiency at meeting water demands.

When many options and permutations require evaluation, resource economists have to trade off between undertaking a thorough CBA and incurring the costs (financial and time) of collecting enormous amounts of data, or undertaking a CEA which has the advantage of not requiring data on the benefits of alternatives – provided each alternative is likely to achieve the same or similar level of benefit. Blignaut and de Wit (2004), however, highlight the limitation of a cost-effectiveness analysis:

> “In a typical cost-effectiveness analysis the most cost-effective solution should be selected to achieve an externally set prescribed environmental objective, such as water or air quality standards. This approach does not, however, tell us whether the benefits realised justify the cost incurred.”

It must also be emphasised that if a CBA is undertaken and all the data are not available, then the alternatives cannot be adequately compared and the results and findings are likely to be inconclusive or unreliable.

Considering all of this, a cost-effectiveness analysis is undertaken in this study to evaluate the numerous alternative technologies and land-use changes available, based on the cost per unit of additional water released by each option. The optimal alternative was chosen as that with the lowest cost per unit of additional water released. As stated above, the benefits of these alternatives are not explicitly incorporated because of the assumption that the benefits derived from the water that is “freed” by each alternative are relatively similar (i.e., used in the same alternative economic activity) and are likely to be large because water is the main factor limiting productivity and economic growth. Estimates of the benefits derived from the additional water (runoff) generated from the changes in technology and/or land use in the upper Ga-Selati River can be derived using one of two techniques, depending on which data are available:

1. The avoided cost of the water that was acquired elsewhere prior to the change; or
2. The value of the additional output generated through the productive use of the additional water.

5. Description of the trade options

The potential for implementing payments for catchment protection services in the Lower Olifants catchment was briefly discussed in Chapter 3. The buyers and sellers in such a scheme are described in detail below, along with the possible payment mechanisms available.

5.1 Potential sellers and options for providing catchment services

Three potential sellers of catchment services exist, namely: the Legalametse Nature Reserve (Limpopo Parks), the Calais community, and the Selati irrigators. A range of land-use, management and technology changes have been identified for these sellers that could provide the services of increased water supply and improved water quality to downstream water users[4]. The options available to the Legalametse Nature Reserve and the Calais community are limited to land-use and management changes, while those that are available to the Selati irrigators are primarily technology-oriented solutions. Each of these sellers and the catchment-protection activities available to them are described below, summarised in Table 1, and discussed in Chapter 6.

5.1.1 The Legalametse Nature Reserve

The three land-use changes that the Legalametse Nature Reserve could undertake to reduce water abstraction from the upper reaches of the river are:

1. Remove the avocado orchard from the Malta Farm in the reserve;
2. Introduce an efficient irrigation system or stop irrigating the avocado orchard altogether[5]; and
3. Remove the invasive exotic vegetation (principally *Acacia mearnsii*) along the course of the river, especially inside the reserve, which could be done through the applicable institutions such as the Working for Water (WfW) programme.

5.1.2 The Calais community

The land-use changes available to the Calais community to reduce water abstraction and increase base flow to downstream users include:

1. Protecting the Machichi Springs by removing the invasive alien plant species present; and
2. Protecting and rehabilitating the riparian zone along the upper reaches of the river.

Unfortunately, no study has yet been undertaken or even commissioned to determine the costs of implementation and the water savings that would result from each of these activities. Consequently, the values used here have been taken from three journal articles in the weeds literature, namely Le Maitre et al. (2000), Marais et al. (2004) and Gorgens and van Wilgen (2004), where costs and impacts of water resources are well documented.

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[4] A study undertaken by Rural Integrated Engineering (RI Eng 2006) determined that improved water management in the upper reaches of the Ga-Selati River and the Slang River (a tributary of the Ga-Selati) will result in increased base flows and water savings of up to 60% of the current use. They also estimated the costs involved in undertaking such conservation measures (Table 1).

[5] Preliminary findings of an agricultural engineering study into the technical options available to improve irrigation practices in the avocado plantation indicate that expensive drip irrigation is not cost effective but that manually operated pipes and hoses will be more efficient and cost-effective (although some indications are that the farming practice may not be viable at all) (Bekker 2006).

Table 1: A list of the possible sellers of catchment services and the activities they can implement to improve water quality and quantity in the Ga-Selati catchment (estimates of the water used and saved, and the costs of implementing the various alternative scenarios, are also given)

Description		**Total water use (m^3 ha^{-1} yr^{-1})**	**Total water saved (m^3 ha^{-1} yr^{-1}) (Rank)**	**Cost of change (R ha^{-1} yr^{-1}) (Rank)**	**Cost of H_20 saved (R m^{-3}) (Rank)**	**Source**
A. Legalametse invasive alien species						
Baseline A	Infested with Black Wattle	1,700	0	0	0.0	*a, b, c*
Scenario A1	Eradicate Black Wattle	0	1,700 **(5)**	1,562 – 2,152[***] **(4)**	0.92 – 1. 27 **(7)**	
B. Legalametse avocado orchards						
Baseline B	Avocado farming	34,600	0	0	0.0	*d, e*
Scenario B1	Remove avocados	0	34,600 **(1)**	3,825 – 4,675[*] **(7)**	0.14 – 0.17 **(1)**	
Scenario B2	Rehabilitate existing irrigation	15,800	18,800 **(3)**	3,500 – 4,000[**] **(6)**	0.19 – 0.21 **(4)**	
Scenario B3	Upgrade irrigation	9,100	25,500 **(2)**	4,500 – 5,500[**] **(8)**	0.18 – 0.20 **(3)**	
C. Calais community – Protect riparian zone						
Baseline C	Clear riparian vegetation	- 0.0012	0	0	0.0	*f*
Scenario C1	Keep riparian vegetation	0	- 0.0012	0	0.0	
Scenario C2	Eradicate invasive plants	0	1,900 **(5)**	1,277[***] **(1)**	0.67 **(5)**	
D. Calais community – Protect Machichi Springs						
Baseline D	Infested with invasive weeds (i) *Lantana camara* (ii) *Chromolaena odorata*	1,404 1,579	0 0	0 0	0.0 0.0	*a, b*
Scenario D1	Eradicate weeds (i) *Lantana camara* (ii) *Chromolaena odorata*	0 0	1,404 **(7)** 1,579 **(6)**	1,534 – 223`[***] **(5)** 1,281 – 1,583[***] **(3)**	1.09 – 1.59 **(8)** 0.81 – 1.00 **(6)**	
E. Selati Irrigation scheme						
Baseline E	Inefficient storage of water	9,124	0	0	0.0	*e, g*
Scenario E1	Line storage dams	2,737 – 4,562	4,562 – 6,387 **(4)**	600 – 1,500/dam[**] **(2)**	0.15-0.19 **(2)**	

Sources:

a. Le Maitre et al. (2000)
b. Marais et al. (2004)
c. Gorgens and van Wilgen (2004)
d. RI Eng (2006)
e. Chapman (2006)
f. Everson et al. (2000)
g. Bekker (2006)

[*] Forgone revenue from the sale of the annual avocado yield.
[**] Excludes annual maintenance costs, and averages establishment cost over 10 years.
[***] Excludes the revenues lost from harvesting firewood.

5.1.3 The Selati irrigators

The only option available to the Selati irrigators is to improve the water storage efficiency and management of their dams. This involves lining the dams and improving the management of the inflows and outflows of water to prevent wastage, because the current situation is characterised by high levels of seepage and excessive overflows of water caused by incorrect management of inflows and outflows.

5.2 Potential buyer scenarios

The main potential buyers for the water that could be released through the implementation of the activities listed in Table 1 include:

5.2.1 Harmony Block commercial farmers

The majority of commercial farms in the catchment are situated in the Harmony Block (Figure 2). The nine farmers in the upper Harmony Block cultivate citrus, sub-tropical fruit and vegetables and obtain their water from the Selati Dam (Harmony Dam) for irrigation. In the lower part of the Harmony Block, however, there are several small-scale farmers whose water supplies are limited and whose options for increasing their water supply are:

1. To drill boreholes, or
2. Pay upstream landholders to implement catchment-protection activities that would release water and/or improve water quality.

Another possible option that is not considered in this study is the implementation of more efficient water-use technologies by the commercial farmers, such as drip irrigation. This alternative was not investigated, however, due to the lack of available data on the costs and water-use implications of such a system. It is recommended that a detailed study be undertaken to determine the economic and biophysical implications of such alternatives.

5.2.2 Selati game farmers

The Selati game farms are privately owned by eleven title-holders. During the drier winter months, there are frequent occasions when water supplies are insufficient and sometimes no water reaches these farms for protracted periods of time. The owners currently use borehole water, but more water is needed to maintain the river in-stream flows and to increase the profitability of the farms. The farmers also state that their property values will increase if the seasonal water flows are returned to historical levels. Again, the available alternatives to these farmers investigated here are:

1. Drill more boreholes, or
2. Pay upstream landholders to implement catchment-protection activities that release water and/or improve water quality.

The introduction of more efficient water-use technologies, such as drip irrigation, is also an option to these farmers but – as explained above – this was not investigated here due to a lack of data.

5.2.3 Palabora Copper Mine and FOSKOR[6]

Palabora Copper Mine and FOSKOR are located relatively far down the Ga-Selati River and quite close to where it joins the Olifants River (see Figure 2). The two mines currently source all of their water from the Lepelle Water Board (LWB), which manages the Phalaborwa Barrage located on the Olifants River. The two mines, however, discharge their wastewater and effluents into two tailings dams on either side of the Ga-Selati River and some of this waste seeps into the Ga-Selati River. The two mines have attempted to reduce this seepage but have not been 100 per cent successful. They therefore often require additional clean water to flow in the river to dilute the seepages sufficiently to meet environmental regulatory standards. Three alternative water sources are available to these two mines to address this water shortage:

1. Purchase additional water from the LWB when required to dilute excessive effluent discharges.

2. Recycle and reuse wastewater.

3. Pay upstream water users to implement catchment-protection activities that release water and/or improve water quality.

5.2.4 The Lepelle Water Board (LWB)

The LWB manages the Phalaborwa Barrage, which is the main source of ‘raw’ water in the Lower Olifants catchment and is located on the Olifants River a short distance upstream of where the Ga-Selati River joins the Olifants River. The LWB is therefore responsible for supplying water to all water users in Phalaborwa town (principally the Ba-Phalaborwa Municipality), the environment, and to the industries and mines in the region, including – but not limited to – the Palabora Copper Mine, Fedmis, and FOSKOR.

Due to the substantial demand for water for production and wastewater dilution, the LWB will benefit from increased stream flows and improved water quality down the Ga-Selati River as this will contribute to meeting the Ecological Reserve downstream of the Barrage and make additional water available for the LWB to sell to industry and mining. The LWB, however, is currently not willing to pay for catchment-protection services because it has relatively cheap alternative water sources available, in the form of transfers from the Blydepoort Dam located on the Blyde River. There is also the option for requesting additional water from the Vaal and Incomati catchments. This stakeholder will therefore only pay for catchment-protection services when these alternatives are no longer available, or become more costly.

5.2.5 The Kruger National Park (KNP)

South African National Parks (SANParks) is concerned about the poor quality and declining quantity of water currently flowing to the KNP. The requirements of the Ecological Reserve, designed to maintain the integrity of the riparian ecosystem, are often not met in the section of the Lower Olifants River that flows through the KNP, and this is particularly the case when sediment and silt in the Phalaborwa Barrage are periodically scoured in order to increase its capacity. SANParks reports significant ecological damage in the KNP as a result of this scouring, including fish kills, and is particularly concerned about the water that is lost in this process. The LWB, however, reports that scouring is essential due to the rapid sedimentation of the Phalaborwa Barrage, which at present only has a capacity of 10 % due to excessive sedimentation (Piet Grobler 2004). The main causes of the low flow and poor

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[6] To reduce the size and complexity of the analysis, the number of alternatives is limited by using these two mines to represent the many mines in the area. It is acknowledged, therefore, that not all the available options to reduce water demand or develop alternative waters sources have necessarily been covered.

quality of water reaching the KNP are poor land management and inappropriate land use along the upper reaches of both the Olifants and Ga-Selati rivers[7]. An opportunity therefore exists for upstream landholders to be provided with incentives (direct payments being one type only) to adopt catchment-protection services that will increase downstream water flows and water quality. The KNP, however, is entitled by law to receive sufficient water of an appropriate quality (the Ecological Reserve) to maintain the integrity of the river ecosystem and is therefore not a potential buyer of catchment-protection services. However, the *National Water Act* (NWA) makes the SA Department of Water Affairs and Forestry (DWAF) responsible for ensuring the Ecological Reserve is met; therefore DWAF can be considered a potential buyer of catchment-protection services as this may provide a cost-effective way for them to meet their legislative requirements.

Table 2: A list of the potential buyers and the alternative sources of water available to them in the Ga-Selati catchment (estimates of the costs and financial returns to water buyers are also included)

Description	Water source	Cost of water (R m^{-3})	Turnover (R m^{-3})	Source
I. Harmony Block				
Baseline I	Ground water and boreholes	Nil Nil	5.09-7.61	*a, b*
Alternative Ia	Boreholes	0.42 – 2.54		*a, b*
II. Selati game farmers				
Baseline II	Ground water and boreholes	Nil Nil	1.52-6.09	*a,b*
Alternative IIa	Boreholes	0.42 – 2.54		a,b
III. Palabora Copper Mine				
Baseline III	Lepelle Water Board	0.802	101.4 – 112.0	*a*
Alternative IIIa	Treatment and recycling	0.23 – 0.30	101.4 – 112.0	*a*
IV. FOSKOR				
Baseline IV	Lepelle Water Board	0.847	60.9 – 68.5	*a*
Alternative IVa	Treatment and recycling	0.23 – 0.30	60.9 – 68.5	*a*
V. Lepelle Water Board				
Baseline V	Phalaborwa Barrage (on Olifants River)	0.048	0.799	*a*
Alternative Va	Water transfers from the Blydepoort Dam	0.048	0.799	*a*

Sources:
a. pers. comm. Bekker (2006)
b. DWAF (2004b)

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[7] The reasons why these practices prevail are listed in detail by Chapman (2006).

6. Economic valuation of the trade options

In Chapter 4 it was stated that CBA and CEA are the most important and widely used tools to assess the economic feasibility of one or more projects, programmes or policies. It was also stated that the more data-intensive CBA is preferable to the CEA if the required data are available. The data collated to evaluate the *status quo* and the options available to both sellers and buyers to address the shortfall of water in the Ga-Selati River catchment are presented in Tables 1 and 2 respectively. These data include: the water used per hectare per year (m^3 ha^{-1} yr^{-1}); the cost of the water (Rand m^{-3}); and the quantity of water released (m^3) due to the implementation of catchment-protection activities (by sellers) or the development of alternative water sources (by buyers). The data were obtained from a range of sources including: reports, papers and journals, and personal communication with experts and local authorities. However, since insufficient data on the benefits (type and value) from the additional water released due to the adoption of selected catchment-protection activities were available, a CEA and not a CBA was undertaken. The findings of the CEA, however, were supplemented wherever possible with a discussion of the potential benefits and their likely magnitudes. To compare the cost-effectiveness of adopting catchment-protection activities with the costs of developing alternative water sources, the raw data were converted to costs per unit of water released (sellers) and costs per unit of water made available from the development of alternative sources (buyers) – so-called “volumetric costs”. Each of these costs was also ranked, separately for both buyers and sellers, to determine the most cost-effective option for each (Tables 1 and 2).

6.1 Discussion of the sellers’ catchment-protection options

The main catchment-protection options available to the three main stakeholders in the upper reaches of the Ga-Selati River catchment (Legalametse Nature Reserve, Calais community, Selati irrigators, Figure 2) were presented and discussed in section 5.1 of this document. These are now evaluated from the perspective of a government agency such as a Catchment Management Authority or Agency (CMA), whose role is to prepare and implement a catchment-management plan that will manage the catchment’s water resources in a prudent and effective manner, with the ultimate objective of improving the social wellbeing of the catchment’s stakeholders. The various land-use and technology options available and listed in Table 1 have been evaluated in terms of their costs of implementation per m^3 of water saved (column 5[8], their time-averaged total costs of implementation (column 4), and the quantity of water saved or released (column 3).

6.1.1 Criterion 1: Cost per cubic metre of water saved

Based on the cost per m^3 of water saved (the volumetric cost), a CMA would prioritise the adoption or implementation of the available options according to their rank, shown in brackets in column 5 of Table 1. Of the nine land-use and technology change options considered in this study, three of the four most cost-effective options are clearly the responsibility of the management of the Legalametse Nature Reserve (Scenario B1, ranked 1st, Scenario B3, ranked 3rd, and Scenario B2, ranked 4th), while one is the responsibility of the Selati irrigators (Scenario E1, ranked 2nd). Four of the remaining five catchment-protection activities involve eradicating the invasive alien plants that are present on Calais community lands and in the Legalametse Nature Reserve. It is noticeable that the volumetric cost of water saved by eradicating weeds (Scenarios A1, C2, D1) is between three and six time greater than the volumetric cost of water saved for the first four options which involve investments in water-use efficiency. The total amount of water saved from eradicating these

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[8] Calculated as the sum of the variable costs and the time-averaged establishment costs, averaged over a 10-year investment period, divided by the total amount of water saved.

invasive alien plants (IAP) in the catchment is 1,331,533 m^3 per year[9], some 3-4 times less than the amount of water that could potentially be saved through more efficient water use in the Selati irrigation scheme. The ninth catchment-protection activity would require the Calais community to maintain and regenerate the riparian vegetation in order to minimise erosion and stream damage. This activity unfortunately cannot be evaluated and compared in the same way as the others, because 1) it does not release additional water but improves the quality of water for downstream users by ensuring the water is filtered of sediment, and 2) insufficient information exists on the quantities of water used and filtered by riparian vegetation[10].

Using a single criterion – such as the cost-effectiveness per m^3 of water saved – to inform and develop policies or management interventions is useful but limited in that it does not consider the following important factors:

- How to compare the new scenarios with maintaining the *status quo*, which obviously incurs no new costs and involves releasing no additional water.
- The budgetary constraints of the stakeholders who would be required to implement the activities.
- The equitable distribution of the costs and benefits from implementing the project or policy (i.e., who would incur the costs, and who would benefit from the water released, as a result of the new activity?).

All of these factors are also extremely important when considering the use of market incentives – such as payments for catchment-protection services – as mechanisms to facilitate efficient and sustainable water use.

In order properly to account for these important factors in the decision-making process, particularly if the aim is to facilitate a system of payments for environmental services, two additional criteria need to be used to evaluate the alternative activities. These criteria are:

1. The time-averaged total cost incurred to implement each activity (column 4, Table 1), and
2. The value of the total benefits derived from the water that is released due to the activity, which depends on both the total quantity of water released (column 3, Table 1), and the productive use to which the water is put.

Estimates of the values for these benefits are not available, and this criterion is discussed qualitatively.

6.1.2 Criterion 2: Time-averaged total cost

The financial capacity of a particular stakeholder to implement the appropriate changes to improve runoff and stream flows in a catchment is an extremely important and very real constraint in most South African catchments. It is therefore essential that the total costs of implementing and maintaining new catchment-protection activities are estimated and that these are taken into account when economically evaluating the various options that are available. This also applies when implementing payments for catchment-protection services, since the potential buyers of such services will need to cover the costs of implementation and (possibly) maintenance.

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[9] The average water use by IAP in the catchment is 1,561m^3 ha^{-1} yr^{-1} and the condensed area invaded is 853 ha (see Chapman 2006).

[10] In terms of the cost of this option, there is little or no cost involved in protecting the existing riparian vegetation (other than the opportunity cost of the use of the vegetation) but regenerating the vegetation already lost requires an initial investment in plant materials, tools and labour.

An attempt has been made to estimate these costs for the scenarios listed in Table 1, but comparison of these costs is very difficult because insufficient data exist to obtain accurate, consistent, and comparable estimates. The main difficulty has been the estimation of a single value (or range) for an investment that involves an upfront establishment cost followed by a stream of payments over an unknown and variable time horizon. Therefore it must be acknowledged that the values presented in column 4 of Table 1 are relatively crude approximations of an expected time-averaged total cost and are based on numerous simplifying assumptions. Two major simplifying assumptions are: 1) the implementation and variable costs incurred for similar activities in other regions are transferable and applicable to this study area, and 2) the investment horizon for each alternative is 10 years. Bearing all of this in mind, an attempt has been made to evaluate and discuss these values in order to supplement the prioritisation given above.

When comparing the time-averaged total costs of changing land-use and technology practices, a very different ranking order for each scenario (bracketed values in column 4, Table 1) emerges from those that are discussed above. For example, based on estimates for the costs of clearing invasive alien plants[11], the preferred option for the Legalametse Nature Reserve is now the eradication of Black Wattle (Scenario A1) instead of removing the avocado orchards (Scenario B1), or improving irrigation efficiency (Scenarios B2 and B3) – as determined using the cost per m^3 of water saved. It is also more cost effective for the Calais community to eradicate invasive species in the riparian zone (Scenario C2) and the Machichi Springs (Scenario D1) than for the Legalametse Nature Reserve to adopt Scenarios B1, B2 or B3)[12]. Finally, the option for the Selati irrigators to build and line storage dams (Scenario E1) still ranks highly using this criterion, as it did when measured in terms of the cost per m^3 of water saved.

Obviously, these costs are avoided if the *status quo* is maintained, which would make inaction the most cost-effective option. However, the “inactivity option” ignores the potentially large benefits that could result through careful and prudent use of the water released by implementing each catchment-protection activity. These potential benefits are discussed below as a third criterion for decision-making.

6.1.3 Criterion 3: Value of potential benefits derived from using saved water productively

The third criterion that is important in informing management and policy intervention is the magnitude of the benefits that could potentially be generated by using the water that is freed when catchment-protection activities are implemented. Theoretically, the shadow prices of this water, on a per m^3 basis, can be calculated by econometrically estimating the relevant production functions for agriculture, mining, and ecosystem functioning. This was not possible in this study due to the lack of available data and time to collect these data. Nevertheless, it can be expected that, since water is the main limiting factor in the catchment, the benefits likely to be generated from using the additional water in alternative productive uses would be large relative to the costs of provision. For example, a cubic metre of additional water will increase financial turnover in the catchment by between R1.52 and R7.61 if used in agriculture, and between R61.00 and R112.00 if used in mining (column 4, Table 2) when the minimum estimate of the benefit from the released water is the avoided cost that would have been spent on developing alternative water sources and associated infrastructure. These costs have been estimated and compared with the costs of implementing catchment-protection activities in sections 6.2 and 6.3 below.

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[11] Marais et al. (2004) state that the initial cost to clear 5,407 ha of *Lantana camara* amounts to R8.97 million, and a follow up clearance of 7,295 ha costs R7.02 million (excluding herbicide costs of R572/ha).

[12] It must be emphasised, however, that containing or eradicating invasive alien species is extremely difficult and costly, and it is likely that these costs will need to be incurred indefinitely – whereas the other scenarios will only incur large costs in the first few years. But if these invasive species are not eradicated, then their influence on water resources will continue to escalate – “penny wise and pound foolish” ?

6.2 Discussion of the alternative water sources available to potential buyers of catchment services

Currently the main alternative sources of water available to downstream users, other than paying for catchment-protection services (which is discussed later in section 6.3), are:

1. Drill additional boreholes and pump water from underground water sources;
2. Treat and recycle water that is currently in use; and
3. Purchase additional water from other nearby dams.

The downstream users of water (i.e., the potential purchasers of catchment-protection services) are listed in Table 2, along with the costs per m^3 of acquiring water by the three means listed above.

At present, both the Harmony Block and the Selati game farmers do not incur any cost for the water they use[13]. Yet their demand for water exceeds the available supply and this is posing a major constraint on their profitability. Their only alternative water source, other than participating in a market for PES, is to drill more boreholes (Alternatives Ia and IIa). The cost of doing so, on a per-cubic-metre-of-water (volumetric) basis was estimated to be between R0.42 and R2.54. This was calculated by dividing the 15- and 10-year time-averages of the establishment cost of R40, 000 per borehole by an expected water yield range of 1,577 – 6,307 m^3 yr^{-1} (DWAF 2004b)[14].

Similarly, the Palabora Copper Mine and FOSKOR, other than purchasing additional water from the LWB when available, have only one alternative source of water that can supplement their current supply from the LWB and this involves treating and recycling their wastewater. The range in the time-averaged cost per m^3 to treat and recycle wastewater is approximately R0.23 and R0.30, which was calculated by dividing the 15- and 10-year time-average costs of R1,400,000 and R1,600,000 by the 7,300,000 m^3 of wastewater that can feasibly be treated each year. This range applies to both the Palabora Copper Mine and the FOSKOR phosphate mine (Alternatives IIIa and IVa). Additional water can, however, be obtained by the LWB to partially meet water shortages through the importation of water from the Vaal, Incomati and Maputo catchments, which is then sold to the mines. In this case the LWB could purchase the water at a cost of R0.048 m^{-3} (Alternatives V and Va) and sell it at a price of R0.847, which is the price currently being paid by the two mining companies. It is worth highlighting that the estimated range of the per-m^3 cost of recycling wastewater for the Palabora Copper Mine is substantially less than the current price paid to the LWB for fresh water – a strong argument for ending the current water-purchase contracts and requiring bulk water users to implement dramatic water saving approaches.

6.3 Evaluation of the options to trade catchment-protection services

As mentioned above, another option that is available to downstream water users to meet their growing water requirements is to pay upstream water users and landholders to adopt land-use and technology practices that increase the quantity and improve the quality of water flowing to the lower reaches of the catchment. Such a system of payments for environmental (catchment) services will now be referred to using the acronym PES. The

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[13] Harmony Block and Selati game farmers argue that they should not have to pay for their water because the upstream water users (Legalametse Nature Reserve, Calais community and Selati irrigators) currently do not pay for the water they use (Bekker 2006).

[14] The borehole yields in the Lower Olifants sub-area are generally between 0.5 and 2.0 litres per second. The yields do, however, increase to 5 litres per second in local areas around Phalaborwa (DWAF 2004b).

catchment-protection activities that upstream users can adopt, the associated costs, and the water savings (services) that would result were listed and discussed in section 6.1. In this section, these activities are evaluated in terms of their potential as an alternative water source to downstream water users. This evaluation focuses only on the economic feasibility of the options by comparing the estimates of the cost per m^3 of water supplied by each alternative water source that is available to the potential buyers. By focussing on the economic feasibility only, we are essentially making the assumption that the necessary institutions and infrastructure are in place to allow and facilitate the payments for the delivery of such services. Such an analysis also requires us to assume that the transaction costs involved are zero, or sufficiently small to allow trading; this is extremely unlikely due to the high information and monitoring requirements and the costs of negotiating, co-ordinating, verifying, and enforcing contracts[15]. This assumption is necessary though because no estimates of these transaction costs exist for African cases.

Another simplifying assumption behind this analysis is that the additional water released as a result of the catchment-protection activities implemented upstream actually reaches the potential buyers downstream. If this does not happen (i.e., if the delivery of a minimum agreed upon volume or percentage of the water is not guaranteed) the potential beneficiaries located downstream will not be willing to pay for the services.

Comparing the costs per m^3 of water saved (column 5 Table 1) with the costs of the alternative sources of water that are potentially available to downstream users (column 3, Table 2), it is noteworthy that:

A. It is more cost-effective for the Harmony Block and the Selati game farmers to address their water shortages through payments for the catchment services provided by upstream landholders adopting any one of the land-use and technology changes listed in Table 1, provided the borehole yields are low (0.5 litres sec^{-1}). If the borehole yields are between 2 and 5 litres sec^{-1} then only the four most cost-effective PES options are less costly than developing a borehole. The order in which buyers would likely pay for the catchment-protection activities is indicated by the rank of the scenario in brackets in column 5 Table 1. It is emphasised that PES will only occur if the water that is released actually reaches the buyers and the transaction costs do not exceed a range of R0.28 – R2.37 m^{-3} (the difference in cost between the most cost-effective Scenario (B1) and the cost of developing a borehole).

B. The Palabora Copper Mine and FOSKOR are able to address their water shortages most cost effectively by paying upstream landholders to adopt any one or all of the four most cost-effective land-use and technology changes (Scenarios B1, B2, B3, and C2) listed in Table 1. Again, it is emphasised that any payments would only occur if the water released reaches the buyers and the transaction costs do not exceed R0.08 –R0.13 m^{-3} (the difference in cost between the most cost-effective Scenario (B1) and the cost of recycling and reusing water).

In the cases above where PES was found to be the most cost-effective option for improving water supplies in the catchment, it is envisaged that the payments could take the form of an annual fee – possibly combined with an upfront payment to cover establishment costs – paid directly to landholders or through an intermediary. If PES is implemented, the downstream buyers could also minimise any risks by paying after they receive the services and not before. This, however, shifts the risk entirely onto the supplier, which is likely to undermine trading. A more appropriate means for dealing with risk might be to discount the price, or pay a premium depending on the level of surety of delivery.

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[15] The implications of these assumptions are discussed further in Chapter 7.

A final point worth mentioning is that the total amount of water released from implementing the catchment-protection activities listed in Table 1, (excluding Scenario C1, for which no data exist), is estimated to be approximately 6,500,000 m^3 yr^{-1}, which is less than the total amount of water that was treated and recycled by the Palabora Copper Mine alone (7,144,000 m^3 yr^{-1}). Consequently PES will not solve the water shortage problems within the catchment and it is likely to be necessary for water users to develop the alternative water sources to meet their needs. This, however, does not mean that PES should not be facilitated and implemented wherever possible as it will contribute to minimising the costs of meeting water demands and will have significant non-use benefits in the form of maintaining stream flows (improving and sustaining river ecosystem integrity and biodiversity[16]) over a much longer section of the river – the economic value of which is extremely difficult, if not impossible, to quantify (and so this has not been attempted here).

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[16] An example of this in the area is the threatened Barred minnow (*Opsaridium peringueyi*) whose survival will be made more secure as a result of improved stream flows in the region just below the Legalametse Nature Reserve.

7. Conclusions and recommendations

The cost-effectiveness analysis presented in this paper contributes to understanding the potential economic implications of the various management practices in achieving the provision of catchment services. The results have shown that the potential buyers (Harmony Block commercial farmers, Selati game farmers, FOSKOR, and Palabora Copper Mine) and the potential sellers (Legalametse Nature Reserve, the Calais community and the Selati irrigators) could all benefit from trading catchment services, provided that the transaction costs of doing so do not exceed R0.13 m^{-3} for the two mines, and R2.37 m^{-3} for the farmers. The results also showed that the Lepelle Water Board would not benefit from the PES opportunities investigated here because cheaper alternative sources of water are available. The Kruger National Park was identified as a beneficiary of improved stream flows (i.e., in terms of sustained biodiversity and ecosystem integrity) that would result as a consequence of PES, but it was not considered a potential buyer. This is because it is 'guaranteed' by law a minimum Ecological Reserve and there is little chance of convincing management that they should pay for what they are due by legislated right. Since it is the responsibility of the Department of Water Affairs and Forestry (DWAF) to ensure this Ecological Reserve is met[17], and because it has not yet been able to do this, a clear and definite opportunity exists for the DWAF to participate in a PES system that will help it meet its legislated responsibilities.

Although the study identified potential traders of catchment-protection services and evaluated the economic feasibility of participating in PES, it did not address the mechanisms by which these payments could be implemented. These mechanisms would require substantial negotiations between stakeholders, and the development of the necessary institutions and infrastructure. The study also did not consider the payment mechanisms that would be appropriate, of which at least 10 have been identified (see Landell-Mills and Porras 2002). It is likely that less-sophisticated mechanisms (e.g., direct transactions between buyers and sellers, intermediary-based transactions, and pooled-buyer transactions) will be most appropriate for this pilot site due to the complex cultural, political and land tenure issues that currently prevail in the area.

A major limitation of this study is the severe lack of data and the consequent uncertainty surrounding the estimates of the costs of implementing the various catchment-protection activities. This is particularly true for the costs of attempting to eradicate the IAP because the reported expenditure values (based on the Working for Water Programme expenditure data) do not give a detailed breakdown of how these costs are calculated. This information is important because the estimates come from different regions across South Africa and it is highly likely that transport and labour costs will vary significantly between regions. The result is that there is uncertainty associated with estimates used here. Despite this, the estimates obtained are useful in that they give a comparative guide as to the direction and magnitude of the change in water supply and cost, and allow comparisons to be made. The rankings of the alternatives, however, must be used with caution. Another limitation – due to the lack of data – is that the assumption of zero transaction costs was made; this is a very unrealistic assumption, but again it allows us to make initial comparisons between the available alternatives. An important recommendation arising from this study is that further, more focussed research should be undertaken into the development and implementation of PES in South Africa.

A final point to note is that when this study started, the Legalametse Nature Reserve and the Selati irrigation scheme were being claimed by the Sekororo community under the

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[17] In addition, DWAF is required to ensure that sufficient water is released down the Olifants River to meet the international obligations with Mozambique – this international requirement is also stipulated in the *National Water Act*.

government's land reclamaition and land restitution processes. These claims have recently been awarded and all of the white commercial farmers[18] have had to leave the area (Bekker 2006, pers. comm.). A new round of negotiations with these new landowners is therefore required, with the view of possibly getting their support and commitment to a system of payments for catchment services in order to improve water-use efficiency and restore stream flows to their natural state. An early-identified impediment to achieving this, however, is that the community is expected to receive subsidies[19] from the Department of Agriculture and therefore may not need to participate in such a market mechanism.

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[18] Only two commercial farmers remain in the Selati irrigation scheme. They were appointed by the Department of Agriculture to farm for the Sekororo community (Bekker 2006, pers. comm.).

[19] For example, the Department of Agriculture has stated its willingness to upgrade the irrigation systems in the Selati irrigation scheme.

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