AN ECONOMIC ANALYSIS OF ERADICATING ALIEN VEGETATION AS AN ALTERNATIVE TO CONVENTIONAL WATER SUPPLY SCHEMES: A CASE STUDY OF THE KROM AND KOUGA.

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ABSTRACT

South Africa is classified as an arid to semi-arid region and water scarcity in South Africa has been identified as a key factor limiting socioeconomic development in the next century. In the Algoa region, the total urban plus agricultural water demand is expected to exceed the supply by the year 2005. The Kouga Working for Water Project aims to increase the base flow to the existing dams which supply the Port Elizabeth metropolitan area through the eradication of invasive alien trees in the riparian areas of the Krom and Kouga catchments.

This thesis analyses the economic efficiency of optimal catchment management as a water supply scheme. A cost-benefit analysis is conducted for the Kouga eradication programme, and its desirability is evaluated in terms of the net present value (NPV) and the internal rate of return (IRR) criteria. In order to compare the cost-efficiency of the eradication programme to alternative water supply augmentation schemes the Unit Reference Value (URV) is calculated for the project.

The NPV for the project is calculated using a discount rate of 7% and amounts to nearly R24 million. This positive NPV indicates that the project is economically desirable in that it results in the improvement of human welfare. The IRR decision rule supports this finding. The URV of the eradication scheme is found to be competitive to that

generated by more conventional schemes. Considered in the evaluation of the project are a host of environmental benefits that accompany the eradication of alien vegetation. This is in contrast to alternative schemes which result in several detrimental impacts to the environment.

The economic analysis concludes that the eradication of alien vegetation is an efficient and desirable alternative water supply augmentation scheme. The conclusions drawn from the analysis of the eradication programme in this catchment area can be extended to other catchment areas, with the aim of promoting the most efficient supply of water.

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Chapter One

Introduction

Alien invading plants have a major impact on the natural resources, and particularly the water resources of South Africa. The high rainfall catchment areas, which are the country's primary source of water, tend to be the most readily invaded areas. Invasion by alien woody plants displaces the indigenous vegetation, increases the biomass in catchment areas and substantially decreases the surface runoff. The cost of clearing alien plant invasions varies considerably, depending on terrain, species, density, method of clearing, ease of access to invaded areas and various other factors (Versfeld *et al.*, 1998). These factors will affect the cost structure of any specific eradication programme and consequently influence the outcome of an economic analysis of that programme. The interrelationship between water scarcity and alien vegetation invasion is therefore set out in some detail in this chapter. This will provide the economic background and context for a study of the economic impact of its eradication as a means of increasing water supplies as an alternative to conventional water supply schemes.

1.1 The water supply problem in South Africa

South Africa, with an average rainfall of a little less than 500 mm per annum, is regarded as generally being an arid to semi-arid region. Exacerbating the problem of scarcity of water is the uneven distribution of rainfall, with some of the areas of highest demand, such as Gauteng, receiving little rainfall. Furthermore, high evaporation rates result in South Africa's runoff to rainfall ratio being amongst the lowest for any populated region of the world (O'Keeffe *et al.*, 1992: 277). Water, consequently, is a very scarce resource in most of South Africa, and is a key factor limiting socioeconomic development (Huntley *et al.*, 1989: 61; O'Keeffe *et al.*, 1992: 278).

The combined run off of South Africa's rivers is estimated to average 53 500 million m^3 per annum, but it is estimated that only 33 000 million m^3 (62%) of this can be exploited economically, due to the high variability of average flows and the high evaporation losses from storage. Total national water demand in 1990 was slightly more than 19 000 million cubic metres per annum and this is expected to increase to 25 888 million cubic metres per annum in the year 2010. While this is within the limits of available water, the spatial and temporal variations in rainfall require that there is sufficient water storage to accommodate periods of extreme drought (O'Keeffe *et al.*, 1992: 282).

1.2 Invasive alien vegetation

The national Working for Water Programme has as its aim the improvement of South Africa's water supply through the eradication of invasive alien vegetation in water catchment areas. Mountain catchments, with an area of only 8% of South Africa's land surface, provide 49% of the total annual runoff of the country. Their management, for the optimum sustained yield of water, of the highest possible quality, is consequently of great importance. Maintenance of water yield entails ensuring that the catchment continues to yield water at historical rates, principally through the maintenance of an adequate plant cover (Seydack and Bekker, 1995: 12).

Riparian zones and the fynbos biome are, however, the most susceptible to invasion by alien trees (Wells *et al.*, 1983). The most significant alien invaders of river systems are trees such as rooikrans (*Acacia cyclops*), silver wattle (*Acacia dealbata*), black wattle (*Acacia mearnsii*), blackwood (*Acacia melanoxylon*), bluegums (*Eucalyptus*) and pines (especially *Pinus pinaster*) (Eastern Cape Ministry of Agriculture, 1995: 3; RDP Water Conservation Programme, 1996: 2). These invasive alien trees are so successful because they grow without the natural enemies (fungi, viruses, bacteria, insects and animals) that restrict them in their countries of origin. They are consequently able to grow and spread more vigorously than the indigenous fynbos, which must contend with natural enemies (Stirton, 1978:36). In addition, the invader trees are usually taller and faster growing than the indigenous vegetation, are evergreen and have a high reproductive capacity, producing a large number of seeds. They consequently quickly overgrow and displace shade-intolerant fynbos (Rutherford *et al.*, 1986). This has serious consequences for the streamflow of infested catchment areas.

The invasion of riparian zones by alien trees can increase the above-ground biomass up to tenfold. This higher biomass results in increased transpiration, leading to a reduction in runoff from the catchment areas (Eastern Cape Ministry of Agriculture, 1995: 3). Because the alien trees are fast growing, they transpire at a faster rate and use more water than the natural vegetation would. In addition, the evergreen alien invasives continue to transpire and use large amounts of water during the dry season, whereas the natural vegetation becomes dormant and uses very little water during these periods (Working for Water, 1998:9).

A number of studies have illustrated the serious effects that the invasion of catchment areas by alien vegetation has on water supplies (Van Wyk, 1987; Versfeld and Van Wilgen, 1986). A study conducted in September 1994 on the SAPPI property of Kalmoesfontein illustrates the significance of the increase in streamflow associated with alien vegetation eradication: the clearing of approximately 25 000 m^2 of invasive trees from riparian zones increased streamflow by 30 480 litres of water per day, sufficient to supply more than a thousand people with a daily allowance of 30 litres of water (Dye and Poulter, 1995: 29).

A feature of fynbos landscapes is the presence, if not dominance, of invasive alien trees and shrubs, especially those of the genera *Acacia, Hakea* and *Pinus*. These taxa now dominate thousands of hectares of natural vegetation, significantly modifying communities and threatening many indigenous species with extinction, as well as significantly reducing water yields (Richardson *et al.*, 1992: 271).

Acacia cyclops and *Acacia saligna* are prominent invaders of fynbos reserves in the lowlands, whereas *Acacia mearnsii* and *Hakea sericea* are found mostly in mountainous areas. The characteristic invaders of the different vegetation types are the following: *Acacia saligna* in agricultural and transformed land; *Acacia longifolia, A. mearnsii, H. sericea* and *Pinus pinaster* in mountain fynbos; *A. cyclops* and *A. saligna* in strandveld; and *A. cyclops* in non-fynbos vegetation (Richardson *et al.*, 1992: 282). All these species have detrimental effects on water yields, with riparian invasions being the most severe.

Transformations associated with alien plants are most severe in the fynbos biome, where it is estimated that, by 1984, 14 321 km^2 (20, 5% of the biome) were invaded to some extent. Dense stands of alien trees result in local extinctions of fynbos species and significantly reduce fynbos community-level richness. Besides the impact on water resources, these invasions currently pose the most serious threat to the survival of biomes and of endangered species (Cowling and Olivier, 1992: 221; Van Wilgen *et al.*, 1992).

1.2.1 History of alien introductions

The first alien species were introduced with the commencement of pastoralism in the biome between 1 700 and 2 000 years ago. The major impact of the people on the biome, however, began after European settlement at the Cape in 1652 AD., when plant species began to be introduced in considerable numbers (Deacon, 1986: 3;

Shaughnessy, 1986). Very few of these species became invasive, however, and only one, *Pinus pinaster*, is currently ranked among the 12 most important invaders of the biome.

These early introductions were virtually all of European origin. It was only after 1830, when tree and shrub species were intentionally imported from areas of similar climate (especially southern and western Australia), that most of the important invaders of natural vegetation became established (Richardson *et al.*, 1992: 279). Forty-five percent of plant species introduced from Australia have become significant invaders, compared with just 3% of those plants introduced from Europe and Asia (Working for Water, 1998:3).

In total, 744 tree species have been introduced into South Africa, although only 110 species of these species are regarded as invasive (Working for Water, 1998:3). Wells *et al.* (1983) estimated that by 1982 109 alien plant species were invading the terrestrial habitats of the winter rainfall area, while 101 alien species were recorded invading stream bank habitats alone (Richardson *et al.*, 1992: 282).

Acacia mearnsii (black wattle) was introduced from Australia in 1858 for the purpose of providing shade, shelter, tanbark and firewood. The high tannin content of the bark of black wattle trees meant that they were soon planted in commercial plantations in Natal on a large scale. The extensive dissemination of black wattle can be attributed to its commercial value to the tannin and timber industries

(Richardson *et al.*, 1992: 272). By 1973 black wattle plantations covered an area of roughly 180 000 ha, while black wattle trees covered an area of about 48 000 ha outside the plantations (De Beer, 1986). It is estimated that approximately 2,5 million ha are currently invaded by black wattle (Working for Water, 1998: 4).

The Agricultural Resources Act (Act 43 of 1983) regulates weed control in South Africa. Under this act invasive alien species are either declared as weeds, in which case their removal is legally required, or, where species have commercial or other value, declared as invaders. The act requires that invaders be controlled if they are, or potentially are, "detrimental to the productive potential of the natural agricultural resources" (Working for Water, 1998: 5).

The Water Act (Act 36 of 1998) seeks to control certain "streamflow reduction activities" and as such requires that riparian zones and wetlands not be planted with alien trees. South Africa is also a signatory to the Convention on Biodiversity (1992) and is consequently obligated to "prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species" (Working for Water, 1998: 5).

1.3 Catchment management

The Mountain Catchment Areas Act (Act 63 of 1970) transferred the responsibility for the management of all public and declared privately owned mountain catchment areas to the then Department of Forestry (Seydack and Bekker, 1995: 9). Under this act private mountain catchment land can be declared and thereby brought under the supervision of the Department of Forestry. The rationale behind the Act is to ensure the catchments are managed in a way that is compatible with maintaining the soil and ensuring a sustained flow of the maximum quantity of high quality water (Ackermann, 1976). Conservation of riparian zones and wetlands of mountain catchments is required under the new Water Law to ensure that the catchments maintain the ability to produce a reliable, high quality flow of water (Working for Water, 1998: 10). The basic premise of catchment management is that the maintenance of natural plant cover, through controlled rotational burning, is the most cost-effective way of protecting catchment areas and ensuring water quality (Seydack and Bekker, 1995: 16).

Optimal catchment management involves, among other criteria, the control of alien invasive trees. The aim is to increase base flow to existing dams, thereby adding water to the system, not simply redistributing the water or controlling the flow pattern as alternative schemes do (Ninham Shand Inc., 1993:12). The traditional approach to the water supply problem has been to provide short-term relief through the capital-intensive construction of new dams, often with severe negative environmental impacts. Alien vegetation eradication is a highly labour-intensive process that improves the reliability of streamflow and has a positive impact on the natural resources of the area.

Water resource conservation is considered to be of overriding importance as a catchment management objective (Seydack and Bekker, 1992: 12). The importance of all water resources must be seen within the context of South Africa's dominantly semi-arid climate. With the present population of around 42 million, South Africa has slightly more than 1 200 kl of available freshwater for each person per annum, placing the country on the threshold of the internationally-used definition of "water stressed". South Africa already has less water per person than some countries perceived to be much drier, such as Namibia and Botswana (DWAF, 1997a: 9). The availability of water is therefore probably the most critical factor in the future development of the country (Bosch *et al.*, 1984). This situation was acknowledged as early as 1970, when the Commission of Enquiry into Water Matters argued that the "overall planning of the use of South Africa's limited water resources should be thoroughly integrated with the economic planning of the country as a whole, taking socio-economic conditions into account ..." (Mirrilees *et al.*, 1994: 1-1).

1.3.1 Invasive alien control

South Africa has a history of alien weed control dating back to 1890, while instances of integrated control were first recorded in the 1940's (Kluge *et al.*, 1986: 295). Phillips (1938) reported that farmers in the Bathurst district first met to discuss the spread of *Hakea sericea* in about 1863 (Macdonald and Richardson, 1986: 85).

The general control strategy for plant invaders is to concentrate on the eradication of invasive exotics in areas of high conservation priority and those areas where infestation is still in its initial stages. The main areas of infestation are subsequently tackled systematically.

Control measures aimed at reducing the detrimental effects of alien plants on biotic diversity must remove the existing dense stands with the least possible additional damage to surviving vegetation and soil-stored seed banks and prevent the establishment of new dense stands. Alien weed species that have commercial value, such as *A. mearnsii*, are the largest problem as continued propagation and dispersal will mean that control programmes can never be scaled down. To prevent wasted effort, a sustained minimum level of control activity is required. Diminishing availability of funds threatens such sustained input on the behalf of the State (Van Wilgen *et al.*, 1992: 364). To counter this the Working for Water Programme has made private landowners contractually obligated to maintain the necessary minimum level of control once the initial clearing has been done and once the Working for Water teams have conducted a couple of follow-up operations.

Fire management and alien invasive control are intricately connected. Ideally, all woody alien plants should be felled prior to prescribed burns, which are usually carried out at approximately 15 year intervals, and the area is burned about 18 months later to kill seedlings. The relatively recent emergence of the hard-seeded *Acacia* species as important invaders of Mountain Fynbos has complicated control programmes. The ability of several of these species to sprout after felling and the density and longevity of the seed bank makes control of these species difficult and expensive (Macdonald and Richardson, 1986: 86). Furthermore, dense infestations make access difficult and consequently fires are more difficult to manage (Working for Water, 1998: 13).

Black wattle seeds do not germinate immediately but form seed banks under the trees, where they can remain viable for 50 years or more. Seed densities of up to 20 000 seeds per m^2 have been recorded (De Beer, 1986). Exacerbating the problem is that fire stimulates black wattle seeds to germinate. While the seeds of the black wattle are able to survive the high soil temperatures associated with intense fires, the seeds of some fynbos species are destroyed after brief exposure to these temperatures. Intense fires associated with the increased fuel loads of alien vegetation thus favour the spread of the invasive species over the indigenous vegetation (Working for Water, 1998:13). Prolific regeneration of these species after fire has meant that the trees have subsequently had to be treated with arboricides, which is expensive, often ineffective and potentially damaging to indigenous plant regeneration (Macdonald *et al.*, 1985; Macdonald and Richardson, 1986: 86).

Effective incorporation of plant invader control measures into fire management plans is probably the greatest challenge facing managers. Careful priority determination for resource allocation between fire management and invader control is required. Invader control priorities should be fitted in with the needs of fire management in a way which allows the maximum area of mature veld to be cleared in advance of prescribed burning. This may be achieved by giving priority attention to mature, sparsely infested areas rather than the densely invaded areas. Invader control should not absorb all the resources at the expense of fire management (Seydack and Bekker, 1995: 23).

The bulk of invader control is carried out by mechanical means. In the case of *Hakea* and *Pinus* species, this entails cutting the plants 12 to 18 months in advance of controlled burning and the pulling out of seedlings a year or 2 after such burns. Burning of the infested areas without the concomitant invader plant control measures should not be considered, since the extent of the problem is then aggravated owing to the favourable conditions created for the spreading of fire-adapted invaders after fires (Seydack and Bekker, 1995: 23). The dense riparian infestations of the Krom and Kouga Rivers are not burned periodically due to the fact that the infestations are so heavy and access is so limited that prescribed burning would lead to unmanageable fires (Buckle, 1998: personal communication).

Control programmes for all the invasive alien plants can be divided into short- and long-term phases. Short-term control is aimed at removing existing stands of the plant, usually by means of mechanical and chemical methods. Chemical invader plant control is limited by factors of cost and practicality. Herbicides may, however, be used to good advantage under certain conditions, provided all legal and other precautionary measures are taken to ensure that no pollution of the environment and particularly of the water resources will take place (Seydack and Bekker, 1995: 23).

Long-term control, usually involving biological agents, is then aimed at maintaining the alien plant population at an acceptable level (Kluge *et al.*, 1986: 297). In the long-term, biological control of invader plants will have to take effect if high and continuous control expenditures are to be avoided. Biological control is the ultimate solution to the eradication of the invader plants producing a high seed load, especially in respect of the *Acacia* species that have colonised the stream and river banks (Seydack and Bekker, 1995: 23; Wilson, 1985).

A number of biological control agents have been established in the fynbos biome and several other control options are available. Clearly, some options are suitable for certain species but inappropriate for others. The effectiveness of any control option depends primarily on the life history attributes of the target species. In many cases, a combination of one or more control options (integrated control) produces the best results. The situation is complicated when more than one weed species is present at a site, especially if the species differ markedly in their life history attributes (Van Wilgen *et al.*, 1992: 354).

In the case of *Acacia mearnsii*, several *Melanterius* species, which attack green developing seeds, are potential biological control agents. None of these species has yet been released, however, due to the perceived threat to commercial plantings of

A. mearnsii (Van Wilgen *et al.*, 1992: 355). The recommended control option for this weed is one of integrated control. Given that the plant resprouts after cutting, has a relatively long-lived seed bank, and the seeds are stimulated to germinate by fire, a combination of cut-and-burn, chemical and biological control is the most effective option.

Follow-up operations are indispensable for successful control and should have priority over new clearings when funds are curtailed (Seydack and Bekker, 1995: 23). Reinfestation of adjoining areas must be anticipated and considered systematically. The Mountain Catchment Areas Act (No. 63 of 1970) accordingly provides for the spending of state money for invader control in areas up to 5 km beyond the boundaries of declared mountain catchment areas (Seydack and Bekker, 1995: 23).

Given that there are still between 12 and 16 million South Africans who do not have adequate access to water (RDP Water Conservation Programme, 1996:2), additional water supply schemes clearly need to be implemented in the near future if the government is to honour its commitment to provide all South Africans with convenient access to clean water. The water supply problem may be illustrated by examining the situation in the Eastern Cape.

1.4 The Eastern Cape

The Algoa Water Resources System Analysis, conducted in 1993, illustrated that the total urban plus agricultural demand (approximately 121 million m^3/a) almost equalled the supply in that year and was set to exceed supply shortly thereafter. The region is dependent on water being supplied from the Orange/Sundays River Scheme (Eastern Cape Ministry of Agriculture, 1995: 3; Ninham Shand Inc., 1993: 5).

It was estimated that the population of the Port Elizabeth - Uitenhage area would increase at a rate of 2,4 percent per annum from 740 000 in 1980 to 1 510 000 in the year 2010. The corresponding water demand would increase by 247 percent from 51 million m^3/a to 177 million m^3/a. This represents an average annual growth rate of 4,2 percent. At present the urban demand, taken from the 1996 forecast, is approximately 79 million m^3/annum. The present water supply system, based on a 1927 to 1983 historical firm yield, is expected to meet demand until 2005 (Ninham Shand Inc., 1996c: 30).

The Kouga Project, which is coordinated by Eastern Cape Nature Conservation, aims to augment the water supply to the Algoa region and improve the reliability of streamflow through optimal catchment management, thereby addressing the water needs of the region in a cost-effective manner. With the total water demand in the Algoa region expected to exceed the total yield by the year 2005, the water supply problem in this area is a microcosm of the problem throughout South Africa. The conclusions drawn from the analysis of the efficiency of alien vegetation eradication in this catchment area can be extended to other catchment areas, with the aim of promoting the most efficient supply of water.

1.5 The Kouga Working for Water Project

The Kouga Project is a sub-project of the national Working for Water Programme, which is managed by the Department of Water Affairs and Forestry. The project aims to eradicate alien vegetation in the mountain catchment areas and the riparian zones of the Krom and Kouga river catchments.

The mountain catchment areas and the riparian zones of the Krom and Kouga river catchments are characterised by fynbos vegetation. Maintenance of this fynbos cover ensures the sustained supply of high-quality water: "fynbos binds the soil, preventing erosion, while its relatively low biomass ensures conservative water use and low-intensity fires, which in turn ensure high water yields and low impact on the soil from periodic fires" (Van Wilgen *et al.*, 1996: 184).

The emphasis of the Kouga project is on the eradication of alien invasives in the catchments of the Krom and Kouga Rivers, which flow directly into the major supply dams for the Port Elizabeth metropolitan area. A map of the study area is provided in Appendix 1. These two rivers provide more than 80 percent of the water supply to this area, as well as water for the Gamtoos Irrigation Scheme and the Patensie, Humansdorp, Jeffreys Bay and Uitenhage municipalities (Eastern Cape Ministry of Agriculture, 1995: 2; Eastern Cape Nature Conservation, 1996: 3)

Alien invader trees, predominantly black wattle, have infested the riparian zones of the Krom and Kouga catchment areas intensively, greatly reducing the water yield from these systems. Black wattle occurs along more than 800km of these rivers and occupies 7 200 ha of this area. This is equivalent to an area of 3 170 ha with a black wattle canopy cover of 100 percent (Ninham Shand Inc., 1993: 11).

Bosch and Hewlett (1982) studied the effect of vegetation changes on water yield and concluded that the excess water use per hectare invaded by aliens is equal to 3 000 m^3 of water per ha per annum. This estimate is based on the assumptions that black wattle in riparian zones uses similar amounts of water to pine plantations and that the fynbos which recovers the cleared areas uses the same amount of water as 100 percent scrub forest cover (Ninham Shand Inc., 1993: 11). The excess water use by the black wattle in the riparian zones of the Krom and Kouga catchment areas is consequently estimated to be 9,5 million cubic metres per annum (3 170ha × 3 000 m^3 per ha per annum) (Ninham Shand Inc., 1993: 11).

It is estimated that, apart from the riparian zones, 30 000 ha of the mountainous upper catchments are infested by invaders. These invaders are mainly pines and hakea which are sparsely spread. The eradication of these invasive is important in order to eliminate the seed sources (Eastern Cape Nature Conservation, 1996: 7). This study will not include the eradication operation in the mountainous areas, but will focus exclusively on the eradication of black wattle in the riparian areas of the Krom and Kouga catchments.

1.5.1 The clearing operation

As most of the black wattle infested rivers are situated on private land, this is where most of the clearing work is conducted (approximately 70 percent). The state-controlled mountain catchment areas (Kouga-, Tsitsikamma- and Elands River mountains) are infested mainly with pines and hakea (Eastern Cape Nature Conservation, 1996: 7).

The clearing operations are performed in a variety of ways, depending on the circumstances. In the mountainous catchments, teams of casual workers have to camp out in the mountains due to the terrain and the distance from towns. The pines and hakea occurring in these areas are slashed or, in the case of larger trees, cut down with chain-saws. On the private land in the Langkloof region, where black wattle has extensively invaded riparian zones, large black wattle trees are cut down and then treated with herbicide or by means of biological control (fungus). Smaller trees are slashed first and the regrowth sprayed with a herbicide. Seedlings are sprayed directly with a herbicide. It is estimated that it will take about ten years to eradicate the 7 200 ha of black wattle in the riparian zones (Eastern Cape Nature Conservation, 1996: 7).

The cost of the clearing operations varies greatly, depending on the species being cleared, the age and density of the stand and the terrain where the work is being undertaken. The cost can be divided into the cost of the initial clearing and the cost of the follow-up operations, which need to be undertaken for at least six years due to the density and longevity of the black wattle seed bank (Macdonald and Richardson, 1986: 86; Ninham Shand Inc., 1993: 12).

Versfeld (1990) estimated that dense stands of mature trees can cost up to R6 000 per ha, while the cost for stands of younger trees is less than R2 000 per ha. Follow-up operations were estimated to cost from R100 per ha to R500 per ha, declining annually due to the reduction in density.

1.5.2 Ecological benefits

Invasive trees and shrubs are thought to have exerted the greatest ecological effects, after direct habitat destruction, on the fynbos biome (Macdonald and Richardson, 1986: 84). These effects include the alteration of coastal sediment movement patterns; the acceleration of river bank erosion; a reduction in streamflow; changes in fire regime; and the alteration of the composition of natural plant and animal communities (Richardson *et al.*, 1992: 272; Versfeld and Van Wilgen, 1986).

Streambanks are particularly prone to invasion for a number of reasons. These include their exposure to periodic disturbances, both natural and human, the perennial availability of moisture, reliable seed dispersal by water and because stream banks act as a seed reservoir (Henderson and Wells, 1986).

Invasion of riparian zones by alien vegetation impacts on the physical structure of the riparian habitat, altering the channel form and processes. If the physical structure of riparian habitats is fundamentally altered then this may have far reaching effects on the viability of these habitats (Rowntree, 1991: 28).

The invasion of riparian vegetation by species such as *Acacia mearnsii* (black wattle), *A. longifolia* (long-leaved wattle), *A. saligna* (port jackson) and *Pinus pinaster* (cluster pine) also results in the acceleration of river bank erosion. While the indigenous vegetation is well adapted to the flash floods that occur in most fynbos catchments, the alien trees have shallow rooting systems and are not able to withstand these floods, resulting in the trees being ripped out, dislodging indigenous vegetation in the process. The exposed soil is then subjected to accelerated erosion (Macdonald and Richardson, 1986: 82; Rowntree, 1991: 34).

In addition, the substantial increase in above ground biomass means an increase in fuel loads and consequently in fire intensity. While typical fuel loads in grass and shrublands are between approximately 0,3- and 4 tonnes per ha, areas which have been invaded have fuel loads of up to 10 to 25 tonnes per ha. Alien trees can consequently burn with flames up to fifteen metres high and with an intensity of as much as 50 000 kW/m, compared to fynbos vegetation which burns with flames up to five metres high and at an intensity of 200 to 5 000 kW/m (Working for Water, 1998: 12). This intensity damages the soil and results in severe erosion, decreasing the water quality. Furthermore, the resultant silting of dams reduces storage capacity and necessitates the construction of new dams (RDP Water Conservation Programme, 1996: 3; Van Wilgen *et al.*, 1996: 3). The national loss of storage capacity due to siltation is estimated at 130 million cubic metres per annum, while the costs of constructing new dams to replace this lost storage capacity is estimated at between R100 and R200 million per annum (Huntley *et al.*, 1989: 63).

Apart from increasing the water yield from the catchments by 9,5 million m^3 per annum (Ninham Shand Inc., 1993: 11), catchments that are cleared of alien invasives provide a wide range of additional ecosystem services. Many of these benefits are a result of the extraordinary biodiversity of fynbos ecosystems (Van Wilgen *et al.*, 1992: 350).

The fynbos mountain watersheds of the Krom and Kouga rivers are part of the Cape flora. The Cape Floristic Region is one of only six biogeographic subdivisions, termed 'plant kingdoms', of the world. In terms of endemic plant biodiversity, the Cape Floristic Region has been recognised as the worlds 'richest hot spot' (Myers, 1990), having the highest recorded species density for any equivalent-sized temperate or tropical region in the world (Cowling and Holmes, 1992: 23). The area, comprising just 4% of the land surface of southern Africa, contains 45% of the plant species of the region (Working for Water, 1998: 15). There are 8 000 vascular plant species in the Cape flora, of which 5 870 species (68%) are endemic (Van Wilgen *et al.*, 1996: 185).

The unique fynbos flora is also of importance as an internationally recognised ecotourist resource. The Cape of Good Hope Nature Reserve, for example, an area of great plant biodiversity, attracts approximately 400 000 tourists each year. Preserving this resource provides the opportunity to generate revenue and employment in an economically and ecologically sustainable way (Van Wilgen *et al.*, 1992: 351; Van Wilgen *et al.*, 1996: 186).

The invasion of the fynbos biome by alien plants is recognised as the greatest threat, after direct habitat destruction, to this biodiversity. It is estimated that approximately 750 species are currently at risk due to invasions by woody aliens (Hall, 1987; Richardson *et al.*, 1992: 271). Invasion by alien plants impacts on biodiversity in the following ways: directly out-competing natural vegetation, altering the fire regime, reducing structural diversity, increasing biomass and disrupting the prevailing vegetation dynamics (Working for Water, 1998: 14). The control of *Hakea, Pinus* and *Acacia* species is thus vital for fynbos flora conservation and consequently takes up a large proportion of the total annual work in mountain catchment management (Seydack and Bekker, 1995: 18).

1.5.3 Economic and Social Benefits

In addition to the numerous ecological benefits that result from the preservation of the fynbos flora, many economic benefits and opportunities are associated with this incredible biodiversity. Fynbos flora has been widely harvested for cut flowers, dried flowers and thatching grass. In 1993, the combined value of these industries was between R58- and R63,6 million, providing jobs for 20 000-30 000 people nationally. In addition, many fynbos plants have been developed for food and medicinal purposes, most notably rooibos tea, while the commercial potential of many fynbos plants has yet to be fully researched and exploited (Van Wilgen *et al.*, 1996: 186).

Alien vegetation eradication is a highly labour-intensive process and the Kouga Working for Water Project consequently generates a large number of employment opportunities for unskilled labour. The Kouga Project has created more than 400 jobs, employing inhabitants from the local communities of Kareedouw, Krakeel, Louterwater, Misgund, Hankey and Tsitsikamma. The dominant economic activities in these areas are the fruit and vegetable farming industry in the Langkloof and Gamtoos Valley, and the forestry and dairy industries in the Tsitsikamma area. Very few other industries exist in the area and there is a high level of unemployment within these communities (Eastern Cape Nature Conservation, 1996: 8).

Table 1.1 shows the population and unemployment figures for the communities concerned.

Table 1.1: Population and unemployment levels in local communities

Local Community	Population (number)	Unemployment Level
Kareedouw	12 500	25%
Joubertina	15 000	19%
Krakeel	1 450	8%
Louterwater	1 450	7%
Misgund	2 000	2%
Gamtoos Valley/Hankey	35 500	36%
Tsitsikamma	2 500	15%

Source: Eastern Cape Nature Conservation, 1998: 12.

Labourers for the Kouga Project have been drawn from the above communities. The creation of jobs and the development of skills in these high unemployment areas has spillover effects on the economies of these various communities.

Small-scale contractors have been established by Eastern Cape Nature Conservation for the completion of the eradication process. Local people are trained and entrepreneurial skills promoted through this development. The local communities are further benefitted through access to the building material and fuelwood of the felled trees.

While the alien trees are detrimental to the water supply system, they are valuable resources of pulpwood, tannin, firewood, charcoal and poles. The utilisation of cleared black wattle trees, which are provided free of charge to the local communities, creates employment and revenue for these communities. The potential economic opportunities arising from the various possible uses of the black wattle will be discussed below.

Black wattle bark is used in the manufacture of a tannin extract for the tanning industry and in the manufacture of adhesives. The South African Wattle Growers Union (SAWGU) administers and controls the sale and processing of wattle bark throughout South Africa. There are only three processing factories in the country, all situated in Kwa-Zulu Natal. The bark needs to be stripped from the tree immediately after the tree is felled and must reach the processing plant within three days in order to ensure bark of sufficient quality. This need for rapid transportation requires that the bark be transported by road, which is prohibitively expensive. While the current price for wattle bark is R228, 50 per ton, the transport cost to get the bark from the Eastern Cape to Natal would amount to R340 per ton. The use of the black wattle bark is therefore not a viable opportunity for the Kouga communities (Deloitte and Touche, ca.1997: 3).

Wattle timber is sold through either the Transvaal Wattle Co-operative or the Natal Wattle Co-operative. The price received for the timber varies between R230 and R300 per ton. Wattle stems of between 5 cm and 50 cm are transported to Richards

Bay where the timber is converted to either pulp or chip form. Mature black wattle thickets can yield an average of 50 tons of pulpwood per hectare and up to 30 tons per hectare of thinner stems. On the private land in the Langkloof region, the black wattle is close to roads and the railway line and thus can be utilised (Eastern Cape Ministry of Agriculture, 1995: 3). Due to the lack of urgency in getting the timber to Richards Bay, since timber needs to be approximately six weeks old before being chipped, rail transport can be used. The average rail rate in 1997 was R110 per ton (Deloitte and Touche, ca.1997: 5). The opportunity therefore exists for the local communities to sell the black wattle timber to one of the timber-processing co-operatives who will then use the timber for pulp, chips, charcoal manufacture, or in chemical production (Deloitte and Touche, ca.1997: 5)

Another possible use for the wattle is to for the local communities to sell the timber to farmers as untreated poles and droppers. This is a limited market as farmers are reluctant to use untreated wooden poles and droppers as iron poles and droppers are cheaper, are easier to plant and last longer than their wooden counterparts. The timber is however used for these purposes in rural settlements (Deloitte and Touche, ca.1997: 7).

The final possible opportunity is for the local communities to sell the timber as firewood (Deloitte and Touche, ca.1997: 12). Black wattle currently sells for R70/ton in the Langkloof region (Buckle, 1998: personal communication).

1.6 Economics of catchment management

To justify the expenditure of public funds on alien vegetation eradication, optimal catchment management must be demonstrated to be the socially optimal water supply scheme, in terms of the betterment of human well-being. An economic justification is especially important given the strong competition that exists for public funding. Policy makers need to be convinced that management of water catchments by eradicating and controlling alien plant invasions would result in the sustainable delivery of water in the most cost-effective manner possible.

It is estimated that it will cost approximately R700 million to clear all existing infestations in South Africa (RDP Water Conservation Programme, 1996: 4). The Kouga Project alone requires a budget of between R7- and R8-million for the next 10 years in order to be completed successfully (Eastern Cape Nature Conservation, 1996: 17). Although the total cost of catchment management is higher when alien trees are cleared and managed, what is of relevance is that the unit cost of water production can be expected to be lower than in unmanaged catchments, due to the greater volumes of water that would be produced (Van Wilgen *et al.*, 1996: 188). The alternative to optimal catchment management is to enhance the water supply by building more dams. In order to evaluate the desirability of the eradication programme, the results of the Algoa Water Resources Stochastic Analysis, which analyses various supply augmentation options, will be looked at and compared to the results from the analysis of the eradication project.

Given that South Africa is an arid country and that water scarcity has been identified as a key factor limiting development (Huntley *et al.*, 1989: 61; O'Keeffe *et al.*, 1992: 278), the efficient management of our water resources is of vital importance. In addition, water has been recognised by the new Water Law as a common resource, meaning that there is no longer ownership of water resources, but rather everyone has right to its use. The Water Law states that each South African has a right to have access to a sufficient quantity, provisionally set at 25 litres per day, of high quality water (Working for Water, 1998: 10). This thesis aims to analyse the economic efficiency of invasive alien vegetation eradication as an alternative water supply scheme, looking specifically at the riparian areas of the Krom and Kouga river catchments, and to compare this option to more conventional supply augmentation schemes. The economic justification for the eradication of alien plant species will be examined and the results extended to other water supply schemes around the country.

In the chapter which follows the methodology of cost-benefit analysis and its economic basis will be discussed. Techniques for valuing unpriced environmental benefits and costs and incorporating them into the analysis will be examined and the evaluation criteria for projects outlined. The method used by the Department of Water Affairs and Forestry to compare different schemes, the calculation of a Unit Reference Value, will also be discussed.

Chapter Two

Literature Review: Cost-Benefit Analysis

The economic basis for the methodology that shall be used in this thesis will now be outlined and some of the central issues discussed. The particular difficulties associated with the economic measurement of unpriced environmental impacts will be highlighted and the criteria for evaluating the desirability of alternative projects discussed.

2.1 Introduction

As opposed to a financial analysis, which is concerned with costs and benefits as measured by market prices, an economic analysis attempts to incorporate all the costs and benefits of alternative development projects, including those that are intangible and unpriced.

The goal of determining the desirability, in economic terms, of the eradication of alien vegetation in water catchment areas, specifically in the riparian areas Krom and Kouga rivers, depends on a reasonably correct evaluation of the economic costs and benefits that are expected to flow from this water supply project. While some of the benefits and costs are easy to quantify, for example consumptive benefits, others, such as the preservation of biodiversity or the aesthetic appeal of indigenous vegetation, are more difficult to incorporate into the analysis (Sherman and Dixon, 1991: 101). The cost-benefit analysis which will be conducted will incorporate the benefits and costs that can be directly valued and, where quantification is not possible, these non-pecuniary benefits and costs will be incorporated into the analysis by being made qualitatively explicit.

2.2 The economic basis of cost-benefit analysis

Cost-benefit analysis (CBA), as a means of identifying policies which society prefers, has its foundation in welfare economics. Welfare economics concerns itself with how society can allocate scarce resources so as to maximise social welfare. Social preference is interpreted as the aggregation of individual preferences. The most popular yardstick in welfare economics is the Pareto criterion, which states that a Pareto efficient action is one that makes at least one person better off without making anyone else worse off (Dasgupta and Pearce, 1972: 54). A project is thus acceptable under the Pareto criterion if at least one person is made better off and no one is made worse off by the project. If some people prefer action *x* to action *y* while others prefer *y* to *x*, then the Pareto optimality condition offers no solution, however, as it precludes the possibility of interpersonal comparisons of utility - there is no way of determining whether the extra utility of those gaining from any action exceeds the loss of utility of those losing from the action (Dasgupta and Pearce, 1972: 55).

To allow for the fact that someone will almost always be made worse off by any given course of action the Kaldor-Hicks principle was developed which states that social state *y* is socially preferred to existing state *x* if those who gain from the move can compensate those who lose and still have some gains left over. This leaves the losers no worse off and the Pareto optimality condition is met. It is this principle which underlies cost-benefit analysis - if the benefits exceed the costs then the gainers can hypothetically compensate the losers and still be in a position of net gain. It should be noted that ethical judgements necessarily underlie the aggregation of individual preferences so as to get a social welfare function. This is the outcome of Arrow's Impossibility Theorem (Dasgupta and Pearce, 1972: 57).

CBA is one of the most accepted and widely used methods of social welfare analysis. CBA involves the identification, enumeration and evaluation of all the relevant costs and benefits that accrue over time from alternative projects. If the benefits of a particular project outweigh the costs, then that project will serve to improve human welfare over multiple generations (Prest and Turvey, 1965: 683; Stauth and Baskind, 1992: 33).

Although a CBA may indicate that a project will yield net benefits, it is important that the opportunity cost of that particular option be examined. While it is beyond the scope of this thesis to analyse alternative water supply schemes, such as the construction of new dams or inter-basin transfer schemes, other studies done in this regard will be examined. The net benefits, or costs, of clearing alien vegetation need to be compared with the net benefits of alternative water supply schemes to determine which option is socially optimal.

2.3 Valuation of benefits and costs

In a perfectly competitive economy the price of a good reflects the equilibrium point at which the social cost of its production is equal to its marginal social value to consumers. Under perfectly competitive market conditions the market price of a good can be used in economic analyses. Many goods, however, have markets that are imperfect. This is especially true in the market for environmental goods and services. The absence of markets for many environmental services, such as biodiversity, existence value and ecological processes, results in an inefficient allocation of resources. Economists argue that these unmarketed goods need to be priced in some way if they are to be allocated efficiently, so that a more rational tradeoff with marketed goods can be achieved (Stauth, 1983: 84). As Aylward (1992: 34) argues, "the presence of market failures in the management of many wild resources prevents markets from fully reflecting the economic value of these resources. As a result, many of these wild resources are managed unsustainably and in a fashion that precludes the full realisation of their value to society".

2.3.1 Sources of market failure

One of the basic assumptions underlying neoclassical economics is the existence of perfect markets. This assumption implies that economic agents have perfect information about the present and the future, that goods are perfectly homogenous and divisible, that there are no barriers to entry into the market, and that there are an infinite number of buyers and sellers (perfect competition). A market for goods and services therefore exists in which trade will produce all the necessary regulation by both positive and negative feedback. As a result, resources will be allocated efficiently within the market (Newson, 1992: 81).

While all sectors of the economy suffer from market imperfections, the natural resource sector is particularly hard hit - "no other sector can claim as many and as pervasive market failures as the natural resource sectors" (Panayotou, 1992: 327). With many natural resources outside the domain of markets, ie. "unowned, unpriced and unaccounted for", the incentive remains for people to utilise these resources inefficiently and unsustainably, shifting their cost to others (Newson, 1992: 324).

Some of the most important sources of market failures, leading to environmental degradation, are:

1. Insecure property rights over resources;
2. The absence of markets for environmental resources;
3. The presence of externalities;

4. Uncertainty and risk associated with the future;

5. Irreversibility; and

6. Public goods and the free-rider

(Newson, 1992: 327).

1) Inadequate property rights

The efficient operation of markets depends upon the existence of well-defined exclusive, secure, transferable and enforceable property rights over all resources. Property rights exhibiting these characteristics are referred to by Randall (1981: 148) as `nonattenuated property rights'.

These nonattenuated property rights are a precondition for efficient use, investment, conservation and management of resources, i.e. to Pareto-efficiency in resource allocation. When an individual does not have the exclusive right to own or gain access to a resource, then he has no incentive to economise on, invest in, pay for or conserve that resource. In the absence of property rights the individual has an incentive to overexploit the common property resource, as any benefits that might accrue from his restrained use will be reaped by others anyway (Mentis, 1990: 176; Panayotou, 1992: 327; Randall, 1981: 148).

2) The absence of markets

Many natural resources are unpriced or their prices are unrelated to market-clearing prices. The lack of adequate property rights results in an inability of any sellers to demand a price for these resources, and, in addition, an unwillingness on the behalf of prospective buyers to pay for these resources, given their free access to the same resources elsewhere. A market for these resources consequently does not develop and their prices remain at zero, even in the situation of increasing scarcity. The absence of prices means that scarcity cannot be gauged or managed through the market forces of demand and supply (Panayotou, 1992: 329; Randall, 1981: 299).

The failure of the market, or government, to efficiently price natural resources according to their scarcity, inevitably leads to their over exploitation, inadequate conservation and inefficient utilisation (Panayotou, 1992: 330).

3) Externalities/"Uncompensated spillovers"

An externality is an effect of one firm's or individual's actions on the welfare of another economic agent, who is not party to the action, with the latter not being compensated for the damages. The presence of externalities drives a wedge between private and social valuation of resources and consequently leads to inefficient pricing (Mills and Graves, 1986: 32; Panayotou, 1992: 330).

Externalities can be positive (eg. downstream farmers benefitting from a forested watershed provided by upstream forest owners) or negative (eg. logging upstream leading to sedimentation and flooding downstream). These external costs or benefits are not borne or reaped by the producer of the externality however, and as such no market incentive exists for the upstream farmer to take into account the interests of the downstream farmer. A divergence of private and social welfare exists and consequently resource utilisation which is less than socially optimal takes place (Panayotou, 1992: 331).

An economic analysis of resource use options therefore needs to internalise these externalities and include them in the economic calculus in order that natural resources be correctly valued and utilised in a welfare-maximising manner.

4) Uncertainty and risk

The lack of information required for decisions affecting the future (absence of future markets/prices) is a market failure which leads to uncertainties and risks. Natural resource management is concerned with the future and, as such, resource allocation decisions need to consider several consecutive time periods. Due to the long-term nature of resource management, great uncertainty is involved in utilisation decisions. This uncertainty results in a bias towards current exploitation at the expense of conservation. The value of conservation in preserving future use options and as a source of income in perpetuity is consequently given very little weight (Panayotou, 1992: 337; Randall, 1981: 236).

While an individual may view it as optimal to generate current income and short-term benefits from the unsuitable exploitation of resources, it is in society's best interest to preserve the long-term productivity of the resource base. Caution should be exercised in order to provide insurance against future uncertainty and to avoid any irreversible degradation and future costs.

5) Irreversibility

The issue of irreversibility is closely linked to that of uncertainty and risk. If resources are utilised in an unsustainable way then the consequence may be irreversible damage to the environment. This serves to limit future resource use options and prevents the reaping of important environmental benefits in the future (Dixon *et al.*, 1988: 83). "The possibility exists that, by permitting the extinction of species that currently seem worthless, yet-to-be-discovered uses (medicinal and other) may be forever foreclosed" (Randall, 1981: 237).

Smith (1977) argues that a renewable resource is optimally utilised by exploiting it to extinction provided that its growth rate is less that the discount rate used to facilitate intertemporal allocation criteria. Puu (1977) and Sinn (1982) disagree, arguing that it is never optimal to exploit a species to extinction. The concept of an "option value" is implicit in this argument.

Krutilla and Fisher (1985) describe option value as the value that arises from retaining an option to a resource for which future demand is uncertain. Panayotou (1992: 339) concludes that "where economic decisions have an impact on the natural environment that is both uncertain and irreversible, there is a value to retaining an option to avoid the impact".

6) Public goods and the free-rider

Environmental quality can be considered a public good in that it is non-rivalrous in consumption, non-excludable and indivisible. The marginal cost of providing the good to another consumer is zero and the utility of existing consumers is not diminished (Mills and Graves, 1986: 34; Panayotou, 1992: 332; Siebert, 1992: 63).

Because the benefits of a public good are non-excludable, consumers will not freely pay for that good. The absence of markets and a marketable product means that the resource will not be allocated efficiently without government intervention or a rationing system to control consumption. The opportunity exists for individuals to take the position of "free-rider" - while valuing and utilising the resource, he is unwilling to contribute to its costs of production. The free-rider will understate his willingness to pay for the public good in expectation of those with a higher willingness to pay bearing a higher share of the costs (Mills and Graves, 1986: 36; Siebert, 1992: 67; Stauth and Baskind, 1992: 37).

The free-rider problem makes it impossible to determine how much the public good is valued, as revealed by willingness-to-pay. This is the source of the market failure, as Pareto-efficient provision requires that the marginal value placed on the good by all consumers should equal the marginal cost of providing it and that there be perfectly discriminatory pricing of the indivisible good (Randall 1981: 180-182).

2.3.2 Valuation techniques

While market values can be used to price benefits and costs in a situation where money is effectively changing hands as a result of development impacts, the value of costs and benefits where no market values exist for the environmental and economic impacts need to be determined using a "shadow-pricing" approach.

A shadow-price is "an estimate of the value that a good or service would have if a market could be established for it" (Stauth and Baskind, 1992: 37). The two main approaches to shadow-pricing, which shall be briefly outlined below, are inferential techniques and contingent valuation techniques.

2.3.2.1 Inferential techniques

Inferential techniques involve identifying some marketed good for which the demand may provide an indication of the value of a particular nonmarket good. A marketed good may be used to infer the value of a nonmarket good when both goods are complementary in consumption (Randall, 1981: 300). An implicit value is estimated by using the price paid for a marketed good as an indicator of their value (Newson, 1992: 89). Examples of inferential techniques are the input valuation approach and the travel-cost approach.

The **input valuation** approach "measures the value of some unpriced input to a system by calculating the changes to outputs of the system which are priced by the market" (Stauth and Baskind, 1992: 37). Stauth (1983: 96) provides an example of valuing a salt marsh using this approach. If the salt marsh were to be filled in the various inputs into an estuarine ecosystem would be reduced, leading to a reduction in the number of fish in the estuary. This, in turn, would lead to a reduction in the number of fishermen visiting the area and a resultant loss of revenue for angling shops, hotels and other businesses. A shadow price for the benefits generated by the marsh is thus calculated, based on the total economic loss resulting from the action.

This approach, although not utilised in this study, could be adopted to quantify some of the benefits which flow from the eradication of alien vegetation in the study area. Data provided by Eastern Cape Nature Conservation on the economic activities of the local communities of Kareedouw, Krakeel, Louterwater, Misgund, Hankey and Tsitsikamma could be used to determine the adverse effect that the continued spread of alien invasives and the consequent reduction in water supply would have on these economic activities. The loss in output resulting from decreased water availability could then be used to estimate a shadow price for the benefits of an uninvaded catchment area

The **travel-cost method** is commonly used to estimate the value people place on outdoor recreational areas. The value of the amenities provided by these areas is inferred by measuring the travel, time and subsistence costs incurred in visiting the area. By treating increasing travel costs as a surrogate for variable admission prices, a demand curve can be derived. The demand curve reflects consumers' willingness-to-pay for the good and therefore indicates the benefit derived from the good. A value can thus be estimated for the unpriced good (Stauth, 1983: 97).

The travel-cost method is limited by its assumptions that all travel costs are undertaken for the sole purpose of visiting one particular area and that the journey itself provides no utility to the consumer (Randall, 1981: 301). The travel-cost method shall not be used in this research as it is not regarded as appropriate for valuing natural areas which are not specifically used for recreational purposes, such as the study area.

2.3.2.2 Contingent valuation techniques

The contingent valuation technique attempts to estimate the value of an unpriced good by asking people to express their willingness to pay for that good. This may be achieved via questionnaires or iterative bidding games. A hypothetical market is, in effect, created for a nonmarket good and survey respondents operate in that market, revealing their willingness to pay for that good (Randall, 1981:304).

This method is limited by the existence of four types of bias inherent in the approach: strategic bias, resulting from the respondent giving a false indication of his or her willingness to pay for a good in an attempt to influence the outcome of the survey; information bias, resulting from respondents having minimal or incorrect knowledge of the subject (Tietenberg, 1992: 81); starting point bias, where the starting point given to a respondent influences the final bid offered (Hanley and Spash, 1993: 60); and hypothetical bias, arising from the respondents providing hypothetical valuations which are systematically different from true values (Du Preez, 1997: 44).

Although shadow-prices are conceptually simple and appealing, there are some problems in measuring them in practice (Dixon *et al.*, 1988: 62). Shadow-prices must be indirectly estimated and, consequently, they are ultimately a subjective valuation. The difficulty of estimating shadow-prices has resulted in two frequent errors in practice: firstly, the non-marketed benefits are ignored and as a result socially desirable projects are not undertaken, and secondly, projects are justified on qualitative bases, making the rational weighing of alternatives difficult (Arrow, 1977: 416).

Despite the problems and shortcomings of shadow-pricing, it is nevertheless regarded as an important tool for estimating prices for non-marketable goods, and thereby improving the rationality of project evaluation (Stauth, 1983: 84).

2.4 Evaluation criteria

In evaluating the economic efficiency of the eradication programme three criteria need to be applied. The three criteria are efficiency, equity and sustainability, or intergenerational equity (Newson, 1992: 102; Stauth and Baskind, 1992: 32).

2.4.1 Efficiency

For a proposed project to be acceptable on an efficiency basis, the yearly generation of benefits associated with the project over the appropriate time horizon must exceed the costs (Dixon *et al.*, 1988: 30).

The benefits associated with the eradication programme in the Krom and Kouga catchment areas include increasing the water yield from these systems by 9,5 million cubic metres per annum; the provision of employment and training to more than 400 people; a reduction in soil erosion and consequently an increase in water quality and reduced silting of dams; economic and ecological benefits resulting from the biodiversity of fynbos vegetation; the utilisation of the cleared alien vegetation as resources of pulpwood, tannin, firewood, charcoal and poles; regaining lost agricultural land; increased agricultural output; reducing the threat of invader trees expanding through the region and avoiding the increased cost of clearing infestations at a later stage (Eastern Cape Nature Conservation, 1996).

The costs which will be incorporated into the analysis include the costs of the initial clearing and of the necessary follow up operations: training, monitoring, salaries, transport, equipment, herbicides, protective clothing and administration costs. This data was provided by the Project Manager for the Kouga Project, Mr J. Buckle.

Three methods are commonly used for comparing costs and benefits: the internal rate of return (IRR), the benefit-cost ratio (BCR), and the net present value (NPV) (Dixon *et al.*, 1988: 30). The most widely used formula for comparing costs and benefits is calculation of the **net present value**. The NPV determines the present value of net benefits by discounting the stream of benefits (B) and costs (C) back to the beginning of the base year. The formula used is:

$$NPV = \sum \frac{B_t - C_t}{(1+r)^t}$$

where r is the appropriate rate of discounting for annual compounding, and t is the appropriate time horizon (Dixon *et al.*, 1988: 30).

The NPV decision rule is that projects which generate a positive NPV are acceptable. The higher the NPV that is generated the more desirable the project is.

The **internal rate of return** is the discount rate that would result in a zero net present value for a project. The calculated IRR must be compared to a chosen discount rate to determine whether the project is economically attractive. The decision rule is to accept projects which offer rates of return in excess of the opportunity cost of capital. The IRR rule will give the same answer as to the acceptability of a project as the NPV rule whenever the NPV of a project is smoothly declining function of the discount rate (Brealey and Myers, 1991: 79). The IRR is equivalent to the discount rate (r) that satisfies the following relationship:

$$\sum \frac{B_t - C_t}{(1+r)^t} = 0$$

(Dixon *et al.*, 1988: 31).

Brealey and Myers (1991: 82) outline four pitfalls which make the IRR criterion less attractive than the NPV approach as an evaluation criterion. Firstly, not all cash flow streams have NPVs that decline as the discount rate increases. If the NPV increases as the discount rate increases, then a project will need an IRR less than the opportunity cost of capital in order to be acceptable. To decide on the desirability of a project one needs to look at the NPV and whether it increases or decreases as the discount rate increases.

Secondly, no unique IRR will be found for projects where there are more than one change in the sign of the cash flows. There can be as many different internal rates of return for a project as there are changes in the sign of the cash flows.

The third pitfall of the IRR rule is that it may be misleading when one needs to choose from among mutually exclusive projects. It is recommended that when a choice has to be made between two mutually exclusive projects then the NPVs should be compared.

The final shortcoming of the IRR rule is that problems arise when short-term interest rates differ from long-term rates and there is therefore more than one opportunity cost of capital. The NPV rule is consequently regarded as a more convenient and reliable criterion (Brealey and Myers, 1991).

The third commonly used formula is the **benefit-cost ratio**. This ratio compares the discounted benefits to the discounted costs. A benefit-cost (B/C) ratio that exceeds unity means that the project generates gains from an economic perspective. The project with the highest B/C ratio should be chosen. The formula is as follows:

$$B/C ratio = \frac{\sum \frac{B_t}{(1+r)^t}}{\sum \frac{C_t}{(1+r)^t}}$$

where r is once again the chosen rate of discount (Dixon *et al.*, 1988: 31).

Projects which produce a positive NPV will have a B/C ratio greater than 1. Ranking of alternative projects according to the B/C ratio can, however, lead to an erroneous investment choice. This is because the B/C ratio discriminates against projects with relatively high operating costs and gross returns, even though they may have a greater wealth-generating capacity than the alternatives with higher B/C ratios (Gittinger, 1982). The B/C ratio will not be used in the analysis of the eradication programme as the NPV method is regarded as the more reliable indicator of the economic desirability of a project.

2.4.2 Equity

While efficiency is measured without regard to whom the benefits and costs accrue, the equity criterion is concerned with the fair distribution of costs and benefits among individuals. A project which is efficient may nevertheless be socially undesirable if it heaps benefits on wealthy individuals while the costs are borne by poor communities (Dixon *et al.*, 1988: 77; Stauth and Baskind, 1992: 32).

Attempts to incorporate the distributional effects of a project into CBA usually involve some form of weighting of the costs and benefits accruing to specific social groups. This is extremely problematic, however, as any weighting formula will inevitably be arbitrary and highly subjective. "All weighting or ranking systems convert political, social and moral choices into pseudo-technical ones. In effect, they allow the analyst to impose his own judgement on all" (Rees, 1990: 331).

An alternative method to weighting is to estimate the net benefits that will accrue to each social group and to provide the decision-maker with this information. The decision-maker must then evaluate the distributional implications of the project and decide on its desirability. The problem of subjectivity is still inherent in this approach (Dixon *et al.*, 1988: 77).

2.4.3 Sustainability/intergenerational equity

A development project is regarded as sustainable if its benefits exceed its costs over a time period of multiple generations. This is important in evaluating public projects as any resource use option will have impacts which will be felt in the future and which will affect the resource endowment available in the future, thereby affecting the welfare of future generations (Dixon *et al.*, 1988: 79; Stauth and Baskind, 1992: 32).

While investment in many public projects will typically involve a present cost, the benefits may only be felt some time later. Due to the fact that benefits and costs occur at different times they need to be discounted back to their present value equivalent for the purpose of comparison (Clawson and Knetsch, 1971: 258; Dixon *et al.*, 1988: 79).

2.5 Choice of a discount rate

One of the most controversial and important aspects of public project evaluation is the choice of the appropriate discount rate (r) to be used in the application of a CBA.

The discount rate reflects individuals' preferences about when benefits and costs are desired. Typically, the later a cost or benefit occurs, the less it matters to individuals - both consumers, via a positive rate of time preference, and producers, via the opportunity cost of capital, are observed to treat the present as more important than the future (Pearce *et al.*, 1989: 133). Choice of a rate involves social value judgements about benefits and costs accruing to different generations and about the overall objectives of the proposed project (Eckstein, 1958: 94).

While the interest rate used in financial analysis usually reflects market rates for investment and working capital, the discount rate used in economic analysis is not usually readily observable in the economy. A number of approaches for determining a discount rate have consequently been developed (Dixon *et al.*, 1994: 39).

The **social rate of time preference** approach relies on the ability of society to reflect more accurately than the private market the tradeoffs between present and future consumption (Dixon *et al.*, 1994: 40). The discount rate that society would choose to express its time preference would be less than the individuals' marginal rate of time preference, which, under perfect competition, is equal to the market rate of return on capital, for three main reasons:

a) Individuals as consumers have different time preferences than they have in their roles as members of a society. As consumers, individuals' time preferences mean that projects which generate immediate net benefits (those with a high discount rate) will be favoured over projects whose benefits will not be realised for a longer period (low discount rates). As members of a society, however, these same individuals will attach a lower discount factor to future costs and benefits. This desire for attaching greater importance to the future is often expressed politically. Governments, it is argued, should thus use a lower discount rate than the rates revealed by individuals in their saving decisions (Hanley and Spash, 1993: 130).

b) Society would choose to save more than is reflected by the sum of individuals' saving decisions. The rationale is that saving now provides consumption benefits in the future, which will be under-supplied by the free market due to the free-rider problem. Governments should thus apply a lower discount rate to public investments than the private sector applies to private projects, in order to make up for this deficit (Hanley and Spash, 1993: 130).

c) The market-determined discount rate is not regarded as suitable for long-term public policy decisions, as only the time preferences of the present generation are reflected in this market rate. Individuals with finite life expectancies will behave differently in their private consumption decisions than a society with a collective commitment to future generations' welfare. A higher discount rate than is socially optimal will occur and the level of investment will be too low to make adequate provision for future generations (Hanley and Spash, 1993: 130).

To avoid sacrificing future generations' welfare by selecting projects which deliver immediate benefits, it has been suggested that very low discount rates should be used, as "[net benefits] accruing only two or three generations hence are reduced to trivial amounts when their present values are determined using social discount rates derived from market interest rates" (Randall, 1981: 236). This view is contested by Norgaard (1991), however, who argues that lowering discount rates can worsen environmental degradation by lowering the cost of capital, so that more resources are consumed in the short-term relative to when discount rates were higher. In addition, low discount rates will result in a larger number of projects passing the efficiency test and the resulting increase in investment would increase environmental stress (Munasinghe and Lutz, 1993: 35).

Randall (1981: 208) argues that while it may be appropriate to use estimates of the social discount rate that are considerably lower than market-generated estimates of r, given that public sector investments have goals other than economic efficiency, the inefficiency of such an investment should be recognised. He argues that manipulating the social discount rate to make inefficient public projects appear efficient serves no purpose.

To derive a social discount rate, Randall (1981: 211) argues that it should reflect the marginal efficiency of investment (MEI). The banks' prime lending rate is regarded as a reasonable indicator of MEI, provided it is adjusted for the rate of inflation and for the corporate income tax. It is argued that public investments are not risk-free, but rather possess about the same amount of risk as loans made by large banks to favoured corporate clients. The banks' prime lending rate, incorporating such a risk premium, is thus appropriate for public investments (Randall, 1981: 211).

Furthermore, if future revenue streams from public investments are valued at constant prices, then it is argued that the social discount rate should be the real rate of interest, requiring that the prime rate of interest be adjusted for inflation. While the prime interest rate reflects anticipated inflation during the period of the loan, it is prudent to consider the real rate of interest over a sufficiently long period so that short-run business cycles and inflation fluctuations do not unduly influence the result (Randall, 1981: 211).

The **opportunity cost of capital** approach is based on the production that is forgone when capital is invested in one project rather than another. The discount rate determined by this approach is closely related to the financial interest rate, although the latter may include an upward adjustment for inflation. This approach is used implicitly by many international development banks, in that these banks require that proposed projects promise an annual rate of return at least equal to a specified rate, which appears to be based on the opportunity cost of capital (Dixon *et al.*, 1994; 39).

The **cost of borrowing money** approach uses as the discount rate the interest rate payable on money that is borrowed, either domestically or internationally, to finance development projects. A problem with this approach is that loans which are secured at favourable rates will favour projects with long-term net benefits and, conversely, high interest rates will favour projects with short-term net benefits (Dixon *et al.*, 1994: 39).

The choice of a discount rate is thus pivotal to decisions concerning whether to undertake projects with long-term benefits or long-term costs. The further into the future benefit and cost streams occur, the lower will be their calculated present values. This time bias increases as the discount rate is increased (Hanley and Spash, 1993: 127). Furthermore, the higher the discount rate, the less influence negative impacts that may arise in the future will have on the decision criteria (Dixon *et al.*, 1988: 79).

2.6 The economic pricing of water

Pricing water is possibly one of the most under-used but potentially most effective tools available for efficiently allocating the resource. Given South Africa's limited water and economic resources, the issue of water pricing as a demand management strategy is receiving closer consideration. Linking pricing more closely to the economic costs involved in supplying water has significant implications for the production of revenue and for reconciling supply and demand. South Africa's water tariffs, using the equivalent basket of goods and services approach as a basis for comparison, are far cheaper than those of many relatively water-rich European nations (Mirrilees *et al.*, 1994: 3-1). In February 1996 the Cabinet decided that the price paid for water by major users should be progressively raised to meet the full financial costs of making it available and to reflect its value to society (DWAF, 1997a: 22).

Economic principles can be used as a basis for management in many other areas. Little (1994: 11) suggests the following objectives for future water policy, given South Africa's needs:

- Guaranteed minimum daily consumption per capita;
- Development of sufficient subsistence irrigation to eliminate nutritional problems;
- No further degradation of natural resources;
- Maintenance of aquatic ecosystems;
- Maintenance of agricultural production;
- Maximum job opportunities in subsistence and commercial agriculture;
- Restriction of water use by afforestation; and
- Promotion of economic self-sufficiency (minimal subsidies).

These objectives are seen in the context of achieving the "optimum, long term, environmentally sustainable, social and economic benefit for society from [water] use" (DWAF, 1997a: 22).

The key to achieving these policy objectives rests on the economic principle that the price of any commodity must reflect the cost to the community of satisfying the demand for that commodity. The costs of water can be grouped into the following categories:

a) Resource-use costs - those costs associated with the infrastructural development necessary for the supply and disposal of water, as well as costs of connection;

b) Depreciation costs - an allowance to provide depreciation, replacement or refurbishment;

c) Natural resource depletion costs - the costs related to transporting water so as to maintain the level of reservoirs, or to supplement groundwater supplies when they become depleted;

d) Damage costs - the cost of environmental deterioration, or the costs involved in maintaining ecosystems;

e) Social welfare costs - arising from the economic values which accrue to society as a whole, resulting from the availability of water; and

f) Catchment management costs (DWAF, 1997a: 22; Little, 1994: 11).

The term "full-cost recovery" is often used to describe a water scheme possessing a tariff structure which ensures the repayment by the customer of the capital, interest, operational and maintenance costs of that particular scheme. These costs do not, however, reflect the true economic cost of any water scheme. To arrive at an accurate economic cost, the following externalities need to be included:

- Social impact costs: while the direct impact on a community may be costed, such as compensation for land inundated by water, spillover effects can have serious implications and need to be costed;
- Environmental impact: the full value of long-term losses of resources needs to be accounted for; and

- Public sector costs: due to the fact that the majority of water resource developments in South Africa are provided by the public sector, and are funded from sources other than the sale of water, these costs are seldom recovered. Water subsidies from the state are equally not costed or recovered (Little, 1994: 13).

In the South African context, a major issue in the pricing of water is to ensure that water pricing approaches enhance the move towards equity of access. The introduction of more realistic pricing of water should not further penalise previously disadvantaged communities (DWAF, 1997a: 23).

The new water pricing policy, as detailed in the White Paper on a National Water Policy for South Africa (DWAF, 1997a), states that all significant water resource use, including the use of water for effluent disposal or the interception of water to the detriment of other users, will be charged for, regardless of where it occurs. An exception is made with respect to the provision of water for basic human needs, which will be provided free of charge. This is in line with ensuring that all South Africans have access to basic services (DWAF, 1997a: 23).

Prices charged for water from Government schemes will be adjusted to cover the full operation and maintenance costs and financial costs of these schemes, including interest and redemption of loans, depreciation and water resource management costs. A resource conservation charge will be introduced where appropriate. Outside of Government schemes, the price of water will reflect water resource management costs as well as an appropriate resource conservation charge (DWAF, 1997a: 23).

Where the adjusted water price discourages the use of available water, provision may be made for some components of the tariff, such as the resource conservation charge, to be suspended for a limited period of time. Provision may also be made to allow trading in water-use allocations in limited areas. This will be subject to varying degrees of control and particular attention will be paid to ensuring fair resource allocations (DWAF, 1997a: 23).

2.7 Problems associated with cost-benefit analysis

Although CBA is conceptually simple, there are a number of well-documented problems associated with CBA (Prest and Turvey, 1965; Stauth and Baskind, 1992). Three major criticisms have been levelled at CBA.

Firstly, costs and benefits for which no market exists, or for which the existing market has substantial imperfections, are difficult to express in monetary terms. As a result, costs and benefits assigned monetary measures have been emphasised, while unpriced costs and benefits have been given relatively little weight (Stauth and Baskind, 1992: 35). The attempt to specify socially optimal prices, through the prescription of shadow prices, to counter the distortions that occur on perfectly competitive markets is potentially dangerous, particularly in a dynamic situation.

There are no *a priori* grounds for believing that these accounting prices are superior to those generated by an imperfect but nevertheless well-developed market economy (Dockel *et al.*, 1990: 9).

Secondly, CBA has usually focused on the easily measured costs and benefits that occur on-site, and often ignored the externalities that occur off-site. The identification and incorporation of externalities are central to CBA and a proper CBA must take both the location of development impacts and their valuation into account to assess the total contribution to social welfare (Dixon *et al.*, 1994: 27).

Thirdly, CBA does not have any particular merits when equity, strategic or other social issues are to be considered (Dockel *et al.*, 1990: 9) No adequate method has been found to compare and trade off distributional effects (intragenerational or intergenerational) with efficiency effects. There has consequently been a tendency for proposed projects to be approved on the basis of passing the efficiency test, despite failing either the equity or the sustainability test (Stauth and Baskind, 1992: 35). Value judgements consequently predominate in the decision-making process.

Another problem is that of choosing an appropriate discount rate in the face of uncertainty and decisions which span multiple generations. Conditions can change drastically within a fairly short time. Furthermore, CBA has proven to be disliked and mistrusted as individuals tend to perceive the results of an analysis as providing the 'wrong' level of environmental quality - environmentalists receive a lower level of environmental quality than they want, while others perceive that level of environmental quality as being too costly for its associated benefits (Mills and Graves, 1986: 39).

Dockel *et al.* (1990: 8), argue that CBA is at best a relatively "soft" technique and it becomes softer as it is extended to encompass greater proportions of non-measurable costs and benefits. It also becomes softer as the degree of uncertainty about future economic states increases. Being a soft technique, it is open to accidental or deliberate exploitation such as the justification of projects favoured for political ends.

Despite these problems, CBA is still regarded as an essential tool to aid in evaluating alternative projects. CBA provides a means to increase the rationality in decision-making and is meant to be a guide to decision-makers, not the final determinant of choice (Clawson and Knetsch, 1971: 255). For a comprehensive analysis of a decision CBA should be treated as one input into the process, and not as a substitute for the techniques that have been developed for non-economic criteria (Mirrilees *et al.*, 1994: Appendix C, 1-9).

Even if certain benefits and costs cannot be quantified, they are mentioned qualitatively in CBA and thereby internalised into the decision-making process. While not necessarily producing fine-tuned numbers, CBA does have the advantage of screening alternatives and excluding options early in the project evaluation cycle (Munasinghe and Lutz, 1993: 45).

2.8 Unit Reference Value

The Unit Reference Value (URV) is a method prescribed by the Department of Water Affairs and Forestry for comparing alternative supply augmentation options on the same basis. The URV is effectively the unit rate which needs to be charged on the additional water over the life of the project to equate the total income stream and the total expenditure stream accruing from the project, given the non-profit nature of water supply. This rate stays constant over the life of the project (Du Preez, 1998: personal communication).

The expenditure stream is the sum of all capital expenditures and running costs discounted to a present value at the chosen discount rate. The income stream is the sum of the product of the volume of water sold each year and the URV. The URV is derived as follows:

$$\text{Discounted income stream} = URV(DF_1 \times VS_1 + DF_2 \times VS_2 + \ldots + Df_n \times VS_n)$$

$$= URV(\sum DVS_t)$$

where, URV = unit reference value (selling price);

DF = discount factor;

VS = volume sold; and

DVS_t = discounted volume sold in period t

Discounted expenditure stream = $DF_1(K_1 + RC_1) + DF_2(K_2 + RC_2) + \ldots + Df_n(K_n + RC_n)$

$$= \sum Df_t\,(K_t + RC_t)$$

where, K_t = capital cost in period t; and

RC_t = running cost in period t

(Du Preez, 1998: personal communication).

The income stream is equal to the expenditure stream where

$URV(\sum DVS_t) = \sum Df_t(K_t + Rc_t)$

$$\therefore URV = \frac{\sum DF_t(K_t + RC_t)}{\sum DVS_t}$$

The annual water supply (=VS) resulting from any scheme is thus discounted back to the base year and divided into the discounted costs of that scheme to yield an effective present day URV (Ninham Shand Inc., 1996a: 6).

The URV does not represent the actual unit cost of water of a specific alternative, firstly because the discount rate used by DWAF (8%) does not always reflect the effective market interest rate, although in this case it can be considered a fair approximation (see Appendix 5), and secondly because the income and expenses flowing from any scheme are discounted over a period of 45 years. This means that annual losses are capitalised and paid for by revenue generated towards the end of the economic life of the scheme, while in practice local authorities are not allowed to do this (Ninham Shand Inc., 1996a: 6).

In practice there will be an under-recovery of the costs in the early stages of the scheme and the interest incurred will be capitalised. Local authorities need to account for the income and expenditure on an annual basis, which leads to the actual unit cost of water to the local authorities declining as the volume of water sold increases over time and as the scheme approaches its full capacity. This is in contrast to the URV which is a constant rate over the life of the project (Du Preez, 1998: personal communication).

Despite these problems, the DWAF and Ninham Shand Consulting Engineers regard the URV as a sound method for the relative comparison of schemes with different capital requirements and running costs (Du Preez, 1998: personal communication).

Having discussed some of the central issues involved in CBA, this thesis will now go on to apply these principles in analysing the data provided. The analysis of the eradication programme will be followed by an examination of alternative supply augmentation schemes. The more conventional schemes have been analysed by Ninham Shand Inc., as part of the Algoa Water Resources Stochastic Analysis, on behalf of DWAF. These alternative schemes are compared on the basis of their calculated URVs, with costs being discounted at 8% over a period of 45 years. Cost estimates are based on 1993 prices. The findings of the Stochastic Analysis shall be looked at and the desirability of the alternative options shall then be evaluated in relation to the eradication programme. For the sake of comparison the URV for the eradication programme will be calculated, as per the DWAF method.

Chapter Three

Cost-Benefit Analysis of the Eradication Programme

3.1 Introduction

In this chapter, an economic analysis of the Kouga Working for Water Project will be undertaken. This project, which was launched in October 1995, focuses on the eradication of invasive alien vegetation in the Krom- and Kouga river catchment areas. Sixty seven percent of the total area of the two catchments is infested.

The Kouga sub-catchment is 3 900 km^2, the Churchill sub-catchment 350 km^2 and the Impofu sub-catchment 480 km^2. A small portion of the land in the catchment areas is afforested and the only significant irrigation is in the Kouga sub-catchment (59,6 km^2). The average rainfall in the catchment areas is low, with the Kouga sub-catchment having a Mean Annual Precipitation (MAP) of 546 mm, the Churchill sub-catchment an MAP of 740 mm and the Impofu sub-catchment an MAP of 640 mm (Ninham Shand Inc., 1994c). A summary of the hydrological data for the catchment areas is provided in Appendix 2.

The project is being coordinated by Eastern Cape Nature Conservation, with a proportion of work subcontracted to the South African Forestry Company Ltd (SAFCOL). Funds for the project are administered by the Department of Water

Affairs and Forestry, through the regional office in Knysna (Eastern Cape Nature Conservation, 1996).

The cost-benefit analysis (CBA) which will be conducted in this chapter will focus on the eradication of invasive aliens in the riparian zones of the catchment areas. This is due to the fact that approximately 70 percent of the clearing work is conducted on private land, along the rivers, as these are the areas which are heavily infested with black wattle and which have the greatest effect on water yields. *Acacia mearnsii* (black wattle) occurs along more than 800 km of these rivers and occupies 7 200 ha of land in this area (Eastern Cape Nature Conservation, 1996: 7).

It is estimated that it will take ten years to complete the initial eradication of the 7 200 ha of black wattle in the riparian areas. The cost of alien control can be broken up into the cost of initial clearing and the cost of follow-up operations. To avoid regeneration, it is recommended that follow-up operations be carried out annually for at least six years, and once every five years thereafter. Follow-up operations involve hand-hoeing and spraying herbicide on the regrowth and on germinating seedlings. The Working for Water Programme involves two years of follow-up operations after which the private landowners are contractually obliged to continue periodic follow-up work to maintain the invasives at an acceptable level.

Biological control, seen as the long-term solution to the alien problem, was experimented with during the 1995-96 financial years. A wood rotting fungus was released into selected stands but this method has been abandoned due to the long time it takes to rot the stump. In 90% of the cases the stumps coppiced again up to the height that the tree was before the initial clearing before the trees fell over (Eastern Cape Nature Conservation, 1998: 9). At present, the release of a seed-destroying weevil has been approved, but not yet implemented (Buckle, 1998: personal communication).

In addition to the costs of initial clearing and follow-up work, a rehabilitation cost is also incurred. This is the cost of rehabilitating those areas that have been heavily altered by dense infestations. At present one rehabilitation team exists, with another team scheduled to be appointed during the 1998/99 year. The main priority of the rehabilitation work is to reestablish natural vegetation cover in order to stabilise the soil and so prevent accelerated soil erosion. Grasses are used initially to produce a quick basal cover, followed by slower growing shrub and tree species (Eastern Cape Nature Conservation, 1998: 30).

Although all areas will receive attention and monitoring, priority areas have been identified and the rehabilitation work will concentrate on these most critical areas. Where no serious risks occur, the areas will be monitored only to ensure that the veld restores itself unaided, or minimal seeding and planting will be done (Eastern Cape Nature Conservation, 1998: 30)

3.2 Cost flow of the eradication programme

The costs involved in the eradication programme include capital costs, operating and maintenance costs for both the initial clearing and the follow-up clearing and rehabilitation costs. Capital costs include the cost of acquiring clearing equipment and this is included in the annual variable cost figures. These costs are incurred throughout the life of the project, from year 0 to year 11. Operating and maintenance costs include herbicide, protective clothing, wages and salaries, transport, and running expenses. These have been incorporated in the figures for the initial and follow-up clearing costs. The relevant operating and maintenance costs for the initial clearing are incurred from year 0 to year 9, while those for the follow-up clearing are incurred from year 1 to year 11. The rehabilitation costs are incurred from year 1 to year 11, starting one year after the initial clearing commenced and continuing for two years after the last initial clearing work has been completed (Buckle, 1997: personal communication).

In working out the costs that will be incurred over the life of the project, the average figures used by Working for Water to calculate their plan of operation, based on the experience of the clearing teams, will be used. As the infestation in the riparian zones is either dense or closed, the costs for clearing these areas will be used in the CBA. The average clearing rate for dense infestations is 0,018 ha/man unit (mu), while the rates for the first and second follow-up operations are 0,37 ha/mu and 0,50 ha/mu respectively. The corresponding costs per ha for the clearing and first and second follow-up operations are calculated to be R3 425/ha, R166/ha and R123/ha respectively. The rate, and consequently the cost, of clearing and follow-up operations varies substantially depending on the level of infestation. It is assumed that all the clearing work is performed in dense or closed infestation areas and consequently the costs of clearing medium or light infestations are not used in the analysis. The average rate at which infestations are cleared and the average cost per ha for clearing the different infestation levels are shown in Appendix 3.

The figure for the cost of initial clearing of dense infestation was calculated as follows:

Table 3.1: Average wage per day

Composition of team	Average wage per day
1 Foreman (@ R71,50/day)	R71,50
10 Unskilled labourers (@ R27,50/day)	R302,50
2 Chainsaw operators (@ R44,00/day)	R88,00
1 Brush cutter (@ R44,00/day)	R44,00
1 Herbicide operator (@ R44,00/day)	R44,00
Average wage per person per day	R36,67

In addition to the wages, there is a further variable cost of R24,46 per man unit. This figure is calculated as follows:

Table 3.2: Variable costs of the eradication programme

Variable costs (per team per month)	Rand
Transport	1 789,35
Equipment	1 497,85
Herbicide	1 509,95
Protective clothing	254,18
Petrol/oil	760,52
Spare parts	852,31
Running expenses	1 407,06
Total	R8 071,22

Source: Buckle, 1998: personal communication

An additional variable cost of R8 071,22 per team per month is thus calculated and if this is divided by 330 man units a rate of R24,46/mu is arrived at. Adding this to the average wage per person per day, a total variable cost of R61,13 per man unit is calculated.

The estimated initial clearing rate for dense riparian infestations is 0,018 ha per man unit, which is equivalent to 56 mu/ha. This work includes the cutting of the trees, carrying the wood out of the cleared area, stacking the wood in wind rows and applying herbicides to the stumps. A team of 15 workers, working 22 days a month is equivalent to 330 man days per month per team. A team should therefore clear

5,89 ha/month (330 mu ÷56 mu/ha), at a cost of R20 173,00 (330 man days × R61,13/man day). The cost of initial clearing of dense riparian infestations is thus estimated to be R3 425/ha.

Of the 7 200 ha of dense riparian infestation, 4% is estimated to be closed infestation. This is an infestation level corresponding to a canopy cover of more than 75%. The cost of clearing closed infestations is estimated to be R7 700,57/ha (Buckle, 1998: personal communication).

This figure is calculated based on the experience of teams working in areas consisting of closed infestations. The clearing of one ha of closed infestation typically consumes 161 labour units. The cost per ha of the clearing operation was calculated as follows:

Table 3.3: Cost (R/ha) of clearing closed infestations

Expense	Rand (per ha)
Salaries and wages	6 022,64
Transport	566,04
Running expenses	1 111,89
Total	R7 700,57

Given that 7 200 ha along the two rivers is heavily infested, with 6 912 ha densely infested and 288 ha of closed infestation, the estimated cost of the initial clearing is R25 891 364 (R3 425/ha × 6 912 ha + R7 700,57/ha × 288 ha). The calculation of annual costs will be based on the estimate that it will take 10 years to clear the infested area. While the actual initial clearing and follow-up work varies from year to year, and therefore the annual costs, for the sake of analysis the simplifying assumption will be made that the flow of costs for the initial clearing is spread out evenly throughout the ten years.

The cost of the follow-up operations decreases each year as the density of the regrowth declines. The cost for the first follow-up operation is estimated to be R166/ha, declining to R123/ha for the second follow-up and R82/ha thereafter (Buckle, 1998: personal communication). As no figures were available on the cost of follow-up operations in the areas of closed infestation, the figures for the follow-up operations in the densely invaded areas will be used in the calculation of annual follow-up costs for the entire area. The Working for Water Programme involves two follow-up operations after which the private landowners are contractually obligated to maintain the riparian vegetation through regular follow-up clearing. It is assumed that the area cleared in one year will receive its first follow-up clearing the following year and receive its second follow-up the year after that. The calculation of the annual follow-up costs is shown in Appendix 4.

In addition to these variable costs there is a fixed cost of R677 383 per year. This figure is made up of the administration cost (R96 000 per year) and the salaries of the administration staff, the production controllers, the liaison person, the rehabilitation expert, the project manager and the area manager (R581 383 per year)

(Buckle, 1998: personal communication). This fixed cost is for the Kouga Project as a whole, including the work done in the upper catchments of the Krom and Kouga catchments. Given that 30 000 ha of the upper catchments are infested, then the portion of the fixed cost applying to the riparian zones will be taken as 19,35% of this total ({7 200 ÷ 37 200}*100), which amounts to R131 074.

The final cost that needs to be incorporated into the analysis is the annual cost of the rehabilitation programme. The costs incurred by this programme are presented in table 3.4.

Table 3.4: Rehabilitation cost per annum

Expenses	R/year
1 Rehabilitation manager	56 500
9 Labourers	71 280
Running cost	36 000
Purchases	18 000
Total	R181 780

Rehabilitation of the riparian vegetation starts in year 1 and continues throughout the clearing phase and for two years after the initial clearing.

3.3 Benefit flow of the eradication programme

The excess water use per ha invaded by aliens has been calculated at 3 000 m^3 per ha per year (Ninham Shand Inc., 1993: 10). In deriving this figure the following assumptions were made:

- Black wattle mapped in the study area has a canopy cover similar to pine plantations;
- Black wattle in a water-saturated environment uses similar amounts of water to pine plantations; and
- the fynbos replacing cleared alien trees uses the same amount of water as 100% scrub forest cover (Bosch and Hewlett, 1982; Versfeld and Van Wilgen, 1986).

Ninham Shand Inc. (1993: 11) calculate that the 7 200 ha of invaded riparian area of the Krom and Kouga Rivers is equivalent to an area of 3 170 ha with a black wattle canopy cover of 100%. The excess water use associated with the black wattle invading the riparian zones is consequently estimated to be 9,51 million m^3 per annum (3 000m^3 per ha per annum × 3 170 ha). This is regarded as a conservative estimate (Buckle, 1998: personal communication).

A study on the effects of black wattle on streamflow in the Sand River in the Zwartkops River Catchment, Eastern Cape (Rowntree and Beyers, 1997), indicates that excess water use by black wattle in riparian area may indeed be much higher than the above figure. The black wattle in the study area was of a heavy infestation level, with about 4 000 trees per ha and an above-ground wet biomass of 162 tons/ha. The study estimated that the clearing of dense black wattle in riparian areas increased the yield by 13,6 m^3/ha/day, or 4 964 m^3/ha/annum (Rowntree and Beyers, 1997).

The more conservative estimate of excess water use (3 000 m^3/ha/annum) will be used in the following analysis in order to provide a more prudent appraisal of the project. It should be noted that using the more generous estimate in the analysis would greatly improve the annual benefit flows, thereby increasing the NPV of the project and lowering the URV of the increased water supply.

The benefit flows from the project are taken to be the annual revenues derived from the increased water yield. It is assumed that the entire additional yield reaches the Port Elizabeth supply dams. This is a reasonable assumption as the allocation to downstream riparian owners of 58,6 million m^3 per annum from the Kouga Dam and 2,4 million m^3 per annum from the Groendal Dam remains constant. The incremental yield will therefore not be abstracted downstream but rather increase the volumes stored in the dams (Ninham Shand Inc., 1996c).

Upstream of the dams, abstraction of water for urban demand is estimated to be less than 1% of the Mean Annual Runoff of these dams and is thus regarded as negligible. In terms of agricultural demand upstream of the dams, the 1992 amendment to the Water Act (Act 54, 1956) restricts the maximum capacity of dams that can be built without a permit to 10 000 m^3 and the maximum allowed abstraction rate from a public stream without a permit to 10 litres per second. The growth in irrigation demand is thus not considered to be significant (Ninham Shand inc., 1996c).

In terms of abstraction for environmental demand, the Impofu Dam is the only dam from which an allocation is made (2 million m^3 per annum). This allocation remains constant (Ninham Shand Inc., 1996c).

Thus, given that the abstractions from the system remain constant, the increased yield resulting from the eradication programme can be expected to reach the supply dams for the Port Elizabeth metropolitan area. Given the forecasts regarding the growth of water demand and the incremental increases in water supply, it can be assumed that all the additional water will be consumed and the revenues realised.

The revenue flows of the project will be discounted back over twelve years, the life of the project. The increased yield will, however, continue to be realised for as long as the catchments are maintained in their cleared state. If the catchments are not maintained after the twelve years then the water yield will diminish as the alien infestation spreads.

The revenue flow is calculated by multiplying the net incremental increase in water yield (m^3/annum) by the value of water (R/m^3). For the purposes of this study the Port

Elizabeth bulk (untreated) water tariff will be used as a proxy for the value of the incremental water yield. In order to achieve an economically efficient allocation of water, the price which the monopoly supplier (in this case the Department of Water Affairs and Forestry) charges for water must equal the marginal cost of supply, which in turn must equal the value of the last unit of water purchased (Mirrilees *et al.*, 1994: Appendix A, 3-17). The bulk water tariff for Port Elizabeth is regarded as an efficient price, and therefore a close indicator of the value of water, as this tariff has been set by the municipality at a rate which is equal to the marginal cost of water supply (Raymer, 1998, personal communication). The bulk tariff as at 01/07/98 was R1,26/m^3.

Due to the unaccounted for costs outlined in section 2.6, the Port Elizabeth tariff for bulk water may be significantly lower than the true economic value of the water supply. These costs have not been included in the calculation of the marginal cost of providing the water. In order to obtain a fairer approximation of the value of water, the Port Elizabeth domestic tariff to consumers will also be used to determine whether this will alter the outcome of the analysis. The domestic tariff is R2,40/m^3.

3.4 Cost-benefit analysis

Having outlined the costs and benefits in the previous sections, these figures will now be analysed to determine the desirability of the project. Table 3.5 lists the annual costs and benefits associated with the project.

Table 3.5: Annual flow of costs and benefits

	Annual Cashflow (R × 10^3)							
Year	Fixed Cost	Initial Clearing	Follow-up Clearing	Rehab Cost	Total Cost	Increased Yield (M m^3/a)	Revenue (Yield* R1,26)	Net Benefit/ (Cost)
0	131.074	2 589,1364	0	0	2 720,2104	0	0	(2 720,2104)
1	131.074	2 589,1364	119,52	181,78	3 021,5104	0,951	1 198,26	(1 823,2504)
2	131.074	2 589,1364	208,08	181,78	3 110,0704	1,902	2 396,52	(713,5504)
3	131.074	2 589,1364	208,08	181,78	3 110,0704	2,853	3 594,78	484,7096
4	131.074	2 589,1364	208,08	181,78	3 110,0704	3,804	4 793,04	1 682,9696
5	131.074	2 589,1364	208,08	181,78	3 110,0704	4,755	5 991,30	2 881,2296
6	131.074	2 589,1364	208,08	181,78	3 110,0704	5,706	7 189,56	4 079,4896
7	131.074	2 589,1364	208,08	181,78	3 110,0704	6,657	8 387,82	5 277,7496
8	131.074	2 589,1364	208,08	181,78	3 110,0704	7,608	9 586,08	6 476,0096
9	131.074	2 589,1364	208,08	181,78	3 110,0704	8,559	10 784,34	7 674,2696
10	131.074	0	208,08	181,78	520,9340	9,510	11 982,60	11 461,6660
11	131.074	0	88,56	181,78	401,4140	9,510	11 982,60	11 581,1860

3.4.1 Net Present Value

The NPV is calculated for these annual flows of costs and benefits using both the real average yield on long-term government bonds and the real prime overdraft rate in order to determine whether the result is sensitive to the different discount rates. The derivation of the discount rates to be used is shown in Appendix 5.

Using a discount rate of 7%, reflecting an approximation of the real yield on long-term government bonds, the eradication of alien vegetation in the riparian areas of the Krom and Kouga catchments will realise a Net Present Value of R23 963 528.

The Net Present Value is lower when a discount rate of 12% is used in the calculation, as the net benefits accruing in the later years of the project are given less weight. Using this higher discount rate, an NPV of R14 989 316 is calculated for the project. The calculation of the Net Present Value of the project, when the price of water is taken to be R1,26, is shown in Appendix 6.

Taking a value for the price of water which is greater than that of the Port Elizabeth's bulk water tariff will increase the net benefits of the project and provide a larger NPV for the project. If the Port Elizabeth domestic tariff (R2,40/m^3) is used as a proxy for the value of water, then the project will yield an NPV of R66 776 269 when a discount rate of 7% is used and an NPV of R46 189 856 when a discount rate of 12% is used. The calculation of the NPV when the domestic tariff is used is shown in Appendix 8. The decision rule of the CBA will therefore not be affected by using a price for water that is a closer approximation of its true economic value. A more realistic price for water increases the NPV of the project and makes this option more favourable when being compared to other supply augmentation schemes.

The above calculation assumed that the demand for water was perfectly price inelastic. There was consequently no reduction in the quantity of water demanded as the price per m^3 of water nearly doubled. The price elasticity of demand for water, however, tends to fall between -0.3 to -0.6 in developed countries and between -0.3 to -0.7 for developing countries, the greater elasticity being consistent with the greater importance of the cost of water for the inhabitants of these countries (Little, 1994: 16; Winpenny, 1994: 44). If we assume that the price per m^3 of water doubles, and that the price elasticity of demand for water in the Port Elizabeth region is equal to 0.3, then the resulting NPV, at a discount rate of 7%, is calculated to be R39 736 642. If the NPV is calculated using a price elasticity of demand for water of 0.7, then a figure of nearly R22 million is arrived at. While these values are significantly lower than that achieved when the demand for water was assumed to be perfectly price inelastic, they still provide a positive NPV, indicating that, within these price elasticity ranges, the project is still economically desirable.

3.4.2 The Internal Rate of Return

The internal rate of return criterion states that projects that offer rates of return in excess of their opportunity cost of capital should be accepted. The internal rate of return is the discount rate that makes NPV=0 (Brealey and Myers, 1991: 80).

Performing a sensitivity analysis with varying discount rates, the NPV of the project changed from a positive value to a negative one at a discount rate between 36% and 37%, indicating that the IRR is between 36% and 37%. This calculation is shown in Appendix 7.

The IRR thus obtained is substantially higher than the discount rates used in the CBA. The project is therefore regarded as an economically desirable option and the outcome of the IRR decision rule thus supports the NPV outcome in terms of the desirability of the eradication programme.

3.4.3 The Unit Reference Value

In order to compare the cost-effectiveness of the alien eradication programme to alternative water supply schemes, the Unit Reference Value (URV) for the eradication scheme will be calculated. This is the method prescribed by the Department of Water Affairs and Forestry (DWAF) to calculate the unit cost of providing water of alternative supply augmentation schemes. Various alternative supply schemes and their relevant URVs, as calculated by Ninham Shand on behalf of the DWAF, are discussed in Chapter 5. For the sake of comparison the 8% discount rate used in the above-mentioned calculations will be applied in the calculation of the URV for the eradication programme. The calculation of the URV is shown in table 3.6.

Table 3.6: Calculation of the Unit Reference Value

Year	Total Cost (R)	Discount factor	Present Value of costs	Incremental yield (m^3/a)	Present Value of incremental yield
0	2 720 210.40	1	2 720 210.40	0	0
1	3 021 510.40	0.92593	2 797 707.12	951 000	880 559.43
2	3 110 070.40	0.85734	2 666 387.76	1 902 000	1 630 660.68
3	3 110 070.40	0.79383	2 468 867.19	2 853 000	2 264 796.99
4	3 110 070.40	0.73503	2 285 995.05	3 804 000	2 796 054.12
5	3 110 070.40	0.68058	2 116 651.71	4 755 000	3 236 157.90
6	3 110 070.40	0.63017	1 959 873.06	5 706 000	3 595 750.02
7	3 110 070.40	0.58349	1 814 694.98	6 657 000	3 884 292.93
8	3 110 070.40	0.54027	1 680 277.74	7 608 000	4 110 374.16
9	3 110 070.40	0.50025	1 555 812.72	8 559 000	4 281 639.75
10	520 934.00	0.46319	241 291.42	9 510 000	4 404 936.90
11	401 414.00	0.42888	172 158.44	9 510 000	4 078 648.80
			NPV = R22 479 927.57		R35 163 871.68
			URV = R0.6392 /m^3		

The URV of the eradication programme will be discussed in relation to other potential schemes in Chapters 4 and 5.

3.5 Environmental benefits of the eradication project

Secondary benefits, such as the preservation of biodiversity and aesthetic values, will not be incorporated quantitatively into the analysis due to the well-documented problems associated with the assigning of monetary values to such nonmarket goods. These benefits have, however, been qualitatively discussed in section 1.5.2 and will be mentioned briefly below.

The environmental benefits flowing from the eradication programme are numerous and significant. These benefits, which are equivalent to the costs of continued alien plant invasion avoided, arise from the restoration of the infested areas to their previous undisturbed state.

Although the environmental benefits associated with the eradication and control of black wattle in the riparian areas of the Krom and Kouga Rivers are not assigned a monetary value in this study, it is important when analysing proposed projects to recognise the relevant non-pecuniary costs and benefits and incorporate these qualitatively into the decision-making process. Some of the benefits accompanying the Kouga Working for Water Project are listed below.

The environmental benefits of alien plant eradication include:

- increased water yield and reliability of streamflow;
- improved water quality;
- the recovery of indigenous species and an increase in biodiversity;
- a decreased risk of severe and unmanageable fires;
- surface stabilisation as the cleared areas are rehabilitated, leading to reduced erosion;
- ecotourism development potential;
- an improvement in the aesthetic appeal of the mountain areas; and
- the recovery of potentially productive agricultural land.

The large number of environmental benefits associated with this project is important in the economic appraisal of this scheme. All other supply augmentation schemes involve various negative environmental impacts which may render the scheme unacceptable, or at least less desirable, from an economic point of view. The eradication of invasive alien vegetation is the only water supply scheme which adds water to the system and has accompanying environmental benefits.

Chapter Four

Comparing the Costs of Alternative Schemes

While the alien eradication programme has been shown to be economically efficient, with an NPV of R23 963 528 at a discount rate of 7% (R14 989 316 when a discount rate of 12% is used) and an IRR of just over 36%, this project needs to be compared to other supply augmentation schemes in order to determine which project is the most economically desirable. First-hand data collection and analysis of alternative schemes lie outside the scope of this thesis. However, studies conducted by Ninham Shand Inc., as part of the Algoa Water Resources Stochastic Analysis, identified and analysed alternative supply options and their results will be examined and compared to those obtained from the analysis of the eradication programme. The calculated URV of the eradication programme (63,92c/m^3) will be compared to those obtained by the Stochastic Analysis for alternative supply schemes and conclusions will be drawn based on the comparisons of the relevant URVs and other considerations.

4.1 Potential supply augmentation schemes

Given that the forecast water demand is expected to exceed the 1 in 20 year risk yield by about 2006, the DWAF commissioned the Algoa Water Resources Stochastic Analysis in 1993 as a follow-on study to the Algoa Water Resources

Systems Analysis. Among the objectives of the Stochastic Analysis were the following: to identify possible future sources of water supply to the Port Elizabeth area; to identify the most economically efficient future augmentation options; and to obtain a preliminary assessment of the environmental impacts of proposed schemes (Ninham Shand Inc., 1996c: iii). Examination of their findings will allow for the evaluation of the eradication programme, in terms of cost-efficiency, relative to alternative supply options.

Twelve possible supply augmentation schemes were analysed as part of the Stochastic Analysis, as well as the option of water demand management. The options considered were as follows:

1) Guernakop Dam on the Kouga River;

2) An inter-basin transfer from Tsitsikamma River to Krom River;

3) The installation of fusegates at Impofu Dam;

4) A canal collecting water from several coastal rivers along the Tsitsikamma coast to the west of the Tsitsikamma River, and the transfer of this water into the Krom River by tunnel;

5) An inter-basin transfer from Groot River to Kouga River;

6) Cambria Dam on the Groot River (tributary of the Kouga);

7) Increase Sundays River utilisation;

8) Echodale Dam on the Elands River;

9) Van Stadens Dam on the Van Stadens River downstream of the existing dams;

10) Recycling of sewage effluent;

11) Desalination of seawater; and

12) Utilisation of rainwater tanks (Ninham Shand Inc., 1996c: 31).

The Stochastic Analysis compared the alternative schemes economically based on the Unit Reference Value (URV), the method prescribed by the Department of Water Affairs and Forestry for estimating relative unit costs of water, using a discount rate of 8%. The historic firm yields of the schemes, based on the 1927 to 1991 hydrological record, were used in the analysis as the yield of the schemes and to calculate URVs.

Of the schemes analysed, nine were regarded as inefficient, having high URVs, or problematical, in terms of water quality or unacceptable levels of impact on the environment. Of the "less conventional" schemes, ie. the recycling of sewage effluent and the desalination of seawater, the former option was found to be the most economical, with a URV of 263c/m^3, compared to the desalination option which had a URV of 578c/m^3 for the double storage process which would produce water with a chloride level of about 40 mg/litre (Ninham Shand Inc., 1996c: 44). These two options were found to be substantially less economical than the surface water alternatives and at this stage should not be regarded as viable solutions to the water supply problem.

The options which the Stochastic Analysis found to be most viable, the Guernakop Dam on the Kouga River, the transfer of water from the Tsitsikamma River to the

Krom River, and further utilisation of the Sundays River water will be discussed in greater detail below.

4.2 Guernakop Dam on the Kouga River

The water allocation to Port Elizabeth from the Kouga/Loerie sub-system is set at 23 million m^3 per annum, although the infrastructure was designed to convey an allocation of 36,5 million m^3 per annum. Surplus capacity thus exists in this infrastructure, making the augmentation of this source an attractive option. The option of raising the height of the Kouga Dam to increase the yield is not regarded as viable due to existing structural problems with the dam wall and unstable foundation conditions.

The possibility of constructing a new dam at Guernakop, approximately 20 km upstream of the confluence of the Baviaanskloof and Kouga Rivers, was thus considered. Water stored in the proposed dam would be released into the Kouga Dam when required to supplement resources or to provide for the environmental needs of the river. The water would be supplied from the Kouga Dam to Port Elizabeth through the existing infrastructure. The analysis considered two dam sizes, 100 million m^3 capacity and 200 million m^3 capacity. The results of the Stochastic Analysis are provided in table 4.1.

Table 4.1: Guernakop Dam: summary of results

Dam Capacity (10^6m^3)	Incremental Historical Firm Yield ($10^6m^3/a$)	Unit Reference Value (c/m^3)
100	14,0	60,2
200	25,8	78,3

Source: Ninham Shand Inc., 1996c: 34

The irrigation farmers in the Gamtoos Valley also receive water from the Kouga Dam and as such portion of this incremental yield would be utilised to reduce the risk of supply to the irrigation farmers in the Gamtoos Valley (Ninham Shand Inc., 1996c: 34).

The dam with a 100 million m^3 capacity was found to be the most economical, with a URV of 60,2c/m^3. This URV is comparable to that for the eradication programme. It must be remembered, however, that the URV for the eradication programme was calculated based on a project life of 12 years. In reality the incremental yield would be realised for a much longer period, given that the catchments are maintained free of invasions, and this would lower the calculated URV. The eradication programme may therefore prove to be more cost-efficient than the proposed dam if the project life was to be extended to include the increased yield over a longer time period.

4.2.1 Environmental impacts of the proposed Guernakop Dam

The location of the proposed Guernakop Dam is in the informal buffer zone of the Guerna Wilderness area, which forms part of the Baviaanskloof Wilderness Complex. The downstream river reach which would be directly impacted by the dam lies within the wilderness area. The Kouga River within the Wilderness Area is considered to have the highest possible conservation status. The river flows through a steep sided gorge and the riverine vegetation and the surrounding fynbos and valley bushveld vegetation are described as "pristine" (Ninham Shand Inc., 1996b).

The construction of a dam at this location would have a significant negative impact on the wilderness experience as well as on the conservation of these sensitive ecological areas. Disturbances to the system will affect the general ecosystem functioning and will probably decrease species diversity. The inundation of the vlei at the confluence of the tributaries and the Kouga River would result in this important habitat being lost. The proposed dam would also inundate the Riverside Camp Site which provides an access point to the Baviaanskloof Wilderness complex. The opportunity costs of the loss of the ecotourism and anthropogenic aspects of the area need to be considered (Ninham Shand Inc., 1996b: 22).

While the Stochastic Analysis considers the impacts of the proposed Guernakop Dam to be ecologically acceptable (Ninham Shand Inc., 1996c: 54), the Initial Environmental Assessment performed by the consultants is acknowledged as limited and the negative environmental impacts should prudently be regarded as significant and prohibitive until a complete and thorough assessment has been conducted.

In contrast to the proposed dam, the eradication programme has a host of associated environmental benefits, as discussed in section 3.5. The incorporation of the relevant environmental impacts into the economic analysis suggests that the eradication programme is the more economically desirable option and should be prioritised.

4.3 Tsitsikamma River scheme

The surplus capacity in the supply infrastructure from the Impofu Dam to Port Elizabeth, coupled with the proximity of the Tsitsikamma catchment to the Krom River Supply System (the Churchill/Impofu Dam System) and the good quality of water in the Tsitsikamma River makes the Tsitsikamma River an important potential source of water supply to Port Elizabeth (Ninham Shand Inc., 1996c).

The Impofu/Churchill sub-system has a peak supply capacity to Port Elizabeth of 53 million m^3 per annum, while the sub-system has 1 in 100 year yield of 39,8 million m^3 per annum. This accounts for the system's surplus capacity. It is thus feasible to treat raw water from the Tsitsikamma River at the Elandsjagt Water Treatment Works and to supply this water to Port Elizabeth via the existing pipelines (Ninham Shand Inc., 1994c: 57; Ninham Shand Inc., 1996c: 36).

The option of constructing a dam on the Tsitsikamma River, which traverses the Huisklip Nature Reserve, and withdrawing water when required was examined, along with the option of constructing a smaller impoundment on the Tsitsikamma River and diverting water into the Impofu Dam. The proposed dam site is 2,2 km from the Tsitsikamma River Mouth.

The construction of a large dam on the Tsitsikamma River, with a maximum storage capacity of 50 million m^3, was dismissed as impractical and inadvisable, given the environmentally sensitive river valley and the fact that the river is steep and runs through a deep gorged river valley. Construction of this dam would inundate an area of 2,4 km^2 of relatively undisturbed Afromontane Coastal Forest (Ninham Shand Inc., 1994b: Appendix C-3; Ninham Shand Inc., 1996c: 36).

The second option, creating a diversion dam on the Tsitsikamma River with a pumpstation and pipeline to transfer water from this dam to the Impofu Dam, was found to be an economically attractive alternative.

4.3.1. Tsitsikamma/Krom transfer scheme

Various dam capacities and transfer capacities are examined in the System Analysis (Ninham Shand Inc., 1994b) in order to determine which combination is the most cost-effective. The estimated total capital costs for the various schemes are summarised in table 4.2.

Table 4.2: Capital costs (R $\times 10^6$) of the Tsitsikamma/Krom transfer scheme

Dam Capacity (million m^3)	Transfer Capacity (million m^3/month)			
	2,6	3,9	5,3	30
2,5	30,5	38,3	48,7	150,1
5,0	32,2	40,0	50,4	151,8
10	35,5	43,3	53,7	155,1
12,5	36,9	44,7	55,1	156,5
30	48,3	56,2	66,6	168,0
50	62,4	70,2	80,6	182,0

Source: Ninham Shand Inc., 1994c: 18

The annual costs for the respective schemes were also calculated in the System Analysis. These annual costs included the cost of replacing capital equipment, maintenance costs and energy costs. It was assumed that electrical equipment is replaced every 15 years and mechanical equipment every 30 years, the energy cost was assumed to have a unit rate of 8,5c/kWh, and the maintenance costs were assumed to be 0,25% of the capital cost for the Civil works, 0,50 % of the capital cost for pipelines and 4,00% of the capital cost for mechanical and electrical equipment Ninham Shand Inc., 1994b: Appendix A-1). The cost of salaries, which may be assumed to be significant, was not included in the calculation. If the cost of salaries were to be included then the resultant URV would be greater than that calculated in the Analysis.

The URVs for the schemes were calculated by discounting the annual costs and water demands of the schemes over a period of 45 years, at a discount rate of 8%, allowing two years for construction of the schemes and four years for the schemes to reach their maximum capacity.

The scheme consisting of a 5 million m^3 weir with a diversion capacity of 2,6 million m^3/month was found to be the most economical, with a URV of 27c/m^3 at a discount rate of 8%. This scheme is the most favourable, in terms of the calculated URV, of the schemes considered. The calculation of the URV, as it is presented in the Algoa Water Resources System Analysis (Ninham Shand Inc., 1994b: Appendix B-3) is shown in Appendix 9.

This scheme has a lower URV than the eradication programme, suggesting that it is the more cost-efficient option. The difference in the calculated URVs may not be as large as that calculated here if we consider two factors. Firstly, the inclusion of the wages expense (which makes up more than 50% of the variable costs of the eradication programme) in the analysis of the transfer scheme would substantially increase the URV for this scheme. Secondly, increasing the period considered for the eradication programme, thereby allowing for the realisation of the increased yield over a longer period, would significantly lower the URV for the eradication programme. Furthermore, the transfer scheme simply redistributes available water, while the eradication programme adds water to the system. The transfer scheme should not, therefore, be regarded as the optimal scheme to the exclusion of the eradication scheme.

4.3.2 Environmental impacts of the transfer scheme

A Relative Environmental Impact Prognosis of the proposed Tsitsikamma Dam was conducted by Ninham Shand on behalf of the DWAF. The results of this preliminary study are presented in Appendix C of the Algoa Water Resources System Analysis Report no. 10 of 12 (Ninham Shand Inc., 1994b). Some of the important environmental impacts will be summarised below:

1. Both the large and the small dams will result in the inundation of:
   - undisturbed riverine and forest vegetation;
   - wetland areas on the coastal plain; and
   - habitats for terrestrial and aquatic species;

2. The reduction in Mean Annual Runoff (MAR) downstream and the change in the flow regime caused by either dam could:
   - result in degradation of downstream habitats;
   - cause changes in water quality, thereby affecting aquatic biota;
   - change the dynamics of the river mouth; and
   - have a detrimental impact on mammals, reptiles and invertebrates which are dependent on the aquatic habitats;

3. The large storage dam could:
   - cause permanent fragmentation of aquatic populations;

- modify sediment characteristics and water quality downstream of the dam;
- create a habitat conducive to invasion by alien plants; and
- cause significant disturbance due to construction and access roads;

4. The small diversion dam could result in:
   - organisms being transferred from one habitat to another, as the water is transferred into the Impofu Dam;
   - temporary fragmentation of aquatic populations;
   - changes to the river mouth dynamics and the flow regime; and
   - reduced water quality and altered thermodynamics.

The benefits listed in the Relevant Environmental Impact Prognosis include the opportunity for recreational development, temporary economic upliftment in the area, possible stimulation of the dairy industry due to the increased availability of water and the stimulation of tourism in the area (Ninham Shand Inc., 1994: Appendix C-8).

The Prognosis concludes that while both options have significant negative impacts due to the high conservation status of the area, the impacts associated with the small diversion dam are less severe as the inundated area would be significantly smaller under this option (0,95 km^2, as opposed to 2,4 km^2 for the large storage dam).

Once again, these environmental costs can be contrasted with the important environmental benefits accruing from the eradication programme. Incorporation of the environmental impacts of the two schemes is vital for an accurate economic analysis of the desirability of the schemes.

4.4 Further utilisation of the Sundays River water

The final supply augmentation option that will be looked at involves increasing the supply of water from the Sundays River supply system. Water for this supply originates from the Gariep Dam. Under this system water is piped from the Orange River and released into the Sundays River. The present maximum supply capacity of this system is 25 million m^3 per annum (Ninham Shand Inc., 1994d: 23). The Port Elizabeth/Uitenhage metropolitan area currently utilises between 12- and 13 million m^3 per annum from the Orange/Sundays River Water Scheme. The augmentation option involves using the existing Nooitgedacht to Grassridge line to capacity and thereafter constructing a low-level supply line to Grassridge. The URV of this scheme was calculated to be 63c/m^3 Ninham Shand Inc., 1996c). This URV is similar to that obtained for the eradication programme.

A problem with this scheme is that the water from the Sundays River Scheme is of low quality, having a high concentration of total dissolved salts. The water consequently needs to be treated to bring it to an acceptable level for urban use. The cost of improving the water quality has not been included in the calculation of the URV (Ninham Shand Inc., 1996c: 59). Another problem is that much of the water released from the Orange River gets lost in the transfer process, necessitating the release from the system of more water than the targeted quota for Port Elizabeth (Du Preez, 1997: 5).

In terms of environmental impacts, the construction of a supply line would incur various environmental costs which need to be investigated more fully. These costs will affect the outcome of the economic analysis and need to be identified and incorporated into the decision-making process.

4.5 Demand management

A further method of reconciling water demand and supply is through water demand management. Following the lifting of water restrictions, which were imposed in the late 1980s and early 1990s in response to the severe drought of the time, the water demand in Port Elizabeth has not returned to its previous level. This would indicate that there is a general awareness of the water problem and consequently of the real value of water (Ninham Shand Inc., 1996c: 32).

It is estimated that losses from the Port Elizabeth water distribution system are approximately 10%. Water losses in the agricultural sector, due to canal seepage losses and inefficient irrigation methods, is also an area of concern. Efficient water demand management, policies of which the Port Elizabeth municipality is implementing, is expected to reduce water losses by 10%, equivalent to less than 4 years growth in demand. This will be achieved through a combination of economic, managerial, technological and behavioural measures. The economic component involves the application of a stepped tariff structure, excess use surcharges, summer surcharges and sewer surcharges (Ninham Shand Inc., 1996c: 33; Raymer, 1998: personal communication).

The effectiveness of water demand management is illustrated by the results achieved in Greater Hermanus, Western Cape, following the implementation of the Greater Hermanus Water Conservation Programme. The introduction of a twelve-point plan of action, that includes the use of tariffs, water loss management, education, and technology that reduces inefficient water use, has realised a reduction in water demand of 32% in its first four months (DWAF, 1997b: 8).

This is an important component in the overall management of water resources. Successful implementation of demand management strategies, in conjunction with the eradication of alien vegetation in the catchment areas, would serve to extend the sufficiency of Port Elizabeth's water supply for many years, postponing the need for the construction of capital-intensive dams.

4.6 Other studies

It is useful, for the sake of comparison, to examine studies done elsewhere in South Africa on the relative costs of alternative water schemes and how the eradication of alien infestations as a supply option compares to the more conventional supply schemes.

Burgers *et al.* (1995) compare the cost-effectiveness of alien vegetation clearing and control to conventional supply options for the Western Cape. The study used 1993 prices. With regard to the eradication and control of alien infestations, the "capital cost" - the cost of clearing and 10 annual follow-up operations to reduce the infestations to very low levels - of eradicating dense infestations of black wattle was estimated to be R10 000/ha. Salaries and overhead costs were estimated to be R104/man day. Differences in the clearing costs of this scheme and the Kouga scheme are attributable to differences in accessibility, clearing methods, wage structures and various other factors.

The regular follow-up operations that occur every 1 to 3 years, after the 10 years of intensive follow-up which is included in the "capital costs", are compared in the study to the "operating and maintenance costs" of conventional schemes. This cost was estimated to be less than R25/ha/annum (Burgers *et al.*, 1995: 110). The relative cost of the water supplied by this scheme is calculated over 45 years and discounted at 8%. The URV, based on an estimate that the clearing and control of the dense infestations would yield 2 500 m^3/ha/annum, is calculated to be 34c/m^3.

This figure is notably lower than that calculated for the Kouga project. The prices used in this study were, however, 1993 prices and the life of the project was taken to be 45 years. The costs also differ markedly between different areas.

The analysis of 17 conventional supply schemes illustrated that the relative cost of clearing dense infestations is competitive with many conventional schemes. The mean URV calculated for the conventional options was 48c/m^3, with the most economical scheme having a URV of 15c/m^3 and the most expensive option having a URV of 80c/m^3. An important point to note is that the relative costs of conventional schemes would increase greatly in the absence of alien control, due to increased water losses as the area and level of infestations increases (Burgers *et al.*, 1995: 108).

The findings of Burgers *et al.* support the observations from the analyses of the alternative supply options for the Port Elizabeth region. The eradication programme is shown to be competitive with alternative schemes in terms of the unit reference value.

Another study, conducted by Van Wilgen *et al.* (1996), examined the effect on costs of developing water supply facilities (dams and distribution networks) in two identical hypothetical catchments, one scheme with and one without concomitant alien vegetation clearing and control. Van Wilgen *et al.* calculated the relevant costs in U.S. dollars and for the sake of comparison these have been converted to rand at an exchange rate of R3,96 to the dollar (the mean of the 1995/1996 average exchange rates). The figures used in the Van Wilgen *et al.* study are shown in Appendix 10.

It was assumed, based on the relationships between rainfall, runoff and aboveground biomass as modelled by Le Maitre *et al.* (1996), that the 10 000 ha catchments, with 1 500 mm of rainfall annually, would yield 742 mm rainfall equivalent of streamflow immediately post-fire. The initial clearing costs were taken to be R3 287 per ha for dense infestation and the cost of follow-up operations were estimated to be R31,68 per ha. The capital costs of building the supply facilities for a catchment yielding 62,7 million m^3/annum was estimated to be R268,09 million. Interest on the capital outlays (the building of the facilities in both cases and the cost of the initial clearing in the one case) was calculated at 8%. The operating costs of the water supply facility were estimated to be R5,11 million/annum.

Van Wilgen *et al* (1996) calculated the URV to be 47,12 c/m^3 in the scheme which included the clearing of alien plants, while the URV for the unmanaged catchment was 54,65c/m^3. This lower URV for the managed catchment, despite its larger total annual costs, is a result of the large increase in water yield associated with this option. The managed catchment yields 14,1 million m^3/annum more than the unmanaged catchment, an increase of almost 30% (Van Wilgen *et al.*, 1996: 188).

This study illustrates the cost-implications of alien vegetation control for water supply options. Apart from increasing the water yield, which is a significant benefit for a water poor country like South Africa, eradication leads to the reduction in the unit cost of water of existing supply schemes.

The studies which have been looked at confirm the viability of alien vegetation eradication as a competitive supply augmentation option. The URV calculated for the eradication project in the Kouga and Krom river catchments compares favourably to the more conventional supply options. When the environmental benefits are incorporated into the analysis the eradication programme becomes an extremely attractive alternative. In the chapter which follows the findings of the analysis will be discussed and recommendations made.

Chapter Five

Conclusion

Water scarcity has been identified as a key factor limiting economic growth in South Africa (O' Keeffe *et al.*, 1992: 278). The efficient management of Port Elizabeth's water supply is of vital importance given the scarcity of water in the Algoa region and in South Africa as a whole. The present water supply to the Port Elizabeth region is sufficient to meet forecast demand until the year 2005. It is thus necessary to implement schemes to augment the supply to the region (Ninham Shand Inc., 1996c: 3).

The Kouga Working for Water project aims to increase the runoff of the Krom and Kouga River Catchments through the eradication and control of invasive alien vegetation in these catchments. Alien vegetation, as outlined in section 1.2, grows faster than the shade-intolerant natural vegetation, displacing it and using more water than the natural vegetation. The infestation of riparian zones has the greatest impact on water resources due to the availability of water in these areas and the fact that alien trees use water whenever it is available.

It is estimated that 3 170 ha of the riparian areas of the Krom and Kouga Rivers are densely infested by alien vegetation, predominantly *Acacia mearnsii* (black wattle). The reduction in runoff associated with this level of infestation is estimated, based on the model by Bosch and Hewlett (1982), to be 9,51 million m^3/annum. The primary invaders of the riparian areas are black wattle trees and this study therefore concentrates on the eradication of these trees.

For the purpose of analysing the economic efficiency of the eradication programme the methodology of cost-benefit analysis (CBA) was adopted. The evaluation criteria of Net Present Value (NPV) and the Internal Rate of Return (IRR) were applied to the eradication programme to determine the economic desirability of the project. The NPV decision-rule is that any project with a positive NPV should be accepted as it satisfies the welfare economics' principle of improving social welfare. The IRR decision-rule is that a project which has an IRR greater than the discount rate is acceptable as it offers rates of return in excess of the opportunity cost of capital (Dixon *et al.*, 1988: 31).

In calculating the NPV of the project a discount rate of 7% was used, to reflect the real yield on long-term government bonds. The value of the water was taken to be the Port Elizabeth bulk tariff rate of R1,26/m^3. The NPV was calculated as R23 963 528, indicating that the eradication project is a desirable option. A sensitivity analysis was conducted using a discount rate of 12%, reflecting the real prime overdraft rate. The NPV thus calculated was R14 989 316. The outcome of the analysis is therefore not affected by whether the opportunity cost of capital or the social rate of time preference approach is utilised to derive the discount rate in this case.

The pricing of water is an issue that has received a lot of attention and attracted a lot of debate. Water is under-priced for a number of reasons, as outlined in section 2.6. To achieve a closer approximation of the true economic value of water, the Port Elizabeth domestic tariff of R2,40/m^3 was applied to the NPV calculation to see the effect on the outcome. This resulted in an NPV of almost R67 million at a 7% discount rate and an NPV of just over R46 million when a discount rate of 12% is used. This higher price for water makes the eradication programme an even more attractive option.

The CBA indicates that the eradication programme is an economically desirable option of augmenting the water supply to the Port Elizabeth region. A complete economic analysis, however, needs to incorporate the unpriced environmental impacts into the analysis. These impacts should be quantified as far as possible through applying various shadow-pricing techniques (see section 2.3). No attempt was made in this study to quantify the environmental impacts of the scheme, but the impacts were incorporated into the analysis by being made qualitatively explicit.

The environmental benefits flowing from the eradication programme include the following: increased water yield and reliability of streamflow; improved water quality; increased biodiversity; a decreased risk of severe and unmanageable fires; and surface stabilisation, leading to reduced erosion. These environmental benefits are important in assessing the overall desirability of this option.

A number of assumptions were made in the analysis. Firstly, it was assumed that the additional runoff resulting from the removal of the black wattle would appear as baseflow in the rivers, meaning that the incremental yield of the system would increase by the full amount of 9,51 million m^3/a. The abstraction of water by the irrigation farmers and environmental water demand were thus not considered in the analysis.

Secondly, the life of the project was assumed to be 12 years. This limited project life means that the benefit flow of the incremental yield after the 12 years is not included in the analysis. A longer period would increase the net benefits and the calculated NPV as the increased yield could be realised indefinitely, as long as the catchments are maintained free of infestations. The analysis also did not include the cost of follow-up operations which need to be undertaken by the private landowners approximately every 5 years to prevent reinfestation. The costs of these follow-up operations, estimated to be R82/ha, are borne by the private landowners yet the benefits of the increased streamflow are predominantly enjoyed by downstream users. Incentives do, however, exist for the landowners to clear the infestations on their land. Firstly, agricultural land that has been lost to alien invasions can be reclaimed; and secondly, the landowners can prevent the loss of further land to alien invasions and incurring much larger clearing costs, as the area and density of invasion increases, at a later stage. There is a need to impress upon the landowners the benefits to be derived from clearing their lands of alien infestations. Once the landowners have signed a contract with the Department of Water Affairs they are legally obligated to maintain their property free of infestations after the Working for Water teams have cleared the infestations and conducted 2 follow-up operations. Under the Kaldor-Hicks criterion, outlined in section 2.2, the Pareto-efficiency condition is maintained as the downstream users could theoretically compensate the upstream landowners for their losses (Dasgupta and Pearce, 1972: 57).

The third assumption that was made was that there was no further spreading of the infestation over the life of the project. In reality, the rate of spread of invasives is estimated to be about 5% per annum. This figure increases if there are disturbances such as floods or fire. Buckle (1998: personal communication) estimates that the entire riparian areas of the Krom and Kouga Rivers could, if the clearing programme were be to stopped at this stage, be infested within 10 to 20 years, depending on disturbances to the system. The costs of clearing increase dramatically as the level of infestation increases, highlighting the need for immediate implementation of clearing programmes throughout the catchment areas of the country. The intensity of these clearing operations cannot be scaled down due to the constant threat of reinfestation and the danger of cleared areas returning to their previous levels of infestation, signifying a massive waste of resources in the original eradication programme.

In terms of the equity considerations of CBA, no weighting was applied to the stream of costs and benefits to take into account any imbalances in the distribution of costs and benefits or the desirability of assigning greater weight to the needs of rural communities. The project does, however, have significant benefits for the rural communities, including job creation, skills development, multiplier effects on the local communities, access to the cleared timber and the associated economic opportunities and increased availability of water and reliability of streamflow. The project thus appears to be favourable in terms of the equity criterion of CBA.

In order to analyse the economic desirability of the eradication scheme it was important to compare that option with alternative schemes to identify the optimal option. Although no direct analysis was conducted, the Algoa Water Resources Stochastic Analysis and the Algoa Water Resources System Analysis which preceded it did examine various supply augmentation options for the Port Elizabeth region. These schemes were compared on the basis of their URVs, the methodology of which is explained in section 2.8. The three most economical options identified were the construction of Guernakop Dam on the Kouga River, the Tsitsikamma/Krom transfer scheme and further utilisation of the Sundays River scheme. For the sake of comparison the URV was calculated for the eradication programme.

Based on the URV method, the eradication programme, with a URV of 63,92c/m^3, was found to be competitive with the Guernakop Dam option (URV of 60,2c/m^3) and the Sundays River option (URV of 63c/m^3), but more expensive, in terms of the URV, than the proposed Tsitsikamma/Krom transfer scheme (URV of 27c/m^3). The difference in the respective schemes URVs would not be as great as this suggests, however, as the URV for the Tsitsikamma/Krom transfer option was calculated in

1993 prices and the annual cost stream did not include the cost of wages, which make up more than 50% of the variable costs of the eradication scheme. Furthermore, the calculation of the URV for the eradication programme did not include the increased yield for the years after the 12 year project life. Incorporation of these benefit flows would lower the URV for the eradication option substantially. The eradication scheme thus compares favourably in terms of cost-efficiency with all the alternative schemes. Given that there are limited sites for the construction of more dams and that the eradication programme results in existing water resources being used more efficiently, the eradication scheme should be seen as the socially preferable option.

In contrast to the eradication scheme, all the conventional options have a host of associated negative environmental impacts. Incorporation of the environmental impacts of the eradication scheme and the alternative schemes in an economic analysis would weigh heavily in favour of eradication being identified as the socially optimal supply augmentation option.

While the necessity of constructing more conventional supply schemes is inevitable, given forecast demand and supply, the eradication of alien vegetation postpones this need. Furthermore, the eradication programme improves the cost-efficiency of existing and future supply schemes by increasing the yield to these systems.

Given Port Elizabeth's, and South Africa's, limited water resources, the efficient management of these resources is vital. The eradication of invasive alien vegetation is a cost-efficient supply option which improves social welfare, as indicated by the positive NPV for the scheme, and has a host of environmental benefits. Furthermore, the eradication of alien vegetation adds water to the system, as opposed to conventional schemes which merely redistribute the water or increase the storage of water. It can be concluded that the eradication option is economically desirable, in terms of both the efficiency and equity criteria, and should be pursued throughout the catchment areas of South Africa.

References

Abbot, S.K. (1986). The History of Introduction of Invasive Alien Plants to Southern Africa. In Macdonald, I.A.W., Kruger, F.J. and Ferrar, A.A. (eds), The Ecology and Management of Biological Invasions in Southern Africa, Cape Town: Oxford University Press.

Ackermann, D.P. (1970). Control of water catchments by the Department of Forestry. South African Forestry Journal, 98: 24-27.

Arrow, K.J. (1977). Criteria for Social Investment. In Dorfman, R. and Dorfman, N.S. (eds), Economics of the Environment: Selected Readings, New York: W.W. Norton and Co.

Aylward, B. (1992). Appropriating the Value of Wildlife and Wildlands. In Swanson, T.M. and Barbier, E.B. (eds), Economics for the Wilds, London: Earthscan Publications.

Bosch, J.M. and Hewlett, J.D. (1982). A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. Journal of Hydrology, 55: 3-23.

Bosch, J.M., Schulze, R.E. and Kruger, F.J. (1984). The effects of fire on water yield. In Booysen, P. De V. and Tainton, N.M. (eds), Ecological Effects of Fire in South African Ecosystems, Ecological Studies, 48, Berlin: Springer.

Boucher, C. and Marais, C. (eds). (1995). Managing Fynbos Catchments for Water, Pretoria: Foundation for Research and Development.

Brealey, R.A. and Myers, S.C. (1991). Principles of Corporate Finance (4th ed), New York: McGraw-Hill, Inc.

Buckle, J. (1997). Project Manager, Kouga Working for Water Project. Personal communication.

Burgers, C.J., Marais, C. and Bekker, S.J. (1995). The Importance of Mountain Catchments for Maintaining the Water Resources of the Western Cape Province and the Need for Optimal Management. In Boucher, C. and Marais, C. (eds), Managing Fynbos Catchments for Water, FRD Programme Report Series No. 24, Pretoria: Foundation for Research and Development.

Campen, J.T. (1986). Benefit, cost and beyond: the political economy of benefit-cost analysis, Boston: Ballinger.

Clawson, M. and Knetsch, J.L. (1971). Economics of Outdoor Recreation, Baltimore: The John Hopkins University Press.

Coetzee, J. (1997). Department of Water Affairs and Forestry, Working for Water. Personal Communication.

Cowling, R.M. and Holmes, P.M. (1992). Flora and vegetation. In Cowling, R.M. (ed.), The Ecology of Fynbos: Nutrients, Fire and Diversity, Cape Town: Oxford University Press.

Cowling, R.M. and Olivier, N.J.J. (1992). Indigenous Plants. In Fuggle, R.F. and Rabie, M.A. (eds), Environmental Management in South Africa, Cape Town: Juta and Co.

Dasgupta, A.K. and Pearce, D.W. (1972). Cost-Benefit Analysis: Theory and Practice, London: Macmillan Press.

Deacon, H.J. (1986). Human settlement in South Africa and archaeological evidence for alien plants and animals. In Macdonald, I.A.W., Kruger, F.J. and Ferrar, A.A. (eds), The ecology and management of biological invasions in southern Africa, Cape Town: Oxford University Press.

De Beer, H. (1986). Black Wattle, Pamphlet produced by the Department of Agriculture and Water Supply, Pretoria: Department of Agriculture and Water Supply.

Deloitte and Touche. (ca.1997). Kouga Wattle Project: Feasibility Study, Johannesburg: Deloitte and Touche.

De Swardt, S.J. (1969). A Study of the Methodology of Benefit-Cost Analysis in Resource Planning, Unpublished M.Sc. Thesis, University of Natal, Pietermaritzburg.

Dixon, J.A., Carpenter, R.A., Fallon, L.A., Sherman, P.B. and Manipomoke, S. (1988). Economic Analysis of the Environmental Impacts of Development Projects, London: Earthscan Publications.

Dixon, J.A., Scura, L.F., Carpenter, R.A. and Sherman, P.B. (1994). Economic Analysis of Environmental Impacts, London: Earthscan Publications.

Dockel, J.A., Mirrilees, R.I. and Curtayne, P.C. (1990). Cost-benefit analysis in project evaluation: a note recalling first principles, Annual Transportation Convention, Pretoria: Council for Scientific and Industrial Research.

Dorfman, R. and Dorfman, N.S. (1977). Economics of the Environment: Selected Readings, New York: W.W. Norton and Co.

Du Preez, M. (1997). A Cost Benefit Analysis of Alternative Forms of Land Management in the Tsitsikamma Mountain Catchment, Unpublished M.Com Thesis, University of Port Elizabeth, Port Elizabeth.

Du Preez, P. (1998). Ninham Shand Inc. consultant. Personal communication.

DWAF. (1986). Management of the Water Resources of the Republic of South Africa, Pretoria: Department of Water Affairs.

DWAF. (1988). Charlie Malan Dam, Kromme River: Government Water Scheme, Pretoria: Department of Water Affairs and Forestry.

DWAF. (1997a). White Paper on a National Water Policy for South Africa, Pretoria: Department of Water Affairs and Forestry.

DWAF. (1997b). The Greater Hermanus Water Conservation Programme, Brochure produced on behalf of the National Water Conservation Campaign, the Department of Water Affairs and Forestry, and the Greater Hermanus Water Conservation Programme, Pretoria: Department of Water Affairs and Forestry.

Dye, P.J. and Poulter, A.G. (1995). A Field Demonstration on the Effect on Streamflow of Clearing Invasive Pine and Wattle Trees from a Riparian Zone. South African Forestry Journal, 173: 27-30.

Eastern Cape Ministry of Agriculture. (1995). Water supply scheme by controlling alien invader trees in the Krom and Kouga river catchments, Unpublished Draft Business Plan, Bisho: Eastern Cape Ministry of Agriculture and Environmental Affairs.

Eastern Cape Nature Conservation. (1995). Kouga Water Conservation Project, Unpublished Draft Business Plan, Port Elizabeth: Eastern Cape Nature Conservation.

Eastern Cape Nature Conservation. (1996). Kouga Working for Water Project, Unpublished Draft Business Plan, Port Elizabeth: Eastern Cape Nature Conservation.

Eastern Cape Nature Conservation. (1998). Kouga Working for Water Project: Business Plan 1998/99, Port Elizabeth: Eastern Cape Nature Conservation.

Eckstein, O. (1958). Water-Resource Development: The Economics of Project Evaluation, Cambridge: Harvard University Press.

Fuggle, R.F. and Rabie, M.A. (1992). Environmental Management in South Africa, (1987). Threatened plants in the fynbos and karoo biomes, South Africa. Biological Conservation, 40: 11-28.

Hanley, N. and Spash, C.L. (1993). Cost-Benefit Analysis and the Environment, Hants: Edward Elgar Publishing.

Henderson, L. and Wells, M.J. (1986). Alien invasions in the grassland and savanna biomes. In Macdonald, I.A.W., Kruger, F.J. and Ferrar, A.A. (eds), The ecology and management of biological invasions in southern Africa, Cape Town: Oxford University Press.

Huntley, B., Siegfried, R. and Sunter, C. (1989). South African Environments into the 21st Century, Cape Town: Human and Rousseau.

Kluge, R.L., Zimmerman, H.G., Cilliers, C.J. and Harding, G.B. (1986). Integrated control for invasive alien weeds. In Macdonald, I.A.W., Kruger, F.J. and Ferrar, A.A. (eds), The ecology and management of biological invasions in southern Africa, Cape Town: Oxford University Press.

Kruger, F.J. and Lamb, A.J. (1978). Conservation of the Kogelberg State Forest. Preliminary assessment of the effects of management from 1967 to 1978. Unpublished report, Jonkershoek Forestry Research.

Krutilla, J.V. and Fisher, A.C. (1985). The Economics of Natural Environments, Baltimore: John Hopkins University Press.

Le Maitre, D.C., Van Wilgen, B.W., Chapman, R.A. and McKelly, D.H. (1996). Invasive plants and water resources in the Western Cape Province, South Africa: modelling the consequences of a lack of management. Journal of Applied Ecology, 33: 161-172.

Little, I.M.D. and Mirrlees, J.A. (1974). Project Appraisal and Planning for Developing Countries, London: Heinemann Educational Books.

Little, T. (1994). Economics and Water Management, Pretoria: Water Research Commission.

Macdonald, I.A.W., Jarman, M.L. and Beeston, P.M. (1985). Management of invasive alien plants in the fynbos biome, South African National Scientific Programmes, Report no. 111, Pretoria: Council for Scientific and Industrial Research.

Macdonald, I.A.W. and Richardson, D.M. (1986). Alien species in terrestrial ecosystems of the fynbos biome. In Macdonald, I.A.W., Kruger, F.J. and Ferrar, A.A. (eds), The ecology and management of biological invasions in southern Africa, Cape Town: Oxford University Press.

Macdonald, I.A.W. and Wissel, C. (1989). Costing the initial clearance of alien *Acacia* species invading fynbos vegetation. South African Journal of Plant Soil, 6(1): 39-45.

Mentis, M.T. (1990). Private provision of wildlife services. In Vorhies, F. and Grant, R.J. (eds), Liberty and Prosperity, Cape Town: Juta and Co.

Mills, E.S. and Graves, P.E. (1986). The Economics of Environmental Quality (2 ed.), New York: W.W. Norton and Co.

Mirrilees, R.I., Forster, S.F. and Williams, C.J. (1994). The Application of Economics to Water Management in South Africa, WRC Report no. 415/1/94, Pretoria: Water Research Commission.

Mishan, E.J. (1971). Cost-Benefit Analysis, London: George Allen and Unwin.

Munasinghe, M. and Lutz, E. (1993). Environmental Economics and Valuation in Development Decisionmaking. In Munasinghe, M. (ed.), Environmental Economics and Natural Resource Management in Developing Countries, Washington, D.C.: The World Bank/The International Bank for Reconstruction and Development.

Myers, N. (1990). The Biodiversity Challenge: Expanded Hot-Spots Analysis. The Environmentalist, 10: 243-255.

Newson, M. (1992). Environmental Economics: Resources and Commerce. In Newson, M. (ed.), Managing the Human Impact on the Natural Environment, London: Belhaven Press.

Ninham Shand Inc. (1993). The Effect of Invader Plants, Acacia mearnsii (Black Wattle), in the Kouga and Krom River Catchments, Second draft of report PM 000/00/1193 prepared by Ninham Shand Inc. as part of the Algoa Water Resources System Analysis, Port Elizabeth.

Ninham Shand Inc. (1994a). Agricultural Water Demand, report PM 000/00/0493 prepared by Ninham Shand Inc. as part of the Algoa Water Resources System Analysis, Port Elizabeth.

Ninham Shand Inc. (1994b). Preliminary Evaluation of Tsitsikamma River as a Source of Water Supply, report PM 000/00/1093 prepared by Ninham Shand Inc. as part of the Algoa Water Resources System Analysis, Port Elizabeth.

Ninham Shand Inc. (1994c). Project Report, report PM 000/00/1293 prepared by Ninham Shand Inc. as part of the Algoa Water Resources System Analysis, Port Elizabeth.

Ninham Shand Inc. (1994d). Summary Report, report PM 000/00/13/93 prepared by Ninham Shand Inc. as part of the Algoa Water Resources System Analysis, Port Elizabeth.

Ninham Shand Inc. (1996a). Possible Future Augmentation Schemes, report PM 000/00/0395 prepared by Ninham Shand Inc. as part of the Algoa Water Resources Stochastic Analysis, Port Elizabeth.

Ninham Shand Inc. (1996b). Initial Environmental Assessment Summary Report, report PM 000/00/0495 prepared by Ninham Shand Inc. as part of the Algoa Water Resources Stochastic Analysis, Port Elizabeth.

Ninham Shand Inc. (1996c). Project Report, report PM 000/00/0795 prepared by Ninham Shand Inc. as part of the Algoa Water Resources Stochastic Analysis, Port Elizabeth.

Norgaard, R.B. (1991). Sustainability as Intergenerational Equity: The Challenge to Economic Thought and Practice, Internal Discussion Paper, Asia Regional Series, Report no. IDP 97, Washington, D.C.: World Bank.

O'Keeffe, J.H., Uys, M. and Bruton, M.N. (1992). Freshwater Systems. In Fuggle, R.F. and Rabie, M.A. (eds), Environmental Management in South Africa, Cape Town: Juta and Co.

Panayotou, T. (1992). The Economics of Environmental Degradation: Problems, Causes and Responses. In Markandya, A. and Richardson, J. (eds), The Earthscan Reader in Environmental Economics, London: Earthscan Publications.

Pearce, D., Markandya, A. and Barbier, E.B. (1989). Blueprint for a Green Economy, London: Earthscan Publications.

Pearce, D.W. and Nash, C.A. (1981). The Social Appraisal of Projects: A Text in Cost-Benefit Analysis, London: The Macmillan Press Ltd.

Phillips, E.P. (1938). The naturalised species of Hakea. Farming in South Africa, 13: 424.

Prest, A.R. and Turvey, R. (1965). Cost-Benefit Analysis: A Survey. The Economic Journal, 75: 683 - 735.

Puu, T. (1977). On the Profitability of Exhausting Natural Resources. Journal of Environmental Economics and Management, 4(3): 185-199.

Randall, A. (1981). Resource Economics, Columbus: Grid Publishing.

RDP Water Conservation Programme. (1996). Working for water, National Water Conservation Campaign brochure, Pretoria: Ministry of the Reconstruction and Development Programme.

Raymer, D. (1998). City Assistant Engineer, Water Operations, Port Elizabeth Municipality. Personal communication.

Rees, J. (1990). Natural Resources, London: Routledge.

Richardson, D.M., Macdonald, I.A.W., Holmes, P.M. and Cowling, R.M. (1992). Plant and animal invasions. In Cowling, R.M. (ed.), The Ecology of Fynbos: Nutrients, Fire and Diversity, Cape Town: Oxford University Press.

Rowntree, K.M. (1991). An assessment of the potential impact of alien invasive vegetation on the geomorphology of river channels in South Africa. South African Journal of Aquatic Science, 17: 28-43.

Rowntree, K.M. and Beyers, G.J. (1997). An experimental study of the effect of Acacia mearnsii (Black Wattle trees) on streamflow in the Sand River, Zwartkops River Catchment, Eastern Cape, in press.

Rutherford, M.C., Pressinger, F.M. and Musil, C.F. (1986). Standing crops, growth rates and resource use efficiency in alien invaded ecosystems. In Macdonald, I.A.W., Kruger, F.J. and Ferrar, A.A. (eds), The ecology and management of biological invasions in southern Africa, Cape Town: Oxford University Press.

SARB. (1996-1998). Quarterly Bulletins, Pretoria: South African Reserve Bank.

Seydack, A.H.W. and Bekker, S.J. (1995). A review of fynbos catchment management policy. In Boucher, C. and Marais, C. (eds), Managing Fynbos Catchments for Water, FRD programme report series no. 24, Pretoria: Foundation for Research and Development.

Shaughessy, G.L. (1986). A case study of some woody plant introductions to the Cape Town area. In Macdonald, I.A.W., Kruger, F.J. and Ferrar, A.A. (eds), The ecology and management of biological invasions in southern Africa, Cape Town: Oxford University Press.

Sherman, P.B. and Dixon, J.A. (1991). The Economics of Nature Tourism: Determining if it Pays. In Whelan, T. (ed.), Nature Tourism, Washington, D.C.: Island Press.

Siebert, H. (1992). Economics of the Environment, Berlin: Springer-Verlag.

Sinn, M. (1982). The Economic Theory of Species Extinction: Comment on Smith, V.L.. Journal of Environmental Economics and Management, 9(2): 194-198.

Smith, V.L. (1977). Control Theory Applied to Natural Environmental Resources. Journal of Environmental Economics and Management, 4(1): 1-24.

Squire, L. and Van der Tak, H.G. (1975). Economic Analysis of Projects, Baltimore: Johns Hopkins University Press.

Stauth, R.B. (1983). Environmental Economics. In Fuggle, R.F. and Rabie, M.A. (eds), Environmental Concerns in South Africa, Technical and Legal Perspectives, Cape Town: Juta Publishing Co.

Stauth, R.B. and Baskind, H. (1992). Resource Economics. In Fuggle, R.F. and Rabie, M.A. (eds), Environmental Management in South Africa, Cape Town: Juta and Co.

Stirton, C.H. (1978). Why are plant invaders so successful?. In Stirton, C.H. (ed.), Plant Invaders: Beautiful, but dangerous, Cape Town: The Cape Department of Nature and Environmental Conservation.

Tietenberg, T.H. (1992). Environmental and Natural Resource Economics (3rd ed), New York: Harper Collins.

Van Der Merwe, A. (1998). Area Manager, Kouga Working for Water Project. Personal communication.

Van Wilgen, B.W. and Richardson, D.M. (1985). The effects of alien shrub invasions on vegetation structure and fire behaviour in South African fynbos shrublands: a simulation study. Journal of Applied Ecology, 22: 955-966.

Van Wilgen, B.W., Bond, W.J. and Richardson, D.M. (1992). Ecosystem management. In Cowling, R.M. (ed.). The Ecology of Fynbos: Nutrients, Fire and Diversity, Cape Town: Oxford University Press.

Van Wilgen, B.W., Cowling, R.M. and Burgers, C.J. (1996). Valuation of Ecosystem Services: A case study from South African Fynbos ecosystems. Bioscience, 46(3): 184-189.

Van Wyk, D.B. (1987). Some effects of afforestation on streamflow in the Western Cape Province, South Africa. Water S.A., 13: 31-36.

Versfeld, D.B. and van Wilgen, B.W. (1986). Impact of woody aliens on ecosystem properties. In Macdonald, I.A.W., Kruger, F.J. and Ferrar, A.A. (eds), The ecology and management of biological invasions in southern Africa, Cape Town: Oxford University Press.

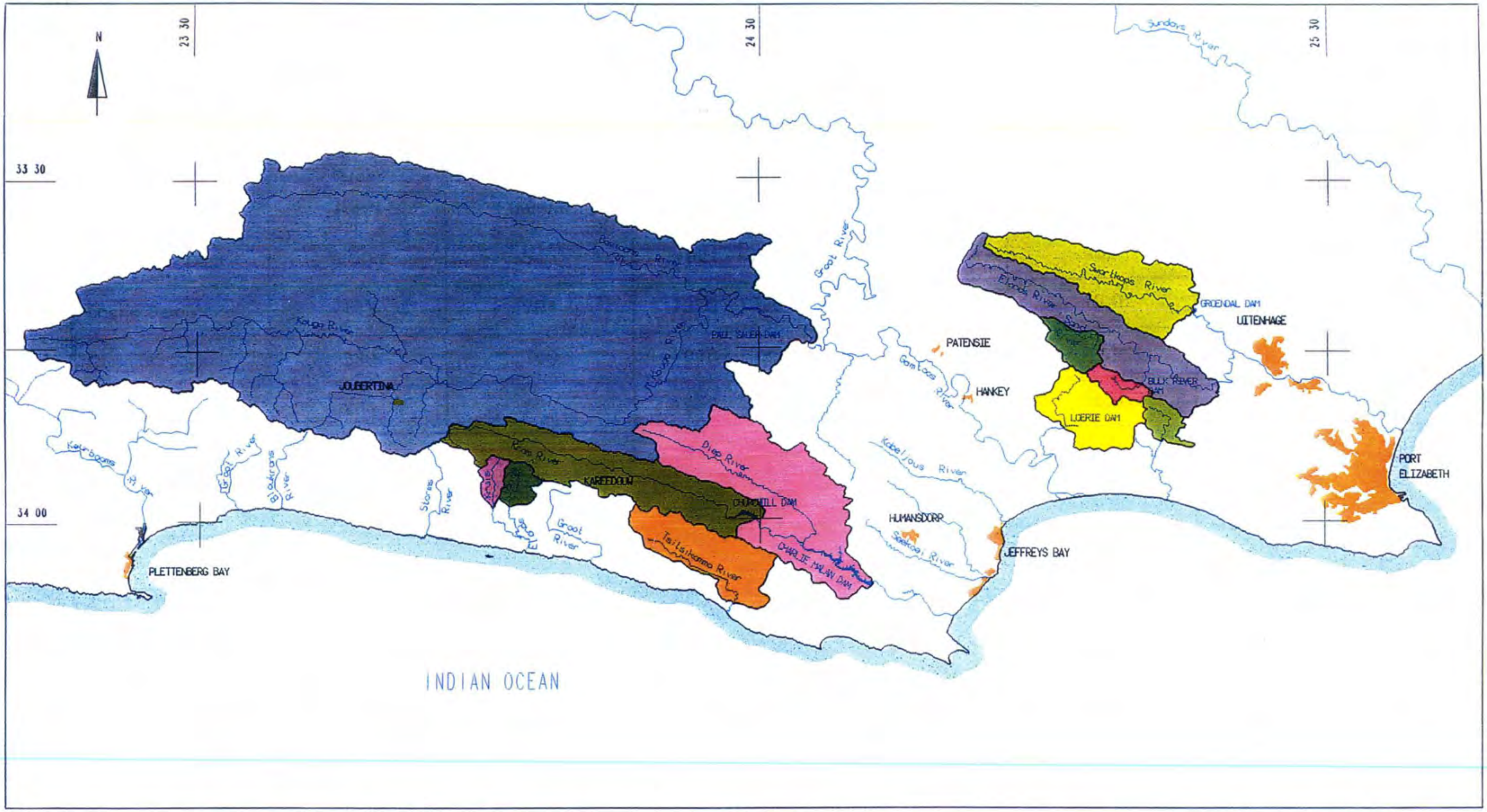
Versfeld, D.B., Le Maitre, D.C. and Chapman, R.A. (1998). Alien Invading Plants and Water Resources in South Africa: A Preliminary Assessment, WRC Report No. TT 99/98, Pretoria: Water Research Commission.

Wells, M.J., Poynton, R.J., Balsinhas, A.A., Musil, K.J., Joffe, H., Van Hoepen, E. and Abbott, S.K. (1986). The history of introduction of invasive alien plants to Southern Africa. In Macdonald, I.A.W., Kruger, F.J. and Ferrar, A.A. (eds), The ecology and management of biological invasions in southern Africa, Cape Town: Oxford University Press.

Wilson. P.A.S. (1985). General Policy Memorandum for the Management of Mountain Catchments in the Western Cape Forest Region, Cape Town: Department of Environment Affairs.

Winpenny, J. (1994). Managing Water as an Economic Resource, London: Routledge.

Working for Water. (1998). Environmental Impacts of Invading Alien Plants in South Africa, Brochure prepared by the CSIR Division of Water, Environment and Forestry Technology for the Working for Water Programme, Pretoria: Department of Water Affairs and Forestry.



Source: Ninham Shand Inc., 1994d

GROENDAL	SWARTKOPS	CHARLIE MALAN	KROM	KRUIS	COASTAL
ELANDS	SWARTKOPS	CHURCHILL	KROM	TSITSIKAMMA	COASTAL
SAND	SWARTKOPS	PAUL SAUER	KOUGA	ELANDS	COASTAL
BULK	SWARTKOPS	LOERIE	KOUGA	VAN STADEN	COASTAL

0 50km

CATCHMENTS - KEYPLAN

Appendix 1

Map of the study area

Appendix 2

Summary of the Krom and Kouga River Catchments hydrological data

Description	Kouga (Kouga River)	Churchill (Krom River)	Impofu (Diep/Krom Rivers)
Sub-catchment area (km^2)	3 900,0	350,0	480,0
Afforested area (1991) km^2	0,3	2,2	1,2
Irrigation area (1991) km^2	59,6	3,5	3,4
Farm dam capacity (1990) ($10^6 m^3$)	22,5	0,2	2,6
Sub-catchment MAP[1] (mm)	546,0	740,0	640,0
Observed MAR[2] for calibration period ($10^6 m^3$)	197,6*	51,5**	10,1***
Naturalised MAR[3] ($10^6 m^3$) (1930 - 1989)	190,0	57,3	16,2
Naturalised runoff coefficient (%)	9,0	22,1	5,3
Present Day HFY[4] (1927 - 1991) ($\times 10^6 m^3$)	70	Combined: 31	

Source: Ninham Shand Inc., 1994c

[1] MAP - Mean Annual Precipitation

[2] MAR - Mean Annual Runoff after the impact of different land uses, afforestation, etc.

* Calibration period: 1961 - 1987

** Calibration period: 1948 - 1991

*** Calibration period: 1983 - 1991

[3] MAR - Mean Annual Runoff which would be expected from a catchment with no impoundments or irrigation and only the natural vegetation present

[4] HFY - Historic Firm Yield: the yield that can be expected from a catchment based on historic data.

Appendix 3

Rates of clearing different infestation levels: ha/man unit and R/ha

Initial clearing	**ha/mu**	**mu/ha**
Dense	0,018	55,55
Medium	0,070	14,28
Light	0,800	1,25
Follow-up clearing		
Dense	0,37	2,70
Medium	0,50	2,00
Light	0,75	1,33

Note: A man unit is equal to a man day

These estimates are based on the experiences of the clearing teams. Working for Water found the average costs per ha to be as follows:

Cost (R/ha) of clearing different infestation levels

Infestation level	**Initial clearing**	**Follow-up clearing**
Dense	3 425	166
Medium	1 027	123
Light	85	82

Source: Eastern Cape Nature Conservation, 1998.

Appendix 4

Cost of follow-up operations

It is assumed that 720 ha are cleared each year (initial clearing), starting in year 0. The area which is cleared each year will receive its first follow-up operation in the next year and will undergo its second follow-up operation the year after that.

	Cost of Follow-up operations		
Year	**No. 1 (R166/ha)**	**No. 2 (R123/ha)**	**Total (Rand)**
1	119 520	0	119 520
2	119 520	88 560	208 080
3	119 520	88 560	208 080
4	119 520	88 560	208 080
5	119 520	88 560	208 080
6	119 520	88 560	208 080
7	119 520	88 560	208 080
8	119 520	88 560	208 080
9	119 520	88 560	208 080
10	119 520	88 560	208 080
11	0	88 560	88 560

Appendix 5.
Derivation of discount rates

Date		Monthly average yield on long-term government bonds		Prime overdraft rate	
End of		Nominal	Real	Nominal	Real
1996:	Jan	13,8	6,4	18,5	11,1
	April	15,8	9,7	19,5	13,4
	May	16,5	10,1	20,5	14,1
	June	15,8	8,4	20,5	13,1
	July	15,4	7,7	19,5	11,8
	Aug	15,8	7,7	19,5	11,4
	Sept	15,4	6,5	19,5	10,6
	Oct	15,8	6,2	19,3	9,7
	Nov	16,2	6,4	20,3	10,5
	Dec	16,2	6,2	20,3	10,3
1997:	Jan	15,8	5,9	20,3	10,4
	Feb	15,0	4,8	20,3	10.1
	March	15,2	5,1	20,3	10,2
	April	15,2	4,9	20,3	10,0
	May	15,1	5,1	20,3	10,3
	June	14,7	5,5	20,3	11,1
	July	14,2	4,8	20,3	10,9
	Aug	14,2	5,2	20,3	11,3
	Sept	14,2	5,7	20,3	11,8
	Oct	14,0	6,2	19,3	11,5
	Nov	14,5	7,3	19,3	12,1
	Dec	14,1	7,6	19,3	12,8
1998:	Jan	13,6	7,5	19,3	13,2
	Feb	13,5	7,7	19,3	13,5
	March	13,3	7,5	18,3	12,5
	April	12,9	7,5	18,3	12,9

Source: SARB, 1996-1998

Real Averages

Period	Yield on long-term government bonds	Prime overdraft rate
1996	7,5	11,6
1997	5,7	11,0
1998	7,6	13,0

For the CBA a discount rate of 7% will be used, as this is a close approximation of the real cost of borrowing money for public investments. The rate advocated by Randall (1981: 211), the social discount rate, is given by the real prime overdraft rate. This rate will be used in a sensitivity analysis.

Appendix 6

Calculation of Net Present Value

Price of water = R1,26

Discount rate: 7%

Year	Net Benefit/(Cost) (R)	Discount Factor	Present Value (R)
0	(2 720 210)	1	(2 720 210)
1	(1 823 250)	.93458	(1 703 973)
2	(713 550)	.87344	(623 243)
3	484 710	.81630	395 669
4	1 682 970	.76290	1 283 938
5	2 881 230	.71299	2 054 288
6	4 079 490	.66634	2 718 327
7	5 277 750	.62275	3 286 719
8	6 476 010	.58201	3 769 103
9	7 674 270	.54393	4 174 266
10	11 461 666	.50835	5 826 538
11	11 581 186	.47509	5 502 106
Net Present Value			R23 963 528

Calculation of Net Present Value

Price of water = R1,26

Discount rate: 12%

Year	Net Benefit/(Cost) (R)	Discount Factor	Present Value (R)
0	(2 720 210)	1	(2 720 210)
1	(1 823 250)	.89286	(1 627 907)
2	(713 550)	.79719	(568 835)
3	484 710	.71178	345 007
4	1 682 970	.63552	1 069 561
5	2 881 230	.56743	1 634 896
6	4 079 490	.50663	2 066 792
7	5 277 750	.45235	2 387 390
8	6 476 010	.40388	2 615 531
9	7 674 270	.36061	2 767 419
10	11 461 666	.32197	3 690 313
11	11 581 186	.28748	3 329 359
Net Present Value			R14 989 316

Appendix 7

Calculation of the IRR

Year	Net Benefit/ (Cost)	Discount Factor (37%)	Present Value	Discount Factor (36%)	Present Value
0	-2 720 210	1	-2 720 210	1	-2 720 210
1	-1 823 250	0.72993	-1 330 844.8725	0.73529	-1 340 617.4925
2	-713 550	0.53279	-380 172.3045	0.54066	-385 787.943
3	484 710	0.3889	188 503.719	0.39754	192 691.6134
4	1 682 970	0.28387	477 744.6939	0.29231	491 948.9607
5	2 881 230	0.2072	596 990.856	0.21493	619 262.7639
6	4 079 490	0.15124	616 982.0676	0.15804	644 722.5996
7	5 277 750	0.1104	582 663.6	0.11621	613 327.3275
8	6 476 010	0.08058	521 836.8858	0.08545	553 375.0545
9	7 674 270	0.05882	451 400.5614	0.06283	482 174.3841
10	11 461 666	0.04293	492 049.32138	0.0462	529 528.9692
11	11 581 186	0.03134	362 954.36924	0.03397	393 412.88842
NPV			-R140 101.10268		R73 829.12582

The IRR for the eradication programme is thus between 36% and 37%

Appendix 8

Calculation of Net Present Value

Price of water = R2,40

Discount rate: 7%

Year	Net Benefit/(Cost) (R)	Discount Factor	Present Value (R)
0	(2 720 210)	1	(2 720 210)
1	(739 110)	.93458	(690 757)
2	1 454 730	.87344	1 270 619
3	3 737 130	.81630	3 050 619
4	6 019 530	.76290	4 592 299
5	8 301 930	.71299	5 919 193
6	10 584 330	.66634	7 052 763
7	12 866 730	.62275	8 012 756
8	15 149 130	.58201	8 816 945
9	17 431 530	.54393	9 481 532
10	22 303 066	.50835	11 337 764
11	22 422 586	.47509	10 652 746
Net Present Value			R66 776 269

Calculation of Net Present Value

Price of water = R2,40

Discount rate: 12%

Year	Net Benefit/(Cost) (R)	Discount Factor	Present Value (R)
0	(2 720 210)	1	(2 720 210)
1	(739 110)	.89286	(659 922)
2	1 454 730	.79719	1 159 696
3	3 737 130	.71178	2 660 014
4	6 019 530	.63552	3 825 532
5	8 301 930	.56743	4 710 764
6	10 584 330	.50663	5 362 339
7	12 866 730	.45235	5 820 265
8	15 149 130	.40388	6 118 431
9	17 431 530	.36061	6 285 984
10	22 303 066	.32197	7 180 918
11	22 422 586	.28748	6 446 045
Net Present Value			R46 189 856

Appendix 9

Tsitsikamma/Krom transfer scheme:

Calculation of Unit Reference Value

ALGOA WATER RESOURCES SYSTEM ANALYSIS: TSITSIKAMMA SCHEME
COSTS IN MILLION RAND
PRICES AT MARCH 1993 VOLUMES IN MILLION CUBIC METRES
SUPPLY IN MILLION CUBIC METRES PER YEAR

SCHEME: Dam Cap. = 5.0 Divers. Cap.= 2.60 mil cub.m./ per month
Annual Supply: 20

COMPONENTS	CIVIL	MECH	ELEC	TOTAL
DAM	4.0			4.0
PUMPSTATION: CIVIL	5.9			5.9
MECH		9.8	2.5	12.3
SUB TOTALS	9.8	9.8	2.5	22.1
PIPELINES	10.1			10.1
TOTAL COSTS	19.9	9.8	2.5	32.2
				32.2

Pipe Diameters (mm):
Rising Main 900
Gravity Main 600

Flow Velocities (m/s):
Rising Main 1.56
Gravity Main 3.50

Hazen Williams Constant 130

Pump and Motor Efficiency 0.675

CALENDAR YEAR	YEAR	DEMAND	DAM COSTS			PIPE COSTS	PUMP COSTS	RUN. COSTS	ELEC. COSTS
1993		0	2.0			5.0	2.9		
1994		0	2.0			5.0	15.2		
1995	1	5						0.57	1.37
1996	2	10						0.57	1.37
1997	3	15						0.57	1.37
1998	4	20						0.57	1.37
1999	5	20						0.57	1.37
2000	6	20						0.57	1.37
2001	7	20						0.57	1.37
2002	8	20						0.57	1.37
2003	9	20						0.57	1.37
2004	10	20						0.57	1.37
2005	11	20						0.57	1.37
2006	12	20						0.57	1.37
2007	13	20						0.57	1.37
2008	14	20						0.57	1.37
2009	15	20					2.5	0.57	1.37
2010	16	20						0.57	1.37
2011	17	20						0.57	1.37
2012	18	20						0.57	1.37
2013	19	20						0.57	1.37
2014	20	20						0.57	1.37
2015	21	20						0.57	1.37
2016	22	20						0.57	1.37
2017	23	20						0.57	1.37
2018	24	20						0.57	1.37
2019	25	20						0.57	1.37
2020	26	20						0.57	1.37
2021	27	20						0.57	1.37
2022	28	20						0.57	1.37
2023	29	20						0.57	1.37
2024	30	20					12.3	0.57	1.37
2025	31	20						0.57	1.37
2026	32	20						0.57	1.37
2027	33	20						0.57	1.37
2028	34	20						0.57	1.37
2029	35	20						0.57	1.37
2030	36	20						0.57	1.37
2031	37	20						0.57	1.37
2032	38	20						0.57	1.37
2033	39	20						0.57	1.37
2034	40	20						0.57	1.37
2035	41	20						0.57	1.37
2036	42	20						0.57	1.37
2037	43	20						0.57	1.37
2038	44	20						0.57	1.37
2039	45	20					2.5	0.57	1.37
PRESENT VALUE @	6.00%	250.9	3.7	0.0	0.0	9.2	19.2	7.8	18.9
		UNIT REFERENCE VALUE =					0.23	(R/m^3)	
PRESENT VALUE @	8.00%	185.0	3.6	0.0	0.0	9.0	17.5	5.9	14.3
		UNIT REFERENCE VALUE =					0.27	(R/m^3)	
PRESENT VALUE @	10.00%	141.8	3.5	0.0	0.0	8.7	16.3	4.6	11.2
		UNIT REFERENCE VALUE =					0.31	(R/m^3)	
PRESENT VALUE @	17.00%	68.9	3.2	0.0	0.0	8.0	13.8	2.4	5.9
		UNIT REFERENCE VALUE =					0.48	(R/m^3)	

Source: Ninham Shand Inc., 1994b

Appendix 10

Summary of the study by Van Wilgen *et al.*, 1996

Catchment descriptor	With the management of alien plants	Without the management of alien plants
Area (ha)	10 000	10 000
Mean annual rainfall (mm)	1 500	1 500
Postfire age (years)	15	15
Vegetation cover	70% short ericoid-restioid fynbos; 30% tall moist fynbos	33% tall alien shrubs; 33% medium alien trees; 33% tall alien trees
Capital cost of clearing initial infestations ($/ha)	830	0
Capital cost of developing water supply facility (millions of $)	67,7	67,7
Capital cost of building water supply facility plus initial clearing f aliens (millions of $)	76	67,7
Annual interest on capital cost at 8% (millions of $)	6,1	5,4
Cost of alien plant management (operating cost, $/ha/yr)	8	0
Operating cost of water supply facility (millions of $ per year)	1,29	1,29
Total operating costs (alien plants plus water supply facility; millions of $ per year)	1,37	1,29
Total annual costs (interest plus operating; millions of $ per year)	7,47	6,69
Aboveground biomass (g/m^2)	3 867	10 964
Streamflow from catchment without vegetation (mm rainfall equivalent)	742	742
Reduction in streamflow due to plant biomass at 15 years postfire (mm rainfall equivalent)	114	256
Water yield (million m^3/yr)	62,7	48,6
Unit cost of water	11,9	13,8

Source: Van Wilgen *et al.*, 1996: 188.

Note: The figures used in the text have been converted at R3,96 to the dollar, the average of the 1995/1996 exchange rates.