Water for Food and Ecosystems in the Baviaanskloof Mega Reserve

Land and water resources assessment in the Baviaanskloof, Eastern Cape Province, South Africa

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ABSTRACT

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This report describes the results of the land and water assessment for the project 'Water for Food and Ecosystems in the Baviaanskloof Mega Reserve'. Aim of the project is to conserve the biodiversity in a more sustainable way, by optimizing water for ecosystems, agricultural and domestic use, in a sense that its also improving rural livelihoods in the Baviaanskloof. In this report an assessment of the land and water system is presented, which forms a basis for the development and implementation of land and water policies and measures.

Keywords: competing claims, IWRM, land management, nature conservation, policy support, water management, water retention

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Preface

As follow-up of the conference on Water for Food and Ecosystems, organised by FAO and the Government of the Netherlands, a partnership between the Dutch Ministry of Agriculture, Nature and Food Quality (LNV) and South-Africa was established. Within the framework of this partnership the project "Water for Food and Ecosystems in the Baviaanskloof Mega Reserve" is being executed.

Given that water is a crucial factor for the present environmental and economical functions of the Baviaanskloof (and its downstream areas), this report provides a land and water assessment. Although issued by Alterra BV/ Wageningen University & Research Centre many organizations and individuals have contributed to this report through valuable data, communications and feedback. The author wants to express his gratitude to:

- The Department of Water Affairs for their excellent and transparent informatior supply through their website and staff. Special thanks to Marica Erasmus, Maureen Fritz, Desireè Hector, Nondumiso Mabe, Jane Mogaswa, Jackie Oosthuizen and Ritha Wentzel.
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Opsomming in Afrikaans

Agtergrond van die projek

In opvolging op die konferensie oor Water vir Voedsel en Ekosisteme ("Water for Food and Ecosystems"), georganiseer deur FAO en die Nederlandse Regering, het 'n vennootskap tussen die Nederlandse Departement van Landbou, "Nature and Food Quality (LNV)" en Suid-Afrika tot stand gekom. Binne die raamwerk van hierdie samewerkings-ooreenkoms is die projek "Water for Food and Ecosystems in the Baviaanskloof Mega Reserve" tot uitvoer gebring.

Die Baviaanskloof is 'n 75 km lange vallei tussen twee bergreekse in die Oos-Kaap Provinsie (Suid-Afrika). Die gebied is 'n biodiversiteit ryke area ("hotspot") en word beskou as 'n unieke Wêreld Erfinisgebied as gevolg van die natuurskoon en biodiversiteit, wat van internasionale belang is. Die gebied is uitsonderlik uiteenlopend met meer as 1000 plantspesies wat opgeteken is, insluitende minstens 52 "Red Data Book" en 20 endemiese plant taxa, asook 'n groot fauna diversiteit. Die gebied is deel van die be-oogde Baviaanskloof Megareserve (BMR) van ongeveer 500 000 ha, wat bestaan uit 'n groot gedeelte staatsgrond binne 'n netwerk van privaat- en gemeenskapsgronde.

Daar bestaan 'n sterk behoefte om die natuurskoon van die Baviaanskloof te beskerm en te bewaar, terwyl die landelike lewenskwaliteit verbeter behoort te word. Hierdie landelike gemeenskappe ondervind toenemende druk op grond en waterbronne en verminderde opbrengste op landbou-insette. Alternatiewe inkomste-genererende aktiwiteite soos (eko)toerisme word tans ontwikkel.

Die Baviaanskloof toon reeds verskeie grond- en waterprobleme, soos verhoogde erosie van rivierwalle en watertekorte, wat weer 'n nadelige uitwerking op ekosisteme en landbou het. Na verwagteing sal hierdie probleme vererger word as gevolg van globale klimaatsverandering.

Beide die Baviaanskloof en die aangrensende gebied (Kougarivier opvanggebied) verskaf water aan die Kougadam. Hierdie dam voorsien water aan die stroom-af besproeiingsgronde en huishoudelike water aan die Nelson Mandelabaai Munisipaliteit. Daar word voorsien dat die reeds bestaande druk op waterbronne in die nabye toekoms sal toeneem.

Projek doelwitte

Die hoof doelwit van die projek is om die biodiversiteit op 'n meer volhoubare manier te bewaar deur water vir ekosisteme en landbou-en huishoudelike gebruik op so 'n wyse te optimiseer dat dit ook die lewensomstandighede in die Baviaanskloof sal verbeter.
Water is 'n noodsaaklike faktor vir die huidige omgewings-en ekonomiese funksionering van die Baviaanskloof en stroom-af gebied. In hierdie verslag word 'n

grond- en water waardebepaling aangebied, wat daarop gemik is om maatreëls voor te stel wat bestaande en toekomstige probleme sal identifiseer. Die grond-en water waardebepaling het ook ten doel om inligting vir 'n finansiële plan te genereer, byvoorbeeld "Payment for Environmental Services" (PES) skemas waarvoor afsonderlike studies van die evaluasie van water en ekosisteme gedoen word.

Waterbronne en gebruike

Die reënval in die Baviaanskloof is betreklik laag. Die gemiddelde jaarlikse reënval is ongeveer 300 mm. Die reënval is egter baie wisselvallig met 'n groot inter-jaarlikse variasie. Die potensiële evapotranspirasie oorskry die maandelikse reënval elke maand van die jaar.

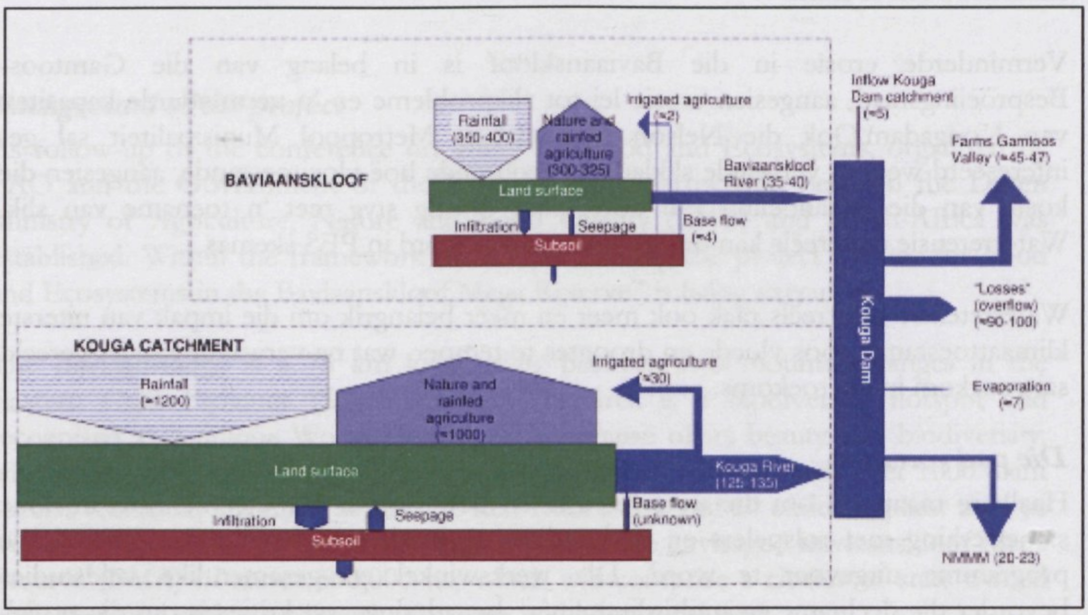
As gevolg van die wisselvalligheid in reënval, wissel die vloei in die Baviaans-en Kouga opvangebiede ook geweldig. Gemiddeld voorsien die Baviaanskloof 35-40 miljoen m^3 per jaar aan die Kougadam (ongeveer 20%). Die Kougarivier voorsien jaarliks 125-135 miljoen m^3. Die bydrae van grondwater tot die riviere is in beide die Baviaanskloof en Kouga opvangebiede gering.

Gemiddeld word ongeveer 40% van hierdie water ekonomies gebruik deur stroom-af gebruikers, met boere in die Gamtoosvallei (ongeveer 2/3) en Nelson Mandelabaai Metropool Munisipaliteit (1/3) met die grootste toekennings. Die volgende tabel gee 'n uiteensetting..

Watergebruiker	Watergebruik (miljoen m^3/jaar)
Landbou Baviaanskloof	2
Lanbou Kouga opvanggebied	30-35
Landbou Gamtoosvallei	45-47
Plaaslike huishoudelike verbruikers	1
NMMM (Port Elizabeth)	20-23
Krag-opwekking*	0

* Daar word tans geen water gebruik vir krag-opwekking nie, maar dit mag 'n potensiële water aanspraak word.

Die volgende diagram toon gemiddelde waterbalanse (in miljoene m^3 per jaar):



Watertekorte

Ten einde (seisoenale) watertekorte in die Baviaanskloof en stroom-afgebiede te verlig, kan addisionele opgaring in die opvanggebied bewerkstellig word. Maatreëls behoort daarop gemik te wees om die basisvloei van die Baviaansrivier gedurende droë tye te verhoog. Moontlike opsies is verbeterde/kunsmatige groundwater opgaring maatreëls deur infrastruktuur (bv. stuwalle, skanskorwe ("gabions"), infiltrasieputte en/of kontoerslote). Bykomend is dit ook moontlik om die hidrologiese eienskappe van die grond te verbeter deur (her)vestiging van inheemse plantegroei. Alhoewel die netto beskikbaarheid deur die jaar mag afneem, (want plantegroei gebruik ook water), kan die vehoogde infiltrasietempo gedurende oormatige reënval 'n verhoogde beskikbaarheid van water in kritiese tye tot gevolg hê. Boere en bewoners in gemeenskappe in die Baviaanskloof (en Kouga opvanggebied) kan betrek word by waterretensie- en waterbewaringsprogramme.

Bykomend tot hierdie voorsienings-bestuur maatreëls kan toekomstige watertekorte verminder word deur die herverdeling van waterhulpbronne, ingestel op die optimalisering van die ekologiese en ekonomiese verhaling van skaars hulpbronne.

Land degradasie

Die huidige erosieprobleme hou verband met veranderinge in die grondbedekking, die vinniger afvloei as gevolg van kanalisering van water vanaf sy-inlope en bergfonteine (bv.die bou van walle), en die (plaaslike) verlaagde watertafel as gevolg van onttrekking. Metodes om erosie te bekamp, behoort daarop gemik te wees om die waterhouvermoë in die opvanggebied te verhoog (bo en behalwe vallei-bosveld/fynbos rehabilitasie programme). Waterretensie maatreëls behoort ook die vergroting van vloedvlaktes deur die verwydering van keerwalle, skep van en/

rehabilitasie van aangrensende vleiland areas en moontlik die bou van stuwalle en/of skanskorwe in te sluit.

Verminderde erosie in die Baviaanskloof is in belang van die Gamtoos-Besproeiingsraad, aangesien erosie lei tot slikprobleme en 'n verminderde kapasiteit van Kougadam.Ook die Nelson Mandelabaai Metropool Munisipaliteit sal ge-intereseerd wees in verlaagde slikladings gedurende hoë vloeitoestande, aangesien die koste van die behandeling van drinkwater drastig styg met 'n toename van slik. Waterretensie maatreëls kan dus ge-inkorporeer word in PES skemas.

Waterretensie maatreëls raak ook meer en meer belangrik om die impak van uiterste klimaattoestande soos vloede en droogtes te temper, wat na verwagting meer gereeld sal voorkom in die toekoms.

Die pad vorentoe

Haalbare maatreëls om die waterretensie en bewaring te verbeter behoort in noue samewerking met rolspelers en deskundiges in biodiversiteit en rivier rehabilitasie programme uitgevoer te word. Die werkswinkel en gesamentlike veldstudies bevorder die deelname en multi-dissiplinêre benadering, wat krities is om die projek se doelwitte te bereik.

Daar behoort goeie begrip van die fisiese omgewing te wees alvorens enige infrastruktuur maatreëls ge-implementeer word. Dit word sterk aanbeveel dat maatreëls om inligting te bekom, gemonitor word ten einde inligting saam te stel wat gebruik kan word om maatreëls op te gradeer of om maatreëls in ander opvanggebiede met soortgelyke probleme in werking te stel.

Executive summary

Background of the project

As follow-up of the conference on Water for Food and Ecosystems, organised by FAO and the Government of the Netherlands, a partnership between the Dutch Ministry of Agriculture, Nature and Food Quality (LNV) and South-Africa was established. Within the framework of this partnership the project "Water for Food and Ecosystems in the Baviaanskloof Mega Reserve" is being executed.

The Baviaanskloof is a 75 km long valley between two mountain ranges in the Eastern Cape Province (South Africa). The area is a biodiversity hotspot and recognised as a unique World Heritage Site because of its beauty and biodiversity, which has global importance. This area is exceptionally diverse with over 1000 plant species recorded, including at least 52 Red Data Book and 20 endemic plant taxa, as well as a large faunal diversity. The area is part of the envisaged Baviaanskloof Mega Reserve (BMR) of about 500,000 ha, which will comprise a cluster of state owned protected land within a network of private and communal land.

There is a strong desire to secure and conserve the natural beauty of the Baviaanskloof, while at the same time the rural livelihoods should be improved. These rural livelihoods experience increasing pressure on land and water resources and declining returns on agricultural investments. Alternative income generating activities such as (eco)tourism are being developed.

In the Baviaanskloof various land and water problems have already become manifest, such as increased stream bank erosion and water shortages, having detrimental effects on ecosystems and on agriculture. These problems are likely to aggravate due to the global climate change.

Both the Baviaanskloof and the neighbouring area (Kouga River catchment) supply water to the Kouga Dam. This dam supplies irrigation water to the downstream agricultural lands and drinking water to the Nelson Mandela Bay Metropolitan Municipality (Port Elizabeth). It is foreseen that in the near future the already existing pressure on water resources will further increase.

Project objectives

The main objective of the project is to conserve the biodiversity in a more sustainable way, by optimizing water for ecosystems, agricultural and domestic use, in a sense that its also improving rural livelihoods in the Baviaanskloof.

Water is a crucial factor for the present environmental and economical functions of the Baviaanskloof and its downstream areas. In this report a land and water assessment is presented, aimed at identifying and recommending on measures that can alleviate existing land and water problems in the Baviaanskloof and related areas, and to anticipate future problems. The land and water assessment is also aimed at generating information for financial schemes, for example "Payment for Environmental Services" (PES) schemes, for which separate studies on the valuation of water and ecosystems are being conducted.

Water resources and uses

In the Baviaanskloof rainfall is relatively low. The average annual rainfall is about 300 mm. The rainfall is, however, very erratic with a large inter-annual temporal variability. During each month of the year the potential evapotranspiration exceeds the rainfall.

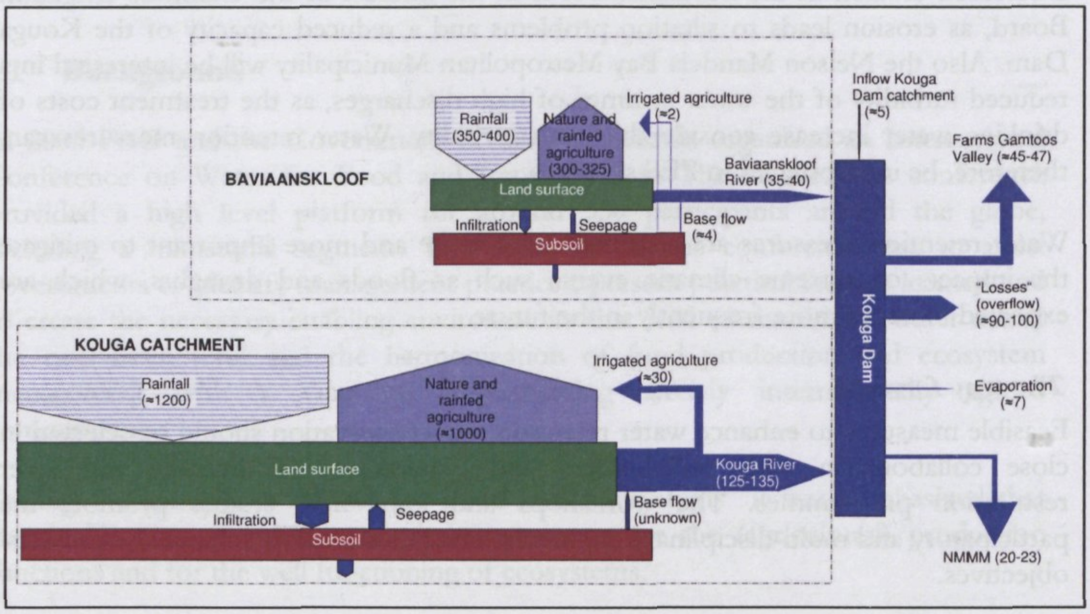
Due to the erraticness of the rainfall the discharges from the Baviaanskloof and Kouga catchments vary largely. On average the Baviaanskloof River supplies 35-40 million m^3 per year to the Kouga Dam (approximately 20%). The Kouga River supplies annually 125-135 million m^3. Both in the Baviaanskloof and in the Kouga catchment the contribution of groundwater to the river discharge is small.

On average approximately 40 % of this water is economically used by downstream users, with the farmers in the Gamtoos Valley (approximately 2/3) and the Nelson Mandela Bay Metropolitan Municipality (1/3) having the largest share. The following table presents an overview.

Water user	Water use (million m^3/year)
Agriculture Baviaanskloof	2
Agriculture Kouga catchment	30-35
Agriculture Gamtoos Valley	45-47
Local domestic water users	1
NMMM (Port Elizabeth)	20-23
Power generation*	0

* There is presently no water used for power generation, but it may be a potential future water claim.

The following scheme presents average water balances (values in million m^3 per year):



Water shortages

To alleviate (seasonal) water shortages in the Baviaanskloof and downstream areas some additional water storage can be created in upstream areas. Measures should be aimed at increasing the base flow of the Baviaanskloof River during dry periods. Possible options are enhanced/artificial groundwater recharge measures through infrastructures (e.g. weirs, gabions, infiltration pits and/or contour trenches). In addition, it is possible to improve the hydraulic properties of soils through the (re)planting of indigenous vegetation. Although the net water availability over the year may decrease (as vegetation also consumes water) the increased infiltration rates during excessive rainfall events can result in an increase of the water availability in the critical periods. Farmers and inhabitants of the villages in the Baviaanskloof (and Kouga catchment) can be involved in water retention and water conservation programmes.

In addition to these *supply management* measures future water shortages can be relieved by the reallocation of water resources, aimed at maximizing the ecological and economical returns of scarce resources.

Land degradation

The current erosion problems are associated with changes in the land cover, the faster diversion of water from the side valleys and mountain springs (e.g. by the erection of embankments), and the (locally) lowered drainage base due to abstractions. Measures to combat erosion should be aimed at increasing the water retention in the catchment (in addition to thicket/fynbos restoration programmes). Water retention measures should include the increase of the floodplain areas through the removal of embankments ("*keerwalle*"), the creation and/or rehabilitation of (riparian) wetland areas and, possibly, the construction of weirs and/or gabions. Decreased erosion in the Baviaanskloof is in the interest of the Gamtoos Irrigation Board, as erosion leads to siltation problems and a reduced capacity of the Kouga Dam. Also the Nelson Mandela Bay Metropolitan Municipality will be interested in a reduced turbidity of the water at times of high discharges, as the treatment costs of drinking water increase considerably with turbidity. Water retention measures can, therefore, be incorporated in PES schemes.

Water retention measures are also becoming more and more important to mitigate the impacts of extreme climatic events such as floods and droughts, which are expected to occur more frequently in the future.

The way forward

Feasible measures to enhance water retention and conservation should be selected in close collaboration with stakeholders and experts on biodiversity and river restoration programmes. The workshops and joint field studies promote the participatory and multi-disciplinary approach, which is critical to achieve the projects' objectives.

The physical environment should be well understood before any infrastructural measures be implemented. It is highly recommended to monitor measures to generate information that can be used to upscale measures or to apply measures in other catchments, which experience similar problems.

1 Introduction

1.1 Background

In 2005 FAO and the Government of the Netherlands organized an International Conference on Water for Food and Ecosystems in The Hague. The conference provided a high level platform for around 350 participants around the globe, including a ministerial segment. The objective of this conference was to assist governments to identify management practices, present practical lessons learned and to create the necessary enabling environments that lead to sustainable water use at the river-basin level and the harmonization of food production and ecosystem management with a view to implementing already internationally agreed commitments.

During the conference "Water for Food and Ecosystems" it was emphasized that sustainable use of water is of vital importance for the (agricultural) production functions and for the well functioning of ecosystems.

As follow-up of this conference and to implement new concepts for sustainable water management for food and ecosystems partnerships between countries were established. The project "Water for Food and Ecosystems in the Baviaanskloof Mega Reserve" is being executed in the framework of the Water Partnership of the Dutch Ministry of Agriculture, Nature and Food Quality (LNV) with South-Africa.

1.2 Problem statement

The Baviaanskloof is a 75 km long valley between two mountain ranges in the Eastern Cape Province, in the southern part of South Africa. The area is a biodiversity hotspot and recognised as a unique World Heritage Site because of its outstanding natural beauty and biodiversity (fynbos[1] and thicket), which has global importance. This area is exceptionally diverse with over 1000 plant species recorded, including at least 52 Red Data Book and 20 endemic plant taxa, as well as a large faunal diversity. The Baviaanskloof Nature Reserve (184,000 ha) is part of the envisaged Baviaanskloof Mega Reserve (BMR)of about 500,000 ha, which will comprise a cluster of state owned protected land within a network of private and communal land.

In the Baviaanskloof, in particular in the upstream areas, most of the private land is owned by farmers, while there are also small settlements. Most of the downstream areas as well as most of the highest mountainous areas is owned by the Eastern Cape Parks Board. There is a strong desire to secure and conserve the natural beauty of the

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1 Fynbos is referred to as the natural shrub land or heath land vegetation occurring in a small belt of the Eastern and Western Cape of South Africa.

Baviaanskloof, while at the same time the rural livelihoods should be improved. These rural livelihoods experience increasing pressure on land and water resources and declining returns on agricultural investments, e.g. due to the long distances to markets. The agricultural production is thus under pressure and various farmers have developed alternative income generating activities such as (eco)tourism. These new activities can have implications for land and water resources.

In the Baviaanskloof various land and water problems have already become manifest, such as increased stream bank erosion and water shortages, both having detrimental effects on ecosystems and on agriculture. In dry periods there are water shortages, while in rainy periods peak discharges cause erosion[2] and (potential) damage to infrastructures. It is expected that these phenomena be aggravated by the global climate change, which causes higher temperatures and more variability in rainfall in the Baviaanskloof. As a result the area can become exposed to more frequent floods and droughts.

Both the Baviaanskloof and the neighbouring area (Kouga River catchment) supply water to the Kouga Dam. This dam supplies irrigation water to the downstream agricultural lands and drinking water to the Nelson Mandela Bay Metropolitan Municipality (Port Elizabeth). It is foreseen that in the near future the already existing pressure on water resources will further increase. In combination with the previously mentioned water shortages, land degradation and extreme events, this will have further impacts on agriculture, domestic water users and ecosystems.

1.3 Objectives

The main objective of the project is to conserve the biodiversity in a more sustainable way, by optimizing water for ecosystems, agricultural and domestic use, in a sense that its also improving rural livelihoods in the Baviaanskloof.

Water is a crucial factor for the present environmental and economical functions of the Baviaanskloof and its downstream areas. The project, therefore, starts with a land and water assessment. The aim of this assessment is to identify and recommend on measures that can alleviate existing land and water problems in the Baviaanskloof and related areas, and to anticipate future problems (listed in Section 1.2).

The land and water assessment is also aimed at generating information for financial schemes, for example "Payment for Environmental Services" (PES) schemes.

[2] Enhanced by changes in land cover.

1.4 Approach and activities

The project starts with an integrated assessment of all interdependent land and water resources, including the Baviaanskloof, the (downstream) land and water uses in the Gamtoos Valley and the adjacent Kouga catchment. Both the water resources system and the water uses are investigated and quantified. The investigation also addresses the spatial and temporal variability of water resources, and trends.

In a separate study the "value of water" (for food and ecosystems) is being investigated. Both the information from the land and water assessment and the study on water valuation are inputs for policy advice about the trade-offs between water for food and ecosystems. Issues to be addressed include the foregone benefits of diverting and reallocation of water. Options that incorporate land and water management measures in PES[3] schemes can also be elaborated.

The project, therefore, consist of the following activities:
1) Hydrological assessment of the Baviaanskloof area and its interrelated catchments, and the identification of measures to improve land and water management for agriculture and ecosystems.
2) Estimation of the value of water for the various water users in the Baviaanskloof Mega Reserve (not only the production value of water will be estimated, but also social and environmental values will be assessed for the various water uses);
3) Investigation of the option of "Payment for Environmental Services" (PES);
4) Implementation of no-regret measures in the catchment of the Baviaanskloof and at the farm- level;

This report presents the result of the hydrological assessment (Activity 1).

1.5 Project organization

The project is being executed by the Research Institute for the Green Environment/Alterra, the Agricultural Economics Research Institute/LEI and the Government Service for Land and Water Management/DLG in the Netherlands.

The project is attuned with the WB/GEF sponsored programme "Cape Action for People and the Environment" (C.A.P.E), which has been established for the entire Cape Floristic Region. The CAPE programme is being coordinated by the South African National Biodiversity Institute (SANBI). A separate Project Management Unit (PMU) was created for the Baviaanskloof Mega Reserve Project. The PMU has elaborated a Conservation Strategy 2004-2006 and a Land Consolidation and Expansion Strategy 2004-2007. The PMU has now been decommissioned and the Eastern Cape Parks Board (ECPB) has taken over the responsibilities for the conservation, land consolidation and expansion of the Baviaanskloof Mega Reserve.

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[3] Payment for Environmental Services.

The project also co-operates intensively with the PRESENCE Network (Participatory Restoration of Ecosystem Services and Natural Capital, Eastern Cape), whose secretariat is executed by Living Lands. PRESENCE are intensively involved in restoration programmes, and they facilitate and co-supervise field work and research on water valuation and on the feasibility of PES schemes.

Since the project is integrated and area-based, many organisations and individuals having an interest or stake in the project have also contributed, being the Baviaanskloof farmers, inhabitants and land owners, as well as the Gamtoos Irrigation Board.

The Ministry of Agriculture, Nature and Food Quality (LNV) is represented by the Agricultural Councillor at the Netherlands Embassy in Pretoria. LNV is also DLG's parent organisation. All the activities in this project have been implemented in close coordination with the Agricultural Councillor.

1.6 Related initiatives and projects

The new South African Water Law provides a good basis for the integrated approach of this project. The law provides for the "ecological reserve" for nature. To determine the ecological reserve of the Baviaanskloof River a monitoring programme for the entire Gamtoos catchment, including the Baviaanskloof River, started in 2008. The results of this programme will be compiled in a 'State of the River report'. This monitoring is part of the nation-wide River Health programme (RHP) that will provide water resource managers with information to manage river health in an ecologically sound and integrated way, as stated in the National Water Act.

This project will as much as possible synergize with these activities and envisages to exchange information and experience.

The project will also liaise with the South African programmes "Working for Water" and "Working for Wetlands", aiming at eradicating invasive non-indigenous species and nature restoration.

1.7 Structure of report

The land and water assessment starts with a brief general overview of the physical setting of the Baviaanskloof, which includes the climate, geology, soils, surface water- and groundwater resources, and land use (Chapter 2). In Chapter 3 the various claims on the water resources are identified and quantified. These claims do not only refer to the Baviaanskloof, but also to its interrelated catchments, being the Kouga catchment and the Gamtoos Valley.

The water resources in the study area are investigated in Chapter 4. In this chapter the various components of the hydrological system are assessed and an overall water balance is elaborated.

The existing land and water problems are analysed in more detail in Chapter 5, being the defragmentation of nature areas, water shortages, land degradation and erosion, and the erratic nature of the water resources. The feasibility and implications of various water management policies to deal with water shortages are also presented.

Chapter 6 presents policy options, possible interventions and measures that can alleviate the existing land and water problems. The feasibility to incorporate these measures in PES schemes is also addressed.

Conclusions and recommendations follow in Chapter 7.

2 Physical setting of the Baviaanskloof

2.1 Location and topography

The Baviaanskloof is situated South-East of Willowmore and approximately 100 km north-west of Port Elizabeth. Its most southern point is 50 km from the Indian Ocean. Approximate coordinates are from 23°35'E to 24°25'E and 33°30'S to 33°45'S.

The area is very rugged and deeply folded with the exception of the valley bottom which consists of a fairly flat floodplain. The mountains are very steep, with only one third having a slope of less than 30% (Illgner and Haigh, 2003). The elevation of the valley floor ranges from approximately 700 to 300 m +MSL (= above mean sea level).

To the north the area is bounded by the Baviaanskloof Mountain range and to the South by the Kouga Mountains. The floodplain is divided into alluvial plains by higher-lying erosion-resistant ground.

Figure 1 presents the surface elevation map. The mountain ranges to the north and south have peaks up to 1626 and 1758 m. +MSL, respectively. The lowest point is at the confluence with the Kouga River at less than 160 m. +MSL (see also Illgner and Haigh, 2003).

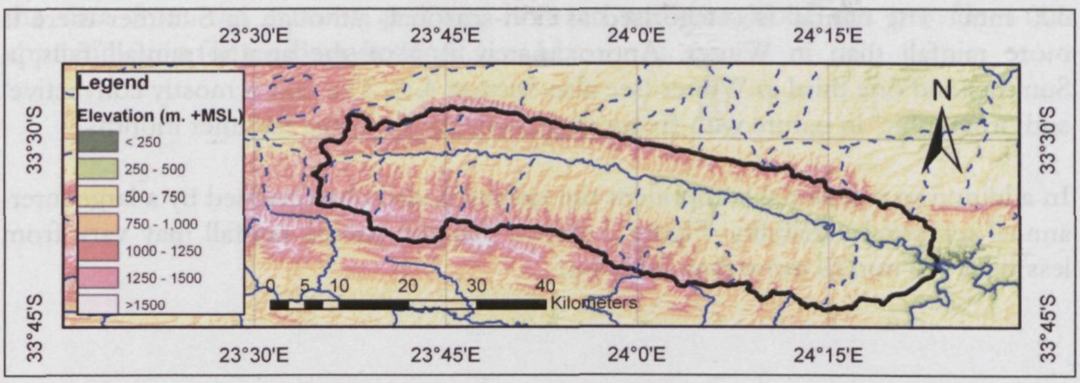

Figure 1. Surface elevation map Baviaanskloof

2.2 Climate

Temperature and wind

The Baviaanskloof has a pleasant climate. In the valley the average maximum temperatures range from 32 °C in January/February to 20 °C in June/July. The average minimum temperatures vary from 16 °C in January/February to 5 °C in July, but extremes down to -3 °C may occur (Figure 2). Frost occurs during the Winter months (June-August) and the mountain tops normally receive snow.

In Summer the prevailing wind direction is south to southeast, and in Winter the prevailing wind direction is northwest. Dry hot berg winds are experienced during Autumn and particularly Winter.

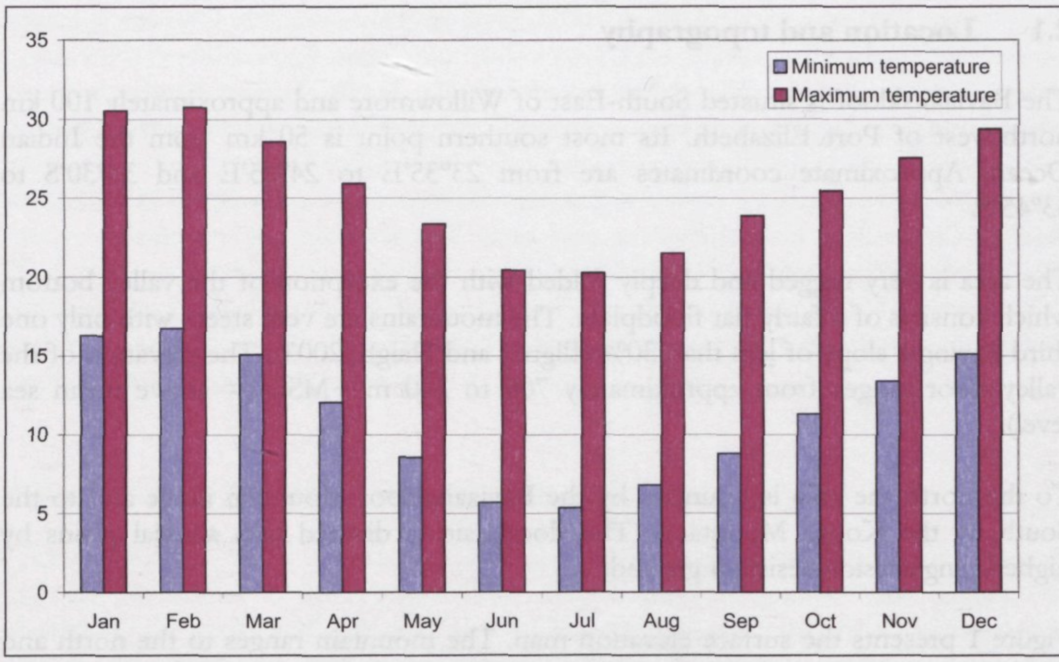

Figure 2. Average monthly temperatures at meteorological station 20237 (Baviaanskloof)

Rainfall

In the Baviaanskloof the rainfall is relatively low. The average annual rainfall is about 300 mm[4]. The rainfall is categorised as non-seasonal, although in Summer there is more rainfall than in Winter. Approximately 2/3 of the annual rainfall falls in Summer and one third in Winter (see also Section 4.3). The rain is mostly convective[5] and orographic[6] in nature with frequent thunderstorms in the Summer months.

In addition to a seasonal component the rainfall is also characterised by a large inter-annual temporal variability. Figure 3 shows that the annual rainfall may vary from less than 100 mm to more than 700 mm.

[4] [DWAF, 2002] reports 448 mm/year. Their reference is unknown. The annual rainfall presented in our report is the weighted area average over the entire catchment (see also Section 4.3).

[5] Characterized by intensive rainfall of relative short duration and storms.

[6] Occurring in mountainous areas: Uplift of clouds (and subsequent precipitation) occurs under influence of mountain slopes.

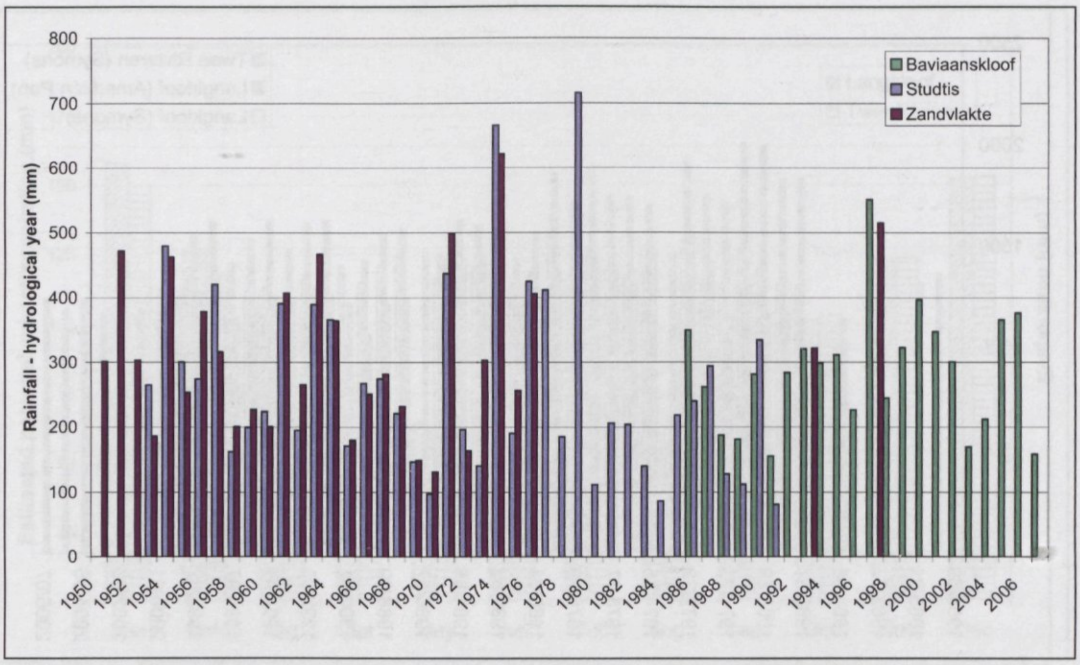

Figure 3. Annual rainfall at three stations in the Baviaanskloof

Evapotranspiration

The potential evapotranspiration is not measured or determined at the meteorological stations in the Baviaanskloof. The data from the stations at Twee Rivieren (near the Kouga Dam) and Langkloof (in the Kouga catchment) show, however, that the spatial variability of the evapotranspiration is much less than the variability of the rainfall (also the temporal variability is limited; Figure 4). Therefore, the data from the stations at Twee Rivieren and Langkloof can provide a fair approximation for the Baviaanskloof.

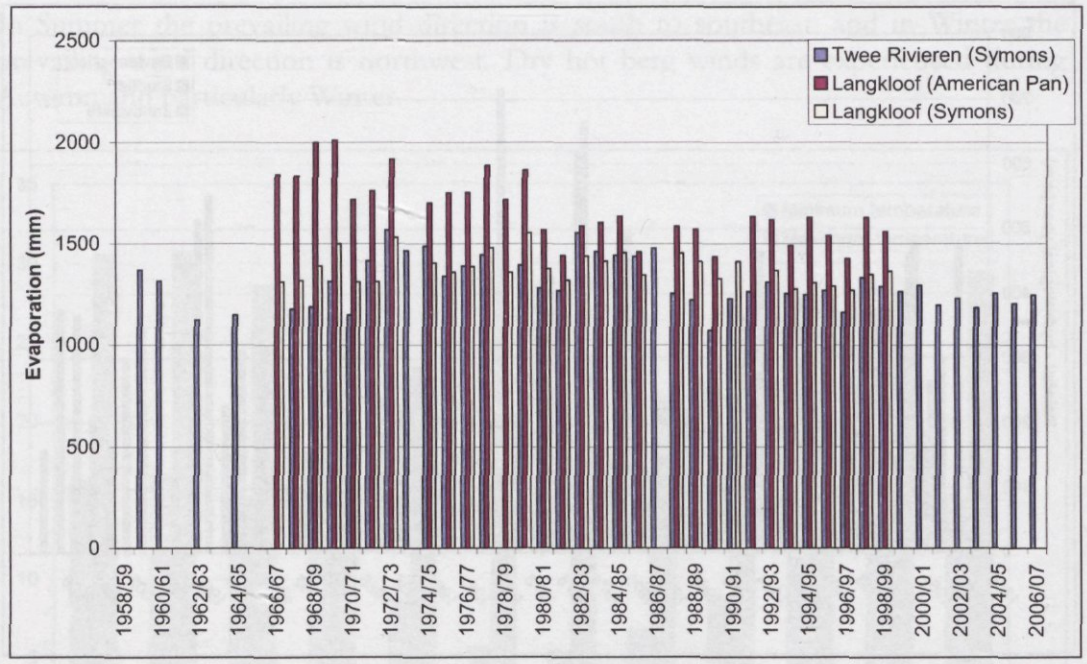

Figure 4. Annual and spatial variability of the potential evapotranspiration.

Figure 5 shows the calculated monthly average reference evapotranspiration at the two stations[7]. Figure 5 confirms that the spatial variability is small compared with the variability in the rainfall. Based on these data the average annual reference evapotranspiration in the Baviaanskloof amounts to 1125 mm.

[7] Unfortunately the meteostations at Twee Rivieren and Langkloof do not provide the FAO reference evapotranspiration. At these stations the evaporation is measured with the Symons Pan and/or American class Pan, which both overestimate the reference evapotranspiration. Multiplication factors for the Symons Pan and American class Pan were derived with the data from George, Beaufort-West, Port Elizabeth and Jansenville. At these four stations both the FAO reference evapotranspiration and the pan data are known. On the basis of these data the multiplication factor for the American Class Pan was quantified ranging from 1.22 to1.57. The multiplication factor for the Symons Pan was 1.06-1.33. For Langkloof and Twee Rivieren the averages of both ranges were used.

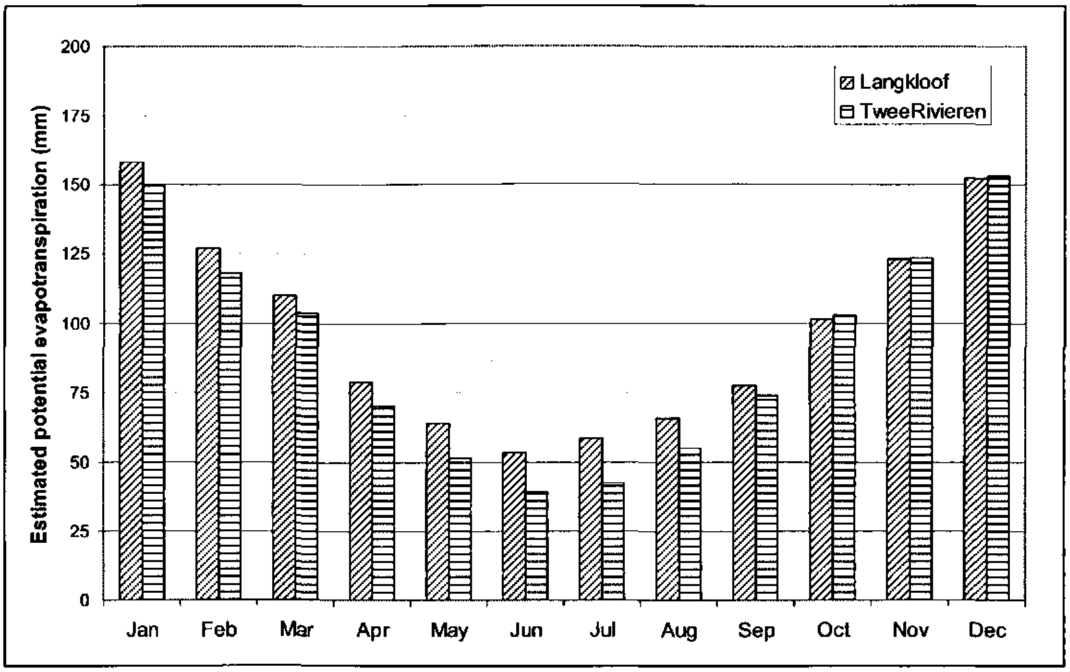

Figure 5. Reference evapotranspiration

2.3 Geology

The geology of the Baviaanskloof is dominated by sandstones and quartzites of the Table Mountain Group (TMG) interspersed with small amounts of shales of the Bokkeveld Group (Illgner and Haigh, 2003).

The mountains in the Baviaanskloof are made up by the arenaceous rocks of the Table Mountain Group, whereas the valley floor (in the central portion of the Baviaanskloof) consists of shales of the Bokkeveld Group (Welman and Barnard, 2007). These shales daylight at a number of farms (Illgner and Haigh, 2003). Both formations have been subject to intensive folding. A major fault is running east-west through the valley, with steep mountain slopes to the north.

The Enon Conglomerate, consisting of rounded to angular pebbles in a sandy matrix, and recent alluvial sands and gravels (mainly present in the valley) unconformably overlie the Bokkeveld shale and low-lying Table Mountain Formations (Welman and Barnard, 2007). Colluvial deposits are covering the lower mountain slopes.

The conglomerates outcrop intermittently from Nieuwekloof in the west to Kruisrivier (near the confluence between the Kouga River and the Baviaanskloof River) in the east (Illgner and Haigh, 2003).

The alluvials are, generally, sandy, but there are also small areas of loamy and clayey soils.

2.4 Soils

In the valley most of the soils are classified as stratified alluvial soils of Dundee type (having a high proportion of sand) with high drainage and high porosity. A soil survey made in the framework of "Review of agricultural potential analysis" showed that 47% of the soils had some clay, which allows for irrigation.

2.5 Hydrogeology

In the area two groundwater systems can be distinguished, being the "Table Mountain Group (TMG) Fractured Aquifer" and the conglomerate/alluvial aquifer (Welman and Barnard, 2007).

TMG aquifer system

The TMG aquifer is a secondary aquifer, characterised by a network of joints and fractures down to a depth of hundreds of meters. Groundwater movement is mostly confined to these joints and fractures. As not all fractures are interconnected the TMG aquifer contains numerous isolated systems, which may have limited groundwater exploitation potential.

The TMG is predominantly situated in the mountainous areas, being relatively high rainfall areas, which is favourable for groundwater recharge. Groundwater recharge has been subject to many studies. Based on various models the groundwater recharge of the TMG was estimated at 2-5 % of the rainfall (Yong Wu, 2005), thus representing 6-15 mm per year. Local variations are most likely to occur.

The electro-conductivity (EC) of this aquifer ranges from 10 to 100 mS/m (Meijer, 1999), which corresponds with a mineralization of approximately 70-700 mg/l. Elevated iron and manganese concentrations were reported (Welman and Barnard, 2007). These elevated manganese concentrations were also reported by farmers in the Gamtoos Valley (Section 3.4).

Alluvial aquifer

The alluvial aquifer is situated along the Baviaanskloof River and consists of reworked Enon Conglomerate mixed with pebbles, cobbles and clay lenses derived from the TMG sandstones and Bokkeveld shales (Welman and Barnard, 2007). The alluvial aquifer is a primary aquifer. Its thickness ranges from a few metres along the sides of the valley to more than 50 in some of the central portions. The longitudinal profile of the alluvial aquifer is unknown. The alluvial aquifer is recharged by infiltrating surface runoff from the mountain slopes and (occasional) rainfall in the valley. According to the hydrogeological map the net average groundwater recharge is in the order of 25-40 mm per year. The alluvial aquifer is in direct contact with the Baviaanskloof River. During dry spells the alluvial aquifer can sustain a certain base flow of the river.

During a field visit in April 2008 the electro-conductivity was measured at various locations. Typical electro-conductivity values range from 30-60 μS/cm (20-40 mg/l), being similar to the electro-conductivity of the river water.

The irrigation water used by farmers originates from the alluvial aquifer. The water is either taken from springs, or pumped from sumps that are dug into the alluvials to below the lowest groundwater table. In addition, a few boreholes pump water from the alluvial aquifer.

It is not clear whether there is direct contact between the two aquifer systems. Recharge of the alluvial aquifer from upstream springs was reported (Welman and Barnard, 2007). This can explain that the manganese contents of the surface water is relatively high during periods of low discharge (see Section 2.6.2).

During a field visit in April 2008 the electro-conductivity of the borehole at Sewefontein was measured, being 19.9 μS/cm (representing approximately 15 mg/l). This artesian borehole discharges water from the TMG aquifer. An (alluvial) spring in the vicinity of this borehole showed an electro-conductivity of 27.2 μS/cm. These values are not discriminative enough to draw conclusions with respect to the interaction between the two aquifers[8].

2.6 Surface water

2.6.1 General characterization

Regional surface water system

Figure 6 shows the delineation of the various catchments in the region and their interrelations. The Baviaanskloof River and Kouga River drain their respective catchments and join at the Kouga Dam. The Kouga Dam receives some additional inflow from its immediate surroundings[9]. From the dam the water is released to downstream water users in the Gamtoos catchment.

In addition to water from the Kouga Dam, the Gamtoos catchment also receives water from the Groot catchment (Figure 6). Although this catchment is large in size (approximately 29500 km^2), the discharge from the Groot catchment is relatively small. Moreover the mineralization of this water is much higher than in the water from the Kouga Dam (which makes it less suitable for irrigation and domestic use).

Because of the poor quality of the water from the Groot catchment this water is hydrologically separated from the water from the Kouga Dam. The latter is directed into a 94 km canal, which supplies the farmers in the Gamtoos Valley and which finally discharges into the Loerie Dam. From the Loerie Dam the water is conveyed to the Nelson Mandela Bay Metropolitan Municipality to be used for the public

[8] To obtain hard evidence a complete hydrochemical analysis is required.
[9] In the figure referred to as "Kouga Dam catchment".

drinking water supply. The water from the Groot River discharges into the original bed of the Gamtoos River and is not being used (economically).

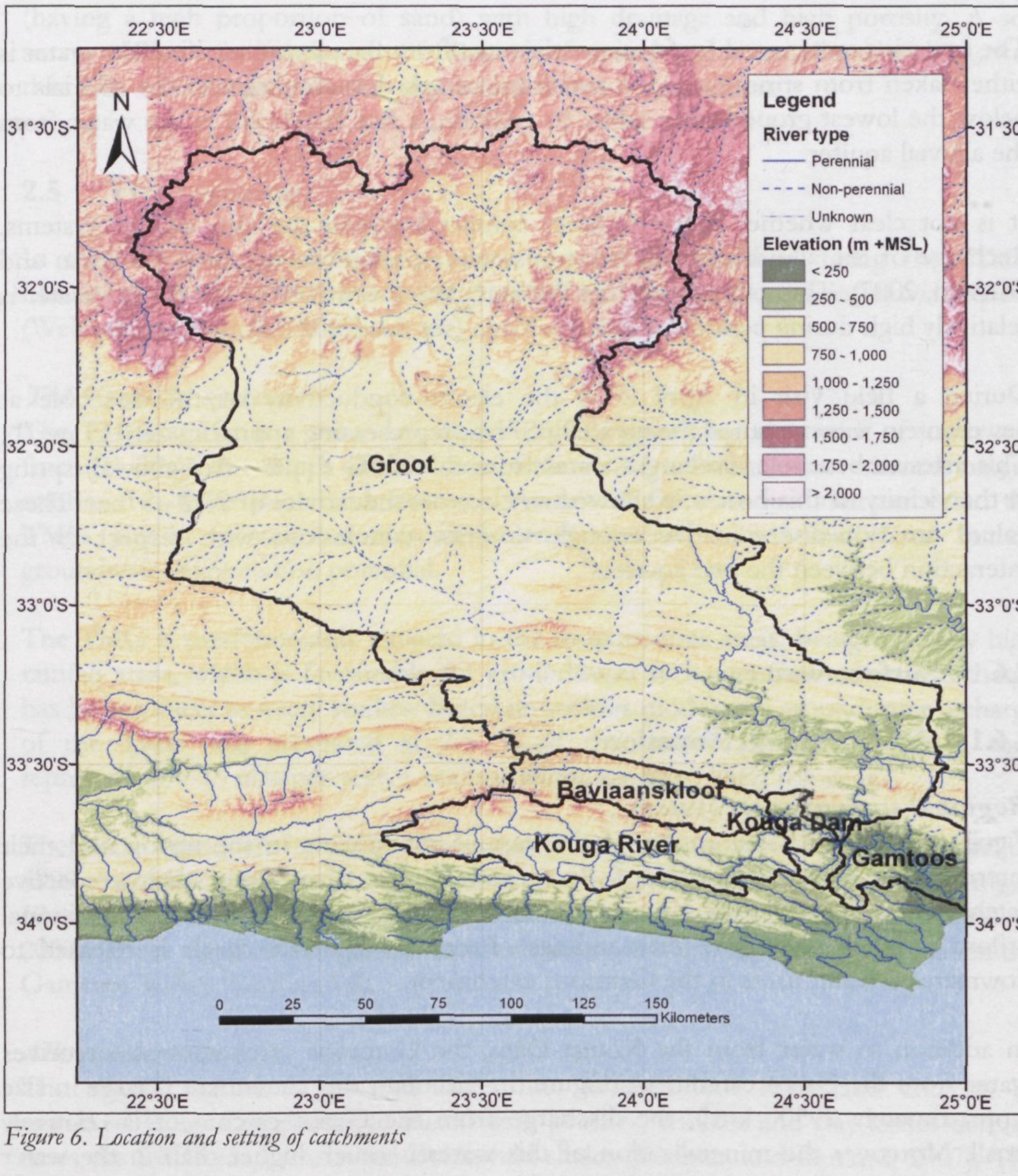

Figure 6. Location and setting of catchments

Baviaanskloof

The Baviaanskloof River is the main river in the Baviaanskloof; it flows through the central portion of the valley. The river is not always visible. At certain sections the river proceeds as interflow[10] through the permeable top section of the alluvial deposits or through joints in the underlying rocks (Figure 7).

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10 Shallow subsurface flow that can re-emerge at the surface further downstream.

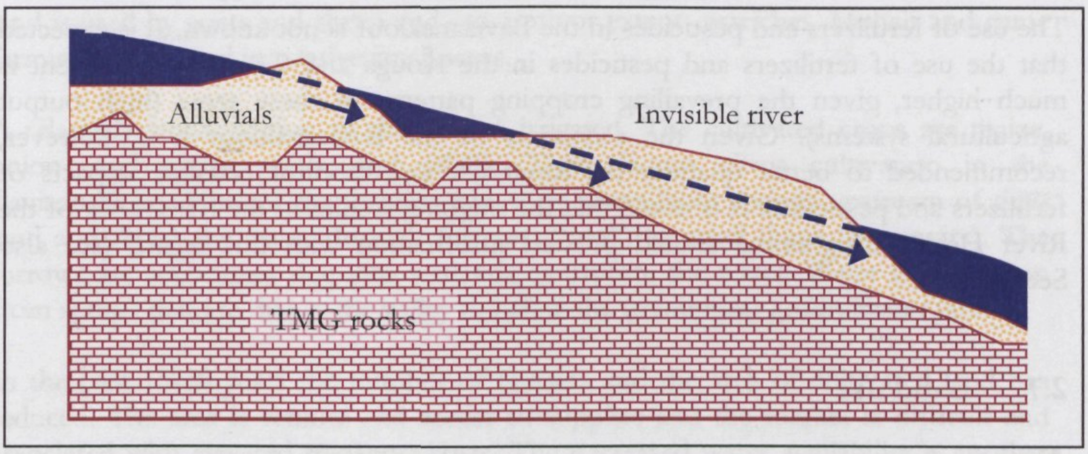

Figure 7. Conceptual flow system Baviaanskloof River

Small tributaries flow from the side valleys into the Baviaanskloof River. Many of these tributaries have been canalised and directed straight into the main channel to protect cultivated areas from flooding (see also Chapter 5).

The Baviaanskloof River permanently carries water. The tributaries often dry up in dry periods.

2.6.2 Water quality

Mineralization

During a field survey in April 2008 the electro-conductivity (EC) of the water of the Baviaanskloof River was measured. The recorded EC was in the order of 35-50 µS/cm, being the equivalent of approximately 25-30 mg/l total dissolved solids, representing excellent water with a very low mineralization.

Also downstream the quality of the surface water is good. The mineralization of the water in the Gamtoos Valley is about 140 mg/l.

Trace elements

It is noted that farmers in the Gamtoos Valley have reported higher concentrations of manganese in periods of low levels of the Kouga Dam (MBB). This would imply that the base flow contains relatively elevated concentrations of manganese, which indicates that there is a significant contribution of the deep groundwater system to the base flow.

Fertilizers and pesticides

Irrigation return flows, either by natural drainage or by artificial drainage systems, can have an impact on the water quality. In the Baviaanskloof no artificial drainage systems were observed. The drainage situation in the Kouga catchment is not known. In the Gamtoos Valley approximately 1% of the land is artificially (man-made) drained. The drainage water is discharged to the Gamtoos River (and, therefore, does not return to the irrigation system).

The use of fertilizers and pesticides in the Baviaanskloof is not known. It is expected that the use of fertilizers and pesticides in the Kouga and Gamtoos catchment is much higher, given the prevailing cropping patterns in these areas (high output agricultural systems). Given the sensitivity of the Baviaanskloof it is, however, recommended to better quantify the input use and monitor possible impacts of fertilizers and pesticides. It is noted that the ongoing studies in the framework of the River Health Programme should provide information with this regard (see also Section 1.6).

2.7 Land use

Nature

The largest portion of the land in the Baviaanskloof is used as nature area (approximately 65%). The area is a biodiversity hotspot and recognised as a unique World Heritage Site (since 2004) because of its beauty and biodiversity, which has global importance (see also Section 1.2).

The conservation area comprises 231386 ha (May 2006) and extends to beyond the Baviaanskloof River catchment (Figure 8). It is one of the three priority areas in the Cape Floristic Region identified as suitable for the creation of mega-reserves (> 400 000 ha in extent). The area also hosts a remarkable number of pre-historical (Stone Age archaeology) and historical sites (Boshoff, 2005).

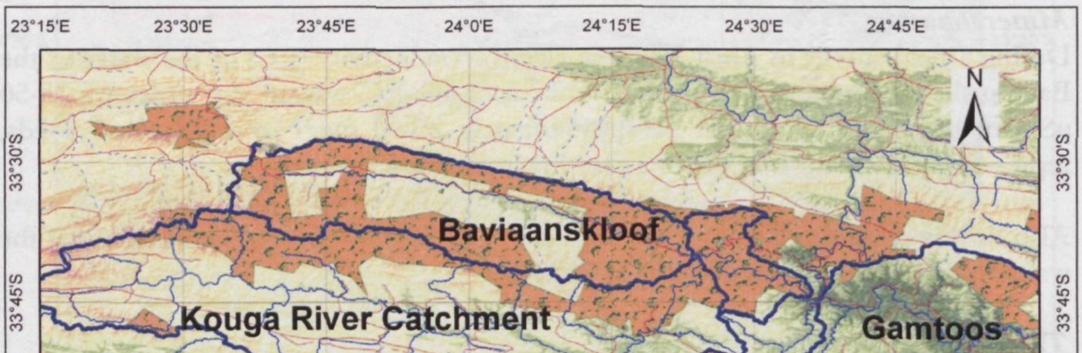

Figure 8. Conservation area Baviaanskloof Mega Reserve (indicated in orange on the map).

Agriculture

A portion of the Baviaanskloof is used for agriculture and small settlements (35%). The size of the farms vary largely. Typical farm sizes are between 1000 and 3000 ha. Most of the agricultural land is used for livestock cultivation. Most of the grazing land is used by goats and sheep and –to a minor extent- ostriches. Mohair and game farming is practiced in relative small areas.

A relatively small portion of the land is irrigated. The cultivated crops are maize, onion- and carrot seeds, and alfalfa. There is no citrus cultivation in the Baviaanskloof. Most of the farmers take their water from springs upstream of their land and direct the water through furrows (*"vore"*) to small dams (by gravity). The furrows are sometimes dug into wetlands to capture the water. Water is also taken from sumps that are dug in the valley to below the (minimum) groundwater table.

In the past 15-20 years the number of farmers and the area of cultivated land has reduced. The area is remote and access to supplies and the market is difficult and associated with elevated transport costs. The decreased water availability is another factor that was reported. Besides the area offers good opportunities for (eco)tourism, which is presently being explored by some of the farmers. Land (especially land adjacent to the river) was also taken out of production after the floods of 1972 (Kruger, 2006).

Tourism
Due to its beauty and remoteness the area attracts more and more tourists. Some of the farmers anticipate this trend and have developed (small-scale) facilities and organise activities (e.g. game drives, hiking trails).

Land use adjacent areas
The Gamtoos Valley is intensively cultivated. The main crops are citrus (22.5%) and potatoes (20.5%; MBB). Most of the remaining area is cultivated with vegetables, mostly on a contractual basis with companies or retailers.

The area in the Gamtoos Valley is permanent under cultivation. The crop rotation varies over the area and also depends on developments and fluctuations of the market prices (MBB). Compared with the Baviaanskloof the Gamtoos Valley has good access to markets and high value crops are produced.

The catchments of the Kouga River is also intensively cultivated, citrus being one of the dominant crops.

3 Claims on water resources

3.1 General outline

Area delineation

To address the availability and use of water, the Baviaanskloof should not be regarded in isolation. Land and water development and management in the Baviaanskloof will impact on downstream water uses (principally the Gamtoos catchment). These downstream water uses are also impacted by land and water management in the Kouga catchment. It is, therefore, appropriate to consider the entire area presented in Figure 9.

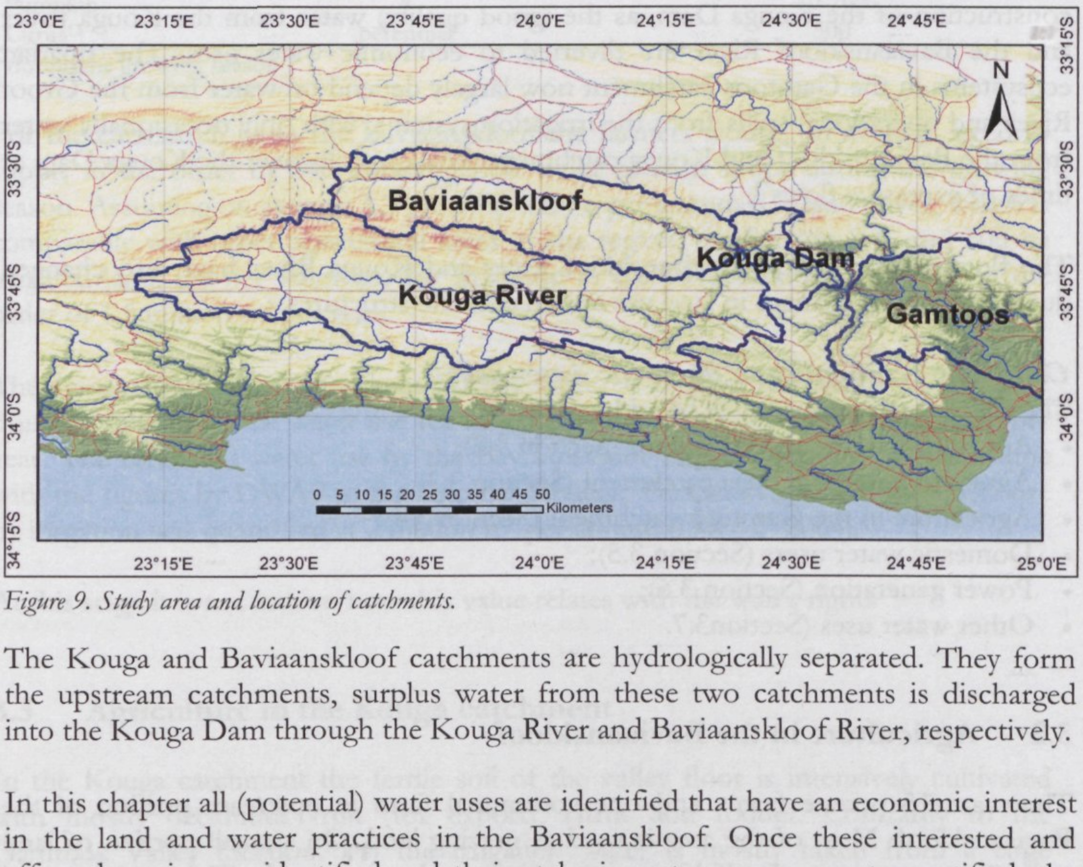

Figure 9. Study area and location of catchments.

The Kouga and Baviaanskloof catchments are hydrologically separated. They form the upstream catchments, surplus water from these two catchments is discharged into the Kouga Dam through the Kouga River and Baviaanskloof River, respectively.

In this chapter all (potential) water uses are identified that have an economic interest in the land and water practices in the Baviaanskloof. Once these interested and affected parties are identified and their stake in water management quantified, the bottlenecks and constraints can be assessed. Based on the demands and resources land and water policy options (including PES schemes) can be elaborated.

Claims by ecosystems

In the South African water legislation ecosystems are not regarded as one of the "regular" water uses to which an equitable share of the available ground- and surface water resources should be allocated. Rather they are considered as the *resource base*, which has to be sustained by the *environmental flow*, which is the flow (regime) required to sustain ecosystems. Claims on water resources for economic purposes should thus only refer to the water resources that go beyond the environmental flow.

It is noted that a distinction must be made between the water use by terrestrial ecosystems (depending on rainfall) and riparian ecosystems. The environmental flows concern the riparian ecosystems.

Information on the (required minimum) environmental flow of the Baviaanskloof River, the Kouga River and the Gamtoos River is presently not available. In this land and water assessment the claims on water resources, therefore, only refer to economic water uses (including domestic uses). The current water use by ecosystems will, however, be quantified in the overall water balances (Chapter 4).

In the Gamtoos Valley the natural flow regime has completely changed since the construction of the Kouga Dam, as the (good quality) water from the Kouga River and the Baviaanskloof River are diverted to economic water uses. The riparian ecosystems in the Gamtoos catchment now largely depend on water from the Groot River and operational spills from the irrigation systems, with only occasionally water from the Baviaanskloof and Kouga catchment through spills over the Kouga Dam at times of excessive flows[11].

The flow regimes of the Baviaanskloof River and Kouga River have also changed due to irrigation, changes in land use and man-made structures.

Claims by economic and domestic water uses
The following water uses will be addressed:
- Agriculture in the Baviaanskloof (Section 3.2);
- Agriculture in the Kouga catchment (Section 3.3);
- Agriculture in the Gamtoos catchment (Section 3.4);
- Domestic water users (Section 3.5);
- Power generation (Section 3.6);
- Other water uses (Section3.7.

3.2 Agriculture in the Baviaanskloof

There are 15 private farms and one communal farm in upstream portion of the Baviaanskloof. Most of the area is used as grazing land. On a small portion of land crops are grown, mostly alfalfa, maize, onion- and carrot seeds. The total irrigated area could not be quantified during this study. Illgner and Haigh (2003) report that the total irrigable area in the Baviaanskloof amounts to 300 ha. During field visits farmers reported that 468 ha is irrigated[12]. A number of farmers operate central

[11] In addition ecosystems in the Gamtoos catchment can benefit from water from mountain streams in the Gamtoos catchment, if not used for irrigation. These streams were not investigated in this study.

[12] [DWAF, 2002] report 1400 ha irrigated area, mainly under pasture. This information seems, however, not up-to-date.

pivots. These pivots can cover approximately 30-50 ha, hence 300-500 ha irrigated area seems valid.

The irrigation requirements were tentatively estimated on the basis of crop water requirements for the various crops. These requirements vary from year to year, depending on the planting dates. Table 1 presents typical irrigation water requirements in the Baviaanskloof.

Table 1. Estimated irrigation water requirements for various crops (Baviaanskloof)

Crop	Assumed growing season (months)	Estimated irrigation requirements (mm)*
Alfalfa	5	165-200
Maize	5	180-250
Onion seed	5	250-280
Carrot	5	250-260
Pumpkin	4	10-160
Citrus[13]	perennial	500

* during the growing season

For the current crops in the Baviaanskloof the farmers would, on average, need to supply in the order of 200 mm irrigation water to their crops during the growing season. Assuming on average 1,5 growing season per annum (i.e. land cover, which is comparable with other agricultural areas in the region; see Section 3.4) and 500 ha irrigated land, the net water use for irrigation in the Baviaanskloof would be in the order of 1,5 million m^3 per year.

The gross irrigation will be at least 5-15 % more, to account for evaporation losses[14] thus resulting in a total water use for irrigation of approximately 1.75 million m^3 per year. The estimated water use by the Baviaanskloof farmers is more or less in line with the figures by DWAF in the Internal Strategic Perspective, where the water use by irrigation was quantified at 2 million m^3 per annum (DWAF, 2004).

At this stage it is not known how this value relates with the water rights[15].

3.3 Agriculture in the Kouga catchment

In the Kouga catchment the fertile soil of the valley floor is intensively cultivated with mostly deciduous fruit (for export), citrus and fodder. Contrarily to the Gamtoos Valley (Section 3.4) the irrigation water is mostly taken from a large number of privately owned dams and reservoirs, or is pumped directly from the Kouga River.

13 Citrus is not cultivated in the Baviaanskloof. The data are given for comparison only.

14 These losses refer to evaporation from the crop canopy and soil, evaporation of water drops leaving the nozzles, and evaporation from the reservoirs. Note that these losses do not include percolation and runoff losses, as these volumes remain in the water system.

15 At the time of issue of this report this information is being collected in the framework of the PES study.

In 1995 the total irrigated area amounted to 7610 ha[16]. There are various water management organizations, such as the Haarlem - 1(PE) Irrigation Board, Misgund East Irrigation Board, Apies River - 2(PE) Irrigation Board, Heights Irrigation Board and Wabooms River Irrigation Board, but only a minority of the farmers is member of one of these boards. The scheduled irrigated area by the boards is approximately 1800 ha.

The Haarlem Dam and Joubertina Dams can together store approximately 5 million m^3. Most of the water is stored in farm dams, having an estimated total capacity of 26 million m^3 (DWAF, 2002). The citrus trees in the Kouga catchment require, annually, approximately 300-350 mm water from irrigation[17]. Based on these data the net water use for irrigation in the Kouga catchment is estimated in the order of 25-30 million m^3 per year. This is well in line with estimates by [DWAF, 2002], who report 32,5 million m^3 (who also include distribution losses and evaporation from the dams).

It is not known whether or not the farmers in the Kouga catchment experience water shortages. As they are situated in the upstream area, while they also have significant water storage capacity, it is expected that problems with their water assurance are limited. It is noted that rainfall is also more in this area.

3.4 Agriculture in the Gamtoos catchment

Prior to the construction of the Kouga Dam in 1964 the farmers in the Gamtoos Valley suffered periodically from severe droughts and floods (MBB). Since the construction of the Kouga Dam they have access to a reliable water supply. The water from the Kouga Dam is released according to a strict protocol to serve irrigated agriculture in the Gamtoos Valley[18]. The Kouga Dam is operated by the Gamtoos Irrigation Board. There are no other major dams for agricultural purposes in the Gamtoos Valley.

An extensive irrigation system has been constructed. The conveyance system consists of a main canal between the Kouga Dam and Loerie Dam of 97 km, with a capacity of 5.6 m^3/s at its inlet, and 3.1 m^3/s at its outlet at the Loerie Dam (MBB). In addition there are 5 branch canals with a total length of 30 km, a network of 91 km of pipelines, small balancing dams, tunnels and siphons. The number of off-takes is approximately 950. Central pivot and drip irrigation systems are the most dominant systems. The drip irrigation systems (as well as micro sprinklers) are mostly used for the permanent crops such as citrus.

The irrigation requirements for the Gamtoos Valley at the time of construction of the Kouga Dam were determined at 52 million m^3 per annum, serving 8660 ha (10000 morgen). The present cultivated area is 9982 ha (MBB). The quota for

16 [DWAF, 2002] reports 6000 ha, but this data is based on older information.

17 Crop water requirements are thus less than in the Baviaanskloof, as rainfall is higher in the Kouga River catchment.

18 Irrigation by groundwater is insignificant. The total abstraction is less than 10 000 m^3 (MBB).

irrigation is currently 59.3 million m^3 per year (the equivalent of approximately 600 mm).

On the basis of data on the actual releases of water from the dam the average gross delivery of water to the farmers is approximately 45-47 million m^3 per year[19], hence the farmers in the Gamtoos Valley experience water constraints and would cultivate more crops if the water was available. In dry years severe water shortages are experienced and farmers have to reduce the planted area and prioritize water supply to the permanent crops (citrus)[20]. They will, therefore, certainly have an economic interest to get more water for irrigation and a higher assurance (reliability) of water supply.

MBB states that the developed area in the Gamtoos Valley is –on average- only 55% of the scheduled area. This seems, however, a figure that is too low[21].

3.5 Domestic water use

In the Baviaanskloof the greatest concentration of people is living in Sewefontein and Zaaimanshoek. The remaining people live on the private farms. The total number of inhabitants of the Baviaanskloof is not exactly known[22]. The water

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19 This includes conveyance losses to the farmers' fields. MBB reported that the actual delivery of water to the farmers' fields is, on average, 31.8 million m^3 (with large annual fluctuations - from 20 to 38 million m^3 – which is probably associated with the rainfall variability). This would imply that the conveyance losses would be in the order of 15 million m^3 per year (approx. 30%). The current conveyance losses were reported to have significantly reduced to approximately 12%.

20 The status of the Kouga Dam is evaluated on 1 March and 1 September every year. Water restrictions are applied if the level of the dam is lower than 60% on 1 March or lower than 49% on 1 September. During periods of restrictions DWAF and the Gamtoos Irrigation Board work out the water requirements on a monthly basis.
During restriction periods municipalities are also not allowed to use water for irrigation.

21 MBB have assessed the average irrigation water requirements in the Gamtoos catchment on the basis of rainfall data, cropping patterns and rotations. They determined the land cover at 134%. This means that - if all crops are considered- the total planting area is 134.67 % of the cultivated area of 9982 ha (most crops are non-perennial). On average 7412 ha would then be permanently cultivated. MBB calculated the total annual irrigation water requirements at 816 mm. With these data the annual water requirements for irrigation would be 60.5 million m^3 (which more or less equals the quota). The table below presents the irrigation requirements of the main crops.

Estimated irrigation water requirements for various crops in the Gamtoos Valley (MBB)

Crop	Growing season (months)	Estimated irrigation requirements (mm)
Citrus	Perennial	781
Potatoes	6	± 350-725
Kikuyu-Ryegrass mix	Perennial	1281
Maize	6	532-624

It seems, however, that the irrigation water requirements are overestimated. Given the climatological conditions the crop water requirements in the Gamtoos Valley are fairly comparable with those in the Baviaanskloof, while the irrigation systems are highly efficient. It is, therefore, expected that the actual irrigation requirements are less than 816 mm and that the actually developed area is larger.

22 Sources state that in the order of 1000 inhabitants live in the Baviaanskloof.

requirements for domestic water use are, however, small in comparison with the irrigation water requirements (estimated at 1-2 %).

In the Gamtoos Valley the water quotas for the municipalities of Patensie and Hankey is 878000 m^3. The actual water use is approximately 441400 m^3, hence there are no shortages expected in the near future.

The main user of domestic water is, however, the Nelson Mandela Bay Metropolitan Municipality (Port Elizabeth). Their present quota is 23 million m^3 per annum. The water is taken from the Loerie Dam, which thus acts as buffer.

The actual delivery of water to the Nelson Mandela Bay Metropolitan Municipality was, on average[23], 20.2 million m^3 per year (22.5 million m^3 in 1999/2000). It is expected that presently their entire quota is being used.

At present the Kouga Dam supplies approximately 30% of the requirements by the Nelson Mandela Bay Metropolitan Municipality (Boshoff, 2005). The population of the metropolis is, however, expected to increase (some sources report an 100% increase in the next 10 years), which will thus put an additional claim on the water resources.

The Nelson Mandela Bay Metropolitan Municipality will certainly have an economic interest to get more water from the Baviaanskloof-Kouga-Gamtoos area.

3.6 Power generation

At the completion of the Kouga Dam a small hydro-electrical power station with three turbines of 1200 kVA each was constructed. The station was decommissioned, as it was not economical anymore (data from the dam brochure). Other sources, however, report deterioration of the mechanical plant and severe leakage from the balancing dam that was a component of the scheme (DWAF, 2002).

It may be possible that power generation becomes economical again when energy prices continue to increase and the current shortages persist.

3.7 Other claims

There is no significant industrial water use in the area, or other uses.

[23] Period 1989-2000

4 Water resources assessment

4.1 General outline

In this chapter the principal water resources are identified and an overall water balance is elaborated. In Section 4.2 the main components of the hydrological system are identified. In the succeeding sections these components are quantified.

This assessment is aimed at quantifying the most determining components of the hydrological system, analysing spatial and temporal trends, and identifying the hydrological components that can best be "manipulated" and incorporated in PES schemes.

This chapter is concluded with an overall water balance of the Baviaanskloof and Kouga catchment and conclusions on feasible land and water interventions to manipulate the water balance.

4.2 Components of the hydrological system

In the Baviaanskloof and Kouga catchments there is no evidence of substantial groundwater inflow, hence almost all water resources in these areas originate from rainfall (and snow).

Rainfall is intercepted by the vegetation, temporarily ponds in surface depressions, or infiltrates into the soil, from where it can directly evaporate or be utilized by crops (evapotranspiration). If the rainfall exceeds the infiltration capacity of the soil, surface runoff will occur. In the case of relatively large infiltration rates, a portion of the rainfall can recharge the groundwater (Figure 10).

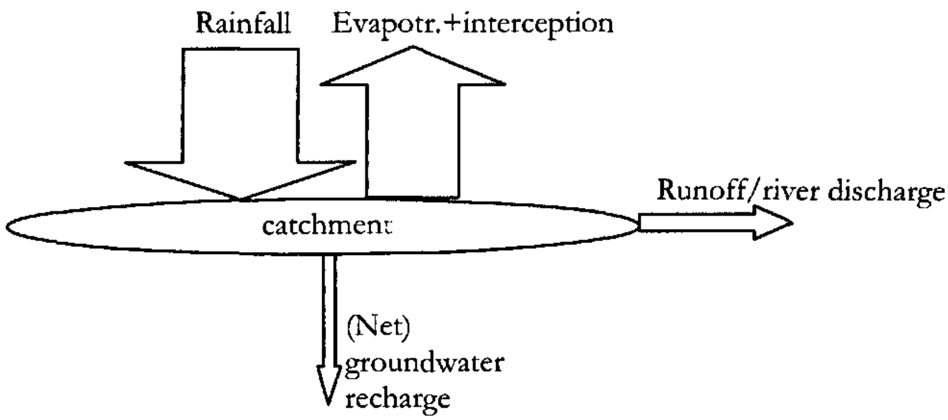

Figure 10. Simplified water balance of Baviaanskloof and Kouga catchment.

The groundwater recharge can discharge into the rivers as base flow, be temporarily stored (in aquifers), or be utilized (e.g. for drinking water, by crops or by the natural vegetation).

4.3 Rainfall

The surface area of the Baviaanskloof catchment is approximately 1234 km^2. The total rainfall over the area was calculated on the basis of rainfall data from 8 stations (from west to east: Voorkloof, Rust en Vrede, Kruisrivier, Nuwekloof, Studtis, Studtis – Police, Baviaanskloof 1 and Zandvlakte). Their locations are shown in Figure 11. An overview of the rainfall meteorological stations that were used in this report is given in Appendix 1.

Based on Thiessen polygons (Figure 11) the total average annual rainfall in the catchment is approximately 369 million m^3, which is the equivalent of about 300 mm. Approximately 2/3 of the annual rainfall falls in Summer (188 mm) and one third (112) in Winter.

The size of the Kouga catchment is twice the size of the Baviaanskloof (approximately 2427 km^2), and the rainfall is significant higher. The total average annual rainfall in this catchment is approximately 1.2 billion m^3, which is the equivalent of approximately 500 mm (based on the data from 20 locations with rainfall data).

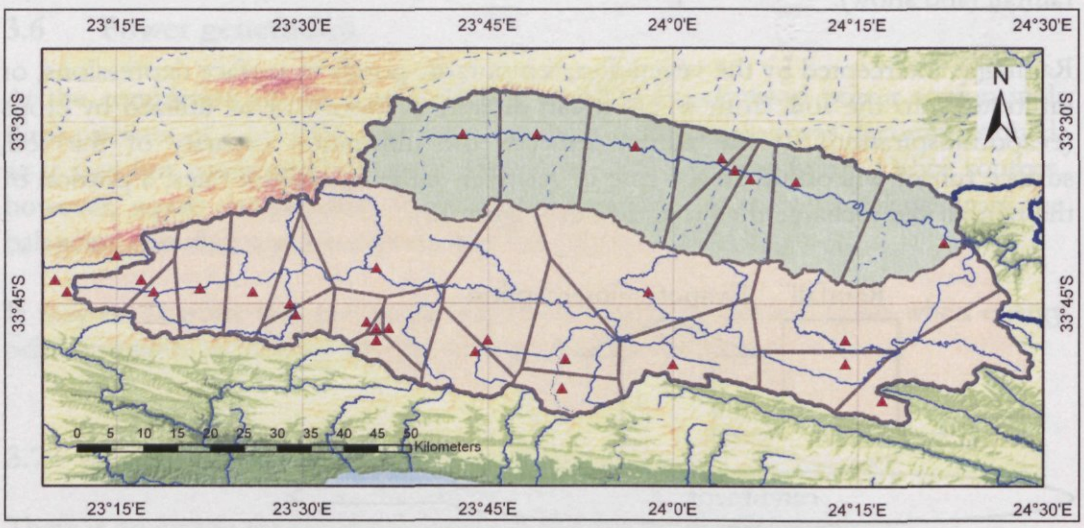

Figure 11. Polygons for calculation of area rainfall (triangle points are rainfall stations)

In the Kouga catchment the rainfall is more evenly distributed over the year, with both seasons accounting for approximately 50 % of the total annual rainfall. Figure 12 presents the monthly (weighted) average rainfall for the two catchments upstream of the Kouga Dam.

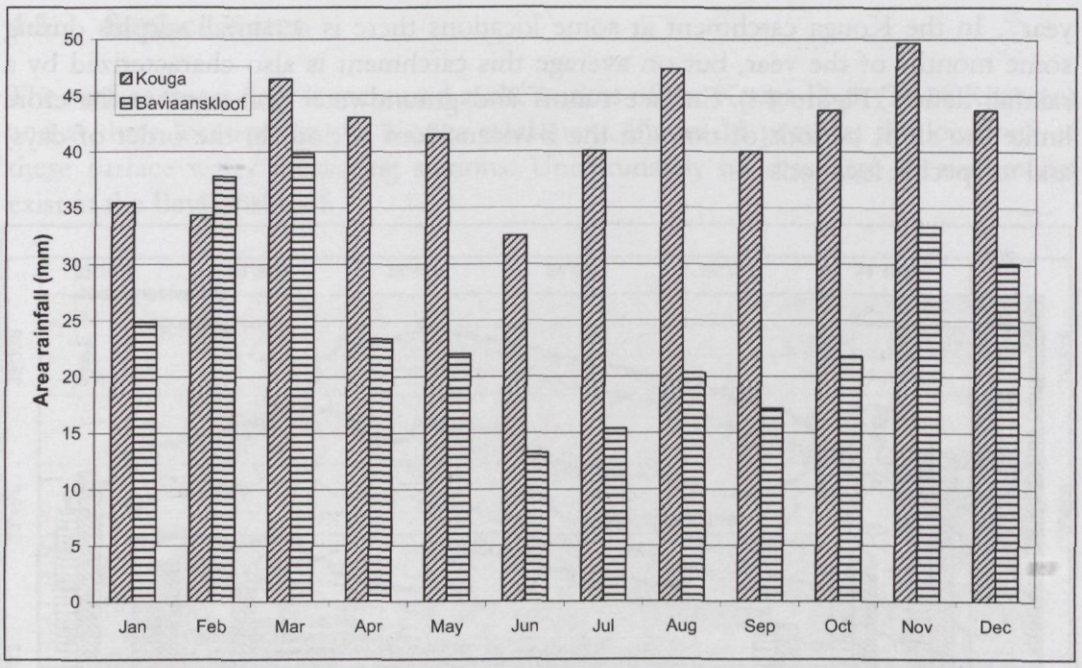

Figure 12. Monthly area rainfall in the Baviaanskloof and Kouga catchment

It is noted that the application of Thiessen polygons can be tentative if in areas with a large component of orographic rainfall. The spatial variability (especially the north-south gradients) were further assessed by constructing isohyets[24]. From these isohyets it seems that the stations in the Baviaanskloof and Kouga catchments are reasonably distributed over the relatively high and low rainfall areas (Figure 13).

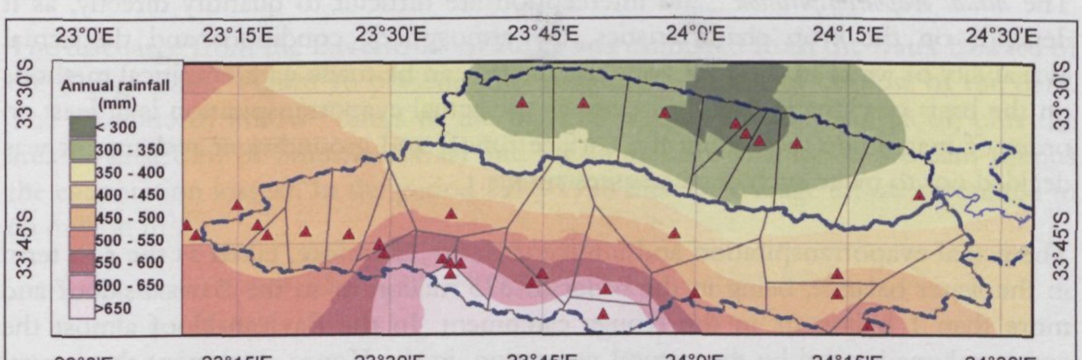

Figure 13. Interpolated annual rainfall (unprocessed/ tentative).

4.4 Evapotranspiration and interception

Most of the rainfall that falls on the Baviaanskloof and Kouga catchments is evapotranspirated. From the meteorological data it can be concluded that in the Baviaanskloof the potential evaporation exceeds the rainfall during all months of the

24 Lines connecting locations with equal rainfall.

year[25]. In the Kouga catchment at some locations there is a rainfall surplus during some months of the year, but on average this catchment is also characterized by a rainfall deficit (Figure 14). Surface runoff and groundwater recharge are therefore limited to short periods of time (in the Baviaanskloof periods in the order of days) and to specific locations.

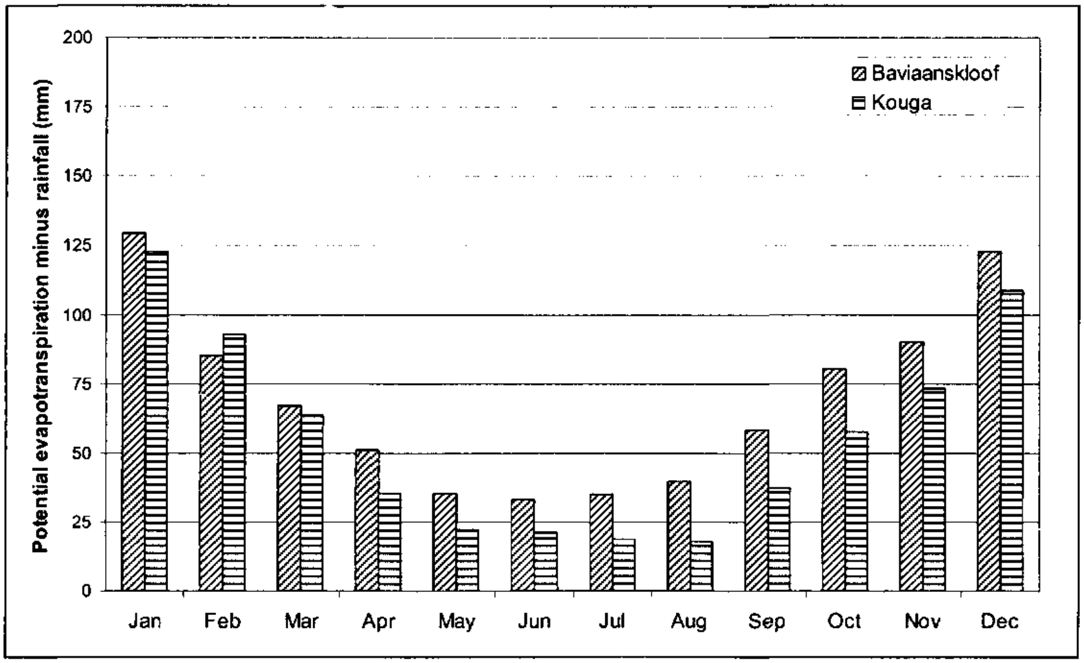

Figure 14. Estimated monthly rainfall deficit.

The *actual evapotranspiration*[26] and interception are difficult to quantify directly, as it depends on the crop characteristics, the atmospheric conditions and the actual availability of water in the root zone. Estimates can be made with empirical methods on the basis of climatic data, however, as the actual evapotranspiration is at least an order of magnitude more than the surface runoff and groundwater recharge, it was decided not to make such detailed assessments.

The actual evapotranspiration and interception are, therefore, taken as the rest term in the water balance, being in the order of 325 million m^3 in the Baviaanskloof and more than 1 billion m^3 in the Kouga catchment. In the Baviaanskloof almost the entire volume is used by the natural vegetation, in the Kouga catchment the natural vegetation uses about 97 %, while the rest is taken by agricultural crops.

[25] Only at the station of Kruisrivier the average rainfall exceeds the potential evapotranspiration in March , but this is merely due to one rather unrealistic value (1234.4 mm in March 1957).

[26] The "reference evapotranspiration" represents the theoretical quantity of water that can be evapotranspirated by a specified crop (reference crop), depending on the prevailing climatologic conditions. The reference evapotranspiration thus assumes no limit of water availability. The "actual evapotranspiration" refers to the quantity of water that is evapotranspirated in reality, given the actual water availability conditions.

4.5 Surface water

The surface water flow is measured at the outlets of the Kouga Dam (Twee Rivieren) and at three locations in the Kouga catchment. Figure 15 presents the locations of these surface water measuring stations. Unfortunately no discharge measurements exist in the Baviaanskloof.

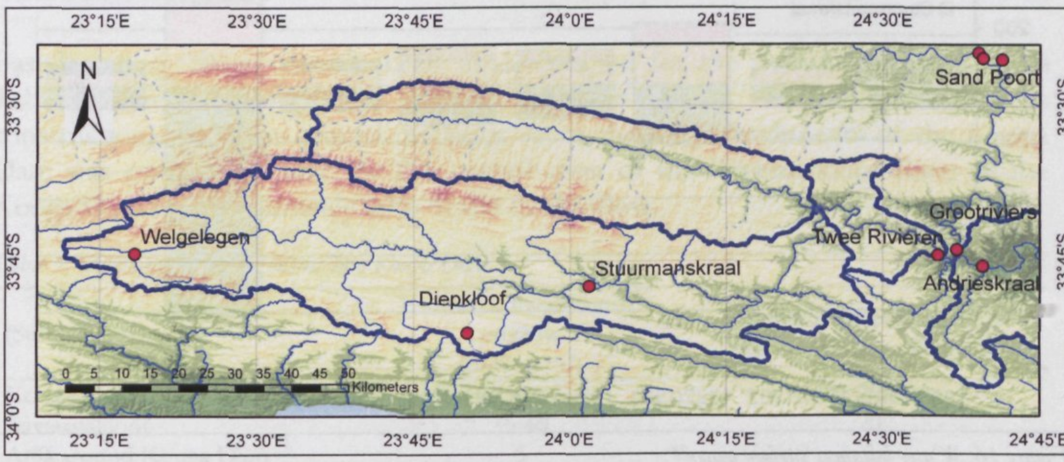

Figure 15. Location of surface water measuring stations

The average annual discharge at Stuurmanskraal in the period from 1990/1991 to 1997/1998 (8 hydrological years) was 120 million m^3. The temporal variability was, however, very large: Minimum, maximum and median annual discharges were, respectively, 16, 484 and 69 million m^3. The variability of the river discharge mirrors the variability in the rainfall.

The discharge from the Baviaanskloof River was estimated from the water balance of the Kouga Dam. Figure 16 presents the measured inflow and outflow of the dam. The "Additional inflow" refers to the net inflow from the Baviaanskloof, plus the area downstream of Stuurmanskraal and the immediate vicinity of the dam (minus the evaporation losses). In the period 1990-1998 this net average inflow amounted to 66 million m^3.[27]

[27] MBB reports 67.5 million m^3 for the period 1989-2000, being very well in line with our assessment.

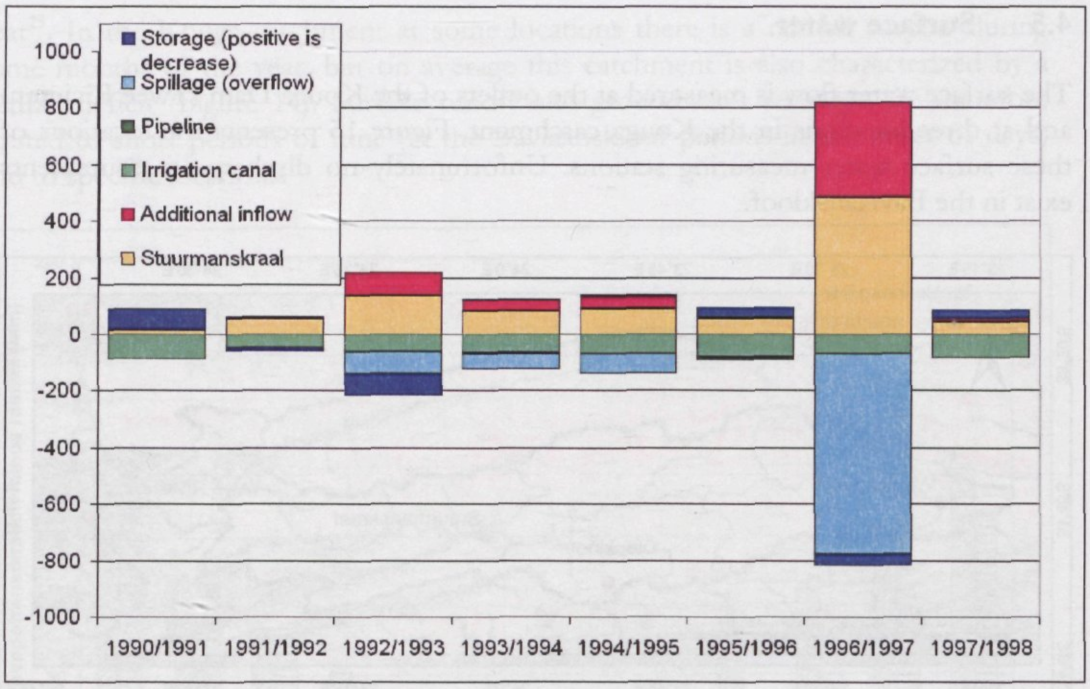

Figure 16. Water balances surface water[28]

DWAF has calculated the mean annual runoff from catchments using hydrological models (DWAF, 1999). From these models the contributions of the runoff from the various subcatchments to the total dam inflow were derived and compared with the measured discharges.

Table 2 presents the measured and calculated mean annual runoff for various subcatchments. The calculated mean annual runoff at Stuurmanskraal is in line with the measured average mean annual discharge in the period 1990-1998. The models are, therefore, useful tools to estimate the relative contributions of the other subcatchments.

According to the models 73 % of the inflow into the Kouga Dam originates from the Kouga River (56%+17%; see Table 2). The measurements indicate that the Kouga River may contribute slightly more (on the basis of Table 2 the contribution is estimated at 77%).

[28] A storage term is added, because the inflow will not exactly equal the outflow in a certain year. At the end of dry years (e.g. 1990/1991, 1995/1996 and 1997/1998) the water level in the dam will have dropped (i.e. water is taken from storage). At the end of wet years the water level in the dam can be higher than at the start of the year (e.g. 1992/1993 and 1996/1997).

Table 2. Runoff from (sub)catchments

(Sub)catchment	Calculated (models) mean annual runoff (million m³)	Measured MAR (1990-1998) (million m³)
Kouga-upstream Stuurmanskraal	106.5 (56%)	120 (62%)
Kouga–downstream Stuurmanskraal	31.4 (17%)	
Baviaanskloof	45.7 (24%)	Total: 72[29] (38%)
Area around Kouga Dam	5.3 (3%)	

Based on the relative contributions as determined for the period 1990-1998 (with Table 2) and the (long-term) discharge records of the Kouga Dam (since its construction) the mean annual discharge from the three catchments of the Kouga Dam was estimated (Table 3). The contribution of the Baviaanskloof River to the Kouga Dam is approximately 20% of the total inflow.

Table 3. Discharge from catchments into Kouga Dam

(Sub)catchment	Estimated mean annual outflow (million m³)	Approximate percentage of inflow of Kouga Dam (%)
Kouga River	125-135	77
Baviaanskloof	35-40	20
Area around Kouga Dam	5	3

It is noted that the temporal variability is large. Figure 16 shows that both the absolute values of the surface water discharge and the relative contributions from the catchment upstream of Stuurmanskraal and the other subcatchments vary largely.

4.6 Groundwater

Due to the lack of measuring points the groundwater system could not be investigated in more detail and groundwater recharge and volumes of groundwater flow are not well known.

The groundwater recharge in the Baviaanskloof was estimated at 25-40 mm per year (Section 2.5). If this value is representative for the entire catchment then groundwater recharge would amount to 30 to 50 million m^3 per year, being 8-13 % of the rainfall. If the same percentages are applied to the Kouga catchment the groundwater recharge in this catchment would amount to 100-150 million m^3 per year. Given the natural environment this value seems somewhat high and should, if possible, be verified.

[DWAF, 2002] reports that in the Baviaanskloof and Kouga catchments the groundwater potential amounts to 151,5 million m^3 per year[30], of which 138 million m^3 per year does not contribute to the base flow of the rivers. This volume of 138

29 The evaporation losses are estimated at 6.7 million m^3/year, based on an area of 555 ha and an annual evaporation of approximately 1200 mm.

30 It is not clear how this groundwater potential was calculated and how this volume refers to the groundwater recharge, i.e. what principles are used to calculate the potential (safe) yield.

million m^3 would then also partly be attributed to the deep aquifer and/or intercepted by the natural vegetation in areas with elevated water tables[31].

If the data of DWAF are correct, then the groundwater outflow into the Baviaanskloof River and Kouga River would be in the order of 10-15 million m^3, which is approximately 5-8 % of the total river flow. Given the high variability of the surface water discharge it is indeed expected that the contribution of the groundwater (base flow) is only a minor fraction of the total river discharge.

Based on the available information it can be concluded that more base flow can only be realised if groundwater recharge is enhanced in carefully selected areas. Target areas for groundwater recharge are the upstream sections of the Baviaanskloof (and Kouga catchment), areas with relatively deep groundwater tables.

4.7 Overview

With the results of the previous sections and Chapter 3 an overall water balance can be drafted, showing the water resources and claims on these water resources in the Baviaanskloof, Kouga catchment and downstream water users (Figure 17). It is noted that this water balance represents an average situation, whereas large annual variability occurs.

On average the Baviaanskloof River supplies 35-40 million m^3 per year to the Kouga Dam (approximately 20%). The Kouga River supplies annually 125-135 million m^3. Both in the Baviaanskloof and in the Kouga catchment the contribution of groundwater (base flow) to the river discharge is small. The volume of surface water discharge represents approximately 10% of the rainfall. Most of the rainfall is used by terrestrial ecosystems and rainfed agriculture.

On average approximately 40 % of the inflow into the Kouga Dam is economically used by downstream users, with the farmers in the Gamtoos Valley (approximately 2/3) and the Nelson Mandela Bay Metropolitan Municipality (1/3) having the largest share. Local domestic water use represents only a very small quantity.

[31] In addition some groundwater use in the two catchments (a total of a few million m^3) is reported. The (preliminary) conclusion that this groundwater is partly associated with the deep aquifer is based on the principle that the safe yield (groundwater potential) is only a fraction of the groundwater recharge.

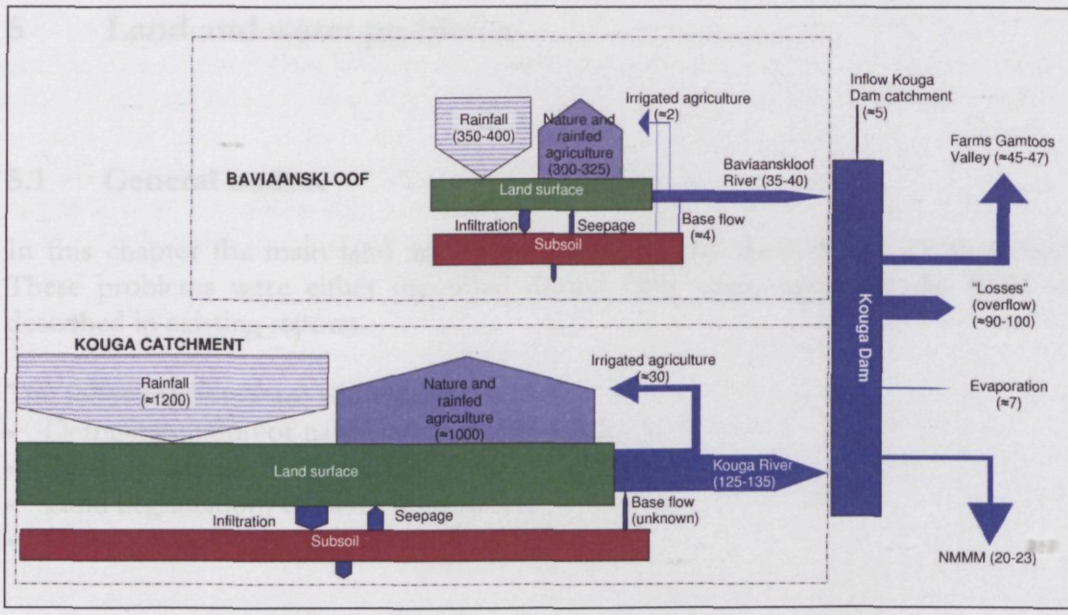

Figure 17. Average water balance of study area (values in million m^3 per year)

5 Land and water problems

5.1 General outline

In this chapter the main land and water problems and their causes are described. These problems were either identified during field visits, raised by the PMU or described in existing reports.

The following issues are addressed:
- Defragmentation of nature areas: Section 5.2;
- Water shortages: Section 5.3;
- Land degradation/erosion: Section 5.4;
- Erraticness of water resources: Section 5.5.

5.2 Defragmentation of nature areas

The Baviaanskloof Nature Reserve comprises a cluster of state owned protected land within a network of private and communal land. Most of the private land is owned by farmers, while there are also small settlements.

Although most of the nature reserve areas are connected the private lands sometimes defragment ecosystems and hinder the free passage of fauna (Figure 8). In addition, wildlife sometimes causes damage to agricultural lands and crops.

These issues are mostly related to land management without having significant water implications. They are, therefore, not further elaborated in this report. Ecological land management (e.g. with PES schemes) may help to solve existing conflicts between the various land uses.

5.3 Water shortages

Chapter 3 shows that water shortages are experienced by the various economic sectors. The water shortages will become more prominent, mainly because of increased (future) demand and increased erraticness of water resources, due to global climate changes. Especially the Gamtoos Irrigation Board and the Nelson Mandela Bay Metropolitan Municipality would be interested to have more (assurance of) water than is presently available.

In the Baviaanskloof-Kouga-Gamtoos area water shortages can be relieved by:
1. Supply Management: Interventions are aimed at getting more water. As (intercatchment) water transfers are considered not desirable, getting more water should be accomplished through better storage (more retention during the wet periods). The goal of supply management is *to get more drops* ("get more water");

2. Demand management/end-use efficiency. Interventions are aimed at water saving technologies and strategies and at reducing losses. The goal is to get *more crop per drop* ("do more with the water") and minimize water consumption (e.g. by increase of efficiencies, price policies, etc.);
3. Demand management/allocative efficiency. Interventions are aimed at the reallocation of water to water uses that generate a high value per unit of water. The goal is to get *more jobs per drop* ("do other/better things with the water").

Supply management

The main storage infrastructure is the Kouga Dam. The filling of the Kouga Dam started in 1961. In 1967 it was filled to its present maximum level of 54.92 m. Ideally, from an economic water use perspective, the inflow from the Baviaanskloof and Kouga catchments should be such that the dam is permanently containing sufficient water, with no spillage occurring. In this situation there is maximum water available to downstream water uses (and minimum losses). From an ecological perspective, however, spillages[32] are important for downstream ecosystems.

Figure 18 presents the recorded water levels in the Kouga Dam and the (calculated) spillage over the surplus weir. The figure shows that sometimes the water level drops rapidly after periods of spillage. This means that the discharge from the Baviaanskloof River and Kouga River is very erratic and that these areas respond rapidly to rainfall events. Water retention measures in these catchments will decrease the erraticness of the discharge (i.e. increase the base flow) and, therefore, contribute to a better water supply and increased water availability to the downstream water uses.

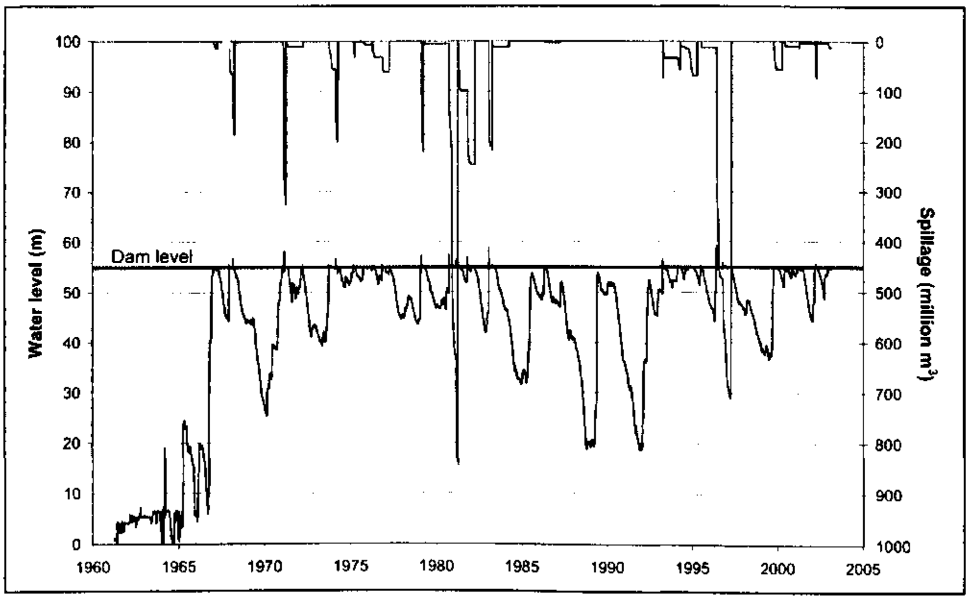

Figure 18. Water levels and spillage of the Kouga Dam

[32] Probably not only the occasional large spillages, but also a rather constant flow throughout the year.

The estimated annual spillage from the Kouga Dam is presented in Figure 19. On average 90 to 100 million m^3 of water flows annually over the surplus weir, with a peak spillage of 844 million m^3 in 1980/1981. This is more than the average volume of water that is released (in a controlled way) to the irrigation canal, which amounts to 70-75 million m^3 per year (Figure 20).

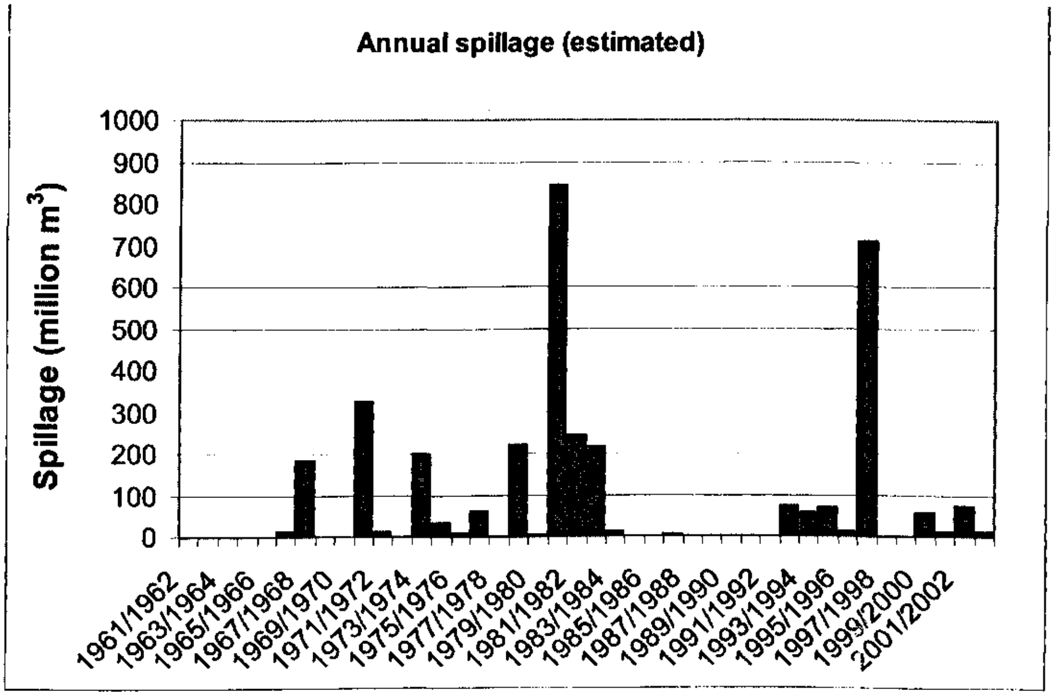

Figure 19. Spillage from the Kouga Dam

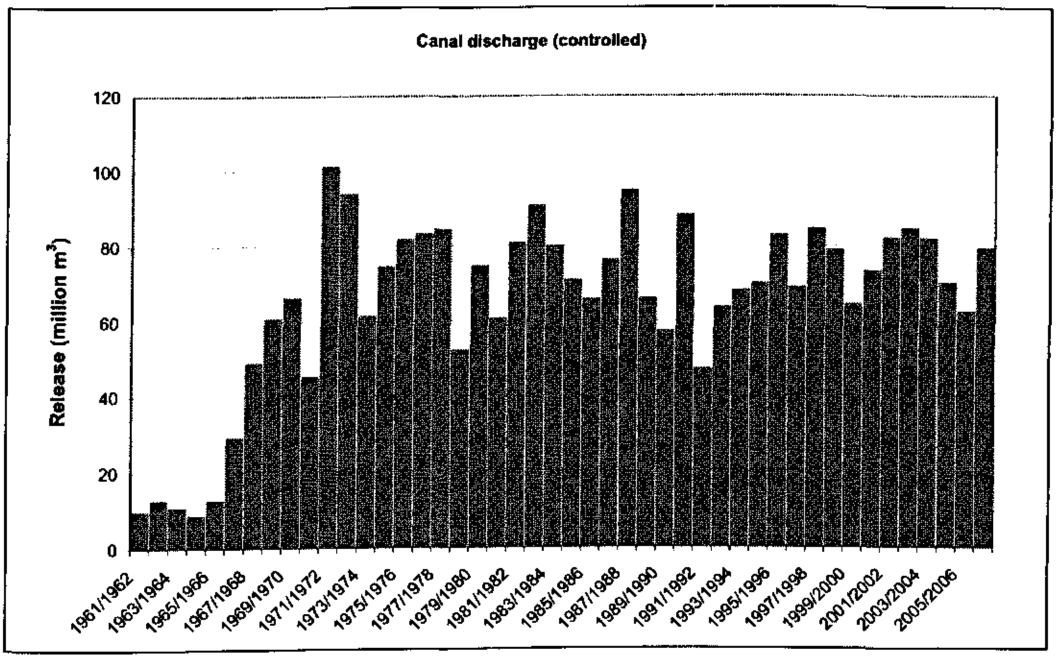

Figure 20. Release of water from the Kouga Dam.

The scope for improvement of water storage in the Kouga Dam was assessed by evaluating the storage efficiency. Figure 21 shows that, on average, the Kouga Dam is filled at 75 % of its total capacity of its 128.3 million m^3. There is some scope for improvement if the inflow would become more attenuated. To achieve a less erratic inflow into the Kouga Dam water retention measures have to be implemented in the upstream catchments. Farmers and inhabitants of the villages in the Baviaanskloof and Kouga catchment can be involved in water retention programmes (e.g. through PES schemes).

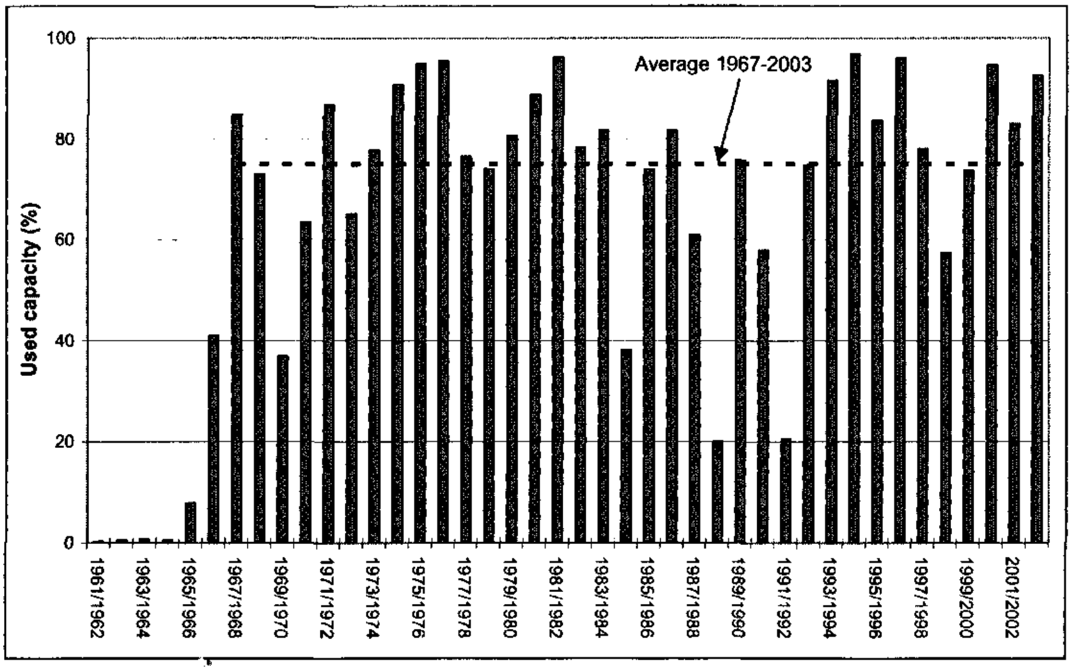

Figure 21. Water storage in the Kouga Dam

Demand management

Demand management is aimed at the improvement of the end-use efficiencies through technical interventions such as efficient irrigation systems, "water-saving" crop varieties and modern drinking water networks. Demand management can also imply constitutional interventions, such as the charging of water, or institutional/managerial interventions (including training). These demand management options are, however, not in the scope of this study.

From Chapter 3 it can be concluded that farmers, generally, use efficient irrigation systems, having little scope for improvement. As significant losses in the transfer of water from the Loerie Dam to the Nelson Mandela Bay Metropolitan Municipality were reported demand management could target these infrastructures. The drinking water supply infrastructures of NMMM are, however, not in the scope of this project.

Allocative water management

Interventions that are aimed at the reallocation of water may imply the withdrawal (or selling) of water and/or water rights from (irrigation) schemes that produce low revenues per unit of water, hence it implies strategic decisions on water use. Allocative water demand management will require social restructuring and entails risks of tension and conflicts in an area. PES schemes should help to avoid such tensions.

In the Baviaanskloof and Kouga catchments allocative water management could imply that farmers in these areas sell their water (rights) to downstream users, or maintain their land in such a way that more water will become available to downstream uses, in particular in periods of water scarcity.

5.4 Land degradation and erosion

In rainy periods peak discharges cause surface runoff and subsequent erosion, with (potential) damage to infrastructures. In the Baviaanskloof stream bank erosion has increased since the nineteen eighties. Some measures have already been taken. Also many areas are affected by hill slope erosion. The main causes of these problems are the diversion of streams from the tributaries to the main river, the channelling of the main stream and changes in land use and land cover. Fires can also aggravate the problems.

Stream diversion
Many tributaries of the Baviaanskloof River have been canalised and directed straight into the main channel to protect cultivated areas from flooding. Embankments have also been erected alongside the main riverbed to facilitate irrigation in and near the floodplain. A subsidy programme to construct embankments (*"keerwalle"*) and overflow furrows was launched by the Government in 1982 after serious floods in 1981 (Kruger, 2006).

These structures have obviously resulted in an increase of the fast component of the discharge of the Baviaanskloof River. Instead of the spreading of water over the floodplain (and the subsequent infiltration of a portion of this water into the subsoil) the peak flows from the side valleys are now rapidly diverted to the main river. The natural attenuation function of the floodplains has thus been destroyed and the almost simultaneous inflow of runoff from the subcatchments into the Baviaanskloof River causes huge peak discharges and high flow velocities. The impacts are clearly visible on aerial photographs. Presently a heavily eroded narrow gully in the floodplain is visible in the central portion of the Baviaanskloof, discharging most of the water. The gully is expected to erode further if no measures are taken.

The eroded gully has also caused the drainage base to lower. Because of the high permeability of the alluvial deposits in the valley the groundwater tables have lowered and, locally, water sources have fallen dry. Besides, riverside wetlands have been washed away.

Some of the *keerwalle* have been removed or were washed away during the floods in 1984 (Kruger, 2006). However, to date many of these structures still exist.

Fires
In 1986 the fire management plan was replaced by a "hands-off" approach. It was reported that, since then, uncontrolled fires stripped large areas of vegetation, causing increased run-off (Kruger, 2006).

Impact to downstream uses
There is ambiguous information about the sedimentation in the Kouga Dam. To date the dam has never been cleaned and the gates to discharge accumulated sediments have never been used (Grundling, 2008). DWAF reports that in the period from 1969 to 1986 the total sedimentation amounted to approximately 1.5 million m^3 (DWAF, 2002), being on average 80000 – 90000 m^3 per year, which is 1% of the storage capacity. Other sources report that siltation has reduced the storage capacity by 3%. It is well possible that the siltation is concentrated at the inflow section of the dam, where the flow velocities decrease, while at the outflow section no sedimentation is experienced yet.

Increased erosion will result in a larger sediment load to the Kouga Dam. The owner of the dam (the Gamtoos Irrigation Board) will, therefore, be interested that measures be taken in the upstream catchments to minimize erosion.

The Nelson Mandela Bay Metropolitan Municipality will be interested in a reduced turbidity of the water at times of high discharges, as the treatment costs of drinking water increase considerably with turbidity. Such measures could also be incorporated in a PES scheme, yet they may be difficult to quantify. Besides also communities in the Gamtoos Valley may suffer from poor quality water during floods.

5.5 Erraticness of water resources

The rainfall in the area is very erratic and serious floods occur periodically, because of the direct response of surface runoff to rainfall. For example, in August 2006 the water level in the dam increased by approximately 24.5 metre in one day time (Grundling, 2008), which corresponds with a volume of more than 90 million m^3. Such extremes are not very exceptional. Another peak inflow was reported in November 1996 (mostly due to huge rainfall in the Kouga catchment), while records show another extreme discharge in 1981. Further back in history (1916) extreme rainfall in the Baviaanskloof caused a devastating flood, claiming the lives of people and livestock and causing huge damage to the rural livelihoods (Scheltema, 2007). Heavy floods occur on average once in every 10 years in the past era. They are principally a natural phenomenon.

On top of the natural erraticness it is expected that the global warming and associated global climate changes will increase the erratic character of rainfall. Based on international studies it is expected that the annual rainfall will not change dramatically, however the Winter rains are expected to decrease, while the Summer rains are expected to increase (IPPC, 2007). This will make the area more vulnerable to extreme events, both droughts and floods.

In Appendix 2 some long-term series of rainfall records are presented. In addition, some of the series were statistically investigated for trends. Although most of the records suggest more rainfall in Summer and less rainfall in Winter, the data do not provide decisive information whether trends are already evidenced.

6 Land and water interventions and measures

6.1 Policy options

In Chapter 5 the main land and water issues were identified and the main causes were described. In this chapter land and water development options, which can reduce or mitigate these problems, are elaborated.

Table 4 summarizes the main land and water problems from Chapter 5 and policy options to alleviate these problems. It is also indicated if policy options can be incorporated in PES schemes[33].

Table 4. Land and water policies.

Land & Water problem	Main cause(s)	Land & Water policy option	Incorporation in PES possible?
Defragmentation of nature areas	Different (conflicting) land uses	Land acquisition and/or alternative land management	Yes ¹)
Water shortages	Increased water demand & losses (spillage)	Water supply management	Yes
		Water demand management	No
		Allocative demand management	Yes
Land (wetland) degradation and erosion, stream bank erosion.	Diversion of natural streams, changes in land use/ land cover, (-historical-) overgrazing	Water conservation, water retention	Yes
	Uncontrolled fires	N/A (fire control)	Yes ¹)
Floods and droughts	Natural erraticness of rainfall, climate change	Water retention	Yes

¹) Not in the scope of this report

Water supply management, as described in Section 5.3, principally refers to water retention and water conservation measures. Allocative demand management refers to the reallocation of water from irrigation to other uses. In Table 5 the objectives of the various policy options in Table 4 that can be incorporated in PES schemes are worked out into more specific land and water interventions and measures.

33 In the Baviaanskloof PES schemes can be used for policy options with respect to land and water resources, which involve the farmers in the Baviaanskloof, and which have a positive impact on nature and/or downstream uses.

Table 5. Methods and effects of land and water policy options.

Objective Land & Water measure/intervention	Measures/interventions	Effect(s):
Water reallocation	Trading of water (rights) and/or ecological land management	• More water for downstream uses • Better (more economical and/or more ecological) use of water resources • More water in the area (for other uses, e.g. nature)
Water conservation	Artificial/enhanced groundwater recharge	• More water in the area • More water for downstream uses • Reduced land degradation and erosion
Water retention	Increase of floodplain areas Artificial/enhanced groundwater recharge Wetland restoration Construction of weirs and dams	• Reduced land degradation and erosion • Reduced impacts of droughts and floods • More water in the area • More water for downstream uses in dry periods[34]

In this report only hydrological measures are addressed. Measures aimed at water (re)allocation require water valuation assessments, which is elaborated in a separate study.

This chapter presents a *generic* description of the hydrological measures inTable 5, whereas the options and implications for the Baviaanskloof are emphasized:
- Artificial/enhanced groundwater recharge: Section 6.2;
- Increase of floodplain areas: Section 6.3;
- Construction of weirs and dams: Section 6.4;
- Wetland restoration: Section 6.5.

All measures are principally aimed at more water retention in the Baviaanskloof, which will result in having more water available in dry periods (increased baseflow) and smaller peak flows in wet periods with, consequently, less erosion. These water retention measures can also be aimed at more water for nature (e.g. rehabilitation of wetlands). A holistic approach is imperative, as retention options are strongly interrelated. They should therefore not be applied as separate, isolated or local solutions, but represent a coherent set of measures, which cover the entire catchment and which take the spatial and temporal relations within the catchment into account.

[34] Some of the possible water retention measures consume water and will, therefore, reduce the overall water availability. Their positive impact is, however, to increase the water availability during periods of scarcity.

6.2 Artificial/enhanced groundwater recharge

Artificial or enhanced groundwater recharge can be achieved by measures or structures that are aimed at increasing the quantity of water that infiltrates into the sub-soil. The generally large storage capacity of aquifers makes them very suitable for seasonal storage, in order to cover periods of droughts and water shortages. An additional positive effect is the increase of the base flow of rivers (and river discharges thus become less erratic), resulting in more water in dry periods.

There is a wide variety of measures and structures possible. Depending on the local physical conditions land preparation (e.g. ploughing), the planting of specific vegetation, terracing, construction of small weirs or bunds, contour trenching and infiltration ponds can be considered[35].

To identify the feasible options the physical environment should be investigated in more detail. Artificial groundwater recharge is only feasible if the thickness of the (unsaturated portion of the) colluvial/alluvial aquifer is sufficient and infiltration can be (somewhat) controlled. Important aspects are the topography, gradients, soils (geometry and hydraulic properties), rainfall characteristics and land cover. In addition the institutional setting should be addressed to assure the proper operation and maintenance (regular inspection, cleaning, repairs) of the system.

As enhanced/artificial groundwater recharge can be a feasible water conservation option its perspectives should be further investigated.

6.3 Increase of floodplain areas

The governmental subsidy programme of 1982 to construct embankments (*"keerwalle"*) and overflow furrows has resulted that tributaries to the Baviaanskloof River have been redirected. These embankments have also narrowed the main river channel. Since then part of their floodplains are protected against flooding and (more intensively) used for crop cultivation.

The net result is a decrease of water retention in the Baviaanskloof: the tributaries discharge their water more directly into the main channel, while the main channel is also ´captured´ in embankments. This has caused serious stream bank erosion and lowering of the drainage base (Section 5.4).

To combat the stream bank erosion of the Baviaanskloof River and its tributaries measures should be taken to increase the water retention in the catchment. An important and effective measure is the removal of the embankments that were constructed in 1982. This removal should be done carefully. The proper locations to remove (parts of the) embankments should be identified and the constructed

35 Reuse of waste water is not yet considered, but may also be an option in future.

diversion channels should be properly closed (by bulldozing or structures). A local terrain survey should, therefore, accompany the restoration works.

By removing these embankments and closing the present diversion channels the natural floodplains can be restored and natural water retention is promoted. Positive side-effects of the increase of water retention in floodplains are enhanced groundwater recharge in the alluvials and the option to restore wetlands in these floodplains.

6.4 Construction of weirs

Through the construction of weirs it is possible to collect and conserve surface runoff after a rainstorm, or water from (intermittent) mountain streams or the main river. The main objectives of weirs (and small dams) are the (temporary) storage of water to improve the water availability in times of scarcity, and the prevention or reduction of erosion and land degradation.

Similar to enhanced/artificial groundwater recharge the feasibility of weirs and dams depends largely on the physical environment, which should therefore be investigated in more detail. It is expected that the perspectives to construct small dams for water storage are limited. Many areas are not suitable to construct dams to store surface water, the soils being sandy (especially the colluvials and alluvials), having good infiltration capacities, while proper building materials (clay) are also scarce. However, if the subsoils permit a good foundation of the weir such weirs can be constructed, even in permeable areas which are most susceptible for erosion. The construction of weirs is then mainly targeted to combat erosion, although they will have positive impacts on groundwater recharge too. The target locations must be very well chosen and will probably be the erosive upstream portions of the valleys (both the main valley and the side valleys). Downstream locations are less suitable, given the risk that periodic strong floods will wash the structures away. For this reason the erection of (large) water retention structures in the main channel of the Baviaanskloof River should also be avoided[36].

If the option to construct weirs is to be investigated firstly the main erosion areas should be identified. Most of these areas are already known or can be identified on aerial photographs. If necessary, the areas susceptible to erosion can also be determined on the basis of (digital) elevation maps, soil maps, land cover maps and detailed rainfall data[37].

[36] Erosion prevention measures along the low water bridges can be extended as they were reported to be effective.

[37] Information obtained from such a desk study could then be supplemented by field surveys, which should include an investigation of the physical environment in these areas, aimed at assessing the construction (geotechnical) issues.

6.5 Wetland and river restoration

6.5.1 Introduction

In the Baviaanskloof wetland restoration can serve a number of water management functions. As the hydrological functions of wetlands are not always fully understood, this section starts with a brief overview of the potential water management functions of wetlands (Section 6.5.2). Thereafter, the options of wetland restoration in the Baviaanskloof are addressed. (Section 6.5.3).

6.5.2 Water management functions of wetlands

The main water management functions of wetlands are:

- Groundwater recharge
- Flood control and mitigation
- Drought control
- Erosion control
- Water purification

In addition they can have a number of non-hydrological and economical functions.

Groundwater recharge
Natural or man-made wetlands can be utilized for groundwater recharge, being an important water management option for water conservation and retention. In addition to creating a strategic storage capacity, (artificial) recharge can also improve the water quality (through filtration), while the attenuation of fluctuations in water quality and temperatures are additional benefits.

Although that riverine wetlands can be used for groundwater recharge they are, generally, not very effective. The infiltration rate through the margins and bottom of the water body is critical and can often not be sufficiently controlled in natural systems. As they would require periodic maintenance (cleaning and/or scraping) it is expected that in the Baviaanskloof the groundwater recharge function of wetlands will not be significant.

It is noted that wetlands are net water consumers. Wetlands may have a positive effect on the water availability during dry periods, which can balance the decreased water availability during wet periods. Their exact hydrological impact depend, however, on the specific local conditions. Wetlands that mostly rely on groundwater and base flow will reduce the water availability during the entire year. Wetlands that capture and store part of the surface runoff may increase the water availability in dry periods.

Flood control and mitigation

Wetlands can help to reduce the adverse impacts of floods. They act as buffers ("sponges"), that can store and release water, and thus attenuate high and low flows. If wetlands are in the floodplain of rivers they serve as floodways, where discharge peaks are gradually attenuated in the downstream direction. This process is referred to as primary buffering.

The attenuation of discharges is further enhanced if the floodplain wetlands can interact with upstream wetlands (e.g. outside the floodplains: backwaters). These backwaters have two peak reducing impacts:

- the overland flow to the river and the inflow from tributaries crossing the wetlands are attenuated;
- a portion of the discharge peak in the river can be temporarily stored in these backwaters.

These processes are referred to as secondary buffering.

A study by the Illinois State Water Survey in 1993 showed that wetlands can significantly reduce the peak flows and flood flows, and increase base flows. (Table 6).

Table 6. Change in flow rates of streams (per one percent of wetland in watershed)

	Peak flow	Flood flow	Base flow
State	3.7% decrease	1.4% decrease	7.9% increase
Northern	7.9% decrease	2.3% decrease	15.0% increase
Central	5.9% decrease	4.5% decrease	5.5% increase
Southern	0.8% decrease	No change	15.9% increase

Additional peak-flow reduction can occur if a portion of the retained water infiltrates into the groundwater system (see above).

In water management the retention function by wetlands can be explored as an alternative for other retention infrastructures (e.g. dams, ponds, trenches, weirs). Sometimes these structures are, however, needed to create or enhance wetlands. On a global level there are many examples of new wetlands being created within the framework of catchment water management.

It is, however, noted that the creation of wetlands in riverine systems can also have negative effects with respect to flood mitigation. If situated in the floodplain they can cause the accumulation of water and higher peak levels. The locations of new wetlands should, therefore, be carefully selected.

Drought control

As previously stated wetlands can help to reduce the effects of extreme conditions, due to their buffering function. This not only applies to floods, but also to droughts. In dry conditions wetlands can provide increased base flow of rivers (see also Table 6).

Erosion control
Wetland vegetation reduces erosion along stream banks by reducing the flow velocities and the forces associated with wave action. They are also effective to stabilize sediments, because rooted vegetation is binding soil and dissipating erosion.

This function is very relevant in areas that are sensitive to erosion (e.g. as a result of changes in land use or overexploitation of lands).

Water purification
Wetlands can have positive impacts on water quality through a wide variety of physical, chemical and biological processes. Wetlands can moderate overland flows to rivers and also the inflow from tributaries, which provides time for sediments, including inorganic (toxic) pollutants, to settle out before the water is released to downstream rivers or other wetlands. Nutrients can be absorbed by the soils or used by vegetation, so wetlands can also produce and store organic matter. Also denitrification is enhanced by wetlands and other chemical compounds may be removed.

The effectiveness of wetlands in producing, removing or cycling nutrients and organic matter is dependent of the wetland type, soil and the hydrology.

Non hydrological and economical functions
In addition to water management functions wetlands are the habitat for many species of vegetation, fisheries and wildlife. Many animals depend on wetlands. Amphibians, reptiles, aquatic insects and many mammals need wetlands for food and for shelter. Migratory birds and wildlife use wetlands as resting areas.

Wetlands are also popular for boating, fishing, hunting and to explore and enjoy nature, while they can sometimes provide economic commodities such as wood, vegetables, fruits and fish (obviously all depending on the size of the wetlands).

6.5.3 Wetland restoration in the Baviaanskloof

The main water management objectives of wetlands in the Baviaanskloof are erosion control and water retention[38]. Not all locations are suitable for wetlands, which means the restoration of the natural terrestrial vegetation is also critical for erosion control.

Wetlands should be created in areas where they can intercept, store and slowly release the surface runoff after storm events. The areas to create or rehabilitate wetlands should be carefully selected. The alluvial deposits are generally sandy, having a high hydraulic conductivity, which complicates wetland restoration, unless the underlying rocks create obstructions or "control points". Some of the alluvial

[38] They are obviously also important to enhance nature.

deposits are loamy and clayey (Section 2.3), which offers better perspectives of wetland restoration.

In addition to an assessment of the environmental factors it is recommended to investigate where wetlands occurred in the past (e.g. before the creation of the embankments) before large-scale wetland and river restoration plans are being planned, as these locations obviously offer the best perspectives.

7 Conclusions and recommendations

7.1 Conclusions

From the land and water assessment it can be concluded that the Baviaanskloof is characterized by very erratic water resources with a seasonal variability as well as a large inter-annual temporal variability. As a result the river discharges vary largely. On average the Baviaanskloof River supplies 35-40 million m^3 per year to the Kouga Dam. The Kouga River supplies annually 125-135 million m^3. On average approximately 40 % of this water is economically used by downstream users, with the farmers in the Gamtoos Valley (approximately 2/3) and the Nelson Mandela Bay Metropolitan Municipality (1/3) having the largest share. These water uses are both facing shortages and both have an economic interest in getting more water (assurance) from the Baviaanskloof-Kouga-Gamtoos area.

The water shortages are principally experienced by downstream water uses. In the Baviaanskloof land degradation and erosion, on the hill slopes as well as stream bank erosion are the main issues, having a negative impact on biodiversity as well as agricultural production. The area is also vulnerable for floods and droughts, which is expected to aggravate in future due to the global climate change.

To alleviate the existing land and water problems interventions and measures in the Baviaanskloof should principally be aimed at:
- decrease of land degradation and erosion;
- increase of water availability, particularly in times of scarcity;
- reduction of detrimental extreme events (e.g. floods and droughts).

Land degradation

The current erosion problems are associated with changes in the land cover, the faster diversion of water from the side valleys and within the river flood plain (by the erection of embankments), and the (locally) lowered drainage base. Measures to combat erosion should principally be aimed at increasing the ***water retention*** in the catchment, in addition to thicket/fynbos restoration programmes. Water retention measures should include the increase of the floodplain areas through the removal of embankments ("*keerwalle*") -together with the proper closure of the previously man-made diversion channels-, the creation and/or rehabilitation of (riparian) wetland areas and, possibly, the construction of weirs and/or gabions in the side valleys.

Measures to combat erosion in the Baviaanskloof will also be beneficial for the Gamtoos Irrigation Board and the Nelson Mandela Bay Metropolitan Municipality, who will benefit from reduced silt loads and a reduced turbidity of the water. Water retention measures can, therefore, also be incorporated in PES schemes.

Water retention measures are also becoming more and more important to mitigate the impacts of extreme climatic events such as floods and droughts, which are expected to occur more frequently in the future.

Water availability
To alleviate (seasonal) water shortages in the Baviaanskloof and downstream areas some additional water storage can be created in upstream areas. This will also enhance the water availability for nature, and possibly restore wetlands. Measures should be aimed at water conservation and retention to increase the base flow of the Baviaanskloof River during dry periods. Possible options are enhanced/artificial groundwater recharge measures through infrastructures (e.g. weirs, infiltration pits and/or contour trenches). In addition, it is possible to improve the hydraulic properties of soils through the (re)planting of indigenous vegetation. Although the net water availability over the year may decrease (as vegetation also consumes water) the increased infiltration rates during excessive rainfall events can result in an increase of the water availability in the critical periods. Farmers and inhabitants of the villages in the Baviaanskloof (and Kouga catchment) can be involved in water retention and water conservation programmes. The removal of the previously mentioned embankments will also improve water availability.

In addition to these *supply management* measures future water shortages can be relieved by the reallocation of water resources, aimed at maximizing the ecological and economical returns of scarce resources.

7.2 Recommendations

As water retention and water conservation measures require specific conditions the physical environment should be investigated in more detail before any of the measures is implemented.

It is recommended to map the existing embankments to assess their impact on the local hydrology and stream bank erosion, and to liaise with the owners on the feasibility of removing these embankments.

It is also recommended to investigate feasible locations for river and wetland restoration. These locations should principally be selected for erosion control and increasing water retention. In addition to an assessment of the environmental factors it is recommended to investigate where wetlands occurred in the past, as these locations obviously offer the best perspectives.

For artificial/enhanced groundwater recharge feasible locations should be identified on the basis of topography, gradients, soils (geometry and hydraulic properties), rainfall characteristics and land cover. Also the institutional conditions should be addressed to assure the proper operation and maintenance (regular inspection, cleaning, repairs).

Weirs and small dams should principally be constructed as erosion control measures (and secondary for enhanced groundwater recharge). Target locations are erosive upstream portions of the valleys (both the main valley and the side valleys). Options for the construction of gabions or weirs in the main floodplain should be carefully examined and planned with utmost caution, since their impact on the hydrological regime can be considerable, whilst the risk of damage by floods is considerable..

The recommended measures to enhance water retention and conservation should be selected in close collaboration with stakeholders and experts on biodiversity and river restoration programmes. The workshops and joint field studies that were organised promote the participatory and multi-disciplinary approach, which is critical to achieve the projects' objectives.

A holistic approach is imperative, as land and water restoration options are strongly interrelated. They should therefore represent a coherent set of measures, which cover the entire catchment and which take the spatial and temporal relations within the catchment into account.

It is also highly recommended to monitor measures to generate information that can be used to upscale measures or to apply measures in other catchments, which experience similar problems.

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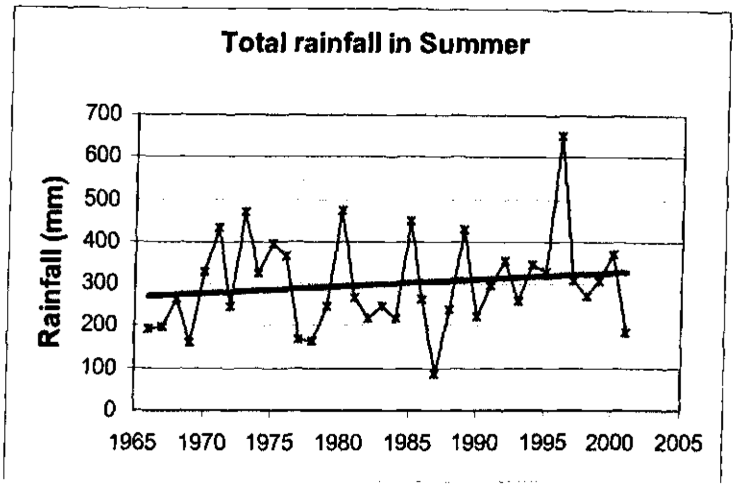
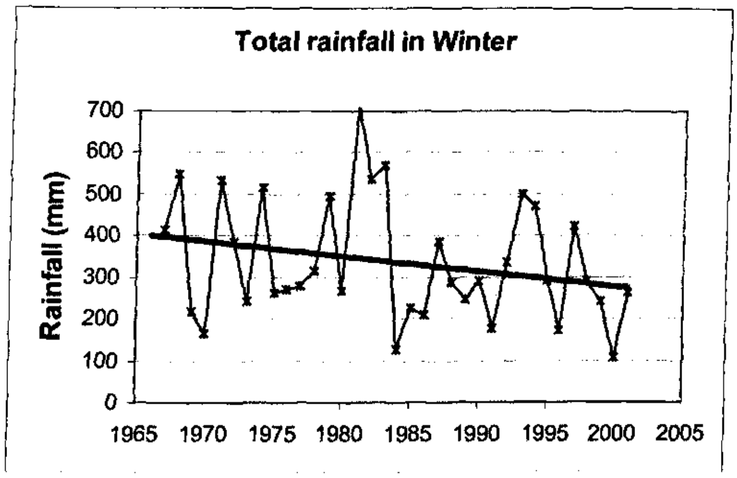
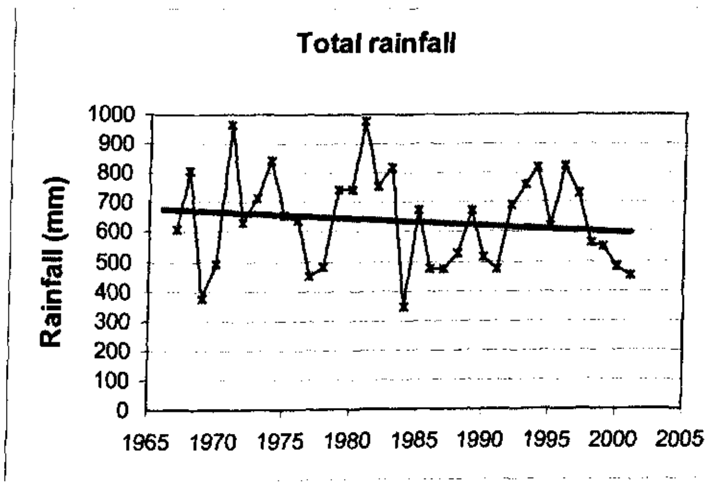
Appendix 1 Overview of rainfall data used

No	Station	Catchment	Start date	End date	Data used:	Number of years with data
10448	AVONTUUR - SAR	Kouga	01/01/1950	31/12/1975	Annual total	26
10455	DE HOOP	Kouga	01/01/1950	31/10/1974	Annual total	24
10456	WELGELEGEN	Kouga	01/01/1972	30/04/2004	Annual total	32
10459	ONGELEGEN	Kouga	01/01/1950	31/08/1977	Annual total	27
10463	KLEINRIVIER	Kouga	01/01/1950	31/10/1970	Annual total	20
10464	VREDENDAL	Kouga	01/03/1983	30/04/2004	Annual total	21
10465	BRUINKLIP	Kouga	01/05/1968	30/04/2004	Annual total	36
10467	VOORKLOOF	Baviaanskloof	01/01/1950	31/01/1957	Annual total	7
10469	KRAKEELRIVIER	Kouga	01/01/1950	30/04/1977	Annual total	27
10471	JOUBERTINA	Kouga	01/01/1950	31/03/1986	Daily	36
10472	JOUBERTINA	Kouga	01/09/1979	30/04/2004	Daily	24
10477	STUDTIS - BOS	Baviaanskloof	01/08/1952	31/08/1991	Daily	39
10479	BRAAMRIVIER	Kouga	01/03/1987	30/04/2004	Annual total	17
10480	RUST EN VREDE	Baviaanskloof	01/08/1978	30/11/1991	Annual data	13
10483	ZANDVLAKTE	Baviaanskloof	01/01/1950	30/04/1999	Daily	49
10485	NOOITGEDACHT	Kouga	01/01/1950	31/03/1979	Annual total	29
10486	BRANDEKRAAL	Kouga	01/07/1979	30/04/2004	Annual total	24
10488	ZUUR ANYS	Kouga	01/01/1950	30/04/2004	Daily	54
10491	KRUISRIVIER	Baviaanskloof	01/01/1950	30/09/1960	Annual total	10
17596	KRAKEEL	Kouga	01/01/1998	31/01/2003	Annual total	5
20020	MISGUND-OOS	Kouga	01/01/1963	31/12/1974	Annual total	12
20110	DENNEHOEK	Kouga	01/06/1979	31/12/1996	Annual total	17
20125	JOUBERTINA	Kouga	01/01/1981	31/01/2006	Daily	25
20132	AVONTUUR	Kouga	01/01/1982	28/02/2006	Annual total	24
20237	BAVIAANSKLOOF 1	Baviaanskloof	01/04/1985	30/04/2008	Daily	23
21931	NUWEKLOOF	Baviaanskloof	01/09/1993	30/04/1999	Annual total	5
22268	DE HOOP	Kouga	01/06/1995	30/04/2004	Annual total	8
22269	MARAISDAL	Kouga	01/03/1996	30/04/2004	Annual total	8
22271	CANAGA	Kouga	01/06/1995	31/12/2002	Annual total	7
22272	STUDIS - POL	Baviaanskloof	01/06/1995	31/03/2004	Annual total	8
22486	APPELVLEI	Kouga	01/12/2002	31/12/2005	Annual total	4
30145	JOUBERTINA; MISGUND	Kouga	01/05/2001	31/05/2008	Annual total	8
40012	JOUBERTINA THE WATTLES	Kouga	01/01/2002	31/05/2008	Daily	7

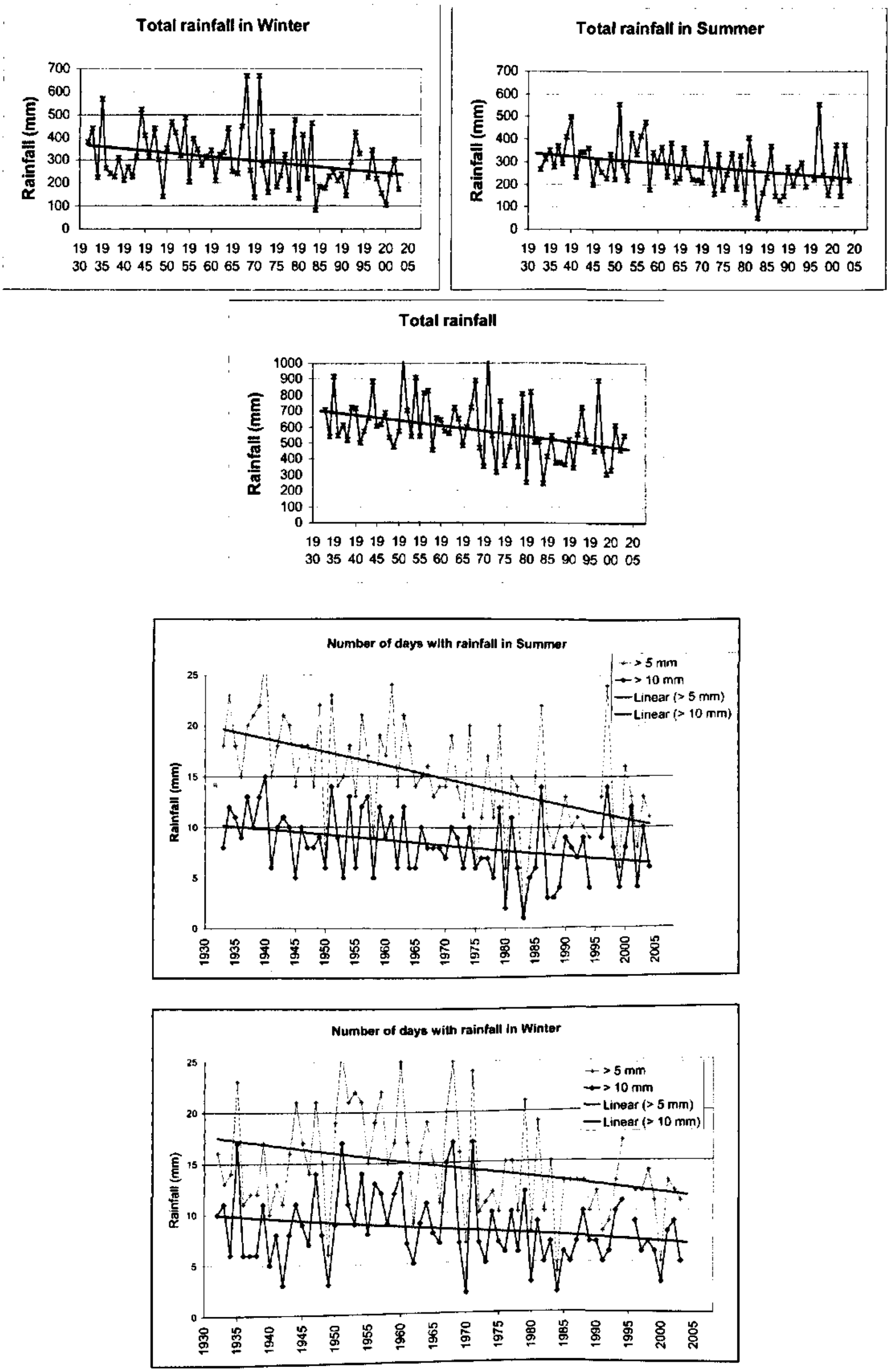
Appendix 2 Long-term rainfall records



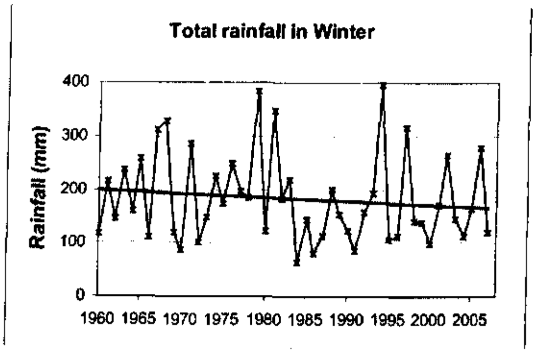


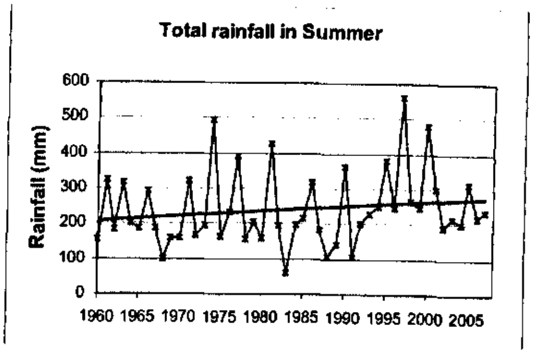


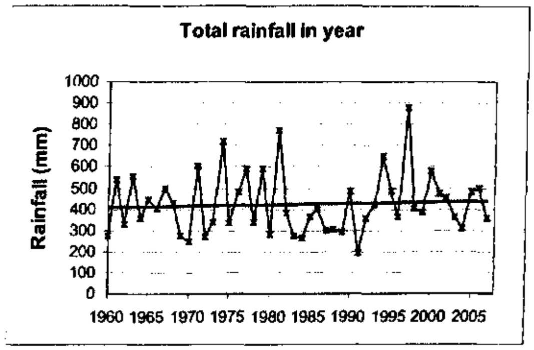
Rainfall trend Langkloof (Kouga River catchment)

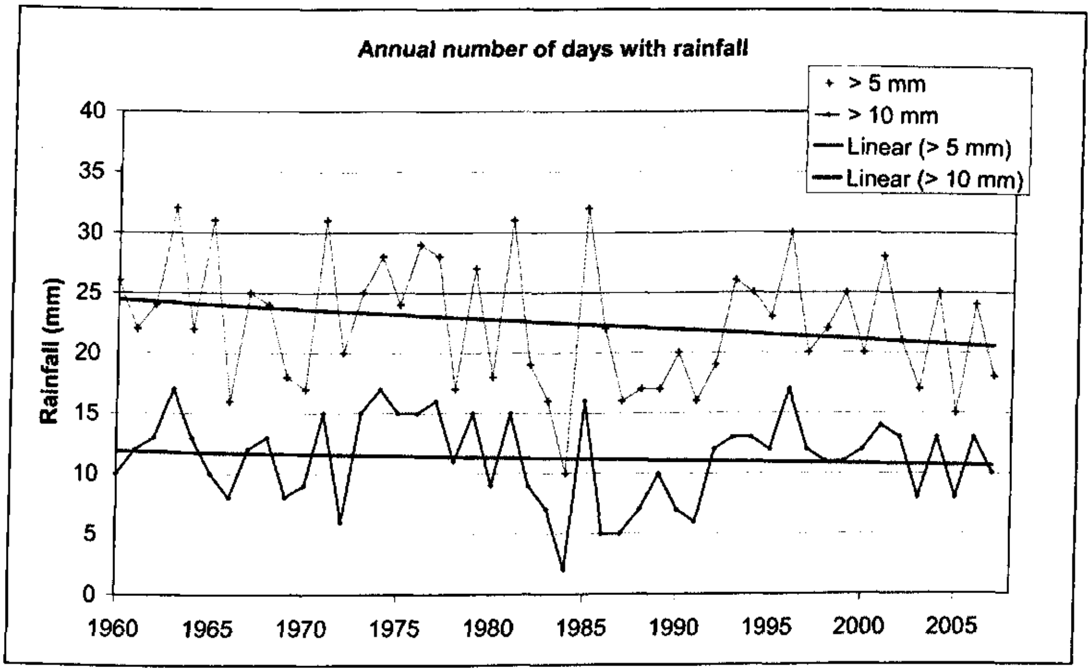


Rainfall trend Zuuranys (Kouga River catchment)

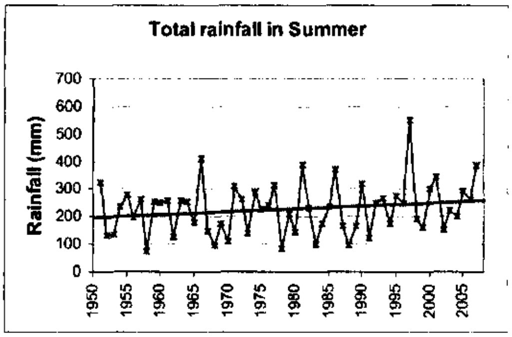


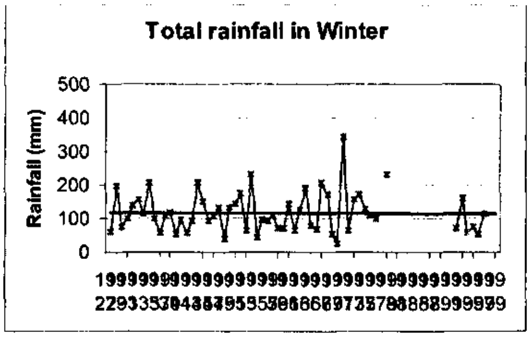


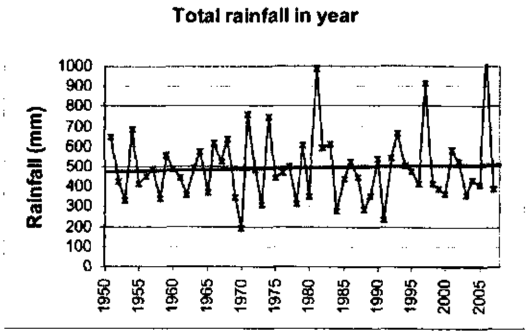


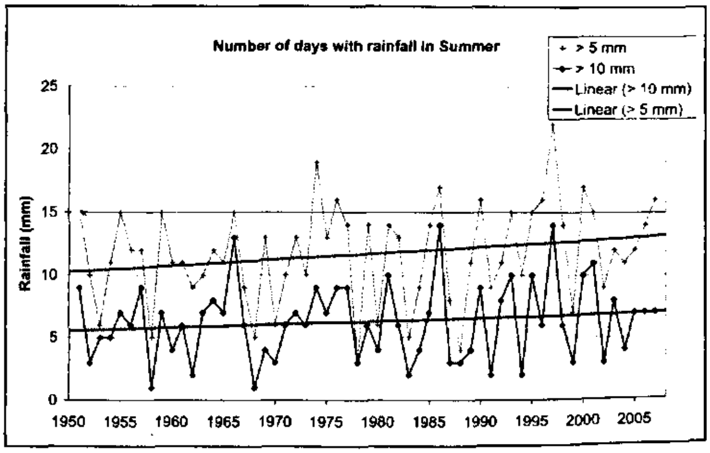


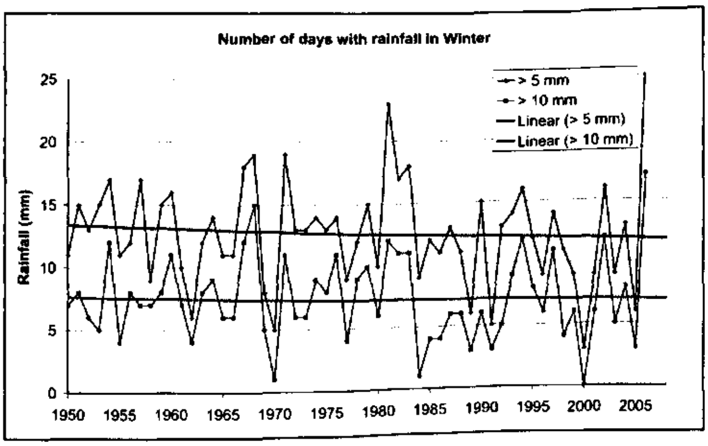
Rainfall trend Twee Rivieren



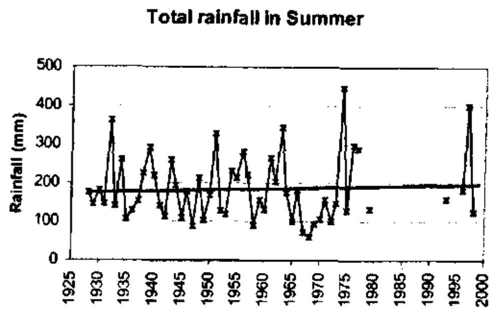


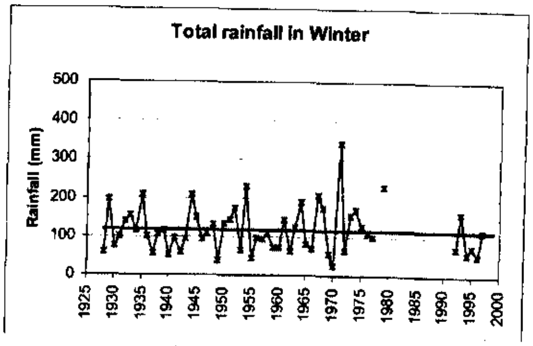


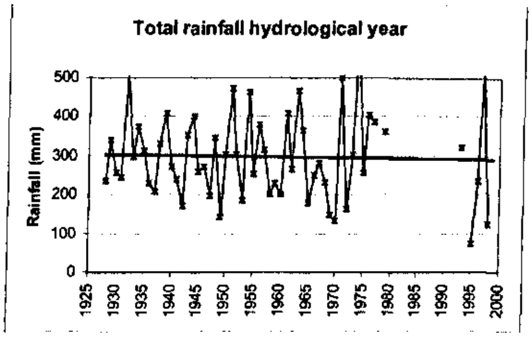


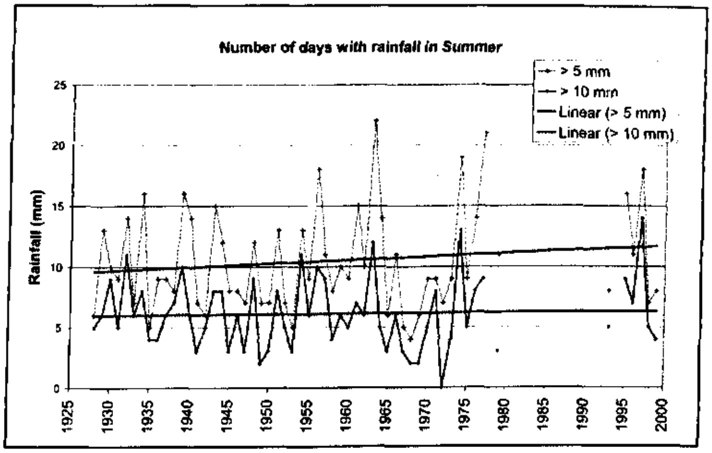


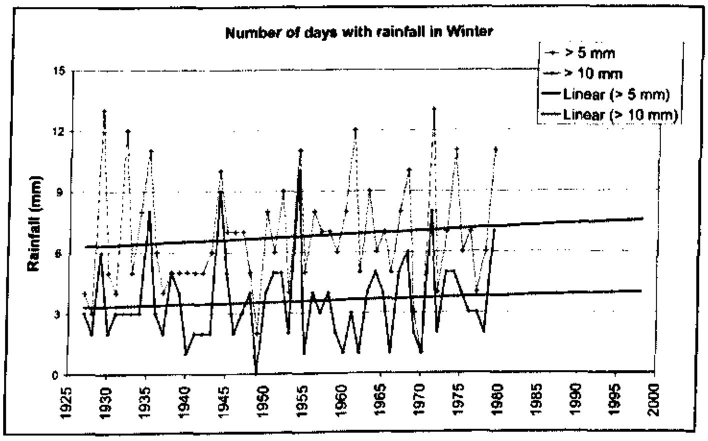
Rainfall trends Joubertina (Kouga River catchment)



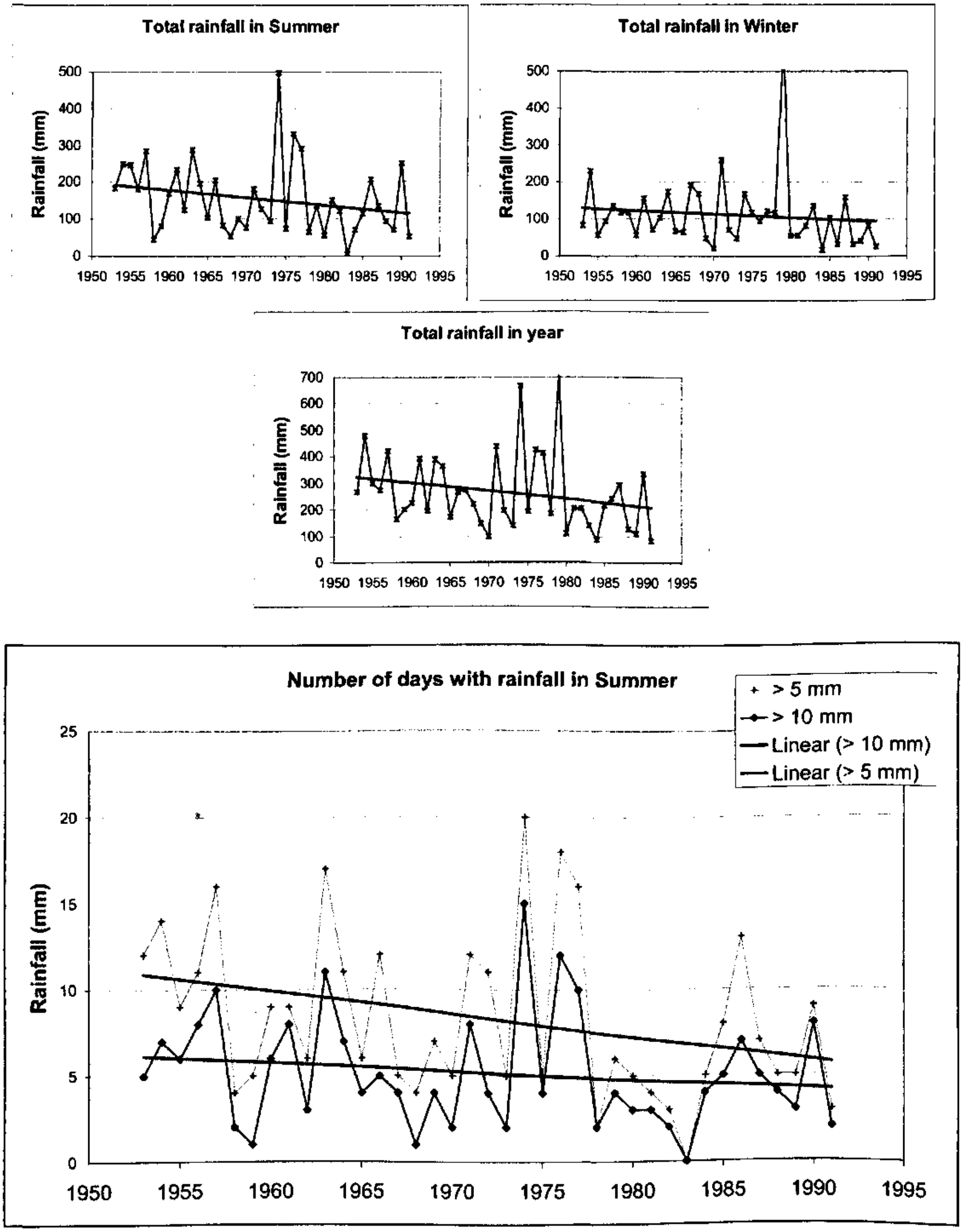








Rainfall trends Zandvlakte (Baviaanskloof)



Rainfall trends Studtis (Baviaanskloof)