Study Name:	Orange River Integrated Water Resources Management Plan
Report Title:	Environmental Considerations Pertaining to the Orange River
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Date of Issue:	August 2007
Distribution:	Botswana: DWA: 2 copies (Katai, Setloboko)
	Lesotho: Commissioner of Water: 2 copies (Ramosoeu, Nthathakane)
	Namibia: MAWRD: 2 copies (Amakali)
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1 INTRODUCTION

The Orange River originates in the Lesotho Highlands and flows in a westerly direction 2 200 km to the west coast where the river discharges into the Atlantic Ocean (see **Figure** 1-1). The Orange River basin is one of the largest river basins south of the Zambezi with a catchment area of approximately 1 million km^2 (Mckenzie and Stoffberg, 1994).

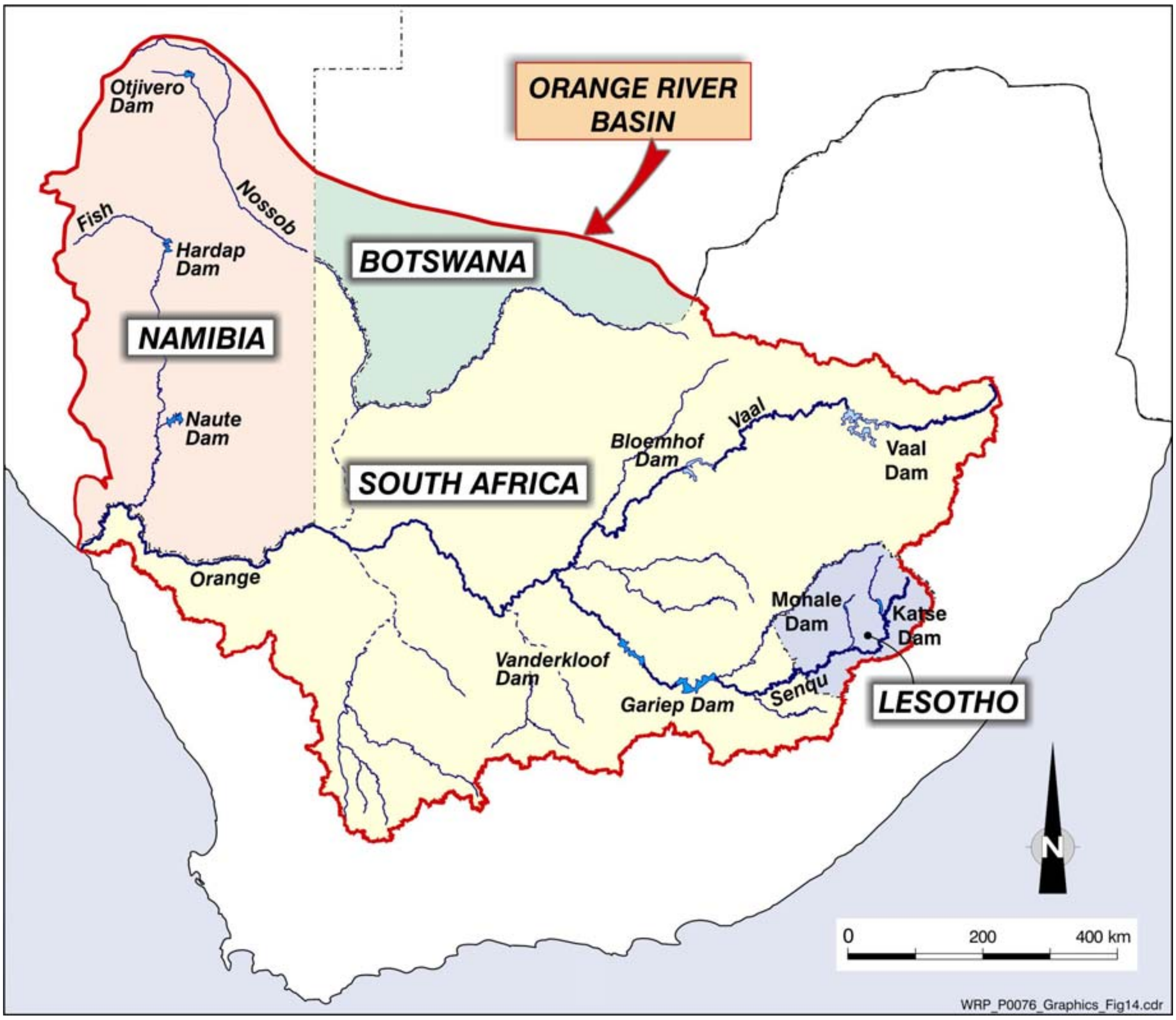

Figure 1-1: Orange River

It has been estimated that the natural runoff of the Orange River basin is in the order of 11 300 million m^3/a of which approximately 4 000 million m^3/a originates in the Lesotho Highlands and approximately 800 million m^3/a from the contributing catchment downstream of the Orange/Vaal confluence which includes a small portion in Botswana feeding the Nossob and Molopo rivers. The remaining 6 500 million m^3/a originates from the areas contributing to the Vaal, Caledon, Kraai and Middle Orange rivers (see **Figure 1-2**).

It should be noted that much of the runoff originating from the Orange River downstream of the Orange Vaal confluence is highly erratic and cannot be relied upon to support the various downstream demands unless further storage is provided.

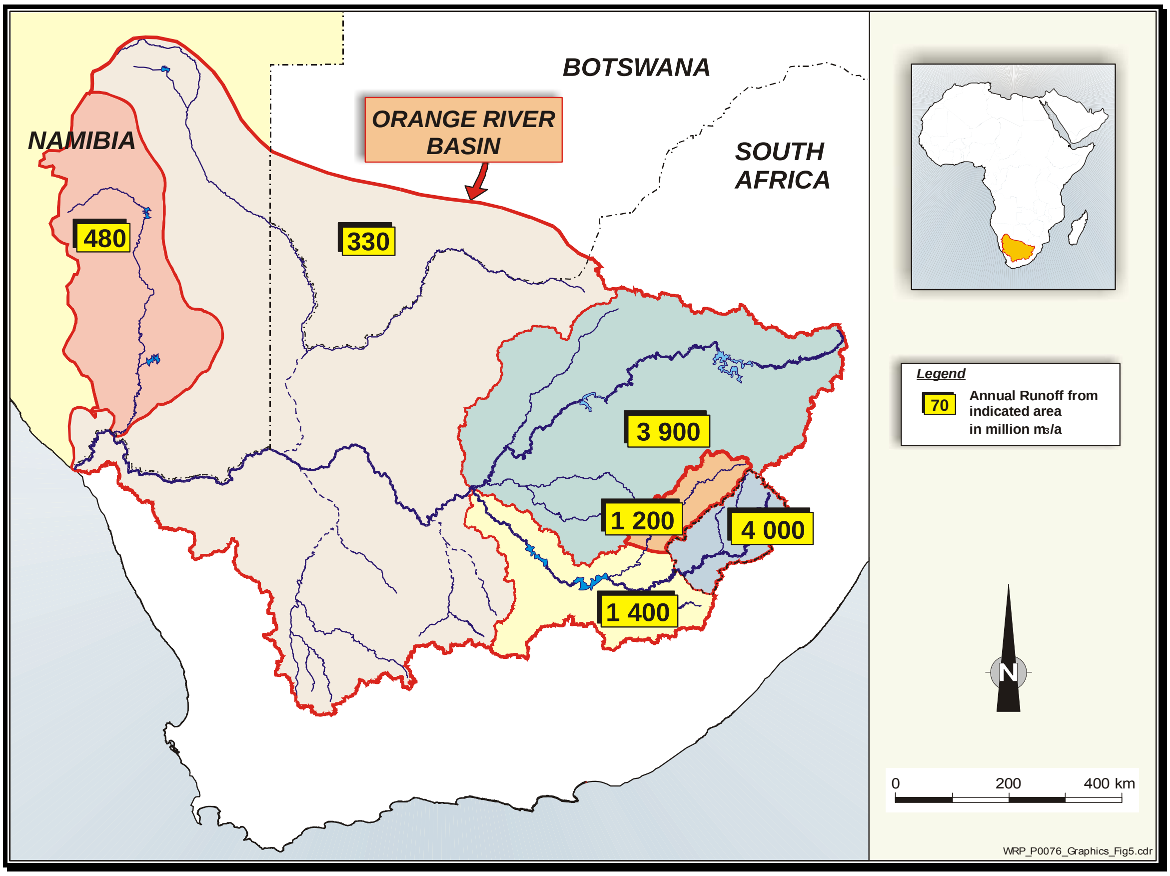

Figure 1-2: Approximate Water Balance for Natural Runoff in the Orange River Basin (ORASECOM Inception report 2004)

The water flowing into the Orange River from the Fish River in Namibia (near the river mouth) could theoretically be used to support some of the downstream demands, particularly the environmental demands at the river mouth. To date, however, the contributions from the Fish River (in Namibia) cannot be utilised to support any downstream demands since these demands are currently supplied with water from Vanderkloof Dam which must be released well in advance since the water takes 2 to 6 weeks to reach the mouth (some 1 400 km away). Any water flowing into the Orange River from the Namibian Fish River will therefore add to the water already released from Vanderkloof Dam since it is currently not possible to stop or store the additional water once it has been released.

It should be noted that the figures indicated in **Figure 1-2** are approximate values which are provided to highlight the variable and uneven distribution of runoff from east to west in the Orange River basin. They refer to the natural runoff which would have occurred had there been no developments in the catchment. The actual runoff reaching the river mouth (estimated to be in the order of 5 500 million m^3/annum) is considerably less than the natural value (over 11 000 million m^3/annum). The difference is due mainly to the extensive water utilisation in the Vaal River basin, most of which is for domestic and industrial purposes. Large volumes of water are also used to support the extensive irrigation (estimated to be in the order of 1 800 million m^3/annum) and some mining demands (approximately 40 million m^3/annum) occurring along the Orange River downstream of the Orange/Vaal confluence (see **Figure 1-3**) as well as some irrigation in the Lower Vaal catchment and Eastern Cape area supplied through the Orange/Fish Canal (see **Figure 1-4**) (Eastern Cape Fish River). In addition to the water demands mentioned above, evaporation losses from the Orange River and the associated riparian vegetation account for between 500 million m^3/a and 1 000 million m^3/a depending upon the flow of water (and consequently the surface area) in the river (Mckenzie et al, 1993, 1994 and 1995).

1.1 Future demands on the Orange River

Several new developments have already been commissioned or have been identified as possible future demand centres for water along the Lower Orange River.

In **Namibia**, possible developments include:

- The Skorpion lead and zinc mine, which is earmarked to be the world's lowest cost zinc producer;
- The proposed Kudu gas-fired power station at Oranjemund, where seawater will most probably be used for the cooling operations of the power station. The only fresh water required from the Orange River will be the demineralised water used in the boilers;
- Haib copper mine. The water demand of Haib Mine would overshadow any other mining enterprises along the Orange River on the Namibian side. Estimates of the water which will be needed annually by the mine range from the initial figure of 60 million m^3 to more recent estimates of approximately 20

million m^{3}. This high water consumption rate is as a result of the water intensive processes that the mine intends to use. There is a 25 year life span for the mine. The viability of the Haib Mine depends to a great extent on the world copper price which in turn depends upon demand and supply.

- Several irrigation projects for communal and commercial irrigation along the northern riverbank.

In general, the vast majority of future urban-industrial growth in the Orange Basin will take place in the Upper Vaal area. According to the State of the Cities Report (2004), the urban portion of Gauteng - comprised primarily of the cities of Johannesburg, Ekurhuleni and Tshwane will be a polycentric urban region with a projected population of some 14.6 million people by 2015, making it one of the largest cities in the world. This growth will be a significant source of growing water demand in the future.

Both South Africa and Namibia have identified considerable development opportunities along the Lower Orange River. The bulk of the opportunities have been identified in Namibia, including irrigation projects for both commercial and communal farmers.

The viability of irrigation schemes in the Orange River Basin can be enhanced through encouraging the cultivation of high value crops through marketing support incentives to the farmers. The use of more efficient irrigation systems will also allow a farmer with the same volume of water allocation to cultivate a larger area (Muir *et al.*, 2004).

Similar potential also exists in South Africa, which has identified a particular need to develop irrigation opportunities for resource-poor farmers and to support poverty alleviation. It appears that the only irrigation developments for which new water rights will be released in South Africa in the Orange River system will be for small-scale farming. Three allocations have been made, including 4 000 hectares each for the Lower Orange WMA, the Upper Orange WMA and for the Fish to Tsitsikama WMA. These proposed developments will lead to a substantial increase in water demand.

In Namibia such developments include the Haib copper mine, Skorpion lead and zinc mine (already developed), the Kudu gas fired power station at Oranjemund.

Similar potential also exists on the South African side of the river with particular need to develop irrigation for previously disadvantaged farmers. In Lesotho there is considerable development planned for the Lesotho Lowlands area and also the potential for further transfers from the Lesotho Highlands Water Project. In Botswana, the developments that may influence the Orange River are restricted mainly to groundwater abstraction.

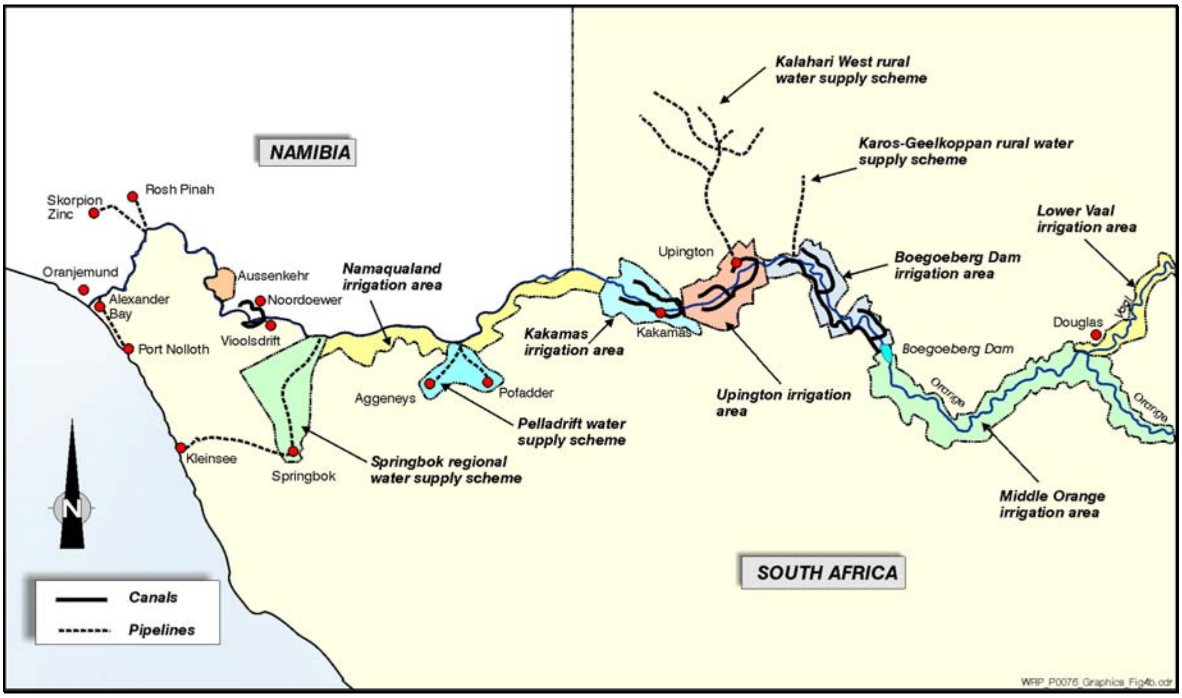

Figure 1-3: Major Water Demands along the Lower Orange River.

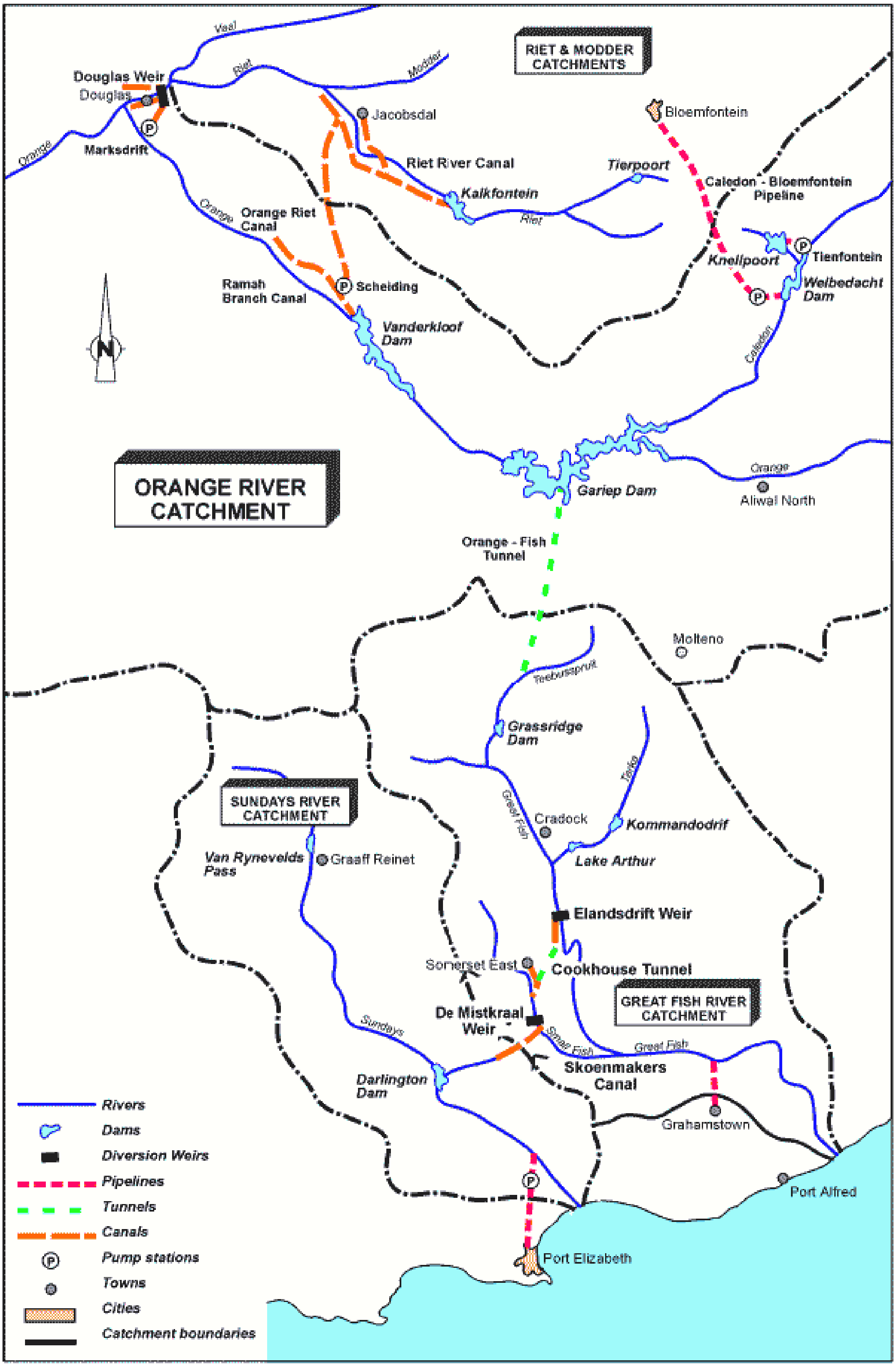

Figure 1-4: Major Water Transfer Schemes from Gariep and Vanderkloof dams.

In Lesotho, Phase 1 of the Lesotho Highlands Water Project represents one of the largest water transfer schemes in the world. Some details of the scheme are shown in **Figure 1-5.**

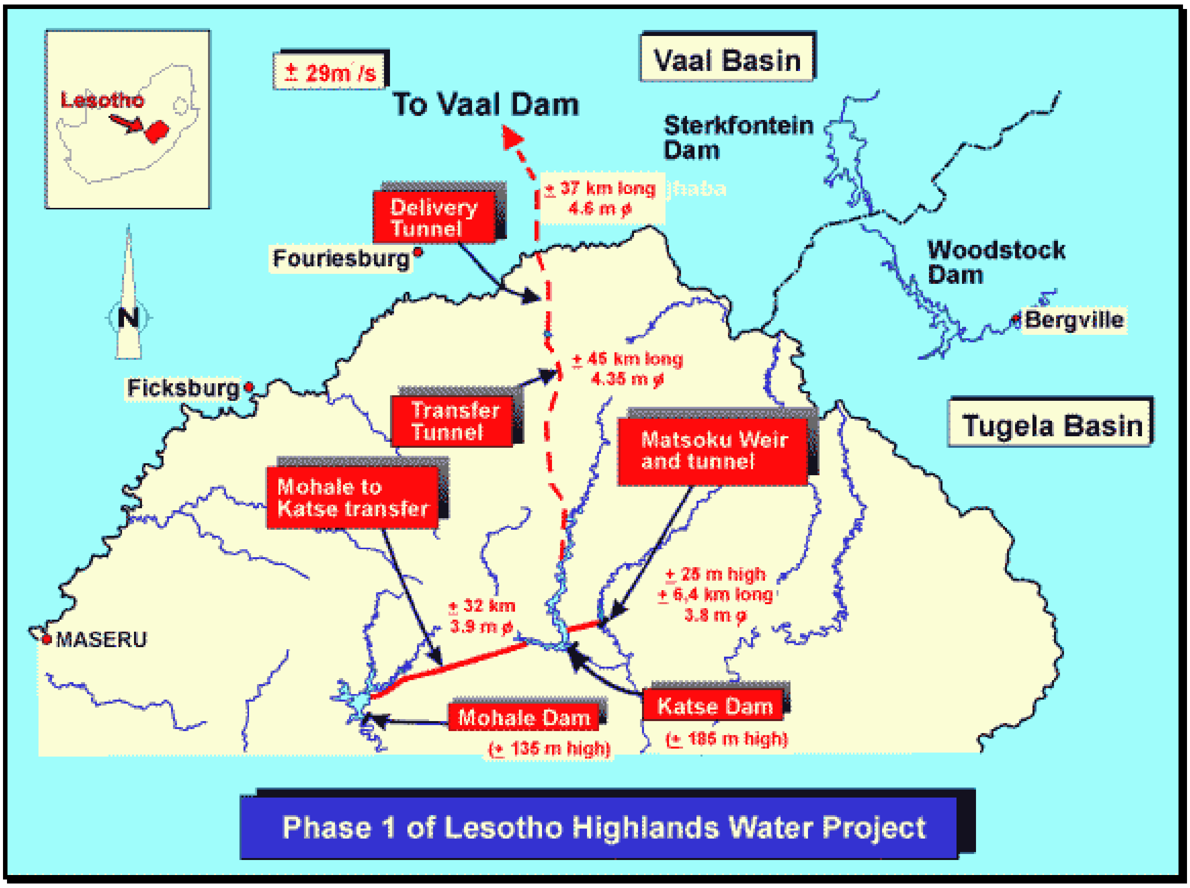

Figure 1-5: Phase 1 of the Lesotho Highlands Water Project.

2 ENVIRONMENTAL ISSUES IN LESOTHO

2.1 Conservation Areas

2.1.1 Lesotho National Parks/Nature Reserves (extract from Mokuku et al., 2002).

National Parks and nature reserves are sites where natural heritage of the country can be preserved *in*-situ. Nature reserves have enhanced the protection to aspects of Basotho natural heritage in terms of conservation of biodiversity and the Basotho cultural heritage in terms of traditional knowledge in medicinal plants and animals. Several sites have been proposed for inclusion as nature reserves and national parks but the following have received official recognition.

- *Sehlaba-Thebe National Park*. It was proclaimed a "Wild-life Sanctuary and National park" and therefore a protected Area on 27th February, 1970 (NES, 2000). It is situated in Qacha's Nek, has an area of 6, 475 hectares and lies at an altitude between 2, 300 and 2, 500 meters above sea level. It has subsequently been established that the Park contains several important rock art (archaeological) sites.
- *Masitise Nature reserve*. This also included an archaeological site and historic mission cave house. It is proclaimed a National Monument in Quthing District. It is a small reserve of about 20 ha, 3 ha of which is thickly wooded.
- *National University of Lesotho (Roma Campus).* It was declared a bird sanctuary by the council of the University on 3rd April 1965. It has an area of about 95 ha and is situated in Highveld Grassland Zone, but the area has been modified by introduction of exotic trees and creation of water areas.

2.1.2 Transfrontier Conservation and Development areas

There are other initiatives to include some areas of biodiversity importance into the national listing of officially declared national parks and nature reserves. The two initiatives are along the border with South Africa. The first of these is the Maloti Drakensberg Area and the second is the wetland area in southern Lesotho.

The Maloti-Drakensberg Transfrontier Conservation and Development area Programme is a World Bank financed Project intended to put measures in place for the conservation of the Biodiversity values of the Maloti Drakensberg area as well as development of the peoples of the adjacent areas along the border between Lesotho an South Africa. The programme is a joint initiative of the Governments of Lesotho and the Republic of South Africa. It is a transboundary conservation and development programme aimed at amongst others, establishing protected areas while promoting sustainable tourism in the Maloti Drakensberg mountains.

Letšeng-la-letsie Protected Area is a wetland area in Southern Lesotho. The current efforts are to engage support to enable declaration of the area as a protected site. Financial support for the initiative is through the Conserving Mountain Biodiversity in Southern Lesotho

project. The project is financed by Global Environment Facility (GEF) and is implemented by the United Nations Development Programme (UNDP). The National University of Lesotho has undertaken a comprehensive Environment Impact Assessment for the establishment of a protected area at Letšeng-la-Letsie.

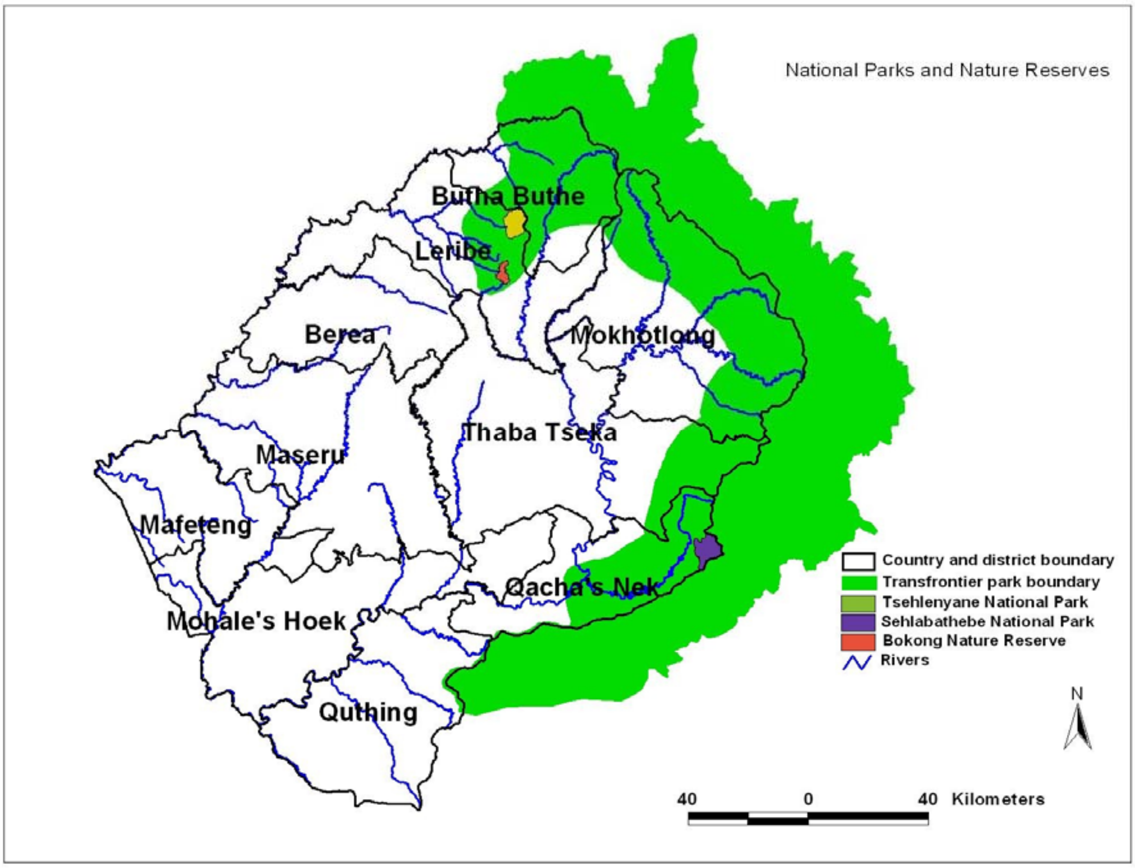

Figure 2-1: Locality of Lesotho National Parks, Nature reserves and Transfrontier National park.

As part of the strategy to conserve the environment around the Malibamatšo river at Katse the Lesotho Highlands Water Project established three protected areas.

- The *Bokong Nature Reserve* is about 1970 hectares and lies between 2, 600 and 3, 200 meters above sea level (m.a.s.l.). It is essentially a sub-alpine grassland with a number of endemic animals and plants species. The numerous endemic wetlands characterising the highlands region support the perennial nature of the mountain streams. The nature reserve has a visitor centre, a bird watching, distinct wetland areas with characteristic vallyhead fens and a lepaqoa waterfall.
- The *Tšehlanyane National Park* is over 5, 600 hectares covers a range of altitudes from 1, 600 to 3, 000m.a.s.l. It is very rugged, with sharp mountains crests and deeply incised ravines. The plant species within the park include one of the few indigenous *Leucosidea* woodlands in Lesotho that are well preserved there than anywhere else in the country. Activities and facilities include, bird watching, small game viewing, crafts, swimming in the streams and picnic sites.
- *Liphofung Reserve* is 4 hectares in size and has a cave area which was inhabited by the San and other Stone Age people some 150 years ago. It also has a historical importance in that the founder of the Basotho nation, King Moshoeshoe I, used it. It has been created mainly for its historical importance, but has its own distinctive fauna and flora. Rock art and rich archaeological deposit of stone age implements are found in the cave. Activities and facilities provided include bird watching, rock art lectures and pony rides.
- *Muela Nature Reserve* is 45 ha around 'Muela reservoir and is being developed as a Nature Reserve. The current plans are to fence it and create a miniature zoo with indigenous plants and animals both terrestrial and aquatic species. This may include reintroduction of species now extinct in Lesotho but still found elsewhere.

LHDA engaged the services of Earthplan consultants to develop the three sites in terms of planning, design, implementation and management for five years. Local communities were engaged in the development of the reserves and the associated eco-tourism facilities. The project also drew on the communities' natural resources related indigenous knowledge. The local communities benefit directly and indirectly from the protected areas in many ways and including 1) employment opportunities during the development and during the subsequent operational stages of the reserves,

2) entrepreneurial and business opportunities within park management and the tourism market and 3) sustainable resource management and use, providing for improved environmental conditions.

2.1.3 Other Conservation Areas in Lesotho include the following:

- A small botanical garden has been established at Katse, although it does not yet have formal protection. There are also proposals to establish a botanical garden in Maseru in the area formerly occupied by the racecourse.
- Range Management Areas (RMAs) specifically designated in the mountain rangelands in which rights to graze one's livestock have been restricted by the chief to a specific group of livestock owners who have formed themselves into a Grazing Association (GA).
- Forest Reserves and Plantation Areas are Government-owned plantations on non-arable land which have been specifically set aside for the establishment and sustainable management of exotic tree plantations. They derive from the Lesotho Woodlot Project, which was set up in 1973. The total area planted to trees was reported by Maile (1999) to be more than 7 000 ha and tree types are mainly pines and eucalypts in the Lowlands and Foothills of Lesotho and few areas in the Maloti.
- Restricted Access Areas (RAAs) are Military Bases and Training Areas, the fenced area of the Letseng-la-Terae Mine, and the Moshoeshoe 1 International Airport. These RAAs have the ability to conserve biodiversity as they limit access to the general public who would otherwise utilize the resources within these areas had they not been fenced off. In so doing they have removed the pressures on biological resources that the public and to domestic animals would have on the flora and fauna within them.
- Agricultural Research Station shares a common site of about 230 ha on the outskirts of central Maseru with the Lesotho Agricultural College. This site may also be considered as a Managed Resource Area.

2.2 Cultural and Historical Heritage

The cultural and historical heritage in Lesotho is unique to the region and provides opportunities and interest for regional and international tourism market and scholarly work. The discussion of the Lesotho cultural and historical heritage will follow a similar pattern as has been established within the previous section, i.e. to state the driving forces, pressures, states and impacts and the responses.

2.2.1 Driving forces

The driving forces that give rise to changes on the state of the Lesotho's cultural and historical heritage are:

a) **Development Projects/initiatives:** The drive to meet people's basic needs. Developments such as construction/upgrading of roads, supply of water and sanitation, development of agriculture, job creation through industrialisation causes conditions that pose threat to Lesotho cultural and historical heritage. For example, the expansion of industry in the attempt to alleviate poverty and to meet the needs of the people give rise to pollution which sets pressure on natural resources. Rock art sites have either been blasted away in road construction, or covered in soil debris.

b) **Education:** The silence of the education curricula and programmes about Lesotho's cultural and historical heritage, limit awareness and knowledge about the heritage.

c) **Globalisation:** The rapidly increasing rate of information exchange, trade, communication, mobility, transportation across nation states is associated with potentials for great influences on material conditions and cultures of societies. This process provides opportunities for improvement of livelihoods but may also adversely impact on powerless cultures.

Table 2-1: Legal Instruments and Special Events as Driving Forces for environmental change.

Legal Instrument/Special Event	Brief Description
SADC Tourism Protocol formulated by Member states in Mauritius.	-
Stockholm International Conference on Cultural Policies for Development.	The UNESCO initiated a meeting that resulted in the establishment of an 'International Network on Cultural Policies' in 1998. Membership is free and open to interested parties.
The 'Draft' SADC Protocol on Culture, Information and Sport.	SADC Heads of States and Governments signed the Protocol in 2000 in Malawi. Ratification in Lesotho was to have been done in 2002.
Constitution of Lesotho [Section 36]	"Lesotho shall adopt policies designed to protect and enhance the natural and cultural environment of Lesotho for the benefit of both present and future generations."
World Decade for Cultural Development	Involved members states undertaking projects on cultural development and increasing awareness of the importance of culture for economic and human development
UN International Year for Cultural Heritage	1992 marked the 30th anniversary of the adoption of the World Heritage Convention (1992). Projects and activities

Legal Instrument/Special Event	Brief Description
	aimed at promoting and protecting the world cultural heritage will be undertaken.
The OAU Cultural Charter for Africa	Concerned with the respect of fundamental right of people to practice and enjoy their culture and lives in harmony with their political, economic, social, philosophical and spiritual ideas.
The Protection of the World Cultural and Natural Heritage Convention	The foremost international legal instrument aimed at protecting cultural and natural treasures. Lesotho has not ratified the Convention
The World Heritage Convention	The protocol provides a framework of UNESCO support for member countries to protect their heritage. Lesotho is in the process of ratifying the convention.
The International Copyright Convention	International Convention relative to the protection of literary and artistic work. By UK signature.
World Intellectual Property Organisation	Concerned with copyrights on musical compositions, book writing etc. [Lesotho has not signed the convention].

d) Religion: The dominant religious institutions, of European origin, devalue local belief systems, knowledge and practices. Thus cultural heritage has remained largely on the periphery of formal mainstream knowledge.

Other Driving Forces are international protocols, conventions and special international events that Lesotho is a party to (Table 2.1) since once Governments have signed and ratified the instruments, they are obliged to live by the spirit of the convention, protocol or special international event.

2.2.2 Pressures

The changes in cultural and historical heritage are exerted by many and varied pressures but important amongst which are the 1) urban and population growth due to aligned industrialization, 2) lack of awareness of the inhabitants of the country upon the cultural and historical heritage and 3) the development projects and initiatives.

a) Urbanisation and Population Growth: More often urbanization and population growth follow industrial development. Development initiatives and more especially industrialization, driven by the need to meet people's basic needs, give rise to landscape modification due to construction of buildings, roads and other infrastructure. Often these developments result in the demolition of buildings of historic significance and destruction of the biophysical environment. Expansion of settlement in urban centers to accommodate growing population results in loss of endemic plants and animals and other valuable natural resources.

b) Lack of Awareness: A report by Chakela (1997) indicated that school pupils in Lesotho know very little about Lesotho's cultural heritage. It is therefore indicative that people in Lesotho may unknowingly be creating pressure on cultural and historical heritage of Lesotho, as people who may not be aware of, or are not knowledgeable about their cultural and historical heritage are likely not to value and protect it. Also contributing to this condition is lack of developed national cultural infrastructure such as national museums, national art gallery and national archives.

c) Development projects/initiatives: The assumptions underpinning development initiatives often disregard the value of local knowledge and often times their orientation often threaten and destroy the cultural heritage of the people whose livelihoods they are intending to improve (Quilan, 1995). Similarly, development initiatives that are not informed in respect of cultural and historical heritage of Lesotho, such as construction of buildings and roads, are likely to destroy that heritage. There are reported examples where road constructions and upgrading have destroyed or put under pressure important cultural and historical heritage of Lesotho. These include rock art sites that either have been blasted away or covered in soil at the dumping sites.

d) State and impact- trends

The state and impacts of the Lesotho cultural and historical heritage are discussed in respect of 1) the palaeontological resources which are the remains and prints of animals that died thousands of years ago, 2) archaeological resources which are the buried remains of humans who lived many thousands of years ago and their artefacts such as tools, 3) ancient rock paintings, 4) historic buildings, 5) historic sites, 6) museums and archives, 7) nature reserves, 8) traditional environmental knowledge and 9) Arts in the country.

2.2.3 Paleontology

Palaentological discoveries in Lesotho have drawn the world's attention and made an important contribution to the understanding of the past forms of life (Ambrose, 1991). The first recorded fossil footprints in sub-Saharan Africa were discovered at Morija in the 1880s. Many more palaeontological findings that were considered to be significant asserts in Lesotho were later discovered. They include discovery of *Tritylodon* a mammal-like reptile which is a fossil that was considered as the worlds earliest 'mammal' for more than fifty years, *Lesothosaurus* which is a dinosaur of about a meter long, *Megazostrodon* which is about 13 cm in length and is generally considered as the world's earliest mammal and *Erythrotherium* which is one of the earliest known mammals (Ambrose, 1991).

Further discoveries were made during the Lesotho Highlands Water Project's operations to rescue valuable resources from damage by project activities. Palaeontological surveys discover some fossils. These include excavations of plant remains from the road construction survey of *Maseru By-pass* in 1997 (Prasad, 1998).

The drawbacks to the development of paleontology have been cited by Chakela (1997) as I) lack of National Museum to facilitate the exploration and storage of fossils, 2) although the Ministry of Tourism, Environment and Culture has formulated tourism plans to palaeontological sites, such as the one at Moyeni, these sites are underutilized and 3) the school curricula do not reflect any content on Lesotho's fossils. Fossil sites in Lesotho are better known to school pupils outside Lesotho, more especially from Europe and America (Ambrose 1991). There are presently no plans to include paleontology content into the school curricula. Furthermore, there is no framework for training locals in paleontology. It is expected that the recent signing of cooperation, in 2002, between the Government of Lesotho and the South African Government will enable increased interaction between Paleontologists from S.A. and Lesotho and promote training and research in the field. Since external researchers coming to do paleontology related work are presently not legally bound to provide the Ministry of Tourism, Environment and Culture with their research findings, their studies often remain unknown locally.

2.2.4 Archaeology

Similar to paleontology, archaeology has a great potential in Lesotho but has not been explored adequately. There are many archaeological sites in Lesotho, but there have not been any locally initiated excavations. Excavations have however been carried out by researchers from South Africa and the United Kingdom as there is lack of capacity to undertake archaeological surveys in the country. In 1997 there was only one professional in Lesotho trained in archaeology. Formal excavation work may be traced back to the 1960s, during the colonial rule. Presently, discoveries include the large rock shelters at Sehonghong which was inhabited for over 50,000 years. The diggings uncovered stone age and iron age implements.

The LHDA rescue operations have initiated some archaeological excavations. They include, archaeological excavation at a rock-shelter in 'Muela in 1993, and within the Senqunyane river catchment, at Lithakong rock shelter, in 1995 where some stone tools, animal remains, bone tools, pottery and other material were found (Kaplan, 1993, 1996). The material is in Cape Town where it was analysed. A variety of artefacts, dating from the later Stone and Iron Ages, have also been excavated at Hololo Valley at the Hololo Crossing rock-shelter in 1990 (Kaplan, 1992). The findings added to archaeological records of Lesotho and are kept at the University of Cape Town where they were analysed. The artefacts will be transferred to Lesotho when appropriate storage facilities have been developed.

The shortcomings inhibiting the development of archaeology in Lesotho are 1) lack of a National Museum for exhibition of findings, 2) lack of local professional archaeologist in the country, 3) lack of archaeological content in the school curricula. For example, the history syllabuses cover about 200 years of Lesotho's history but are silent about the 100,000 years of human inhabitation.

2.2.5 Rock Paintings

The San (*Baroa*) people once inhabited Lesotho and have left an extremely rich rock art heritage. The paintings they made on rocks and cave walls reflect the ancient environment and the their beliefs. The total number of rock painting sites is estimated at 3,000 throughout Lesotho but is diminishing as a result of natural processes and vandalism. There is much diversity in the San rock paintings but many showed animals that have now disappeared from Lesotho such as lions, hippopotamus, baboons, bush pigs, ostriches, elands and many kinds of antelopes. The paintings that reflect aspects of the religion of *Baroa* have also been identified (Lewis Williams, 1981). The first rock paintings to be copied and published in Southern Africa were recorded in Lesotho (Orpen, 1874).

The Lesotho Highlands Water Project rescue operation has conserved a number of painted rocks that would have been inundated by the impounding of the dam. The salvage programme recovered painted panels or rocks from the sites affected by the project at Muela rock-shelter for storage and curation (e.g. Loubser, 1993). Liphofung project, phofung meaning 'Place of the eland, has undertaken to protect Bushman paintings at the site. Liphofung is located in the base of a tributary of the Hololo River in the Lesotho highlands. The place has been developed into a tourist site. The development of Liphofung involves construction of a Basotho village, Rock Art interpretation centre, protection of paintings and archaeological deposits.

Preservation of the rock art in Lesotho is limited by 1) lack of museum facilities and a functioning national archives to keep and display the findings and 2) lack of protective measures against natural processes and vandalism. However, the Ministry of Tourism, Environment and Culture is developing strategies to protect Rock Painting sites. Furthermore, the Ministry is engaged in making regular visits to such sites and to raise awareness among communities of the adjacent sites. The Ministry is also compiling a list of rock painting sites. Most of the Ministry's activities are at Ha Baroana, where there are organised visits to the caves and the community participates in the management and protection of the paintings. Other developments have been undertaken at Ha Baroana to enhance its tourism potential. The Ha Baroana site has a nature reserve and cave rock paintings. A bridge and a 4km road from Ha Matela to Ha Baroana have been established to enable easy access to the site. Offices for caretakers and structures for a site museum have been built, though the latter is not yet functioning.

2.2.6 Historic Buildings

Historical buildings are old buildings associated with certain significant historical developments in the country. They are located mainly in district headquarters or towns, villages of former principal chiefs Christian missionary stations. Whilst many of these buildings have been lost and many are threatened, there are some that are still intact.

The problems of preserving the integrity of the historical building are many but the most important ones have been identified as firstly, minimal attention is given to buildings of historical importance as only three historic buildings are legally protected. These are the *Major Bell's Tower* at Hlotse, the remains of a Fort at *Fort Hartley* in Quthing District and the Christian *Mission Cave House* at Masitise. The latest report indicates that the *Major Bell's* Tower has now been affected by the elements and neglect *(Molibeli 2002, Pers.Comm.).* Secondly, many buildings of historic significance have been or are being lost. These are mainly Church buildings and District Administration buildings in Major towns. Many of these historical buildings have been lost through developments. The existing development framework does not provide for the Ministry of Tourism, Environment and Culture to be informed or consulted when construction of roads or buildings that would affect the buildings of historic importance is being undertaken. Thirdly, there is no National Museum to guide activities needed to preserve the historical buildings.

An abbreviated inventory of historic buildings was undertaken in 1987 and since then none has been undertaken. Therefore, there is a need for an inventory or systematic listing of historic buildings for purposes of preservation in Lesotho. The official listing was last done in 1969 and has not been updated since (see Legal Notice No.36).

2.2.7 Historic Sites – Proclaimed National Monuments

Historic sites are important places in the history of Basotho. The importance of these places has let them to be proclaimed as National Monuments in terms of the Proclamation of Monuments, Relics, Fauna and Flora Legal Notice No.36 of 1969. The sites may include archaeological and rock art sites, group of buildings, fortresses and battlefields. There are presently nine legally proclaimed monuments. They are 1) the rock Painting site at Ha Khotso in Maseru District, 2) the deposits of petrified wood on the top of the slopes of Thaba-Tšoeu in the Mohale's Hoek District, 3) the fossil bed and fossil footprints site of Maphutšeng in the Mohale's Hoek District, 4) the fossil footprint site at Moyeni in the Quthing District, 5) the nature reserve archaeological site and cave house of Masitise Seqhobong in the Quthing District, 6) the top of Thaba-Bosiu Fortress in the Maseru District, 7) Major Bell's Tower at Hlotse in the Leribe District, 8) the remains of the Fort at Fort Hartley in the Quthing District and 9) the top of the Mount Moorosi Fortress in the Quthing District (Protection and Preservation Commission, 1983). The Dutch inscription, dating 1868, on the summit of Qeme is a historic site but it is neither legally protected nor officially recognised.

The listing of historic sites was last made in 1969. However, more information on possible historic sites is being compiled by the Ministry of Tourism, Environment and Culture. Compilation of information would also include an evaluation of existing and officially proclaimed sites for protection and suitability as National Monuments.

2.2.8 Museums and Archives

Lesotho is one of the few African countries without a working National Museum. Museum development has been undertaken by a mission-promoted enterprise at Morija, where attractive small displays are both for visitors and schools. The situation for archives is a little better, thanks to pre-independence efforts by the colonial administration to keep records satisfactorily. In any-event, their keeping is now wanting as their access and updating are no longer undertaken. A well functioning National Museum and National Archives are required. A national Museum should work hand in glove with the national archives and must participate in the work of the national Monuments Commission. In their present form these facilities are neither able to protect and promote Lesotho's cultural heritage nor compile existing information into a National Museum and Archives system. A lot of valuable data from Lesotho is still found outside Lesotho due to lack of a National Museum and functioning Archives.

The problems faced by the Museum and Archives facilities are many and varied but the following represent an abbreviated compilation of these problems. First, temporary 'museum' quarters, situated in the Ministry of Tourism Environment and Culture, are presently used to store items intended for display. The Ministry of Tourism, Environment and Culture has developed a proposal for building of the National Museum in Maseru city, but its implementation has not occurred due to lack of finances. Second, the Museums Act of 1967 does not provide for any direct financial support from Government for the operation of the museum. Third, the national archives are not well functioning. The archives were transferred from NUL in 1997 to Maseru, where they were reported to be inaccessible (Chakela, 1997). Presently the archives are in the Department of Culture and plans are to move them to the National Library in Maseru where they will receive more efficient storage and management. Funding for the construction of the National Museum and Archives as well as the National Library has been sourced from the People's Republic of China.

2.3 Biodiversity in Lesotho

2.3.1 Genetic Diversity

Cultivated plants and domestic animals bred for particular selected traits are genetically less variable than their wild counterparts. An example is the Basotho potato (*Litapole tsa Sesotho*), introduced into Lesotho over 160 years ago, before potatoes began to be cultivated for the market and progressively standardised. Genetic diversity in livestock kept by Basotho is also low because the government encourages the rearing of only economically important breeds.

Lesotho has a variety of plants and animals, even if they are not as obvious as those in other African States that have well-established parks and game reserves (NES, 2000). Recent compilations show that Lesotho has 2961 documented plant species and at least 132 species of Thallophytes: algae and fungi. The total number of endemic plant species is estimated at 27 and one subspecies. Similarly, Lesotho has a limited variety of faunal species. There are 63 mammal species recorded in the country. However, historical records indicate an additional 19 species formerly present in Lesotho and are now locally extinct. Unfortunately, two of them are globally extinct. Table 6.6 shows the total number of species recorded for Lesotho. The vertebrate fauna includes 318 bird species, 40 reptile species, 19 amphibian species and 14 fish species. For its size, Lesotho exhibits a great diversity of birds and furthermore there are 22 bird species for which there are only historical records - "Historical Species" refer to species for which there has been no record in the past 50 years and most were commonly present in the past and these can be regarded as extinct in Lesotho, although most still exist in neighbouring countries (NES, 2000). Records also show three historical reptile species. The fish species include eight indigenous species of which one, the Maloti minnow (*Pseudobarbus quathlambae*), is endemic to Lesotho. Unfortunately this Lesotho endemic fish species is highly threatened by water project developments. Lesotho invertebrates are likely to be more numerous than all other animal and plant species put together, but they have been inadequately documented, and at present there are 1279 species recorded and of which 134 species are endemic.

Lesotho is an egalitarian society where access to land is unrestricted. As a consequence, therefore, natural resources and in particular biodiversity are under constant threat. Threats to Lesotho's biodiversity resources are many and varied but all are human induced. Habitat degradation, fragmentation, the impact of introduced species, and the altered regimes (reservoirs and weirs) are all human induced threats to biodiversity in Lesotho. Amongst all these threats, habitat destruction is considered to be the most damaging and in particular threats relating to overgrazing and extensive land clearing have resulted in the loss and fragmentation of habitat across the country. Overexploitation of plants used for medicinal purposes is an additional serious threat to biodiversity because of the destructive nature of harvesting of medicinal plants as roots form the larger portion of medicines used. However, Lesotho has played a pivotal role in preserving a genetic strain of wild potatoes (Basotho potatoes, *Solanum tuberosum*). These wild Basotho potatoes are found virtually in all districts of the country and grow amongst wild shrubs or between rocks along river courses.

Threats to Lesotho's biodiversity resources are not only limited to those in the wild but are also real to the domestic or agricultural biodiversity. In agriculture, genetic diversity is very limited as national efforts have over the past years concentrated on a small number of high yielding varieties or breeds.

Table 2-2: Biological Diversity in Lesotho

Group	Number of Current Species	Number of Historical Species	Total
Mammals	63	19	82
Birds	318	22	340
Reptiles	40	3	43
Amphibians	19	-	19
Fish	14	-	14
Invertebrates	1 279	-	1 279
Plants and Thallophytes	3 092	-	3 092

Source: NES (2000)

2.3.2 Flora

The flora of Lesotho, even though it has been profoundly modified by human activities, contains a diverse range of plants, of which the vascular plants ranging from the primitive *Psilotum* to a wide range of flowering plants, of which a significant but unknown number is Lesotho endemics (Table 2.3). There are 3093 plant species comprising the thallophytes, bryophytes, pteridophytes, gymnosperms and agiosperms. It is estimated that there are at least 44 endemic species, including lower plants, as well as some endemic subspecies. The best known floral endemic is the spiral aloe (*Aloe polyphylla*) (Plate 2.1).

Table 2-3: Numbers of known Lesotho Plant taxa

Category	No. Of Families	No. Of Genera	No. Of Species	No. Of Subspecies	No. Of Varieties
THALLOPHYTES (Algae and Fungi)	>32	74	132	-	-
BRYOPHYTES (Liverworts and Hornworts)	>10	39	60	1	1
Mosses	>28	102	219	2	6
PTERIDOPHYTES (Ferns & fern allies)	20	32	85	1	15
GYMNOSPERMS	6	16	62	1	8
ANGIOSPERMS (Monocotyledons)	24	187	776	43	72
Dicotyledons)	106	466	1759	129	158
TOTALS	>226	916	3093	177	260

Source: NES (2000)

The diversity of vegetation types is commonly used to express ecosystem diversity, since vegetation influences the occurrence and distribution of animals. The grassland biome is subdivided into three grassland types as has been described in the recent work of Acocks in the **Vegetation of South Africa, Lesotho and Swaziland** which was edited by Low and Rebelo (1996). Probably the most useful work of Low and Rebelo are the three vegetation types, Highveld Grassland mainly representing the moist cold highveld grassland extending to some 1800 m.a.s.l, the Afromontane Grassland representing the Afro Mountain Grassland extending from 1800 to 2500 m.a.s.l and the Afroalpine Grassland representing the Afroalpine Grassland above 2500 m.a.s.l.

Of great significance amongst these grassland biomes is the Afroalpine grassland that contains the greatest diversity of plant and animals. Descriptively, the sub-alpine scrub occurring within the sub-alpine belt has a variety of indigenous forest in a number of deep valleys, where it has survived firewood gatherers. The forests occur as narrow strips along river banks in remote areas. Thickets of indigenous trees can exist in favourable areas up to 2,500 m.a.s.l. Some areas are typically dominated by *Rhus* (*Kolitšane/tšinabele*) (Plate 6.9) while others are dominated by *Leucosiodea sericea* (*cheche*), *Buddleia salviifolia* (*lelothoane*) and *B. loricata* (*lelora*). Tall patches of herb meadows in wetter areas and drier grassland on the ridges also dominate this grassland zone. The Buddleia – Leucosidea scrub was sometimes continuous with shorter *Passerina, Cliffortia, Phillipia and Inulanthera* scrub species mainly on northern slopes, which are drier. This vegetation type has apparently been converted into temperate grassland by fire (Jacot – Guillarmod, 1971; Weiland, 1982).

The alpine belt, which occurs above the sub-alpine scrub at 2, 800 m.a.s.l., contained numerous spring bogs, wet herb and sedge meadows. *Merxmuellera* (*moseha*), *Festuca* (*letsiri*), *Pentaschistis* (*hlokoana*) and various heaths of *Erica* and *Helichrysum* dominated the grassland. Heavy grazing of livestock, construction activities and mining have adversely affected the spring bogs. The grassland of Lesotho appears to be deteriorating at an alarming rate due to unsustainable range management practices. At present, approximately 359,680 ha of rangeland have been invaded by Karoo shrub, *Chrysocoma ciliata* (*sehalahala*). This degraded area represents about 16% of the entire rangeland.

The best known and largest endemic is the spiral aloe (*A. polyphylla*, Kharatsa, Plate 2.1) which grows at heights of 2500 to 2800 m.a.s.l. Its market value is well known and it has vanished in the past 30 years from virtually all sites in the Front Range of the

Maloti and also from sites within a few kilometers of roads. The plant however still occurs in remote parts of eastern Lesotho where there are still thousands of plants.

Plate 2.1: Spiral aloe (*Aloe polyphylla*)

2.3.3 Fauna

Although hunting and intensive agriculture have had disastrous impact on the larger wild mammal species, Lesotho, for its size and more importantly population distribution, still has an impressive biodiversity with 63 remaining mammal species, 318 birds, 40 reptiles, 19 amphibians, 14 fish and 1279 recorded invertebrates, more than 100 of which are endemics. The state and impacts of the Lesotho fauna - mammals, birds, reptiles, amphibians, fish and invertebrates is discussed below.

Mammals

Present knowledge of Lesotho's mammals is largely derived from Lynch (1994). His mammalian survey was based on 13 field trips made during the years 1988 to 1992. He recorded 52 mammal species and for each of them he provided a distribution map. Eleven additional mammal species, other than those recorded as historical mammals, were subsequently added to Lynch's list by Ambrose (1999c). Three of these, the house mouse, the house rat and the feral domestic cat, may have been omitted by Lynch because of their close association with man. Other mammalian species in Ambrose List are the Brown Hyena (*phiri*), the Silver Jackal or Cape Fox (*mopheme*), the Antbear or Aardvark *(thakali*), the Cape Ground Squirrel, the South African

Hedgehog (*tlhong*), the Klipspringer (*sekome*), the Small Spotted Cat (*qoabinyane*) and the Natal Multimammate Mouse (*lephoho*).

The overall Lesotho record has mammalian representatives of 11 orders and 26 families. They could however be 27 families if the Springhare is, as suspected, also present in Lesotho. The Lesotho mammalian biodiversity complex compares well within Southern Africa as a whole as the region has a total of 15 orders, 2 of them are marine animals (Skinner and Smithers, 1990).

Table 2-4: Mammals which are found in Lesotho's checklist

Extinct mammals	Vulnerable species	Rare species	Intermediate species
Quagga (H)	African wild cat (R)	S A hedgehog (R)	Sciater's golden mole (U)
Blue antelope (H)	Honey Badger (H)	Aardwolf (H)	Lesueur's hairy or wing-gland bat (R)
	Antbear (S)	Brown hyena (S)	Winton's (=De Winton's) Long-eared bat (S)
	Oribi (R)	Leopard (R)	
	White-tailed mouse (U)	Caracal (S)	
		Hippopotamus (H)	
		Blue duiker (H)	
		Red duiker (H)	

A=Abundant, C=Common, U=Uncommon, R=Rare, S=Single record, H=Historical
Source: NES, 2000

The state of the Lesotho mammals may best be assessed in the regions Red Data Listing (Table 2.4). The Red Data Book is a convenient mechanism by which public and scientists are alerted to the status of threatened species of animals. The South African mammal Red Data Book assesses mammals which are threatened in South Africa and it includes mammals found in Lesotho.

Birds

Overall, Lesotho has 340 recorded bird species represented by 21 orders and 61 families. Historically, there were 23 orders and 65 families of birds in Lesotho. Records show that up to 16 bird species that occurred in Lesotho prior to 1940 could be extinct (Osborne, 1992). This could be due to many factors but the most important is habitat destruction. The Lesotho bird complex is a complement of the Southern African bird complex where there is a total of 26 orders and 91 families (Maclean, 1993). However, 143 out of the 340 bird species recorded for Lesotho, 42% of the total have been recorded less than 10 times, and amongst these are 22 species which are purely historical, i.e. there have been no records during the past 50 years. Fifty-six other species have not been recorded during the past 15 years. The best known red data bird is the bearded vulture (Plate 2.2).

Plate 2.2: Bearded vulture

Although a number of records from the distant and more recent past are of vagrants which never became established in Lesotho, a significant number of species have vanished because of habitat loss. Amongst these are grassland species such as the Ostrich and various species of Crane and Bustard. Changes in agricultural practice and animal husbandry, as well as the extinction of most antelope species have led to the loss of other species such as the Redbilled Oxpecker. On the other hand, increasing numbers of trees in towns and woodlots have provided opportunities for new species, as the Redbreasted Sparrowhawk (which hunts from tree cover) and species of Barbet, notably the Blackcollared and Crested Barbets (which nest in holes in trees and have recently become established in Lesotho). Some other species such as the European Starling and Indian Myna are newest additions to Lesotho territory as part of their migrations throughout the subcontinent. Six areas in the Maloti have been designated Important Bird Areas (Barnes, 1998) because of their importance as nesting or foraging areas for local and migratory birds.

Infrastructure developments can also provide unforeseen opportunities for birds as in some cases wild fauna advantageously exploit them. The Cape Weaver normally depends on trees for building its intricate hanging nests but in the early 1980's, these birds were seen building their nests on electricity wires on the line crossing the Maloti from Maseru to Thaba Tseka. It was thus able to establish itself in new areas where it had previously been unable to breed because of lack of trees.

The bald Ibis or Southern Bald Ibis (*mokhotlo*) was once regarded as 'vulnerable' species is endemic to Lesotho, South Africa and Swaziland and has made a remarkable comeback. The status of many birds is however precarious in Lesotho and the adjacent territory in South Africa. The Cape Vulture is an increasingly threatened species and today there are no breeding colonies remaining in the Free State. Table 2.5 shows the red data checklist of birds found in Lesotho.

There are six officially designated Important Bird Areas (IBA) in Lesotho (Barnes 1998). The IBAs have been chosen on the basis of ecosystems enabling the habitation of the Cape Vulture *Gyps coprotheres*. Owing to the homogeinity of much of the Lesotho's highlands landscape, the Cape Vulture breeding colonies have been used as a skeleton for IBA selection, so that 64% of Lesotho's breeding Cape Vultures fall within an IBA. The six IBAs- Liqobong in Northern Lesotho, Upper Senqu River in the North-Eastern Lesotho, Mafika Lisiu in North-Western Lesotho, the Sehonghong and Matebeng and Sehlabathebe National Park both in Eastern Lesotho and the Upper Quthing Valley in Southern Lesotho cover 216 805 ha or 7.15% of Lesotho's land area.

Table 2-5: Red Data Book Checklist of bird species occurring in Lesotho

Vulnerable Species	Rare Or Near-Threatened Species	Of Special Concern	Intermediate Species
Bald Ibis (C)	Bearded Vulture (U)	Wattled Crane (R)	Black stock (U)
Cape Vulture(U)	Black Harrier (U)		South African Longclawed Lark (=Rudd's Lark) (S)
Lesser Kestrel (C)	Drakensberg Siskin (C)		
Yellowbreasted Pipit (U)	Ground Woodpecker (C)		
	Mountain Pipit (C)		
	Orangebreasted Rockjumper (C)		
A=Abundant, C=Common, U=Uncommon, R=Rare, S=Single record, H=Historical			
Source: NES, 2000			

Reptiles

There has not been any reptile survey in Lesotho comparable to those undertaken for mammals and birds. However, systematic reptile surveys have only taken place in the Lesotho Highlands Water project Phase 1A and Phase 1B areas, as well as downstream from the Mohale dam site along the Senqunyane and Senqu Rivers. The summary Table 2.6 shows a large number of species for which there has so far been no authenticated record.

Table 2-6: Checklist of Lesotho's reptiles

Reptile species status (1999)	Number of species
Abundant (A)	3
Common (C)	11
Uncommon (U)	1
Rare (R)	16
Single Record (S)	9
Historical (H)	3
TOTAL	43
No Authenticated record (N)	19

Amphibians

There is no published survey of Lesotho amphibians but a Southern African Frog Atlas project to gather information on the state of the amphibians and to develop a checklist is being undertaken. There is a possibility that once the Atlas has been produced, the checklist for Lesotho will exceed 19 as new species maybe recorded particularly in the lowlands where previous surveys were not as extensive. A couple restricted species - the aquatic river frog and the Lesotho River frog may be noted. In any event, recorded amphibians for Lesotho are presented in Table 2.7. Lesotho has no newts or salamanders and all its amphibians belong to the single order Anura, which consists of frogs and toads. Overall, Lesotho has 19 known anuran species and for its size compares favourably with approximately 98 species in South Africa and some 1600 species worldwide.

Table 2-7: Checklist of Lesotho amphibians

Amphibian Species Status (1999)	Number of species
Abundant (A)	6
Common (C)	2
Uncommon (U)	4
Rare (R)	5
Single Record (S)	2
Historical (H)	-
TOTAL	19
No Authenticated record (N)	9

Fish

Although worldwide the number of fish species outnumber any other vertebrate species, Lesotho has a limited number of fish species. The country's terrain coupled with poor land management systems and practices have all but driven fish stocks out. Additionally, the Orange-Vaal river system is relatively low in species diversity as it effectively has just 13 indigenous species, of which 8 species have been recorded in Lesotho. The best known Lesotho endemic fish species is shown in Plate 2.4.

Apart from the eight indigenous fish species, five species have been introduced; the common Carp (found in both dams and rivers; and also is farmed commercially in fish ponds on a small scale), small and wide mouth bass (introduced into Lowlands dams as part of the nutrition improvement programme) , rainbow and brown trout (introduced into the Lesotho higlands and now found in the Katse Dam). The checklist of Lesotho fish species status is presented in Table 2.8.

Red Data Book species occurring in the Lesotho are the **endangered species**, Maloti Minnow (U) and **rare/intermediate species**, Rock Catfish/Rock Barbel (Plate 2.5).

Plate 2.3: Maloti minnow (*Pseudobarbus quathlambae*)

Amongst the two red data book species, the Maloti Minnow is Lesotho's only known true endemic vertebrate species. The fish was first discovered in the headwaters of the Mkhomazana in Kwazulu-Natal (NES, 2000), but was subsequently feared extinct. It was rediscovered at Sehlabathebe in Lesotho in November 1970. The Maloti Minnow has subsequently been found to occur in the headwaters of a number of Lesotho Rivers. Apparently, the survival of the Maloti Minnow is dependent upon the preservation of the structural integrity of our river systems. On the Senqunyane River, the Semonkoaneng waterfall, 3.5 km downstream from the Mohale Dam, prevents other fish species from migrating upstream. The Maloti Monnow is consequently the only species found in the upper Senqunyane and its tributaries. The creation of the Mohale Reservoir and the possibility of trout being introduced through the tunnel connecting Mohale and Katse reservoirs are threats to the continued existence of the Maloti Minnow.

The Rock Catfish (*Austroglanis sclateri*), although rare downstream in the Orange, has been found to be fairly common in Lesotho. It is considered to be the best indicator species for instream flow requirements (IFR) need when designing future water projects even in the Lesotho Highlands Water Project.

Plate 2.4: Rock catfish (*Austroglanis sclateri*)

Table 2-8: Checklist of Lesotho fish.

Fish Species Status (1999)	Number of species
Abundant (A)	1
Common (C)	8
Uncommon (U)	5
Rare (R)	-
Single Record (S)	-
Historical (H)	-
TOTAL	14

Invertebrates

Lesotho has 1279 recorded invertebrate species composed of 835 genera, 242 families and 45 orders. The South African Red Data Book lists butterfly Species and Lesotho records are included. The list include the **Rare species**; *Torynesis pringlei, Lepidochrysops loewensteini, Lepidochrysops oosthuizeni* and *Metisella syrinx*. The Pringle's Widow, *Torynesis pringlei*, was discovered in 1977 at Ha Rafolatsane, is a Lesotho endemic and has since also been found in Sehonghong valley in Mokhotlong District.

2.4 Impacts of Dams on Lesotho

Broadly speaking an impoundment will impact on (a) the part of the river basin that is flooded, i.e. upstream of the dam wall; (b) the immediate area surrounding the dam; (c) the rest of the river downstream of the dam; (d) and any river basin that is linked to the dam through a transfer system such a tunnel or a pipeline.

Land and water are ecologically linked in a natural system called a catchment. From the smallest droplet to the mightiest river, water works to shape the land, carrying with it sediment and dissolved materials downstream (in most cases) to the sea. Rivers are a product of the land they drain; their shape, size, composition and flow are determined by the types of rocks, soils and vegetation through which they flow. In each watershed land and water are tied together in unique patterns going back millions of years, together supporting a complex web of life.

When these ties between the land and the river are broken by a large dam, the consequences are felt throughout the watershed. Of all the ways to tamper with or harm a river, a large dam usually has the most immediate and far-reaching environmental impacts because of the huge changes it causes to river hydrology - the very circulation system of the watershed. Some 40,000 large dams, most of which were built in the past 50 years, now obstruct the world's rivers. More than 400,000 square kilometres - an area 13 times the size of Lesotho - have been inundated by dams worldwide, sometimes with devastating social and environmental consequences.

In order to limit the damage caused by dams it is important to understand the type of changes an impoundment brings to a river and all the associated life forms. In this section we look at the most immediate of these. First we consider the likely environment impacts dam construction that takes place before the water can be impounded and which may have to be endured for many years, depending on the size of the dam.

2.4.1 Changes upstream

As soon as water is impounded two things happen: first, the speed at which it flows is immediately changed as it is transformed from a moving body (‘lotic’) into a still one (‘lentic’). Second, as the water accumulates it becomes deeper and deeper, forming different layers or ‘substrata’. Still, deep water is very different from shallow, moving water. As the water gets deeper it become colder and has less oxygen, conditions that are not easily tolerated by life forms. Equally important as it slows it is no longer able to carry small particles of silt (sediment) with it and these slowly drops to the bottom of impoundment. At the same time these the impounded water, at the warmer up levels, can encourage the growth of planktons and aquatic plants not usually found in running water.

By trapping silt dams deprive downstream deltas and estuaries of materials and nutrients that help to make them productive ecosystems. By filtering out woody debris they reduce habitats and nutrients that sustain food chains.

The changes in flow, temperature, sediment and oxygen levels result in changes to water chemistry. In deep water the concentrations of metals (iron, manganese) and, sometimes gasses (hydrogen sulphide and methane) can be increased. At the upper levels or surface of the dam nutrients and oxygen stimulate the growth of plants and algae, accumulate during warm periods.

The amount of sediment that gathers upstream of a dam will be influenced by many factors, including land use, climate, topography, erodability of soil, rainfall and runoff. Generally speaking, dams which are constructed in a dominant geology of basalt (such as the Malibamatšo) will have less sediment than those constructed in a dominant geology of sandstone watersheds. The river channel of the Mohokare River has a sediment bed, weirs have been inundated with silt and the Welbedacht Dam downstream of Lesotho has lost 80% to 90% of its storage capacity because of sedimentation. This section rather on its own our should be with issues relating to water abstraction from a river.

Not surprisingly the changes brought about by a dam can have profound implications for the flora and fauna that once depended on a flow river. The increase in algae can, for example, be toxic to fish. However, within the impoundment certain species of exotic fish (such as trout) are likely to respond positively to the new environment, and are quite likely to out-compete local species. This may be of some benefit to local people or other fishermen, whose catch may increase.

Local species can decline rapidly because, unlike introduced (exotic fish), they usually require minimum temperatures and depend on ‘special events’ (such as annual floods) to trigger spawning (the release of eggs). In still water these are not experienced, so the local fish may no longer produce. Equally important, the dams change the availability and type of foods that local fish depend on, notably plankton, drifting invertebrates and fauna found on the bottom of river beds.

Dams are also a physical barrier to any fish migrations, which are often essential for breeding. Katse Dam, for example, prevents any upstream migration of the Small Mouth Yellow Fish, which may eventually reduce their number in the Malibamatšo upstream of Katse. Indeed, globally dams are the main reason that 20% of the world’s freshwater fish are endangered as they have disrupted migration routes, fragmented the habitats, and greatly reduced the quantity of nourishing silts flowing onto nursery areas in floodplains. However, a new dam may attract waterfowl, including migratory species, which are likely to increase.

2.4.2 Impacts to the area around a dam

A recent concern in Southern Africa is reservoir-induced seismic activity, which has occurred as the result of filling of Katse Reservoir in Lesotho. Current predictions estimate that seismic events associated with major dams could continue and may reach magnitude 4 to 4.5 on the Richter Scale. Any earthquake damage to transfer tunnels and other infrastructure could have severe effects on water supply, and would present a potential threat to human life and damage property.

The most immediate post construction impact on the local human settlements is the flooding of a wide variety of buildings and natural resources, some of which may not be immediately evident. While houses, kraals, graves fields, range lands and trees can be measured relatively easily it is much harder to assess the loss of shrubs, medicinal plants, wild vegetables, thatching grass, reeds, river sand, stream crossings and baptismal sites to inundation (see ‘Social Impact’ and ‘Compensation’ sections for more details). Equally important are the possible health impacts that a large body of water is likely to have. Although Lesotho is fortunate not to have many of water-related diseases that plague warmer parts of Africa there are concerns (such as the increase in certain vectors) that need to be taken into account.

2.4.3 Changes downstream

In the case of the Lesotho Lowlands Water Scheme the main objective is to store/supply water for transfer to needy areas. However, if any dam is used for hydroelectric power careful consideration will have to be given to the impacts downstream, as discharges from such reservoirs tend to be highly variable, usually resulting from the requirements for hydroelectric power and not related to natural cycles. Flow below hydroelectric dams can rapidly alter from almost standing water to torrential flows and water depth, velocity, oxygen concentration, temperature, suspended solids, pollutants and chemical composition can change in a very short period of time.

By holding back the natural flow of water dams have a profound impact on the river and all the life forms it supports downstream of the impoundment. In a most extreme case, if all the water in a river was to be held back, a formerly living environment could effectively become a long linear desert. Assessing the more likely impacts of reduced flow is a complex task because the different life forms are so dependent on each other.

One of the first attempts to assess all the likely impacts of reduced flow took place in Lesotho, under the auspices of LHDA (Lesotho Highlands Development Authority). In brief these can be summarised as follows:

A). Biophysical Impacts

The main impacts under this heading relate to: streambed geomorphology (the shape of the river bed), sedimentology, water quality, vegetation, macroinvertebrates, fish, amphibians, mammals and birds. Very briefly we consider each of these in turn.

Under **geomorphology**, the scientists noted that the river bed is likely to have increased sediment. This is because as the speed at which the river flows is reduced so is its capacity to carry sediment away. As a result the sediment sinks to the river bed and river pools will decline in depth and number. Small islands can be formed that encourage the growth of reeds resulting in the rivers flow path changing which can further result in flooding such as of agricultural lands and houses.

Water quality will deteriorate due to the increase in the total suspended sediments as well as an increase in the mean temperature, both of which are factors affecting fish and other living organisms. Where river flows include untreated or insufficiently treated effluent (as for example downstream from factory estates) the reduced river flow will obviously result in higher levels of pollution.

The larger dry bank zone of trees and shrubs will be reduced but in the aquatic zone algae and reeds will increase. Sedges and grasses will also increase, some of which may be beneficial to livestock and people.

The **aquatic insects** balance will change, with undesirable increases in disease carrying snails and some blackfly species.

Fish will generally be very severely affected, except for the Orange River Mudfish, which is a bottom feeder grazing on algae and organic debris. This is the one species which will probably increase, although obviously not if the flow regime results in a river drying up altogether.

There will be probably some decline in river species of frogs such as the Common River Frog, while species capable of living in polluted streams such as the Common Platanna, will multiply.

Mammals and birds which depend on river fauna (fish and amphibians) for food will generally be adversely affected. This reduced flow will impact on some species of kingfisher, duck and heron, but in the case of the Cape Clawless Otter, which depends very largely on eating crabs, reduced river flow might in some areas reduce and in other areas increase its opportunities to survive.

B). Social Impacts

The riparian zones of the highland rivers are typically used by villagers on a daily basis for grazing animals, growing crops, catching fish and harvesting reeds, thatching grass, grass for handicrafts, wild vegetables, trees, medicinal plants and sand. A decreased river flow can both decrease and increase available resources. For example, there may some increase in reeds which flourish in slow moving water that is not subjected to sudden flooding. However, in most cases, resources used by people will be reduced by reduced flow.

It was noted that rivers are also used for leisure activities, baptism, casual drinking (particularly during severe droughts when springs have dried up), for watering animals and for washing clothes and washing motor vehicles. In most of these cases a reduced or absent river flow has obviously serious effects in curtailing activities. On the other hand, communications across a larger river may be facilitated by low flows, particularly in cases where children on one bank attend school on another bank. There should be less drownings of humans and animals. But improved communications across a river, particularly when it is an international boundary (such as the Tele, Makhaleng, Senqu, or Mohokare) also provide opportunities for transborder crime such as stock theft, with consequential ongoing feuds between communities on the two sides of the river.

The report noted that stomach illnesses are generally expected to increase as a result of reduced river flows. Skin and eye diseases are also expected to increase. Amongst animal diseases likely to be adversely impacted by reduced river flows is Bluetongue Disease in sheep and goats. Stagnant backwaters and pools are a favorable habitat for the breeding Bluetongue vector gnats or midges.

2.4.4 Minimising downstream impacts through an environment flow (IFR)

The amount of water to be released is not the only factor to consider. In order to maintain minimal ecological condition downstream it is essential that water should be released in ways that *mimic* (as far as possible) natural patterns. For example, in order for fish to spawn, flooding is important as this acts as a trigger for new breeding cycles. Floods are also important to maintain certain habitats (by preventing the accumulation of sediment) and plant varieties. For this reason dams should be either be designed to allow for the release of large flows, or else should be situated upstream of large tributaries.

Earlier we pointed out the water in an impoundment is very different from that of moving river. Water that is released from the deeper levels of a dam will have a lower temperature, little oxygen and different chemistry from that in the river below. For this reason dams should also be designed to allow for water to be drawn off at various depths depending on where the best water quality is that is typical of the natural downstream quality – this statement is not totally true.

Releasing water from a dam constructed directly on a river is one way of providing the required environment flow. Another way of doing this is by carefully situating dams off the main river channels, as is the case with the Maqalika Dam (Maseru's main supply) which is situated off stream of the Caledon River (Mohokare – standardise on name) but draws water from it. This is the case with the dam that currently provides Maseru's water supply; the Maqalika Dam is situated off stream of the Caledon River but draws water from it. Another way is situate dams upstream from major tributaries, so that the flow from these maintains what is required by the environment (this is one option for the proposed Metolong Dam on the South Phuthiatsana River).

Whatever measures are put in place it is important to recognise that even the most successful environmental flow programme will only partially mitigate against the effects of a dam. Nothing is gained at no cost – if flow regimes are manipulated, the targeted rivers will change and there will be negative impacts. Society decides, pro-actively or through neglect, on the extent of that change and degree of the impacts. A pro-active approach offers the opportunity of minimising negative impacts and optimising positive ones.

Once decisions are made regarding the preferred options for the Lesotho Lowlands Scheme it will be necessary to carry out an environmental flow assessment for each river to be damned. However, it is also likely that some of the information already generated for the Lesotho Highlands Water Project could be used to good effect, particularly that for the sites situated on the middle and lower Senqu River. Indeed, for any water resource developments on the mainstream of the Senqu, Senqunyane or Malibamatso Rivers, relevant environmental flow studies have been completed and, provided permission to use the data were forthcoming from LHDA, they would require relatively little updating and adjustment for use in the Lesotho Lowlands study.

2.4.5 Changes through Interbasin Water Transfers

Dams are often built so that water can be transferred from a river basin where there is adequate water to a basin where there is not enough water to meet the needs of the population in the latter basin, as is the case with the LHWP where water is transferred from basins that feed the Senqu into one that feeds the Vaal River. The invariable result of such transfers is that both the river that is damned (the donor river) and the river that receives the transferred water (the recipient river) lose their natural flow patterns. This can have serious environmental impacts, unless carefully managed.

The characteristics of the recipient river will change according to the way in which the water is released into it. If the flows are much higher and faster than was previously the case this can result in rapid erosion in the recipient river system.

Dams slow the flow of rivers and in doing so they prevent sediment (fine particles of soil and other matter) from being carried down stream. The water that is released, either downstream of the dam or into the recipient river through an IBT, is usually sediment free. The clear water moves more freely and rapidly, causing more erosion than would have been the case had the river maintained its sediment. The result can be a transformation of the bed of the river as its shape and character are changed.

International experience shows that some vegetation along the recipient river or upstream from dams will respond to being flooded (inundation) with prolific growth, e.g willows, other exotic trees and various aquatic plants. Further, as water is taken out of the donor river some grasses, weeds and poisonous plants are likely to respond by growing vigorously as waters recede. In some cases this increased growth may be beneficial (e.g. increased grazing areas), but in many cases this growth is not desirable (e.g. increased poisonous plants).

If the water levels of the recipient river rise significantly some vegetation types will experience severely reduced growth rates, or will be killed as a result of the prolonged inundation. Examples include grasses and most small plants. Even some native tree species that grow on edge of rivers (riparian varieties) can be killed if completely inundated for prolonged periods.

A major concern associated with IBTs is the transfer of water quality problems from donor to recipient catchments. The damning of the donor river changes the water chemistry of the river by preventing its flow. Transfers in South Africa have been shown to increase levels of sodium, magnesium, potassium, calcium, sulphate and chloride. In the Western Cape there have been cases of fish being affected by chemicals transferred from one basin to another.

Water transferred from a dam could have a combination of low temperatures and low levels of oxygen and this would have a detrimental consequences for the various life forms living in the recipient river, particularly fish.

Certain aquatic insects that inhabit the gravel layers (substratum) of rivers bed can be seriously impacted by changes in flow resulting in reduced sediment and increased erosion. As the gravel habitats are destroyed by faster moving water the number of aquatic insects will decline, as will the number of fish that depend on them.

As water is transferred from one basin to another so are the various life forms inhabiting the water. In particular, the transfer of phytoplankton, a microscopic potential food source for invertebrates, facilitates dispersion of species, including unwanted “nuisance” species, predators, fish diseases and parasites. In the cases of LHWP there are concerns that trout may be able to cross from the Katse Dam (on the Malibamatšo River basin) through the tunnel to Mohale Dam (on the Senqunyane basin), thus threatening the survival of the rare Maluti Minnow.

In other words, an important consequence of water transfers is the transfer of diseases and disease vectors between catchments, or the creation of habitats which are suitable for the establishment of pests which pose threats to humans and animal health. For example, as rivers are regulated black fly, an irritating pest of both cattle and humans, is likely to increase.

IBTs may impact on soil, water logging and groundwater levels as there is evidence that if water is transferred from one basin to another by way of an unlined transfer canal this may have impacts on the groundwater in areas adjacent to the canal.

The motivation behind the transfer of water is to provide water to human communities in order to improve quality of life, or to facilitate further municipal, agricultural, or industrial development. However, many of the ecological effects of IBT’s will have detrimental impacts on socio-economic, cultural and political aspects of these human communities. In some cases, the health of individuals or communities may be affected.

The transferring of water from one basin to another involves tunnels or pipelines. The main problem associated with tunnels is dealing with the rock and other material that is extracted from underground.

Pipelines built transfer water can also result in environmental impacts, most of which can be identified in the environmental impact assessment and mitigated through an Environmental Management Plan (see section on Impacts on national heritage for more details). The impacts of pipelines vary according to whether the pipeline is on the surface or underground. Surface impacts are mitigated by the choice of the best environmental and economical routing, avoiding, where possible, urban and suburban settlements, water courses, environmentally sensitive areas and sensitive landscapes (erosion areas).

In the case of water transported the only major possible impacts after construction would be associated with a high pressure pipe burst or leak. A water pipe leak can result in human health risks, flooding of property, erosion and undermining of homes. If the pipeline is within a residential area a servitude of a certain distance is required by legislation to reduce the risks associated with potential pipeline breakages. Access roads and servitudes need to be as far as possible coordinated with existing servitudes and roads so as to reduce the impacts of building new roads (such as dust, soil erosion, safety etc). Spill prevention and emergency response plan are important for a pipeline if it passes under or over major roads or within urban areas. The construction impacts of a pipeline are short lived relative to the “lifetime” of the pipeline. If appropriate rehabilitation (EMP) of a buried pipeline is undertaken (top soil replaced etc) then the long term environmental impacts are minimal.

2.4.6 Impacts of Dams on species diversity on Lesotho

The effects of large dams have also played a role in threatening Lesotho’s biodiversity. The effects of large dams on Lesotho’s biodiversity was studied when considerations for the instream flow requirements of LHWP dams were undertaken. The study predicted that there would be dense algal growths throughout the system, which can be toxic to fish. Additionally, the study predicted that the encroachment of exotic plants at the expense of native plants and the species that depend on them would be severe. Further the study showed that there would be moderate to critically severe increases of blackfly and other pest populations that would prey on livestock. Other effects of the dam on the natural resources were reductions in most fish populations, with some species like the Maloti minnow and trout reaching the point of extinction, declines in waterfowl and an explosion in rodent populations, which could affect crops along the riverbanks. Indicative effects were that these changes to the ecosystem will have major social impacts as many fish and wild vegetable species will be reduced by over 50 % (www.irn.org, 29/11/02).

3 ENVIRONMENTAL ISSUES IN SOUTH AFRICA

3.1 Introduction

The Orange River basin is the largest river basin in South Africa with a catchment area of more than 1 million km^2 of which almost 600 000 km^2 is within the Republic (Figure 3.1). This catchment covers nearly 50% of the country. The basin incorporates portions of six of the nine provinces in South Africa as well as three neighboring states namely Namibia, Lesotho, and Botswana. It stretches 2 300 km from the source to the ORM at Oranjemund and Alexander Bay where it discharges into the Atlantic Ocean.

The Orange River is of great importance to South Africa since the natural flow represents more than 22% of the country's surface water resources. The natural water resources of the Orange River basin are estimated to be in the order of 12 000 million m^3 /annum, although less than half of the available water is currently abstracted by various developments in the Orange and Vaal basins.

The Vaal River, which is the main tributary of the Orange River, provides water to the Vaal River Supply Area. This supply area is the economic powerhouse of South Africa, producing approximately 60 % of the national GDP. Several major strategic industries, numerous large mines and most of the country's power stations are located within its boundaries. As a result of the growing water demands in the area, particularly in the Gauteng Province (due to population growth and improving living standards), water must be transferred from various parts of the country where water resources are more plentiful and demands relatively small. Several transfer schemes already exist but even these are no longer sufficient to supply the growing demands for water from the rapidly increasing urban population and associated economic activity in the area. As a result, the Lesotho Highlands Water Project was proposed and the first of five possible phases has been complete (Phase 1 and b). This scheme transfers water from the upper reaches of the Orange River to the Vaal River basin. Obviously, such a large transfer of water from the upper reaches of the Orange River will have a significant influence on the water availability further downstream and therefore influences the supply capabilities of the ORP.

The general topography of the Orange River rises in the Lesotho Highlands on the eastern Drakensberg plateau at an altitude of about 3 300 m above mean sea level.

The Orange River flows through four of the five seasonal rainfall regions. Upstream of the Gariep Dam summer is the rainy season and the rains come ever later in the summer in a downstream direction, until from the Fish River confluence downstream there is winter rain, if any.

The mean annual precipitation (MAP) is 1 800 mm at the source of the Orange River in Lesotho. The upper section of the Orange experiences an average annual rainfall of greater than 400 mm, while the MAP is below 400 mm in the middle and lower Orange River. This is less than half the world average of 860 mm per annum (DWA&F 1986). Average yearly rainfall is between 400 mm and 200 mm from Vanderkloof Dam to Boegoeberg Dam and the rainfall declines the further west the river flows until it is less than 50 mm per annum. In the Namaqaland sub-section of the river the rainfall is erratic and provides less than 1% of the flow of the Orange River .

A major factor in the South African water cycle is that the mean annual evaporation (MAE) often exceeds the MAP, and the Orange River catchment is no exception. In the upper Orange the MAE from surface waters is relatively low (1 400 mm and 2 200 mm). However, evaporation increases as the river runs westwards towards the desert region on the West coast, with the estimated average evaporative loss downstream of Vanderkloof Dam being about 14% of MAR. The MAE peaks at between 2 000 mm and 2 400 mm from above Boegoeberg Dam to upstream of Vioolsdrif and then declines slightly towards the coast. In the Namaqualand section of the river, the evaporation exceeds rainfall by a factor of 25:1, creating the desert region typical of that section.

The Orange River Project (ORP) was first proposed in 1961 to irrigate thousands of hectares in the Eastern Cape, Northern Cape and Free State areas. It currently utilises the two largest storage dams in South Africa, namely the Gariep Dam (commissioned 1971) and the Vanderkloof Dam (commissioned 1976, formerly known as the Hendrik Verwoerd and the PK le Roux Dams respectively). These two dams form the main storage elements of the ORP with a combined capacity in excess of 8 500 million m^3. Water is transferred to the Eastern Cape through the 80 km Orange-Fish Tunnel from the Gariep Dam, while the Riet River valley is supplied with water from the Vanderkloof Dam via the Orange-Riet Canal. Details of the main reservoirs and weirs in the Orange River are indicated in Table 3.1.

Presently the main functions of the Orange River Project are to:

- provide water for irrigation and urban users along the Orange River;
- provide irrigation water to the fertile, but water deficient, Great Fish and Sundays River valleys in the Eastern Cape;

- provide irrigation water to areas in the Riet River catchment;
- to alleviate water quality problems in the Vaal River at Douglas
- to provide water for mining (Skorpion and zinc mines in Namibia);
- to generate peak clipping hydro-power to the Eskom network from the hydro-power; and
- supply water for urban use to cities and many small towns including Bloemfontein, Botshabelo, Upington, Prieska, Springbok, Kleinsee, Rosh Pinah, Oranjemund, Port Elizabeth, Grahamstown, Alexander Bay and Port Nolloth.

Table 3-1: Details of main reservoirs and weirs on the Orange River

Name of reservoir	River	Purpose	Capacity (M m^3)
Gariep	Orange	Irrigation/hydropower	5 348
Vanderkloof	Orange	Irrigation/hydropower	3 189
Welbedacht	Caldedon	Urban water supply	20
Knellpoort	Rietspruit	Urban water supply	137
Boegoeberg	Orange	Irrigation	21

The Gariep and Vanderkloof dams are no longer sufficient to supply the growing demands for water from the rapidly increasing urban population and associated economic activity in the area. As a result, the Lesotho Highlands Water Project was proposed and the first of five possible phases has been completed to transfer water from the upper reaches of the Orange River to the Vaal River basin. Obviously, such a large transfer of water from the upper reaches of the Orange River will have a significant influence on the water availability further downstream and therefore influences the supply capabilities of the ORP.

3.2 Flow Changes in Orange River

The hydrology of the Orange River basin is discussed in more detail in Task 4 (Surface Hydrology).

The Gariep and Vanderkloof Dams, which fall in the Upper Orange, are the two largest conventional hydropower installations in the country and they are also the two largest storage reservoirs in South Africa. Details of the main Reservoirs are provided in Table 3.1.

Another major inter-water management area transfer of water is from the Gariep Dam, via the 80 km long Orange-Fish Tunnel, to the Fish and Tsitsikamma water management area, while a significant portion of the yield is also released along the river for use in the Lower Orange water management area as well as by Namibia. In total, close to 70% of the yield released in the Upper Orange water management area and Lesotho together, is used in other water management areas.

A major impact on the water management area is by the Lesotho Highlands Water Project. South Africa and Lesotho have only committed to Phase 1 of the Lesotho Highlands Project but the treaty between the countries allows for a further phase with a maximum diversion capacity of 2 200 million m^3 per year (Figure 1.3). Other joint current investigations are to further developments in the Caledon River catchment, which extends over the Lesotho Lowlands and parts of the catchment in South African territory, which will have an effect on the lower Caledon and the Upper Orange water management area.

The development of 8 000 ha new irrigation for the purposes of rural development, poverty relief and settlement of emerging farmers has in principle been sanctioned by the Minister of Water Affairs & Forestry. While these developments are likely to be located in the Lower Orange and Fish to Tsitsikamma water management areas, the water will have to be sourced from the Upper Orange water management area. Other priorities are for urban and industrial use in Bloemfontein/Botshabelo and for augmenting supplies to the Port Elizabeth area (Fish to Tsitsikamma water management area). Additional water for use by Namibia may also have to be released from the Upper Orange water management area, via the Lower Orange water management area (Figure 1.4).

Draining the Highlands of Lesotho, the Senqu River contributes close to 60% of the surface water associated with the Upper Orange water management area, at the point where it enters South Africa to become the Orange River. The climate varies considerably over the region, and rainfall ranges from over 1000 mm per year in the foothills of the mountains, to as little as 400 mm per year in the region of Vanderkloof Dam (DWAF, 2002).

These conflicts will make the task of environmental management increasingly complex in the years ahead.

Influence of the Phase 1 of the Lesotho Highlands Scheme on the flows at Oranjedraai upstream of the study area is relatively small at present. If further phases of the

Lesotho Highlands Scheme are fully developed however the influence would be critical. The influence of the Lesotho Highlands Scheme at Gariep Dam inflow is negligible at present (DWAF, 1998a). The proposed IFR releases from the Katse Dam will increase the natural seasonal flows in the river once Lesotho Highlands Development Agency has accepted these recommendations.

It is estimated that the demand for water from the Orange River will increase by 27.4% (343.6 million m^3/a to 473.3 million m^3/a) from 1994 to 2030. The main increase in demand is as a result of urban area growth predicted (DWAF, 1998b).

The Orange River Mouth (“ORM”) is one of very few areas of sheltered shallow water along southern Africa’s arid Atlantic coastline, and a site considered important primarily for sustaining substantial numbers of waterbirds, including an appreciable number of Red Data-listed species such as the Cape Cormorant, Damara Tern and Hartlaub’s Gull. In recognition of this exceptional ecological significance, the ORM was designated a Wetland of International Importance in terms of the Ramsar Convention on Wetlands in 1991. When Namibia designated its portion of the ORM a Ramsar site in 1995, it created the potential for this wetland to become the first jointly managed transfrontier Ramsar site in southern Africa.

As a result of severe deterioration of the mouth’s general condition, and especially the salt-marsh component, the ORM has continued to deteriorate subsequent to its designation as a Ramsar site. This has resulted in the South African portion of the ORM being placed on the Ramsar Convention’s Montreux Record, which lists wetlands in need of urgent conservation action.

The real issue is that relatively little has been done over the years since the salt marsh degradation began to remedy the situation. The State has failed to ensure compliance to the Minerals Act and the provisions of the Ramsar convention. The mining company has not rehabilitated in an appropriate manner, the conservation authorities have been ineffectual (mainly due to land ownership issues) and even the environmental lobbyists have failed to alert the world to the environmental damage that has been done.

The causes of the environmental degradation of the Orange River Mouth and especially the salt marsh are many and varied. Some of the impacts are directly associated with the mining activities whilst others occur thousands of kilometres upstream as a result of water demands for irrigation and hydro-power (see section 3.2.1).

3.2.1 Impacts on flow

If the flows in the upper Orange River (Weir D1H003 Orange River at Aliwal North Upstream of Gariep Dam) over the past 5 years are compared to the flows up to 1998, the following trends can be seen (Figure 3.1 and 3.2):

- The mean monthly flows recorded at each site are similar for both periods
- Higher maximum flows were recorded before 1998
- There is a seasonal summer maximum for both time periods
- The flows from 1998 to 2003 indicate a slightly flatter seasonal flow regime
- There are flow releases from most of the dams all year round (winter Eskom requirements) (Heath, 2004).

These data indicate that the current water demands and transfers are similar for both the periods studied. Furthermore data indicate flow deliveries to South Africa that the Lesotho Highlands Water Scheme has not had a marked effect on the flows of the Orange River at Oranjedraai over the past 5 years. If and when the Katse Dams' IFR releases are activated the flows into South Africa will mimic the natural hydrograph and have a minimal impact on the flow delivers to South Africa (Heath, 2004).

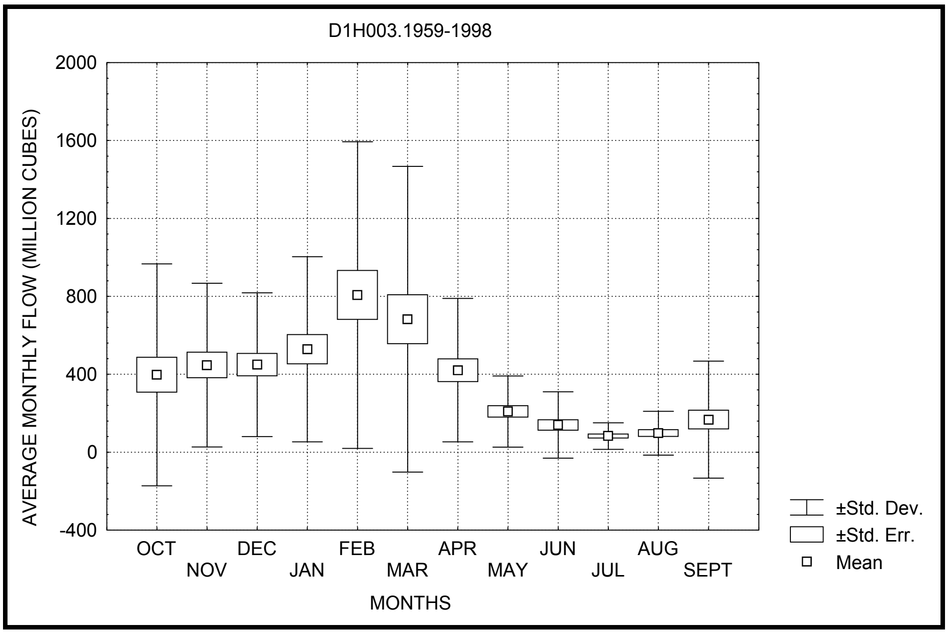

Figure 3-1: Box and whisker plots of the average monthly flows for weir D1H003 for the period 1959 to 1998

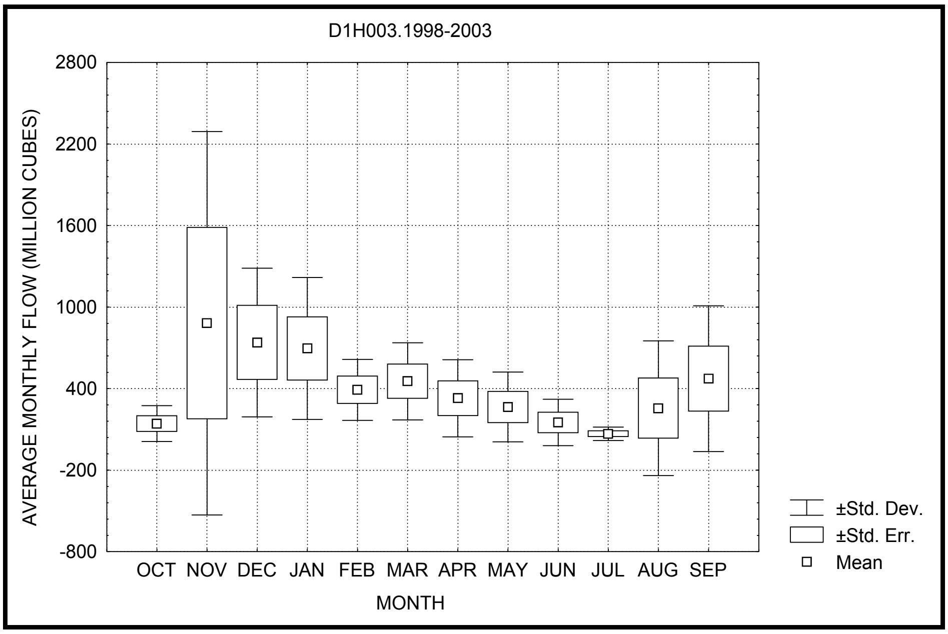

Figure 3-2: Box and whisker plots of the average monthly flows for weir D1H003 for the period 1999 to 2003

The observed flow data from D7H008 (Zeekoebaart-Upington) in the Orange River were converted to monthly data, divided into *c.* 10-year periods and analysed for: (Figures 3.3 and 3.4)

- MAR and Seasonal distribution; and
- Seasonal index.

There has been a gradual decline in the MAR of the river over the period of record (**Figure 3.3**). The seasonal distribution of flows (monthly averages) for each ten-year period is provided in **Figure 3.4**.

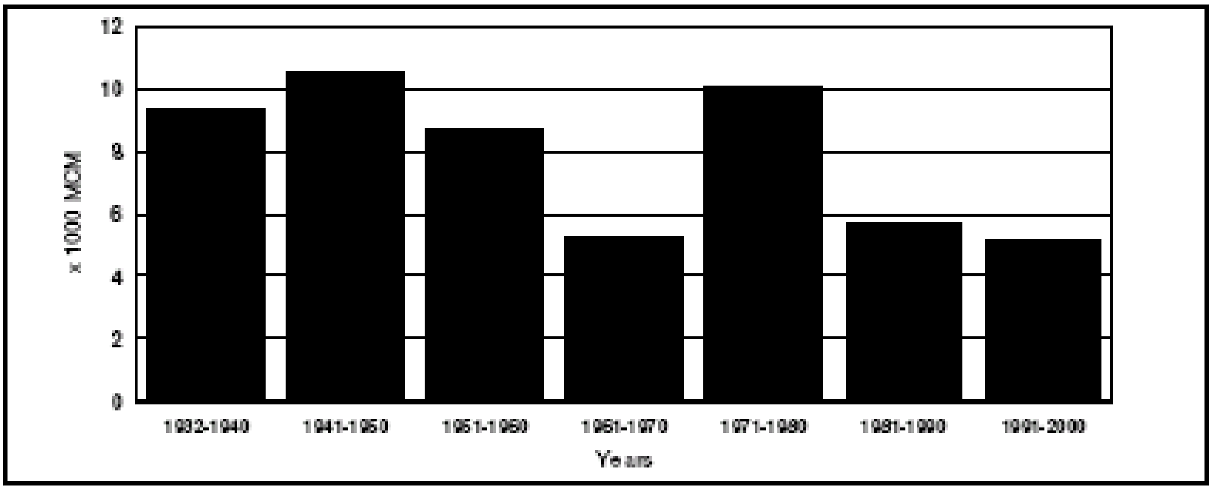

Figure 3-3: MAR for 10-Year Periods of the Observed Records from D7H008

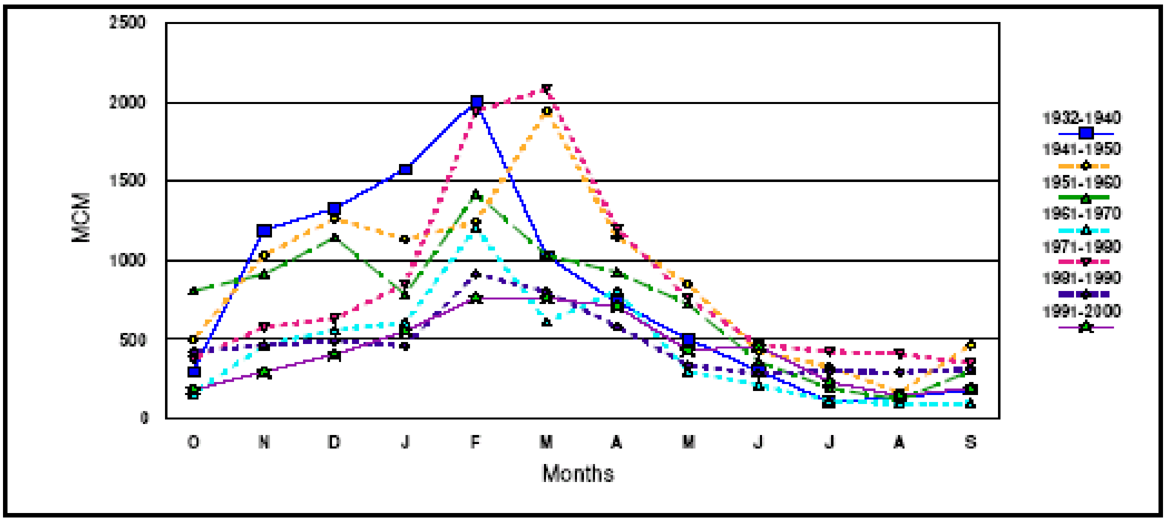

Figure 3-4: Seasonal Distribution of Flows (Monthly Averages) for Each 10-Year Period

Before 1960 there was little damming of the river and the flow regime was natural. This was marked by strong floods that occurred in the wet summer months, peaking in March, which alternated with periods of very low flow during the dry winter months inland. The Orange River Mouth (ORM) intermittently closed up in August and September, due to the action of long shore movement of beach sands and settling out of river sediments at the mouth. This **alternating flow pattern** gave rise to a very dynamic system that was most pronounced at the ORM. This pattern included scouring out of sediments and flushing of the whole area during floods, and slowing down of the system during the dry season with increases in salinity at the mouth when it closed.

With the construction of dams during the late 1960s and early 1970s this flow pattern have been changed from a 82:18 summer to winter distribution to a 59:41 summer to winter distribution pattern. This is well illustrated in Figure 3.5 (Boegoeberg Dam), which shows a reduction in flow variation following impoundments, but no change in long-term, wet-dry cycles.

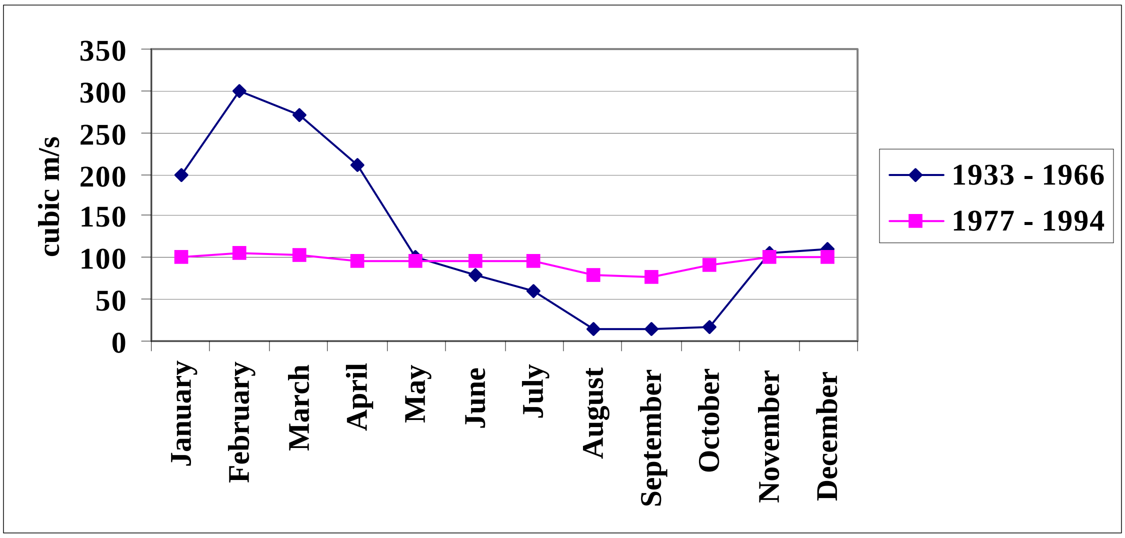

Figure 3-5: Mean monthly flows measured at Boegoeburg Dam before and after upstream dam regulation.

One of the major challenges facing river management worldwide is the allocation of compensation flows, which not only satisfy the water demands of downstream users, but also maintain the river as a viable and healthy ecosystem.

3.3 Water Quality Changes

A detailed assessment of the water quality issues in the Orange River Basin can be seen in Task 9.

The quality of surface water in the Upper Orange River was considered good, particularly for water that flow from the Highlands of Lesotho in the Senqu River. The Upper Orange River is a turbid system (approximate turbidity 232NTU). The Gariep and Vanderkloof Dams act as sediment traps (DWAF 1999). Water in the Caledon River is naturally of high turbidity and carries a concerning high sediment load.

The water quality trends for pH clearly indicate a false trend with the pre 1998 values being significantly different to the post 1998 values (Figure 3.6). The difference is due to the analytical methods that were used by DWAF's analytical laboratories changing consequently no trend can be determined. All that can be said is that all the values of pH recorded in the Orange River are alkaline.

There are no turbidity values on the DWAF database that we received but the electrical conductivity values can be used to determine this trend (Figure 3.7). The graph indicates that the Gariep and Vanderkloof dams act as sediment sinks as the electrical conductivity values are lower below these dams. The sodium, magnesium and Sodium Absorption Ratio (SAR) values indicate an increasing trend down the river (Heath 2004). These trends are due to the influence of return flows of irrigated lands down the river.

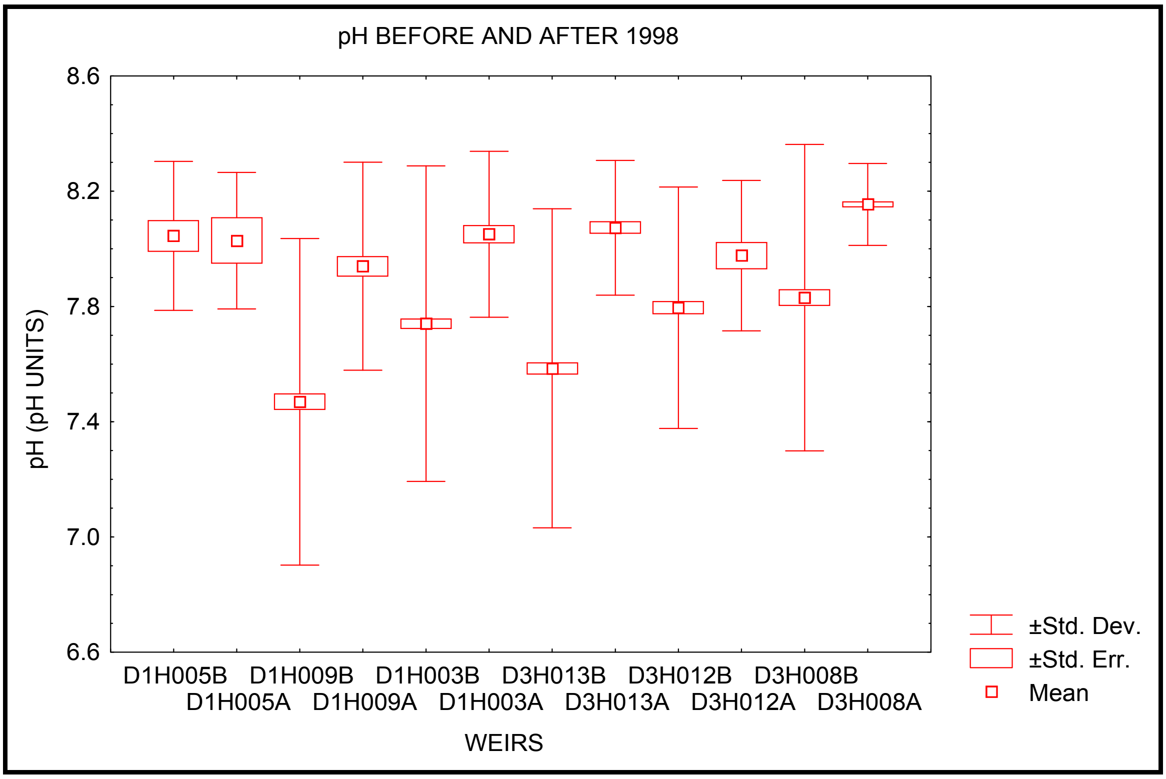

Figure 3-6: Box and whisker plots of pH for the different weirs before and after 1998 (B = before 1998; A = After 1998)

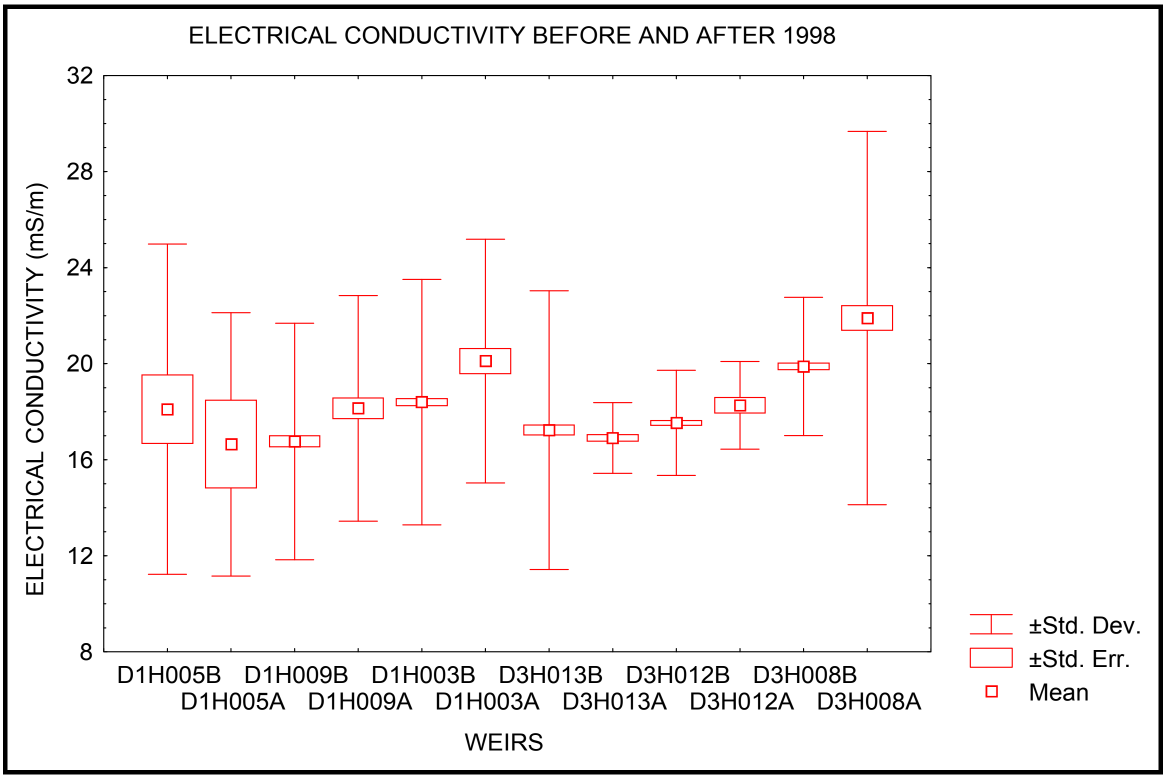

Figure 3-7: Box and whisker plots of electrical conductivity concentration for the different weirs before and after 1998 (B = before 1998; A = After 1998)

If the mean nutrients values (Kjeldahl-N, nitrate and nitrite and ammonia) are compared down the Orange River the following can be concluded (Heath 2004):

- Kjeldahl- N values are reduced down the river from Oranjedraai
- Ammonia and nitrate and nitrite values show a marked increase below Gariep dam hereafter then reduce gain to Marksdrift
- The irrigation return flows impact on salinity is managed by water blending and water quality management process (DWAF 2003).

The Upper Orange River could be classified as mesotrophic with algal blooms occurring occasionally in the dams. Four algal families are mostly present in the Upper Orange River namely Cyanobacteria, Bacillariophyceae, Chlorophyceae and Euglenophyceae (Venter, 2000).

3.4 Trajectory of Change in Orange River

The main reasons for the predicted trajectory are:

- **Reduction in short interval flow variability** through interception by dams and constant releases. Weirs are causing abnormal pools and are intercepting small-scale flow variations.
- Marked decrease in summer flows (primarily November to March);
- Marked decrease in magnitude of inter-annual floods – due to flood attenuation in the system and especially Gariep and Vanderkloof Dams.
- Increase in summer flows (primarily July and August).
- **Reduction in water clarity** as algal blooms increase from nutrient enrichment.
- **Reduction in scouring of sand** as floods are reduced (captured in dams).
- **Reduction in the extent of the river channel** through vegetation invasion and increased trapping of sediments.
- **Reduction in channel flood retention capacity** as the riverbank and floodplain vegetation is removed, and levees installed, thereby cutting of access to area that would normally absorb floodwaters.
- **Increase in agricultural activity** invading the riparian zone (illegally?).
- **Increase in *Phragmites* beds**, which are invading into the river channels and into the Drybank vegetation.
- **Increase in** fine sediment loads from soil erosion from agriculture.
- **Increase in** runoff of salt laden (from fertilizers) irrigation water to the river during lowflows, which negatively affects the Aquatic and Wetbank communities.
- **Increase in** erosion where the vegetation along the banks is disturbed.
- **Increase in t**he use of fire to "control" *Phragmites* invasion.
- **Increase in** exotic plants as disturbance increases and controls are not implemented. These plants interfere with the functioning of the indigenous vegetation and some utilize more water than indigenous species. They increase biomass and thus temperatures during fires, thereby increasing the damage done by fires.

3.5 Habitat Integrity of Upper Orange River

An assessment on the Habitat Integrity of the Upper Vaal gives a good indication of the typical changes in the Orange River (Heath et al, 2004).

3.5.1 Instream Habitat Integrity

The most prominent modification to the instream habitat of the Orange River is the channel, bed and flow modification as a result of Gariep and Vanderkloof Dams. Some abstraction of water for irrigation also has an influence on the flow and water quality in the river. The upper reach of the Orange River (from Lesotho border to Kraai/Orange confluence) is relatively natural with some modification due to abstraction and erosion in its catchment area. The middle and lower reaches (from Kraai/Orange River confluence to Vanderkloof Dam) is critically modified as a result of flow regulation. Water is also released from Gariep Dam for Hydroelectric power generation and these sporadic releases result in the deterioration of the biota in the river.

The Instream Habitat Integrity Class of the Upper Orange River varies from a Class B in Reach 1, Class C in Reach 2 and Class E in Reach 3. The deterioration in Instream Habitat of the Orange River from Class C (Reach 2) to E in Reach 3 is the result of the regulation of flow by Gariep and Vanderkloof Dams. (Figures 3.6 and 3.9)

3.5.2 Riparian Habitat Integrity

Small patches of exotic vegetation occur in the riparian zone of all the reaches of the Upper Orange River. Weeping willow (*Salix babylonica*) and poplars are present along the whole stretch of the Orange River. Overgrazing and erosion in the riparian zone of especially the southern banks of reach 1 has a small to moderate effect on the habitat.

The inundation of the riverbanks by Gariep and Vanderkloof Dams is the largest modifier of riparian habitat in the Upper Orange River.

The Riparian Habitat Integrity of the Upper Orange River is a Class B for Reach 1 & 2 and Class D in reach 3 (Figures 3.8 and 3.9).

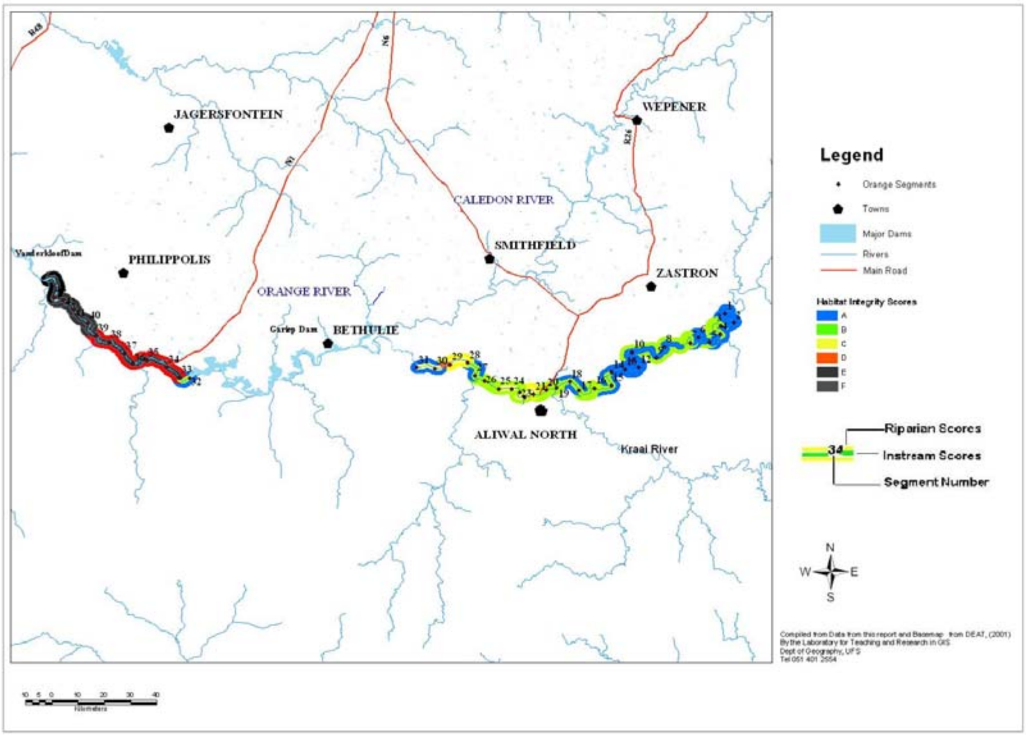

Figure 3-8: Habitat Integrity for Riparian and Instream habitats for segments of the Upper Orange River

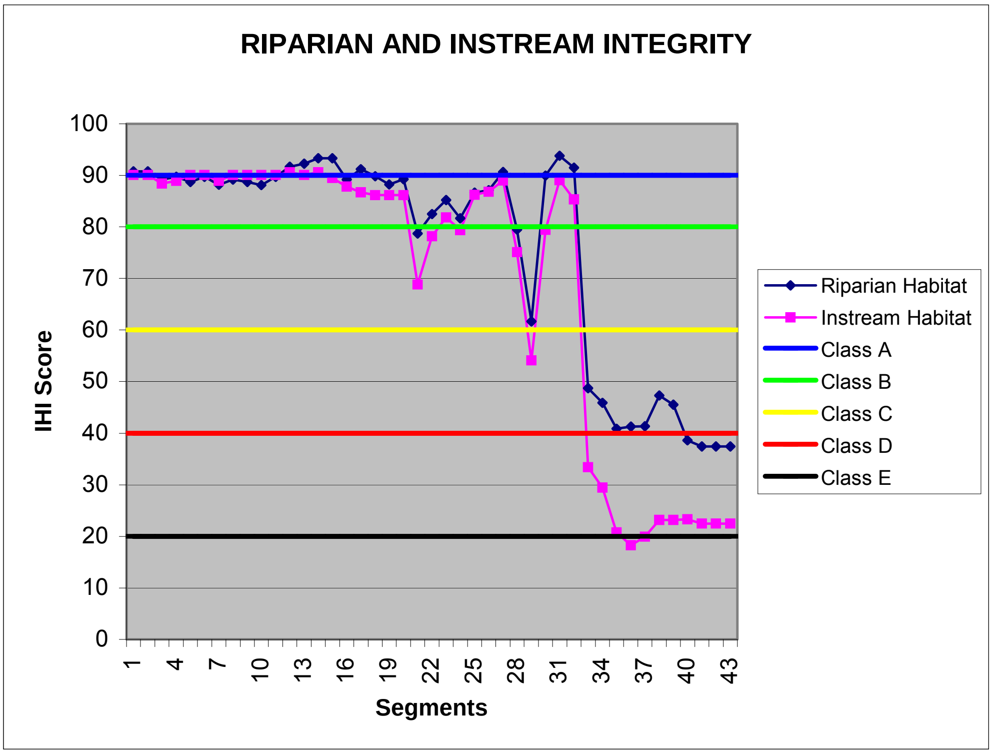

Figure 3-9: Index of Habitat Integrity scores for Upper Orange River

3.6 Ecological Consequences of Flow Changes

3.6.1 Conservation of representative ecosystems

There are still parts of the Orange River in reasonably natural condition which represent ecosystem types not conserved elsewhere. Areas of particular conservation importance include:

- Archaeological sites near the confluence with the Vaal River.
- Representative example of Orange River Broken Veld veld type between Prieska and Boegoeberg.
- Undeveloped floodplains downstream of Kanoneiland.
- Undeveloped floodplains downstream of Blouputs.
- The gorge downstream of Augrabies Falls.
- The Falls at Onseepkans.
- The Richtersveld National Park.
- Archaeological sites at Arrisdrift and Daberas.
- The estuary.

3.6.2 Species conservation

Barbus hospes, the fish found only in the Orange River downstream of Augrabies Falls, is a known species which should be considered of special conservation importance. Within the distribution range of *B. hospes*, geographically isolated populations of two fish species, *Mesobola brevianalis* and *Barbus trimaculatus*, occur. These two species are of considerable interest for they may provide evidence of an ancient link between the drainages of the Okavango system and the Orange. Should it become necessary to develop a dam in the lower Orange River, the conservation of these species would best be served by preserving as long an uninterrupted stretch of the lower river as possible. For example, siting the dam as near the estuary as possible could do this. The only other thus far recognised endemic species is a blackfly, *Simulium gariepense*. The impact of present development on *S. gariepense* would, from the little data, available, appear to have resulted in a decline in the abundance of the species, without the species disappearing over the approximately 20 years that the river has been regulated.

3.6.3 Loss of species diversity

The review of available information has shown that loss of species diversity has taken place in the riparian vegetation, which is highly modified in many places. This cannot be directly ascribed to development of the water resources of the river. Its importance lies in the fact that river reaches with natural riparian vegetation are limited and considered to be of conservation importance. Impacts of proposed new dams on areas with natural riparian vegetation have to betaken into account. Due to electric power generation (that is between Gariep and Vanderkloof Dams and below Vanderkloof Dam for some 200 km) loss of species diversity is severe. The river immediately below Vanderkloof has been described above as an ecological desert. The creation of further "ecological deserts" would not be desirable. They would be unacceptable in parts of the river of particular conservation importance.

3.6.4 Conservation of the river estuary

The Orange River estuary has been ranked as the sixth most important coastal wetland in South Africa. It is an important resting site on the migration route of many aquatic bird species. However, recent studies show significant damage to the wetland due to reduced flow reach the mouth as well as construction a track on the northern edge.

3.6.5 Reed encroachment

Reports note that reed encroachment of the channel in the middle reaches of the Orange River has been considerable, subsequent to the regulation of flow by the Gariep and Vanderkloof Dams. It is regarded as undesirable for several reasons which have been described earlier. It has been considered that reed control may be achieved through flow regulation, though this remains to be proved in the Orange River.

3.6.6 Blackfly increase

The Team has identified reports showing that flow regulation has been accompanied by the appearance of major outbreaks of *Simulium chutteri*, which have resulted in annual losses to livestock farmers estimated at R 33 million along an 800 km stretch of the river. As in the case of reed encroachment, these outbreaks are ascribed to the artificial flow regime and it is considered that other flow regimes may contribute to their amelioration.

3.6.7 Loss of water through evaporation

Evaporation from the surface of water bodies is one of the major causes of water loss and, if large enough, can have severe economic implications. As mentioned earlier, the Lower Orange River passes through a region, which has high evaporation and low rainfall. To ensure that evaporation is kept to a minimum, man-made lakes in this region should have a high depth to surface area ratio. Annual evaporative losses for the river below the Vanderkloof Dam were estimated by BKS and Stewart Scott (1993) to be as much as 800 million m3. This figure will increase with every new reservoir on the Orange River.

3.6.8 Soil and water salinity

Although water quality is dealt with in detail by another task, the Environment Team has noted that salinisation of irrigated soils will lead to greater salt loads on the river, ultimately to the point where quality may be impaired and the uses of the water restricted. It may be predicted that the salt *load* from the Vaal River will increase and should be taken into account in the siting of future dams.

3.6.9 Sediment transport

Sediment yield is highest in the upper Orange catchment. Because of the silt retention capacity of the two major dams in the Orange, silt and sediment loads in the lower Orange have been considerably reduced. Sediment yield potential in the lower Orange is low, and it is unlikely that any reservoirs in this area will silt up quickly. This is an issue favouring the siting of new dams in the lower river. Severe soil erosion in Lesotho, especially in the Caledon system, is contributing factor.

3.6.10 Turbidity

Studies note that the Orange River is a turbid river. The growth of benthic algae and phytoplankton, which include important nuisance organisms, is limited by light availability which is restricted by the turbidity. New dams, or an increase in the salinity of the water (with which flocculation and sedimentation of suspended solids is associated), or both factors acting together, could reduce the turbidity allowing blooms of algae and phytoplankton.

3.6.11 Water temperature

Dams modify the temperature regime of downstream rivers. Broadly speaking in winter they release warmer water than occurred in the unregulated river and in summer they release cooler water. The range of variation of temperature over a 24-hour cycle is reduced below dams. A changed temperature regime has profound impacts on the life of rivers and can result in conditions totally unsuitable for certain organisms. In the Orange River the temperature regime is likely to be modified for some 130 to 180 km downstream of Vanderkloof Dam.

3.6.12 Conflicting demands

In the Orange River, conflict arises between the:

- demands of agriculture,
- generation of hydro-electricity,
- demands for mining,
- international obligations (increased demands in Namibia); and
- environmental requirements (instream flow requirements, Reserve allocation)

3.7 Macroinvertebrates in Lower Orange River

The invertebrates in the lower Orange River are largely modified due to the overwhelming and persistent abundance of filter-feeders, in particular the pest proportion numbers of the blackfly, *Simulium chutteri*. The large-scale programme to control this pest, using aerial applications of insecticides, highlights the extent of the problem (Palmer, 1997). The outbreaks are attributed to stable flow conditions, in particular high winter flows, deterioration in water quality and encroachment of instream vegetation. These changes are explained as follows:

High winter flows. High winter flows allow over-wintering of larval blackfly populations. Larvae that develop in winter are significantly larger and carry larger fat reserves than larvae that develop in warm temperatures. As water temperatures rise in spring, the winter larvae pupate, and the adults that emerge carry large fat reserves and are suspected to be able to lay their first batch of eggs without the usual need for a blood meal. These eggs hatch and the larvae develop quickly because of warmer water temperatures. By the time they emerge as adults, the first generation of winter adults are still alive, and this leads to an overlapping of generations, which leads to rapid increases in population size (i.e., pest outbreaks). Under natural conditions this occurred from time to time, but not persistently every year.

Water quality. Deterioration in water quality has provided ideal conditions for filter-feeding invertebrates. The deterioration is partly attributed to the construction of dams, which allow the developments of micro-algae not normally associated with river systems. Increased clarity following impoundment has caused a shift in trophic status from a dominance of terrestrial-derived organic matter to a dominance of autochthonous primary production, and this has favoured filter-feeding invertebrates. Deterioration in water quality is also attributed to the decomposition and burning of

Phragmites reeds, which is likely to contribute significant quantities of fine particulate and dissolved organic material, upon which filter-feeding invertebrates feed. Water quality is also likely to have deteriorated from agricultural return flows carrying elevated nutrients, particularly nitrates.

Phragmites reeds. The encroachment of *Phragmites* reeds is a recent phenomenon related primarily to disturbance of riverbanks. Photographs taken as recently as 1976 show an almost complete absence of reeds. There are sections of river, particularly in the lower reaches, where reeds are absent except where the bank is disturbed. Upstream of the estuary the riparian vegetation is dominated by the Cape willow (*Salix mucronata*), except at a pumping station, where *Phragmites* sp. are abundant. It is clear that *Phragmites* reeds are pioneer plants, quick to colonise disturbed areas. The extent of bank disturbance may be appreciated when one considers that almost the entire length of the river between Grootdrink and Kanoneiland (over 110 km) has been channelised. Reeds trailing in the current significantly increase the surface area available for blackfly larval attachment. It is likely therefore that the blackfly problem in the Orange River has been aggravated by reed encroachment, both because of the increased surface area for larval attachment, and because of the suspected increase in fine organic material. The rampant growth of reeds is also likely to have had a significant impact on particle retention.

Vegetation. Floodplain developments have all but removed the floodplain vegetation in riparian areas near to Upington, Kakamas and Onseepkans. Similar activities are also in evidence at Raap and Skraap, but are not serious outside of these areas. Removal of this vegetation reduces the river's buffer against nutrients and sediments being washed off the surrounding farmlands. In the heavily developed areas the effects of water abstraction are masked by mechanical damage to the riparian zone. Flow reductions and a more constant flow regime have contributed towards the spread of *Phragmites* reeds into the channel. Here again, management of the reed through burning has increased the damage to the riparian vegetation and promoted the occurrence of densely rooted reed beds.

3.8 Conservation Areas in Orange River

3.8.1 National Parks

The National parks within South Africa that occur within the Orange River catchments are indicated in Figure 3.10. These are:

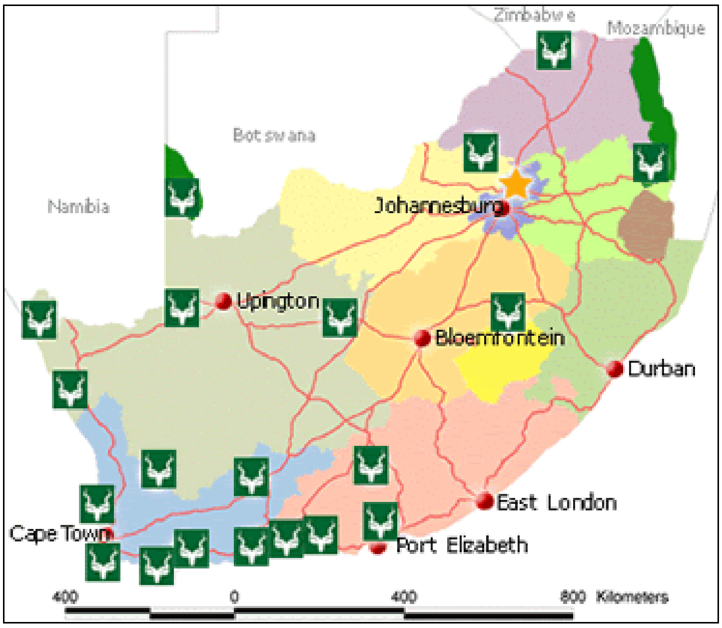

Figure 3-10: National Parks of South Africa

Kgalagadi Transfrontier Park

Together with the adjacent Gemsbok National Park in Botswana, this park comprises an area of over 3,6 million hectares – one of very few conservation areas of this magnitude left in the world.

Ai-Ais/Richtersveld Transfrontier National Park

This is a harsh and unpredictable land where water is scarce and life-sustaining moisture comes in the form of early morning fog which rolls in from the cold waters of the Atlantic Ocean, sustaining a remarkable range of small reptiles, birds and mammals. A staggering assortment of plant life, some species occurring nowhere else in the world, is to be found here.

Augrabies Falls National Park

Water plummets 56m over the Augrabies Waterfall into the Orange River. The Khoi people called it 'Aukoerebis', or place of Great Noise, as this powerful flow of water is unleashed from rocky surroundings characterized by the 18-km abyss of the Orange River Gorge. The 28 000 hectares on both the northern and southern sides of the Orange River provide sanctuary to a diversity of species, from the very smallest succulents, birds and reptiles to springbok, gemsbok and the endangered black rhino.

Golden Gate Highlands National Park

Nestled in the rolling foothills of the Maluti Mountains of the north eastern Free State lies the Golden Gate Highlands National Park. This 11 600 hectares of unique environment is true highland habitat, providing home to a variety of mammals – black wildebeest, eland, blesbok, oribi, springbok and Burchell's zebra - and birds, including the rare bearded vulture (lammergeier) and the equally rare bald ibis, which breed on the ledges in the sandstone cliffs.

Vaalbos National Park

The Vaalbos National Park is an extraordinary area along the Vaal River where wildlife such as roan antelope, black rhino, white rhino, buffalo, eland, red hartebeest and tsessebe are to be seen in the former heart of the alluvial diamond diggings near Kimberley.

3.8.2 Transfrontier National Parks

The Transfrontier National Parks that occur with the Orange River basin are indicated in Figure 3.11. For more details on these parks see Chapters 4 and 5.

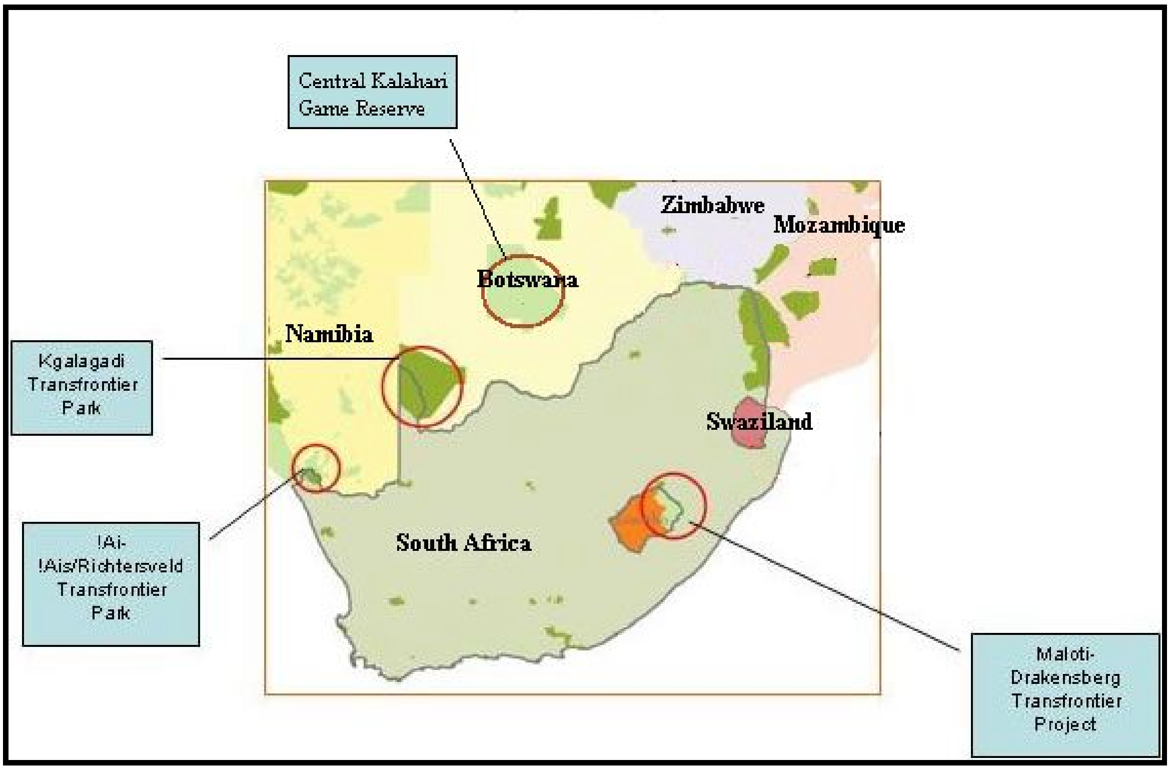

Figure 3-11: Trans frontier National Parks within the Vaal And Orange River Catchment areas.

3.8.3 Red data species

The localities of the lists of Red data species of plants and animals that occur with the Orange River basin within South Africa can be found in Appendix B. The numbers of red data fish that occur per province in South Africa and Lesotho is indicated in Table 3.2.

Table 3-2: List of red data species of fish per province in South Africa and Lesotho.

Region	Northern Cape /Free state	Gauteng	Lesotho	Namibia
Endemic freshwater fish				
Endangered			**1**	
Vulnerable		**2**		
Rare	**2**	**2**	**1**	**3**
Endemic estuarine fish				
Endangered				
Vulnerable				
Rare				**2**
Marginal freshwater fish				
Endangered				
Vulnerable		**1**		
Rare		**6**		
Marginal estuarine fish				
Endangered				
Vulnerable				
Rare				**2**

A gap analysis for river ecosystems was done (DEAT 2004) as part of the National Biodiversity Strategic Action Plan. The results tell us that most of South Africa's river ecosystems are not protected at all.

There are two important issues to note with respect to the gap analysis of river ecosystems:

- Even if part of a river (incorporating one or more river-scape signatures) is well protected, impacts upstream on the same river may mean that the river's biodiversity is not effectively protected.
- Rivers are often used to delineate the boundaries of protected areas. About a third of the river signatures that are "protected" according to this analysis are actually on the boundaries of protected areas rather than inside them, and are thus not effectively protected.

3.9 National Heritage Sites

A list of national Heritage sites is available per province in South Africa (www.sahra.org.za).

In 1999 the National Monuments Act was replaced by the National Heritage Resources Act, No. 25 of 1999.

Section 58 of the National Heritage Resources Act stipulates *inter alia* that all heritage resources that were protected as national monuments in terms of the previous Act shall continue to be protected in terms of the new Act as provincial heritage sites. This is with the provision that within five years of the commencement of the new Act, provincial heritage resources authorities in consultation with the South African Heritage Resources Authority (SAHRA) must assess the significance of such sites and SAHRA must declare any place, which fulfils the criteria for Grade I status a national heritage site.

4 ENVIRONMENTAL ISSUES IN BOTSWANA

4.1 Environmental Overview of the Molopo River Basin

4.1.1 Location

The Molopo River Basin (Nossop River Basin included), which forms part of the northern portion of the Orange-Senqu River Basin, is located in the southern part of Botswana with an area of approximately 71,000 square kilometers. Molopo and Nossop are the major rivers in the Basin and they form part of the international boundary with the Republic of South Africa.

4.1.2 Geomorphology and Surface Drainage

Relief

The Molopo River Basin is located in the Kalahari, which is a large sand filled basin in the west of the southern African sub-continent, covering nearly one third of the area and forming what is probably the largest sand-veld area in the world (National Parks Board & Department of Wildlife and National Parks, 1997). The physical landscape of the area is generally flat to undulating. Spot height data from the Department of Geological Surveys, though limited in terms of spatial distribution, indicate that the highest point in the Basin is about 22 km to the northwest of Werda, with an elevation of 1522 meters above sea level. Generally, the relief of the Basin is relatively higher in the eastern and northern parts and it gently slopes southwestwards towards the Molopo River. The Maiphitwane-Gathwane-Ramatlabama area in the eastern part of the Basin has an elevation of about 1320 meters above sea level whereas the elevation along most parts of the Molopo River Valley ranges from about 1000 to 1100 meters above sea level. The relief is lowest in the south-western area of the Basin. For instance the Molopo valley at Rappel’s Pan has an altitude of 850 meters above sea level, at distance of about 27 Km from the Molopo-Nossop River confluence.

Sand dunes

Sand dunes are found in the Molopo River Basin, just like in most other parts of the Kalahari environment, and they contribute to the undulating topography of the area (See Figure 4.2 and Plate 4.1). The sand dunes are aeolian depositional landforms though accounting for their development in terms of modern and ancient environmental conditions is still fraught with difficulty. Thomas and Shaw (1984) observe that this is a consequence of several factors, including the nature of the predominant dune types found in the Kalahari and the general question of the climatic and atmospheric conditions conducive to their development, whether some of these dunes are currently geomorphologically active or relict features, and, in the case of the latter, considerable problem of dating the time of development. Thomas and Shaw classify the dunes of the Kalahari into 3 major dunefields namely Northern dunefield, Southern dunefield and Eastern dunefield. The Molopo River Basin falls in the Southern dunefield as shown in Figure 4.3. A summary of the dune types identified by Thomas and Shaw in the Kalahari is presented in Table 4.1.

Over 90 per cent of the dunes in the Basin are linear, varying in height between 2 meters to greater than 30 meters above the inter-dunes, with some of the highest dunes occurring immediately adjacent to the fossil valleys. The barchan dunes trend NNW whereas the seif dunes trend in NNE direction. Lunette dunes, which are crescent in shape, are often found on the south or south-south-western margins of pans in the Southern dunefield. Thomas and Shaw report that Hills (1940) observed that the lunette dunes and their associated pans share a common origin, with the location of the dune indicating the prevailing wind direction at the time of their formation.

Table 4-1: A summary of the dune types present in the Kalahari

Dune Type	Location
Linear dunes (general)	All three Kalahari dunefields are dominated by linear dunes (est. 85 % of the southern dunefield where the Molopo River Basin is situated). These may be divided into linear ridges and seif dunes:
Linear ridges	Low degraded forms dominate the eastern and northern dunefields. Partially vegetated forms dominate the southern dunefield
Seif dunes	Linear forms with sharp sinuous crests: present in the drier parts of the southern dunefield and where the vegetation of linear ridge crests has been destroyed e.g. around Bokspits area
Transverse dunes (general)	Within and beyond the western margin of the Makgadikgadi Depression:
Barchan dunes	On the floor of Ntwetwe Pan
Transverse ridges	West of the Gidikwe Ridge
Parabolic dunes	Southern dunefield and Bakalahari Schwelle:
Lunette dunes	On downwind margins of pan depressions
Nested parabolics	Isolated patches in southern dunefield, where vegetation cover is disturbed
Blowouts	Widespread location, especially in the southern dunefield, where local vegetation disturbance has occurred. In some places, may evolve into parabolic and nested parabolic forms

Source: Adopted from Thomas and Shaw (1984)

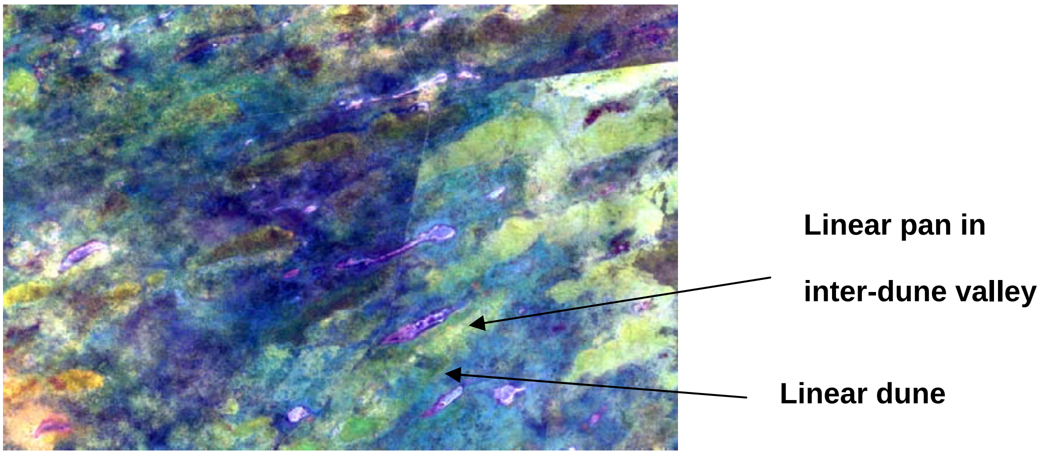

Figure 4-1: Linear Sand Dunes on a Landsat TM Satellite Image in the Kalahari

Figure 4-2: Sand dunes encroaching into the Molopo Valley at Welewerdierd (Source: Roughton International, 2001)

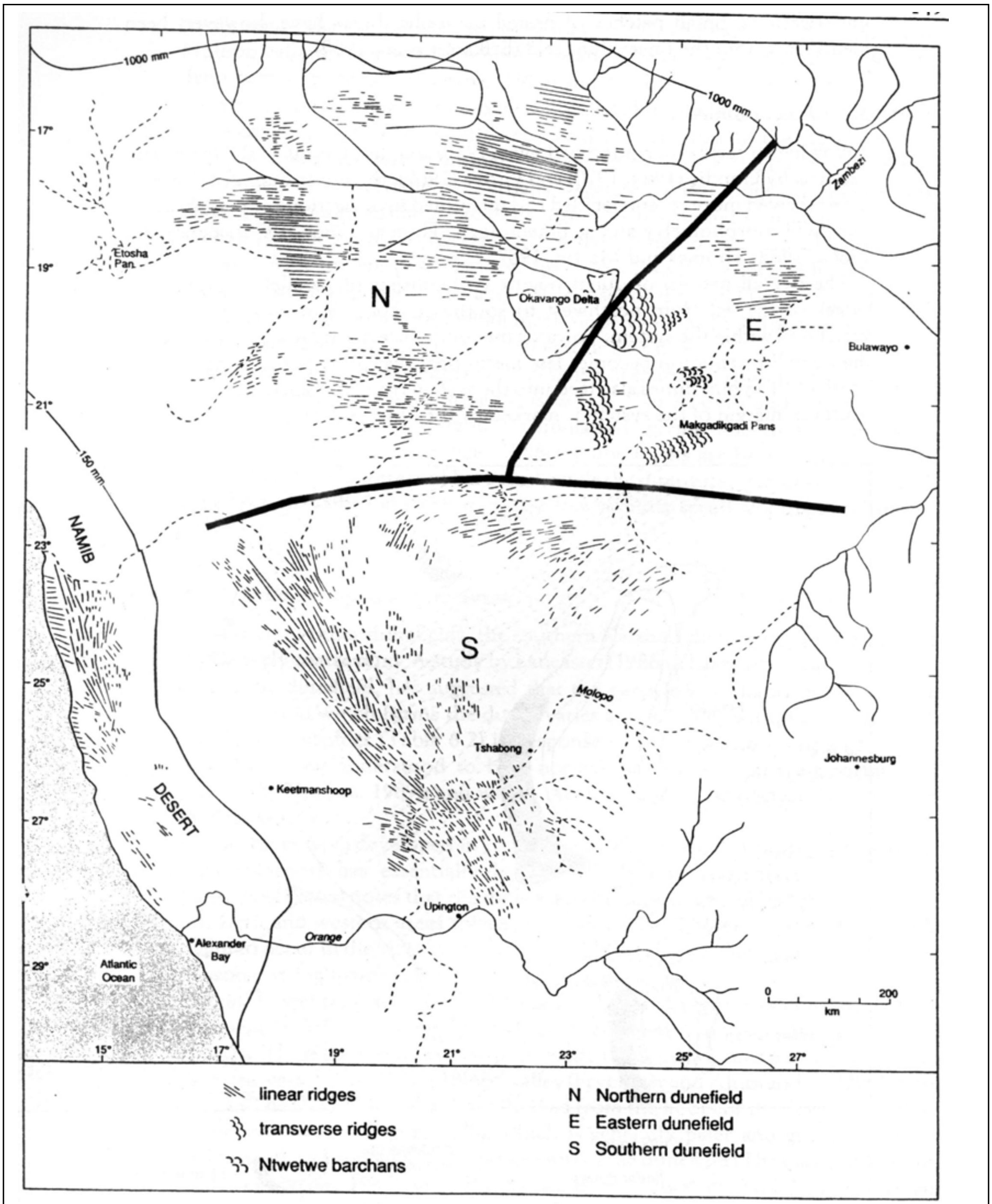

Figure 4-3: The three Major Dunefields of the Kalahari Source: Adapted from Thomas and Shaw (1984)

Pans

Pans are shallow depressions typical of arid and semi-arid environments with low relief and have been identified as an important component of the southern African landscape in areas with an annual rainfall of less than 500 mm per year, particularly where the surficial materials are either shales or unconsolidated sands (Thomas and Shaw, 1984). In the Molopo River Basin, pans of various shapes and sizes can be found in some parts of the area. The pans are spherical, oval, or elongated in shape. Linear-shaped (elongate) pans are usually found in inter-dunal valleys of linear sand dunes. Such pans can have a length of about 5km and a width of 1km, and are visible on satellite images and aerial photographs especially during rainy seasons when they may have water. In the Molopo River Basin, the elongated pans can be found in the areas with linear dunes such as to the west of Khakhea Village and in the western part of the Basin towards the Nossop River. Another common and distinctive type of pan in the region occurs in the Southern Kalahari and on the Bakalahari Schwelle, particularly between the settlements of Tshane, Kokong and Mabuasehube, around the Nossop-Molopo confluence and in the vicinity of the Nossop at Aminuis in Namibia (Thomas and Shaw, 1984). These pans are characterized by a sub-circular, sub-elliptical or kidney shape, and characteristically display one or more lunette dunes anchored to their southern or southwestern margin (See Figure 4.4).

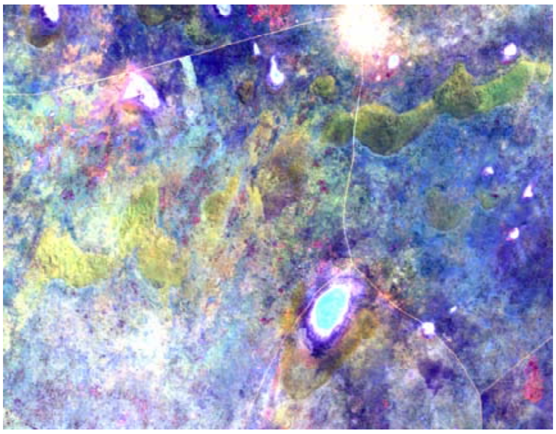

Figure 4-4: Lunette dunes on a Landsat TM Satellite Image in the Kalahari

The pans commonly lack surface inflows, though short, poorly developed channels at times feed into them, supplying run-off to the pans during major rainfall events. The size of the pans in the area tends to range from 1 to 16 square kilometer, with depths up to 20 meters at times. Lancaster (1978) observes that the majority of the pans occur in the Kalahari Sand, although where the sand cover is thin, as at Khakhaea and Mabuasehube, Karoo and Precambrian basement rocks may be exposed. The pans are also associated with the presence of calcrete, which tends to form a rim around the pan periphery, and may extend for several hundred meters beyond the pan depression. Silcretes sometimes occur on the pan surface, or within the calcrete surround, as a result of calcium replacement or by direct precipitation, while ferricretes are also present in the eastern Kalahari (Thomas and Shaw, 1984).

Lancaster ascribes the formation of the pans to groundwater controlled aeolian deflation. The main phase of pan deepening is likely to be an in-situ process. The present day climate gives rise to sporadic pan flooding and evaporation in an environment in which chemical dissolution and reprecipitation might be expected. Wind erosion (deflation) of the fine-grained clays, salts and carbonates is likely to occur during each drying out phase.

Surface Drainage

The Southern Kalahari is dominated by a broad, featureless interfluve at 1000-1100 meters above sea level, called the Bakalahari Schwelle (Thomas and Shaw, 1984). This separates the Middle Kalahari, with its endoreic drainage, from the Molopo River and its tributaries, which used to drain to the Orange River, and subsequently into the Atlantic Ocean. Generally the Molopo River Basin is poorly endowed with surface water as a result of the arid and semi-arid climatic conditions that prevail in the area and the Kalahari sandy soils, which have poor water retention capacities. The Molopo and the Nossop Rivers are the major surface drainage features in the area. These rivers are ephemeral, flowing occasionally after heavy rainfall events. In the area, dry fossil river valleys which used to drain into the Molopo River in the past are found. These dry fossil river valleys are locally known as *mekgacha* (single: *mokgacha*). Thomas and Shaw argue that the Molopo River System, whose major valleys include the Molopo, Kuruman (in South Africa), Auob (in Namibia) and Nossop, represents a transitional stage between permanently dry *mekgacha* and the seasonal rivers typical of the semi-arid hardveld. All the 4 major river valleys rise on bedrock, and this is considered to contribute to their unusual hydrological regimes, which vary between the rivers. The Kuruman is reported to have the most reliable flow and at its upstream end is a perennial river, fed by a series of dolomite springs, including the famous Eye of Kuruman, which has yielded a constant 750m^3 per hour since at least 1820 (Thomas & Shaw, 1984). In most years the water rapidly percolates into the streambed a few kilometers downstream, but it may flow throughout the length of the river in high rainfall years, in a channel of ‘sand river’ type. The Molopo River flows sporadically in its upper reaches, but the water does not proceed beyond Water’s End, between Werda and Tsabong. Beyond this point, the Molopo is reported to have typical *mekgacha* form, as do its tributaries in the Moselebe network (e.g. Khekhe, Malatswana, Moselebe and Kwi). The Auob and Nossop have partially dune-obscured, broad, flat beds, which are typical of flash floods in arid environments. Roughton International (2001) report that after very exceptional rains, localized flows are possible in the Molopo but their duration is short and flows do not run until ponding occurs in the lowest points of the valley. From Middlepits to Bokspits, ponding is reported to be most frequent downstream of Khuis, occurs less frequently at Middlepits, Gakhibane, De Brak, Inversnaid, Vaalhoek, and Bokspits.

Both the Nossop and Auob rivers have their sources in the Anas Mountains near Windhoek, Namibia. They flow south easterly, joining in the Kalahari Gemsbok National Park 6 km north of Twee Rivieren and continue on as the Nossop to the Molopo and Kuruman rivers 60 km to the south. It is reported that the Molopo River with its origin near Mafikeng, no longer reaches the Orange River as sand dunes near Noeneput have blocked its course for at least the last 1000 years (National Parks Board & Department of Wildlife and National Parks, 1997). The rivers are predominantly dry, only flowing for short periods after abnormally high rainfall. The intermittent fluvial activity has left terraces and fluvial sediments along the Molopo River. Some of these features have been dated to the late Quaternary while the high terraces, beyond the confines of the present valley, are presumed to be older (Thomas and Shaw). Flooding occurs very infrequently in response to very large-scale short-term precipitation. Floods have been recorded in the Nossop in 1806, 1963, and January 1987 and in the Molopo River as well in 1934. For the most part these floods occur in response to rainfall over the upper catchment and are short lived, with the water being rapidly absorbed into the riverbed. There are no river gauging stations along the Molopo River.

4.1.3 Soils

Detailed soils studies have not yet been carried out in the southwestern part of the country. The 1: 250,000 Soil map of the Republic of Botswana largely covers the eastern and northern parts of that country which have comparatively higher crop farming potential. In the Molopo River Basin, the map only covers a small portion in the east up to longitude 24^{o} East near Sekoma Village. The 1: 1,000,000 Soil Map of The Republic of Botswana (Ministry of Agriculture, 1990), reproduced in this report as

Figure 4.5, shows that about 90 percent of the soils in the Molopo River Basin are Arenosols. These soils are sandy in texture and they occur on the Kalahari Sandveld. The soils are generally 100 centimeters in depth or deeper and well drained. As a result of their low water holding capacities, low organic matter and paucity of plant nutrients, the Arenosols generally have low agricultural potential for crop production. In the eastern part the Molopo River Basin, residual soils are found in the hardveld environment. The main soil types in the area are Leptosols, Regosols, Lixisols, Luvisols and Vertisols. The Leptosols and Regosols are sandy in texture like Arenosols. They are well drained and have low contents of clay. In terms of crop production, these soils have low potential in part due to their shallowness (Regosols are generally less than 100 cm in depth and Leptosols less than 50 cm). The Lixisols, Luvisols and Vertisols have relatively higher clay contents as compared to the other soils – thus their water retention capacities are better. Consequently, these soils are moderately good for crop production.

Areas along river valleys in the Basin have soils whose formation was influenced by former fluvial activities. For instance the areas along the Nossop River have Haplic Luvisols whereas those along the fossil river valleys such as Khekhe, Moselebe, Sekhutlane and Malatswana, have Petric Calcisols. These soils have relatively high silt and clay content. As a result of these characteristics and their relative low topographic positions (thus acting as sinks for surface runoff and nutrients), the areas covered with these soils have a good potential for plant growth. The pans in the area generally have calcareous soils with fairly high clay content. The calcareous soils have good water holding capacities because of their compact soil structure. As a result the pans are valuable water sources for the wild animals and domestic livestock in the Kalahari, particularly after heavy rainfall events.

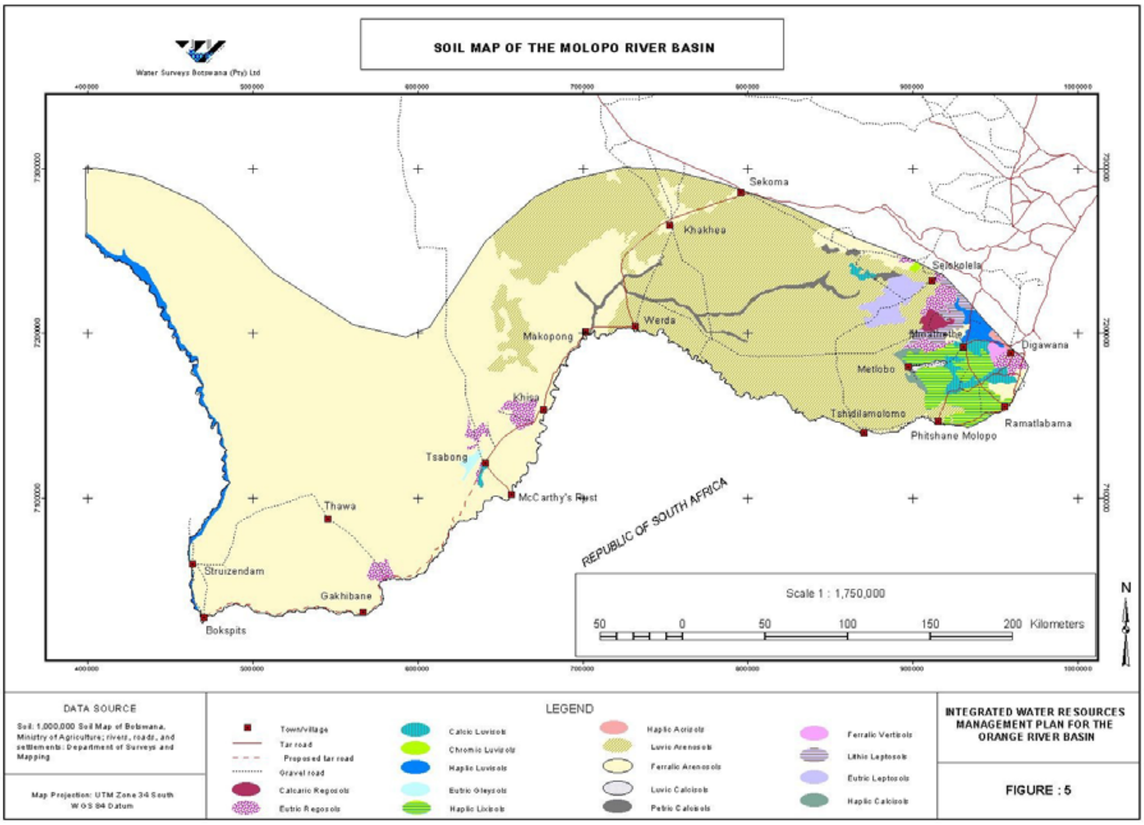

Figure 4-5: Soil map of the Molopo River Basin

4.1.4 Climate

The Molopo River Basin has a semi-arid to arid climate, which is characteristic of southern Botswana. The area receives the least amount of rainfall in the country, the amount generally increasing northwards towards Kasane area. The synoptic systems controlling Botswana's climate are dominated by a combination of the seasonal movement of the large tropical and temperate zonal systems over southern Africa and their interaction with localised convective processes. North of the 20°S latitude, primarily the Inter Continental Convergence Zone (ITCZ) and the Zaire Air Boundary (ZAB) complex influence the zonal system. The ITCZ attains its most southern position in January when it approaches the northern border of Botswana. The ZAB lies over central Zambia during the mid summer period when the low pressure also troughs into the extreme south of the continent. The rainfall weakens south of latitude 20°S as the drought producing sub-tropical anticyclones (high pressure systems) become more dominant. This is reflected in the more meridional alignment (airflow patterns) of rainfall isohyets across South Africa, Botswana and Namibia with drier areas to the west and wetter areas to the east. The latter reflects the differential in rates of subsidence of the air masses between the east and west coasts of Southern Africa.

On the western coast, stronger subsidence occurs as a result of the interaction between the almost stable Atlantic Ocean anticyclone and cold waters of the Benguela Current whereas to the east the warm waters of the Agulhas Current, more numerous rain producing disturbances and the marked eastward displacement of the Indian Ocean anticyclone during summer result in weaker subsidence.

Rainfall

The mean annual rainfall isohyets of the study area are shown in Figure 4.6. The Bokspits area receives less than 300mm of mean annual rainfall and this increase north- and east-wards with the eastern part of the Basin receiving over 500mm of mean annual rainfall. The rainfall is predominantly convective and comprises instability showers and thunderstorms (Bhalotra 1987). The rainfall is unreliable and highly variable in both spatial and temporal terms. Almost all of the rainfall occurs during the summer period (October to April) with the winter period accounting for only 5% of the annual total (van der Maas, 1994). Rainfall data from the Department of Meteorological Services and the spatial distribution of the weather stations in the Molopo River Basin are presented in the Task 6 Report on Groundwater.

Temperature

In summer, days are hot and nights warm whereas in winter the days are warm and the nights cold. Extreme diurnal ranges, which are characteristic of arid and semi-arid environments, occur in the area. Data from the Department of Meteorology indicate that the warmest month in Tsabong is December with a mean monthly maximum temperature of 34.8^{0}C and the coolest month is July with a mean minimum temperature of 4^{0}C. Mean monthly maximum temperature in Tsabong varies from 22.1^{0}C in June to 34.8^{0}C in December. The mean monthly minimum temperature varies from 4^{0}C in July to 19.7^{0}C in January. Highest temperatures (+35^{o}C) are recorded for November, December and January with minimum temperatures occurring during June and July (below zero degree centigrade).

Although the western region of Botswana is unsuitable for rainfed farming, the Tsabong area is considered to be highly suitable for deciduous tree plantation with very good potential to produce high-quality fruits for the local and the export markets because of the local climatic conditions (Tahal Consulting Engineers, 2000). The Engineers estimated in the National Master Plan for Agricultural Development (NAMPAD) that a total of nearly 7,000 tons of apples and over 1,500 tons of grapes could be obtained from this area provided the groundwater potential along the Molopo River (Waterberg formation) was proven by site investigations. The local climate was considered to be conducive to this form of horticulture because it is relatively dry, having low relative humidity levels and relatively cool nights in summer. The rather high duration of daily sunshine would ensure good growing conditions and no major disease problems would be expected. The suggested fruit trees in the region represented by Tshabong meteorological station are: high quality peaches and nectarines, low-chilling-requiring Japanese plums, low-chilling-requiring apples and pears, and possibly also low-chilling-requiring apricots. In addition, this area is suitable for growing table grapes and other Mediterranean fruit trees like figs and olives.

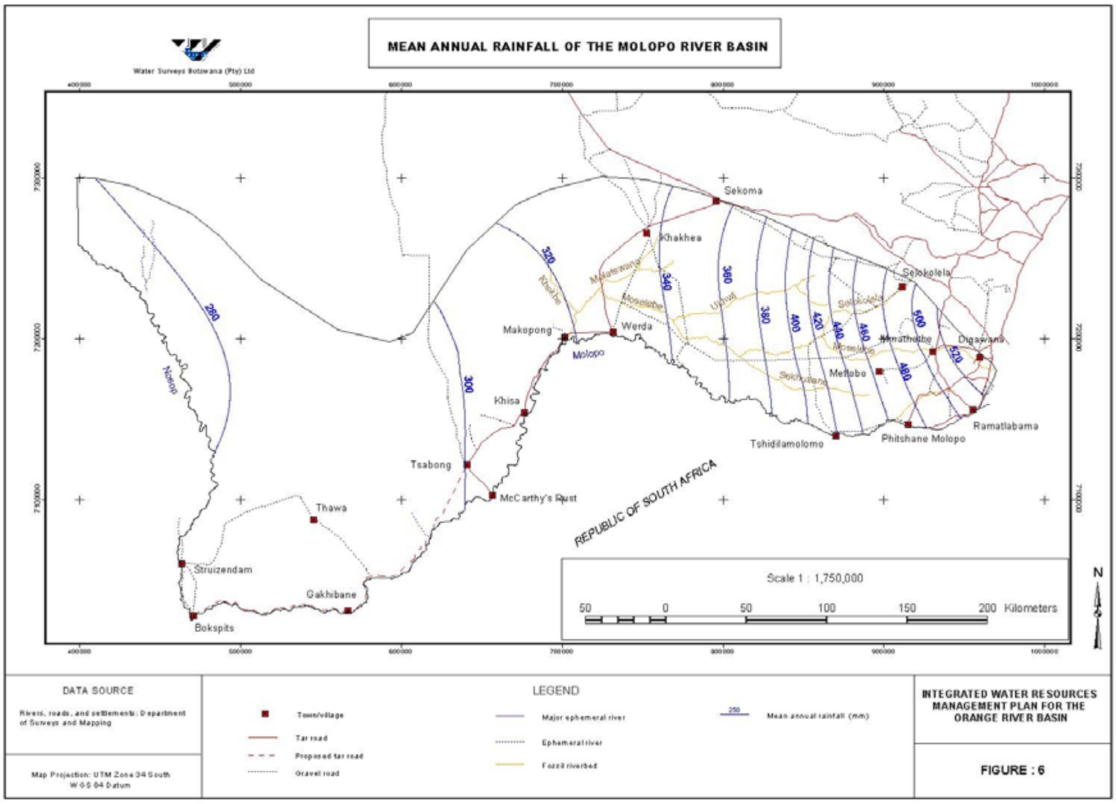

Figure 4-6: Mean Annual Rainfall of The Molopo River Basin

The suggested varieties for this region are:

- plums: Methley, Ogden and Santa Rosa;
- peaches: Maravilla, Earligrande, Flordaprince and Flordaglo;
- nectarine: Fiesta Red, Aprilglo and Sunsnow;
- apricot: Canino;
- pear: Spadona, Coscia and Tomer;
- apple: Anna, Dorset Golden, Gala, and Orleans;

- Grapes: Muscat of Hamburg, Italia, Superior, Early Superior, Dan Ben Chana and Thompson seedless;
- Kiwi: Hayward, Bruno.

4.1.5 Vegetation

The Molopo River Basin, which is located on the Kalahari Sandveld, is covered with savanna vegetation. A savanna is a plant community with discontinuous layer of woody species whose individuals are spaced more than one crown diameter apart, and with a usually dense ground layer of grasses and forbs. This vegetation occurs in the tropics and it can be looked at as a transition between the closed tropical forests of humid areas and the open grasslands of arid areas (Thomas and Shaw, 1984). Like in any other semi-arid environment, soil moisture availability is one of the key factors that influences the diversity and spatial distribution of the vegetation in the area. In the entire country, the diversity and biomass of the Kalahari vegetation generally increases in a northeasterly direction along the rainfall gradient. In the Molopo River Basin, the vegetation is relatively homogeneous in terms of floristic composition, but different vegetation structural types may be distinguished on a local scale as a result of differences in soil types and geomorphological effects, with the ephemeral and relict river valleys, pan depressions, and intra-dunefield topography being particularly important. These subtle vegetation differences are difficult to discern on national vegetation maps covering the Basin. Human activities such as livestock grazing and fire also influence vegetation structure and dynamics in the area.

There are no detailed vegetation maps covering the entire Molopo River Basin. The study of Weare and Yalala (1971) shows that shrub and tree savanna vegetation grows in the Molopo River Basin. The savanna plant community whose woody component is predominantly composed of shrubs is classed as shrub savanna whereas that which is dominated by trees is tree savanna. On the basis of physiognomic characteristics of the vegetation, Weare and Yalala identified five vegetation types in the area as follows:

- Arid Shrub Savanna;
- Southern Kalahari Bush Savanna;
- Molopo Thornveld;
- *Acacia giraffae* Tree Savanna; and
- Arid Sweet Bushveld.

The vegetation map of Weare and Yalala is reproduced and presented in this report as Figure 4.7. From the map, the role of moisture availability in influencing the distribution of vegetation communities in the area is noticeable. The southwestern part of the Basin that receives the least amount of annual rainfall is grown with Arid Shrub Savanna whereas relatively wetter places along the Molopo River and in the eastern part of the area have various forms of Tree Savanna. Thus land use changes or human developments that can significantly impact on soil moisture availability have the potential to influence the vegetation dynamics in the area. The extreme eastern area of the Basin is a transition zone from the sandveld to the hardveld environment, thus it may be argued that existing soil conditions, as determined by their parent rock material, may also have an influence on the *Acacia giraffae* Tree Savanna and the Arid Sweet Bushveld communities found in this area. Bekker & de Wit (1991) classified the vegetation of the southern part of the Gemsbok National Park as Dune savannah. Structurally, dune savannah is an open savannah with scattered shrubs and trees growing on sand dunes. In some places, the area is covered by seif dunes where trees and shrubs are commoner on the dune slopes than on the crests or in the inter-dunal valleys (also referred to as streets or straats by some scientists). In those areas covered by barchan dunes the inter-dune streets are a much smaller component of the landscape and woody species are much more prominent. Where sands are very thin, the community may grade into grassland with woody species other than low shrubs almost absent.

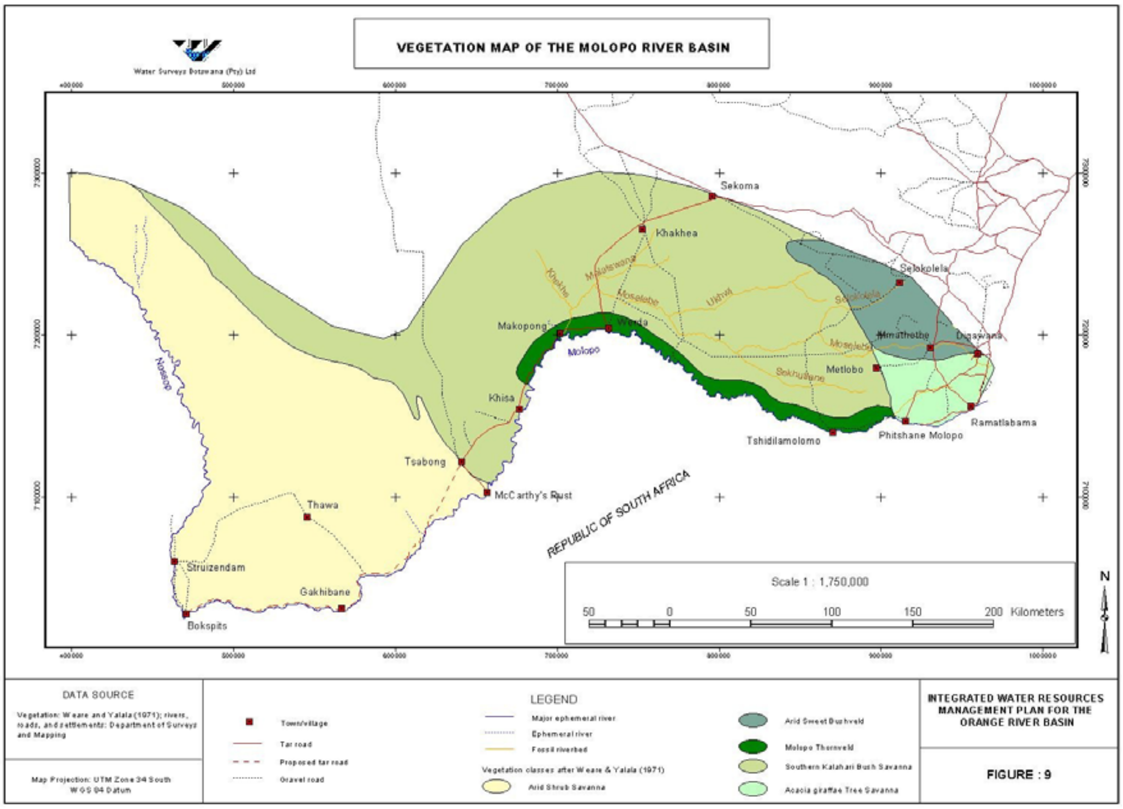

Figure 4-7: Vegetation Map of The Molopo River Basin

Timberlake's (1980) study shows that there are 6 vegetation associations in the Molopo River Basin as follows:

- Acacia haemotoxylon / Rhigozum trichotomum
- Acacia mellifera, Acacia luedritzii / Boscia albitrunca
- Catosphractes alexandri / Rhus tenuinervis
- Peltophorum africanum, Acacia tortilis, Acacia karro / Ziziphus mucronata
- Terminalia sericea, Acacia tortilis / Ziziphus mucronata
- Terminalia sericea, Lonchocarpus nelsii / Acacia erioloba

Over 70 percent of the area is covered by the *Acacia mellifera, Acacia luedritzii / Boscia albitrunca* plant association as shown in Figure 4.8. The *Acacia haemotoxylon / Rhigozum trichotomum* plant association is largely found along the Nossop River and around Khuis Village. The *Peltophorum africanum, Acacia tortilis, Acacia karro / Ziziphus mucronata* and the *Terminalia sericea, Acacia tortilis / Ziziphus mucronata* plant associations are found in the eastern area, occurring in the transitional zones from the sandveld to the hardveld. *Schmidtia kalariensis* and *Stipagrostis uniplumis* are some of the most common grass species in the area. *Erogrostis rigidior* and *Stipagrostis amabilis* grasses commonly grow on the sand dunes whereas *E. lehmanniana* and *E. rotifer* in the inter-dunal valleys. The pans of the area are known to have certain vegetation associations. Thomas and Shaw (19984) reports that Van Straten categorised the pans of the region as follows:

- Grassed pans - pan sediments consist of dark sandy clays, which support a dominantly grassy cover. Saline concentrations are low and calcrete generally not well developed
- Un-grassed Pans - pan sediments consist of dark sandy clays, which support sparse halophyllic vegetation.
- Saline Pans - pan sediments consist of saline and highly alkaline sandy clay with no plant growth. The pans are commonly deeply eroded into calcrete or a calcareous sandstone deposit

The National Parks Board-South Africa (NPB) and the Department of Wildlife and National Parks-Botswana (DWNP) (1997) state that Leistner and Werger observed the following pan vegetation communities in the Kgalagadi Transfrontier Park (composed of Kalahari Gemsbok National Park and Gemsbok National Park) in 1973:

- The *Sporobolus nervosus - Zygophyllum tenue* community was recorded mainly on the pan-like alluvial flats in the riverbed of the Nossop;
- The *Sporobolus coromandelianus* community is found on the central parts of pans which consists normally of very compact and almost impervious clayey soils. This community is encountered only for a few weeks following rains;
- The *Sporobolus rangei* community is found along the pan periphery or on small sand accretions where a thin layer of white calcareous sand covers the hard pan; and
- The *Lycium cinereum* community was recorded on small dunes of white or grey loamy sand usually less than 1 meter high occurring on pan floors, along the edges of pans and sometimes in or along dry riverbeds.

In addition, the NPB & DWNP observe that the *Rhigozum trichotomum* community occurs on fine, compact whitish sand and fine material on the outermost zone of pans whereas the infrequent *Odyssea paucinervis* community is only found in pans with white brackish sand in the Gemsbok National Park.

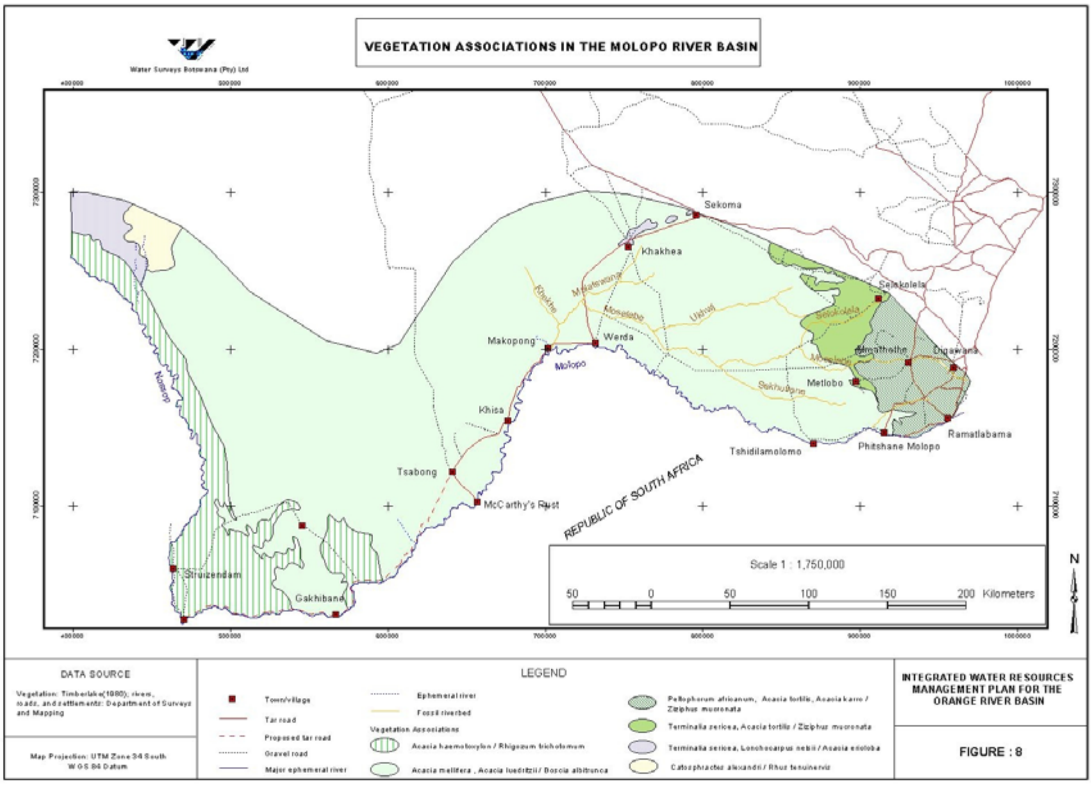

Figure 4-8: Vegetation Associations in the Molopo River Basin

4.1.6 Wildlife

Wildlife refers to any form of un-domesticated life. In this context therefore, all forms of living things such as plants, mammals, birds, reptiles, amphibians and invertebrates that are not domesticated are Botswana's wildlife resources. Information on some forms of wildlife such as invertebrates, reptiles and amphibians is scanty especially in the southern and western part of the country. The Department of Wildlife and National Parks (DWNP) under the Ministry of Environment, Wildlife and Tourism is responsible for conservation and protection of wildlife resources in the country. In this regard, the Department usually carries out annual aerial wildlife surveys in the country for monitoring of population trends (Broekhuis, Jan F, DWNP, Pers. comm., 11th November 2005). From 1989 to 1991, the DWNP carried out an aerial survey and the average population for the three years was taken at the end of the survey (Central Statistics Office, 2000). The findings from the survey indicate that areas outside protected areas in the districts where the Molopo River Basin is situated, i.e. Southern and Kgalagadi Districts, have relatively less wildlife diversity as compared to the wet northern parts of the country as shown in Table 4.2. This may be attributed to scarcity of food resources, water constraints and the nature of habitats found in the area due to the relatively drier climatic conditions and the sandy soils. The animals commonly found in the area are herbivores that do not rely much on water such as hartebeest, wildebeest, springboks and gemsbok.

Table 4-2: Unprotected Wildlife Population by District (1989-1991)

Species	Central	North east	Chobe	*Ghanzi	*Kgalagadi	Kweneng	Ngamiland	Southern	Total
Elephant	6,744	-	9,798	**-**	**-**	-	30,324	-	46,866
Zebra	2,473	-	1,008	**39**	**-**	-	15,617	-	19,137
Hippopotamus	-	-	147	**-**	**-**	-	2,034	-	2,181
Warthog	308	73	8	**68**	**61**	-	4,577	-	5,095
Giraffe	883	-	345	**-**	**-**	-	5,511	-	6,739
Eland	1,149	-	227	**140**	**2,923**	19	1,213	-	5,671
Kudu	2,479	374	231	**2,245**	**1,332**	353	8,154	203	15,371
Sitatunga	-	-	11	**-**	**-**	-	1,470	-	1,481
Gemsbok	1,216	-	31	**6,495**	**20,912**	1,930	9,629	97	40,310
Roan	-	-	188	**-**	**-**	-	695	-	883
Sable	20	-	1,588	**-**	**-**	-	1,236	-	2,844
Waterbuk	-	-	-	**-**	**-**	-	135	-	135
Lechwe	-	-	-	**-**	**-**	-	39,988	-	39,988
Reedbuck	-	-	21	**-**	**-**	-	2,050	-	2,071
Tsessebe	-	-	112	**-**	**-**	-	8,258	-	8,370
Hartebeest	1,716	-	-	**2,216**	**15,054**	4,796	547	2,978	27,307
Wildebeest	7,554	-	-	**4,036**	**8,549**	579	13,992	161	34,871
Impala	18,499	419	85	**-**	**-**	-	17,129	-	36,132
Springbok	16,055	-	-	**4,299**	**74,089**	488	2,985	9,684	107,600
Duiker	3,966	31	28	**5,567**	**2,559**	682	2,947	930	16,710
Steenbok	6,084	70	113	**3,967**	**3,331**	1,259	5,381	1,968	22,173
Buffalo	113	-	570	**-**	**-**	-	31,848	-	32,531
Ostrich	19,573	-	76	**3,513**	**11,210**	2,853	10,573	3,963	51,761
Crocodile	-	-	-	**-**	**-**	-	148	-	148
Lion	105	-	-	**-**	**50**	-	61	-	216
Jackal	393	-	-	**135**	**162**	29	80	24	823
Baboon	-	-	-	**-**	**76**	223	474	929	1,702
Hyaena	13	-	14	**9**	**12**	-	268	-	316

Source: CSO, 2002. *Districts where Molopo River Basin is situated; the other districts are only included for comparison.

The biggest part of the Gemsbok National Park, which is part of the Kgalagadi Transfrontier Park, falls in the Molopo River Basin. The wildlife populations of this Park as per the surveys carried out by the Department of Wildlife and National Parks in 1989/1991, 1994, and 1996 are presented in Table 4.3. The 1996 census was not carried out in the former Mabuasehube Game Reserve which now forms part of the Park, thus the figures presented in the table for that year are not for the entire present Gemsbok National Park.

Table 4-3: Estimates of Wildlife Numbers by Species inside the Gemsbok National Park

Species	Period of Wildlife Census		
	1989 to 1991	1994	1996*
Eland	1,617	1,362	8,877
Kudu	12	96	-
Gemsbok	22,852	35,397	43,684
Hartebeest	3,362	13,026	6,589
Wildebeest	246	4,446	554
Springbok	5,028	15,584	2,326
Duiker	389	765	491
Steenbok	1,490	3,466	3,210
Ostrich	2,630	3,466	-
Lion	25	-	-
Hyaena	12	-	-

Source: CSO, 2002. * The census was not carried out in the former Mabuasehube Game Reserve

Analysis of the 1994 wildlife data both inside and outside protected areas (i.e. Gemsbok National Park) indicates that the Ghanzi and the Kgalagadi Districts are vital for wildlife conservation in the country. For instance 88 percent of the springboks, 58 percent of the hartebeests, 45 percent of the gemsboks and 35 percent of the wildebeests that were counted in the entire country in 1994 were found in theses two districts. This highlights the significance of the Molopo River Basin in particular and the region as a whole as a habitat for wild animal conservation in the country.

4.2 Environmental Protection and Conservation

4.2.1 Institutional Framework

The responsibility of environmental protection and conservation of natural resources in Botswana lies with the Department of Environmental Affairs (DEA), formerly known as the National Conservation Strategy Co-ordinating Agency (NCSA), in the Ministry of Environment, Wildlife and Tourism. The NCSA was set up under the National Conservation Strategy Policy, which was approved by Parliament in December 1990 (Ministry of Finance & Development Planning, 2003). In addition, a 17-member National Conservation Strategy Advisory Board chaired by the Minister of Local Government, Lands and Housing was established under the Policy. During the 8th National Development Plan, the Ministry of Local Government, Lands and Housing was divided into two, namely the Ministry of Local Government and the Ministry of Lands and Housing. The NCSA and the National Conservation Strategy Advisory Board were assigned to the Ministry of Lands and Housing, which was later re-named Ministry of Lands, Housing and Environment in recognition of the environmental coordination mandate. The National Conservation Strategy Advisory Board advised Government on all matters concerning the implementation of the National Conservation Strategy by coordinating the various environment and natural resources institutions of Government whereas the NCSA acted as a secretariat (Ministry of Finance & Development Planning, 2003). Recently, the NCSA was transformed into the Department of Environmental Affairs and the ministry re-named Ministry of Environment, Wildlife and Tourism.

Given the complexity of the environment and the inter-linkage of its various components, the DEP works in collaboration with other Government ministries, departments and stakeholders such as the Ministry of Agriculture, the Ministry of Lands and Housing and the Botswana National Museum and Art Gallery in order to appropriately protect the country’s environment and natural resources. The Ministry of Environment, Wildlife and Tourism’s goals include enhancement of environmental and ecological quality and serenity; conservation of genetic resources and essential life support systems; and protection and conservation of country’s natural, scenic, aesthetic and cultural heritage.

At the district level, institutions such as Land Board, Conservation Committee, District Land Use Planning Unit and District Council handle environmental conservation issues (Kgalagadi District Council, 2003). Thus such institutions in the Kgalagadi and the

Southern Districts would be involved in any conservation issue in the Molopo River Basin.

4.2.2 Policy and Legal Framework

Botswana Government considers conservation of natural resources and biological diversity as one of the pillars of sustainable development. In this regard therefore, the Government has various environmental policies and laws in place, some of which are discussed below.

National Conservation Policy (1990)

This Policy was formulated by Botswana Government and approved by the National Assembly on the 17th December 1990. It aims at promoting conservation of natural resources in the country such as fresh air, water, vegetation, wildlife, soils and archeological features. The goals of the Policy are:

- the conservation of all main ecosystems, wildlife and cultural resources;
- the protection of endangered species;
- the maintenance of stocks of renewable resources (e.g. veldt products), whilst increasing their sustainable yields;
- the control of the depletion of exhaustible resources (e.g. minerals) at optimal rates;
- the distribution of incomes and rewards more equitably, in the interests of conserving natural resources;
- the cost-effective restoration of degraded renewable natural resources, including improved capacity for generation of the veldt; and
- the prevention and control of pollution.

Waste Management Act (Cap 40.01 of 1998)

The Department of Sanitation and Waste Management is responsible for implementation of the Act in the country. The Act is intended to guard against pollution of the environment, to conserve natural resources, to cause the provisions of the Basel Convention to apply in regulating the trans-boundary movement of hazardous wastes and their disposal. Section 34 prohibits littering. Subsection 34 (1) states that a person shall not deposit in any place anything which may contribute to the defacement of any place by litter, except as authorized by law or done with the consent of the owner or occupier of that place. Any person who contravenes this section commits an offence and is liable to a fine not exceeding P300 or to imprisonment for a term not exceeding two months or to both. For purpose of proper waste disposal in the country, each district is supposed to have a sanitary landfill. Recently the Kgalagadi District Council constructed a sanitary landfill in Tsabong in the Molopo River Basin.

Environmental Impact Assessment Act (2005)

In order to foster sustainable development in the country, the Government of Botswana enacted the Environmental Impact Assessment (EIA) Act in 2005. The Department of Environmental Affairs implements the EIA Act, which commenced on the 27th of May 2005. The Act is intended to assess the potential effects of planned developmental activities; to determine and to provide mitigation measures for effects of such activities as may have a significant adverse impact on the environment; to put in place a monitoring process and evaluation of the environmental impacts of implemented activities; and to provide for matters incidental to the foregoing. Section 4 states that any person who undertakes or implements an activity in contravention of the Act commits an offence and is liable to a fine not exceeding P100,000 or to a term of imprisonment not exceeding 2 years or to both.

Community Based Natural Resources Management Policy

This policy aims at fostering conservation of natural resources by local communities. It is intended to promote rural development through community participation and the creation of economic incentives. In the Kgalagadi District, the Policy has benefited some communities and trusts such as Khawa, Koinaphu, Maiteko and Ukhwi. These communities mostly utilize Wildlife Management Areas with the exception of Maiteko which is based on salt harvesting (Kgalagadi District Council, 2003).

Wildlife Conservation and National Parks (1992) Act

The Wildlife Conservation and National Parks Act of 1992 protects any form of undomesticated life in Botswana and its implementation lies with the Department of Wildlife and National Parks. The Act is intended to foster conservation, protection and sustainable management of wildlife in the country. It has provisions for establishment of national parks, game reserves, sanctuaries, and private game reserves for protection and preservation of wildlife, vegetation and objects of geological, archaeological and scientific interest.

Herbage Preservation Act no. 27of 1977

This Act deals with control of veld fires and stipulates penalties for offences. According to the Act, permit for controlled fire is given by the Agricultural Resource Board based on the purpose of the fire, time of the day and wind speed to anybody that might need to burn portion of his area.

Monuments and Relics Act of 1970 (as Amended, 2001)

The Monuments and Relics Act protects all archaeological and/or historic monuments and sites in Botswana, whether they are recorded in National Museum Sites Register or not. The National Museum, Monuments and Art Gallery implements the Act. Section 18 of the Act prohibits any alteration, damage or removal from original site of any national monument, relic or recent artifact. The Act recognizes the fact that alteration, damage or removal of monuments and relics may occur through development. Section 19, therefore, provides for pre-development Archaeological Impact Assessments (AIA) and mitigation where planned developments are likely to disturb the earth's surface. The National Museum, Monuments and Art Gallery requires that Archeologists registered with them carry out such studies in order to ensure that archeological studies are of acceptable standards. This ultimately ensures that development takes place in appropriate ways without obliterating the archeological and cultural resources of the country.

Water Act (34:01)

The Water Act intends to define ownership of any rights to the use of water and to provide for grant of water rights and servitude. Water in rivers, streams, lakes, pans, swamps or beneath a watercourse or underground water and in works such as canals, reservoirs and dams is public water. The use of such water can only be with permission granted by the Water Apportionment Board in the Department of Water Affairs. Application for the water user rights to the Board is done through the Water Registrar who shall issue a certificate. The Act bars pollution of public water with any matter derived from such use likely to cause injury either directly or indirectly to public health, livestock, animal life, fish, crops, orchards or gardens which are irrigated by such water or to any product in the processing of which such water is used. The holder of a water right is obligated to take precautions to prevent accumulations in any river, stream or watercourse of silt, sand, gravel, stones, sawdust, refuse, sewage, waste or any other substance likely to affect injuriously the use of such water. A holder of water right who contravenes the Act shall be guilty of an offence and liable to a penalty under the Act.

4.3 Conservation Areas

The Government of Botswana takes conservation of natural resources in high regard. For instance the national vision (1997), Vision 2016, advocates for use of renewable resources at rates that are in balance with their regeneration capacity. The Vision further underlines the importance of good attitudes towards natural resources in order to have a fair distribution between present and future generations. As part of the Government's conservation efforts, some land has been designated for the protection and conservation of the natural resources of the country. Game reserves and national parks cover 17 percent of the land area while an additional 22 percent is designated as Wildlife Management Areas (Botswana National Agenda 21 Coordinating Committee, 2002). The conservation areas found in the Molopo River Basin are presented in Table 4.4 and shown in Figure 4.9. There are no other planned protected areas in the Basin (Broekhuis, Jan F, DWNP, Pers. comm., 11th November 2005). The significance of the existing conservation areas may be observed in Figure 4.10, which shows that during the dry season of the year 2004 the majority of the wildlife biomass observed by the DWNP in the Basin was in such areas.

Table 4-4: Conservation Areas in Molopo River Basin

Name	Code	District	*Estimated Total Area (Km2)	Estimated Area in Molopo River Basin	Percentage of Area in Molopo River Basin
Gemsbok National Park	KD\4	Kgalagadi	26,208	17,389	66
Khawa Wildlife Management Area	KD\15	Kgalagadi	7,712	7,573	98
Inalegolo Wildlife Management Area	KD\12	Kgalagadi	10,004	2,691	27
Corridor Wildlife Management Area	SO\2	Southern	2,520	1,627	65

* Area estimated by GIS using DWNP spatial data.

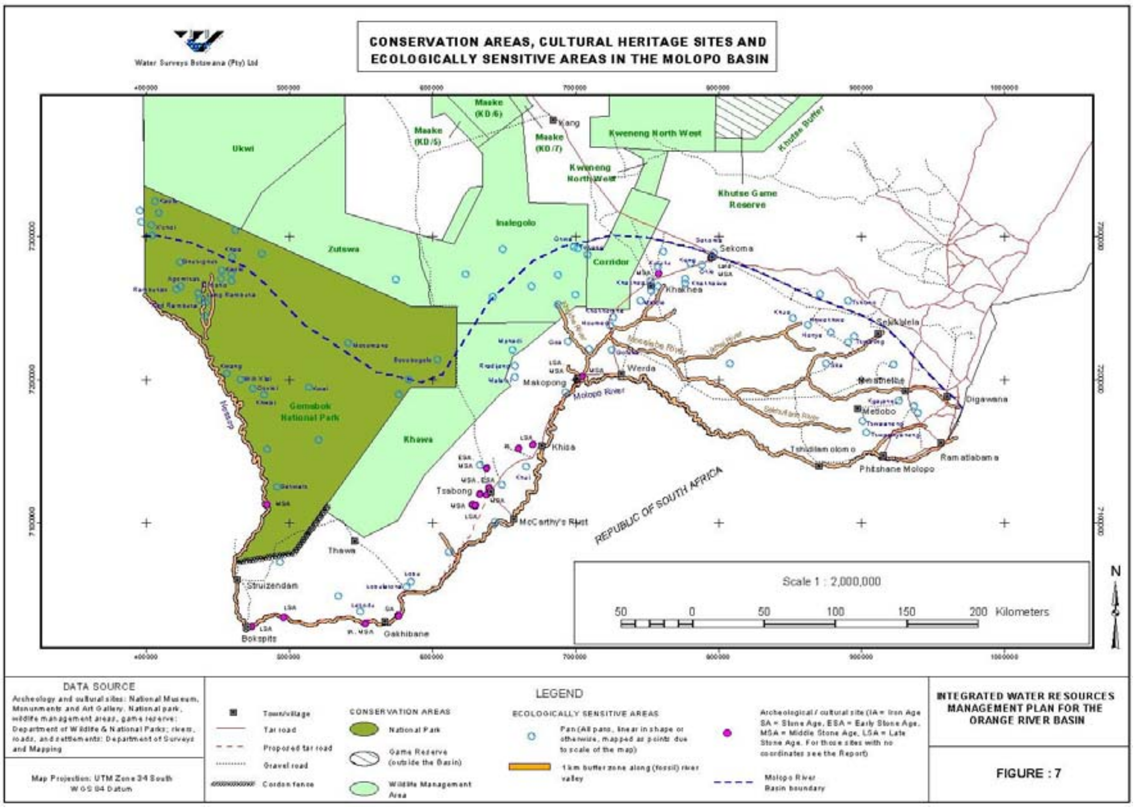

Figure 4-9: Conservation Areas, Cultural Heritage Sites and Ecologically Sensitive Areas in the Molopo River Basin

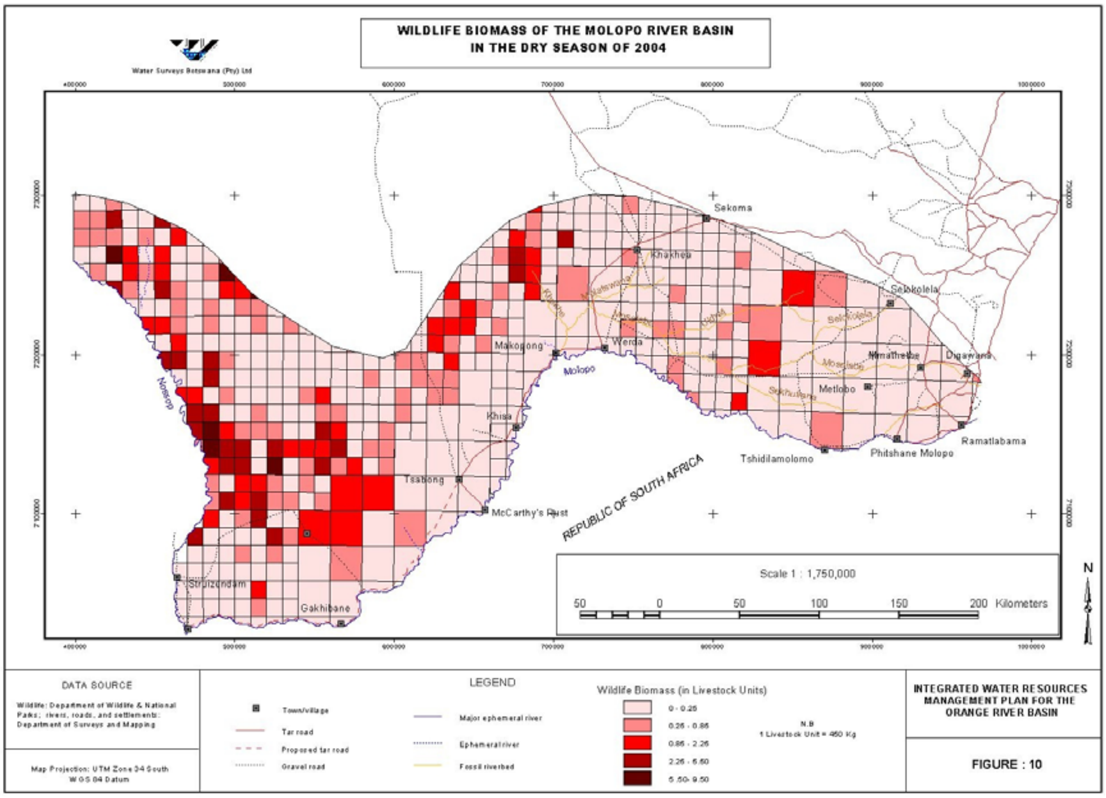

Figure 4-10: Wildlife Biomass in the Molopo River Basin in the Dry Season of 2004

Gemsbok National Park

The Gemsbok National Park, which forms part of the Kgalagadi Transfrontier Park, is the biggest and most valuable conservation area in the Molopo River Basin. The Park has an area of about 26,200 Km^2, with 66 percent of the land area found in the Basin. The park is protected and managed by Department of Wildlife and National Parks under the Wildlife Conservation and National Parks Act of 2002. A number of activities are prohibited in the parks of Botswana under the Act. For instance, Section 8.1 states that except as provided in subsection 2, no person other than a wildlife officer or a gate attendant acting in the exercise of his official duties or any other employee of the Government with the written permission of the Director and acting in the exercise of his official duties as such employee, shall:

- convey into or be in possession of any weapon, explosive, trap or poison within a national park;
- without lawful excuse, be in possession of, or kill, hunt, injure, capture or disturb any animal, or take or destroy an egg or nest, in a national park;

- cause any damage to or disturb any object of geological, ethnological, historical, archaeological or other scientific interest within a national park, or remove an y such object from a national park;
- introduce any wild or domestic animal or any fish or any vegetation into a national park, or permit any domestic animal to stray into a national park;
- remove from a national park any animal or part of any animal or any vegetation, whether alive or dead, other than an animal he has lawfully introduced into the park;
- cut, damage or destroy any tree or other vegetation in a national park;
- erect any structure, whether permanent or otherwise, or make any road or airstrip, or otherwise alter the natural environment, except as may be expressly permitted by the Minister or by a wildlife officer authorized to give such permission;
- destroy or deface any object, whether animate or inanimate, in a national park; or
- willfully or negligently cause any veld fire in a national park.

Sections 8.2 and 8.3 empower wildlife officers and park attendants to confiscate or destroy vegetation and animals brought in the parks unlawfully.

Wildlife Management Areas

Wildlife Management Areas (WMAs) such as Khawa, Inalegolo and Corridor found in the Molopo River Basin play a significant role in the management of wildlife resources. The Wildlife Conservation and National Parks Act empowers the President to declare any area to be a Wildlife management Area, or to abolish existing ones, or amend its boundaries by deleting or adding new areas, by order published in the Gazette. In the WMAs, community utilization of wildlife resources is permissible but it is regulated with a view of ensuring its sustainability. Some of the activities regulated in these areas under the Wildlife Conservation and National Parks Act (1992) include the following:

- the hunting or capture of animals therein by virtue of any licence or permit to hunt or capture;
- the erection of any dwelling house or other building therein, or the residence therein of any person, or the size of any settlement therein;
- the grazing of any stock therein and any conditions or limitations concerning the husbandry of stock therein;

- the cultivation of any land therein, the conditions under which persons may cultivate, and the allocation of land for cultivation;
- conditions governing the drilling, allocation and use of boreholes;
- conditions governing the use therein of vehicles, aeroplanes, microlight aircraft and boats;
- the entry or the presence therein of persons other than residents thereof; and
- the culling of animals therein in accordance with any approved game animal utilization scheme.

Section 15.4 of the Wildlife Conservation and National Parks Act requires the Director of Wildlife and National Parks to consult with the responsible Land Boards and District councils when formulating their management plans and carrying out duties relating to management of these areas.

The Wildlife Management Areas in the Molopo River Basin are significant to wildlife conservation in the area because they act as buffer zones to the Gemsbok National Park. In addition, they act as corridors for migratory animals such as wildebeests and hartebeests between the Park and the Central Kalahari Game Reserve and the Khutse Game Reserve to the northeast.

4.4 Archeological and Cultural Heritage Resources

Archeological investigations in Botswana are quite a recent phenomenon. Unlike in other African countries where archeological traditions were established in the early colonial era, the Bechuanaland Protectorate (present Botswana) witnessed remarkably little archeological development at the time (Lane, P., Reid A and Segobye, A, 1998). The establishment of the National Museum in the late 1960's did not immediately generate interest in archeological research. This only came in the 1970's with the recruitment of an archaeologist to the staff of the National Museum, Monuments and Art Gallery. From this recent development of archaeological work, almost 2000 sites are now recorded in the sites register of the National Museum, Monuments and Art Gallery. However, the majority of the sites are found in the eastern part of the country where most research studies have been undertaken. Thus the archeology of the other parts of Botswana such as the Molopo River Basin is generally poorly understood due to paucity of information.

The archeological and cultural sites in the national register of the National Museum, Monuments and Art Gallery that are found in the Molopo River Basin are presented in Table 4.5 and those with geographical coordinates shown in Figure 4.9.

Table 4-5: The National Museum, Monuments and Art Gallery Archeological and Cultural Sites in the Molopo River Basin

No.	Site Name	Type	Geographical Coordinates	
			Latitude	Longitude
1	Okwane (Tsabong)	IA?? (Early to mid 1900's)	-25.744	22.598
2	Sewe (Maleshe)	ESA, MSA	-25.870	22.381
3	Maleshe	ESA		
4	Khisa	LSA	-25.717	22.700
5	Kolonkwaneng	LSA		
6	Malatsuane	MSA	-25.283	23.033
7	Molopo River	LSA, MSA	-25.300	23.000
8	Molopo Ranch (Boshoek)	MSA		
9	Phitsane Molopo	MSA		
10	Welverdiend	LSA	-26.815	20.960
11	Inversnaid	LSA	-26.874	20.738
12	Ramatlabaki	MSA		
13	Sekoma Pan 1	Late MSA	-24.508	23.917
14	Sekoma Pan 2	Late MSA	-24.521	23.913
15	Khakhea Pan	MSA		
16	North of Khakhea	MSA	-24.624	23.551
17	Rappel's Pan (Molopo Line)	IA, MSA	-26.856	21.540
18	Next to Lobu Pan, Middlepits	SA		
19	De Brak	SA	-26.800	21.767
20	De Brak	SA	-26.807	21.773
21	Tsabong	MSA	-26.100	22.283
22	Maralaganyane	MSA, ESA	-26.033	22.333
23	Tshabong	MSA	-26.033	22.383
24	Tsabong	MSA	-26.200	23.567
25	Kwegwe	LSA	-26.108	22.300
26	Lekhubu	LSA	-26.102	22.304

Source: National Museum, Monuments and Art Gallery

IA = Iron Age, ESA = Early Stone Age, MSA = Middle Stone Age, LSA =Late Stone Age, SA = Stone Age

The majority of the sites in the area are found along the Molopo and the Nossop River valleys. The other sites are found near settlements that are close to big pans in the area such as Sekoma, Tsabong and Khakhea. This seems to indicate that water availability in the Basin was a significant factor in the influence of human settlement patterns in the past.

In 2005, Walker carried out an Archeological Impact Assessment (AIA) study for the proposed Tsabong-Middlepits tar road. In the study, the proposed borrow pits and the road alignment route was visited. The AIA identified some Stone and Iron Age archaeological artifacts such as sherds, ostrich eggshell and flakes but none of them seems to be of high archeological significance. The AIA study for the Middlepits-Bokspits Road project identified 7 sites ranging from the Palaeolithic (2 million to 120,000 years ago), Mesolithic (120,000 to 40,000 years ago) to the Neolithic era (40,000 years ago) (Roughton International, 2001). The sites from Roughton International's archaeological study are presented below:

Table 4-6: Archeological sites in Middlepits-Bokspits area after Roughton International (2001)

Site Name	UTM Co-ordinates (Arc1950)		Description
	Easting	Northing	
Khuis-Gakhibane	580344	7050356	Lithics, choppers, core, scrappers
	580860	7050717	Hand axes, scrappers
	582756	7051324	Scrappers
	582748	7051444	Possible abandoned graveyard
	482656	7034088	Graveyard
Hoekrans	482632	7034078	Lithics, faunal remains in cave context
Rappel's Pan	473732	7028710	Reported but unvisited site
	463479	7042288	Reported but unvisited site
	582972	7051362	Reported but unvisited site

Source: Roughton International (2001)

4.5 Ecological Sensitivity

The areas that are considered to be ecologically sensitive in the Molopo River Basin are listed below.

- ***The Gemsbok National Park and the Wildlife Management Areas*** – considered to be sensitive ecologically due to the wildlife populations that they support
- ***The Molopo and Nossop Rivers and their fossil river tributaries*** – Even though these palaeo-river systems have no surface water flow nowadays, groundwater may be flowing underneath them. As a result, soil moisture in the valleys is comparatively high and as such these areas tend to support relatively unique habitats and plant species in the region (Monna, S., DEA, pers. Comm., 7th November 2005). Unsustainable use of the underground water resources in these areas may degrade the ecosystems along these palaeo-river systems.
- ***The Pans* -** The Molopo River Basin has pans as observed in Section 1.2. In the Kgalagadi District, some of the villages are built around the pans whereas the others are even built on the pans such as Tsabong (Kgalagadi District Council, 2003). This has subsequently resulted into the pans experiencing gradual degradation, as they become sources of quarry raw materials. The pans are spectacular geomorphological features in the region and are useful water sources for wildlife and domestic livestock particularly after heavy rainfall events due to the compact structure of their calcareous soils. However, their soil structure is sensitive and susceptible to physical disturbance.

4.6 Environmental Impacts from Previous Developments in the Molopo River Basin and other Concerns

The 2001 Population and Housing Census data (Central Statistics Office, 2001) indicate that the Molopo River Basin is sparsely populated. The entire area had a population of 47,661 people in 2001. With an approximate land area of 71,000 square Kilometers, the population density was thus 1 person per square Kilometer. The population density is assumed not to have changed significantly since then. The population centers in the area include Goodhope, Gathwane, Mogojogojowe, Mmathethe, Digawana, Thareseleele, Ramatlabama, Mokatako, Phitshane-Molopo Mmakgori, Tshidilamolomo, Mabule, Selokolela, Metlobo, Magoriapitse, Sekoma, Khakhea, Makopong, Khisa, Omaweneno, Maleshe, Tsabong, Werda, Maralaleng, Struizendam, Rappelspan, Khuis, Bogogobo, Middlepits, Khawa, Gakhibane and Bokspits (See Task 10 Report for details on demographic characteristics of the area).

The area is relatively less developed compared to other parts of Botswana. In part this may be due to the low population density, scarcity of water resources due to the arid to semi-arid climate and the low production potential of the sandy soils in the area. Most of the developments take place in and close to big villages like Tsabong, Goodhope, Khakhea, Werda and Sekoma. Such developments usually entail construction of public facilities like clinics, Government offices and residential houses in the villages. The potential environmental impact from such developments on the general ecology of the Molopo River Basin is generally of low significance.

The Tsabong Groundwater Resource Investigation, Assessment and Development project (1999) by the Department of Water Affairs under the Ministry of Minerals, Energy and Water Resources is one of the recent major developmental projects in the Molopo River Basin. The project aimed at identifying and quantifying the groundwater resources in the exploration area. The overall impact on the environment from the groundwater exploration activities in the area was minor. Another developmental project in the area is the proposed Tsabong-Bokspits Tar road by the Department of Roads under the Ministry of Works, Transport and Communications. Under this project, it is intended to up-grade the current gravel road from Tsabong up to Bokspits. Presently, this road is situated in the Molopo River valley along much of the area with the exception at a few places near some villages such as Tsabong and Middlepits (See Plate 2). The presence of active sand dunes in the areas adjacent to the road and the absence of water flow in the river over the decades may have influenced its alignment in the valley. The EIA for the Middlepits-Bokspits section of the proposed road indicates that the new road will follow the existing gravel road with the exception of two short sections through the villages of Middlepits and Khuis and the section between Khuis and Gakhibane, where the new road alignment will be moved out of the Molopo valley (Roughton International, 2001). Apart from the engineering advantage of building on an already compacted base, Roughton International argues that the selected road alignment (amongst 3 options) is advantageous because it would reduce the need for earthworks and compaction, require less materials and minimize the amount of virgin ground subjected to disturbance, thus substantially reducing both the visual impacts of construction of the new road and its overall ‘environmental footprint’. Two other alternative routes and the “no-project option” were considered and rejected as they all had much higher environmental impacts and lower benefits as compared to the selected option. The other options would have involved extensive construction work in the sand dunes, which would have had major negative environmental impacts (Roughton International, 2001). The EIA identified a number of potential environmental impacts that could accrue from the road project during the construction and the operation phases. The construction impacts were considered to be short-term in nature and related to disruption of established patterns of access to essential assets and resources, heavy construction traffic, and generation of noise and dust. The possibility of establishing borrow pits in the Molopo River valley was noted by the EIA as a major project impact. The area of greatest concern was the length of the Molopo valley between Khuis and Gakhibane, where it was proposed to develop a large calcrete borrow pit. The study observed that the proposed borrow pit site was situated in the most spectacular part of the valley (between Middlepits and Bokspits) where there is no topsoil. It was thus considered by Roughton International that use of the pit would do irreparable damage to the unique scenic resource of the Molopo River valley. Two other borrow pit sites between Gakhibane and De Brak were expected to have similar impacts. The study noted that rehabilitation of the borrow pits after use would be difficult because:

- Calcareous sites are inherently difficult to rehabilitate;
- Rehabilitation is always difficult in an arid and variable climate due to the lack of soil moisture for plant growth; and
- There is no soil for the plants to grow in.

Figure 4-11: Gravel road to be up-graded in Molopo River Valley at Hoekrans

(Source: Roughton International, 2001)

The EIA recommended that no further material for road construction should be obtained from the Molopo Valley between Khuis and Gakhibane Villages. The risk to the road infrastructure in case of future water flow in the river was not evaluated in the study nor the vulnerability of underground water resources in the valley to pollution incase of accidental pollutant release, for instance during a road accident.

Apart from the above road project, there are no other major construction works in the Molopo River Valley or any of its tributaries. Furthermore there are no river impoundments or inter-basin water transfers because as observed earlier water no longer flows in the rivers of the Basin.

A significant challenge facing environmental protection and conservation of natural resources, particularly wildlife resources, is increasing pressure from other forms of land use. Traditional livestock rearing, which requires large expanses of land, is the main form of land use for the majority of the people in the Basin. This form of land use poses a significant challenge especially to wildlife conservation in the area. Data from the Department of Wildlife and National Parks show that areas with high populations of livestock have low populations of wild animals. In addition, some people in the area are of the view that the protected areas (i.e. Gemsbok National Park and the Wildlife Management Areas) deprive them of land, which could have been used for livestock grazing (Broekhuis, Jan F, DWNP, Pers. comm., 11th November 2005).

5 ENVIRONMENTAL ISSUES IN NAMIBIA

5.1 Background

There are five catchments recognized in Namibia that form part of the Orange River system. They drain the central and eastern parts of southern and central Namibia (Figure 5.1), as follows:

- Fish River catchment
- Auob system, which joints on the South Africa-Botswana border with the
- Nossob system, and
- Two small catchment areas in the extreme south and south-east of Namibia.

The Fish River is the only system that provides any significant volume of water into the Orange River, and this is highly variable because of the arid and unpredictable rainfall in southern Namibia.

The Orange River catchments drain most of the Karas and Hardap regions (only omitting the hyper-arid Namib Desert in the extreme west), the south-eastern third of the Khomas region and the western and southern edge of the Omaheke region.

Median annual rainfall ranges from just on 300 mm in the north-eastern part of the catchments to less than 50 mm in the extreme south west along the Orange River. Most of this zone (about 75%) receives less than 200 mm. Rainfall is also highly variable (coefficient of variation between 50 and 90%) and the highest evaporation rates in Namibia are experienced in this zone (2.0-2.7 m per year). This results in an average water deficit per year of about 1.9 m in the northern of the catchments to about 2.6 m in the Keetmanshoop area. This zone also records the most extreme temperature range in Namibia, with the average maximum temperature during the hottest month being above 36^{o} C and the average minimum during the coldest month being less than 2 ^{o} C. The Fish and Orange River basins are particularly hot, with temperatures in the mid-40^{o} C not being uncommon.

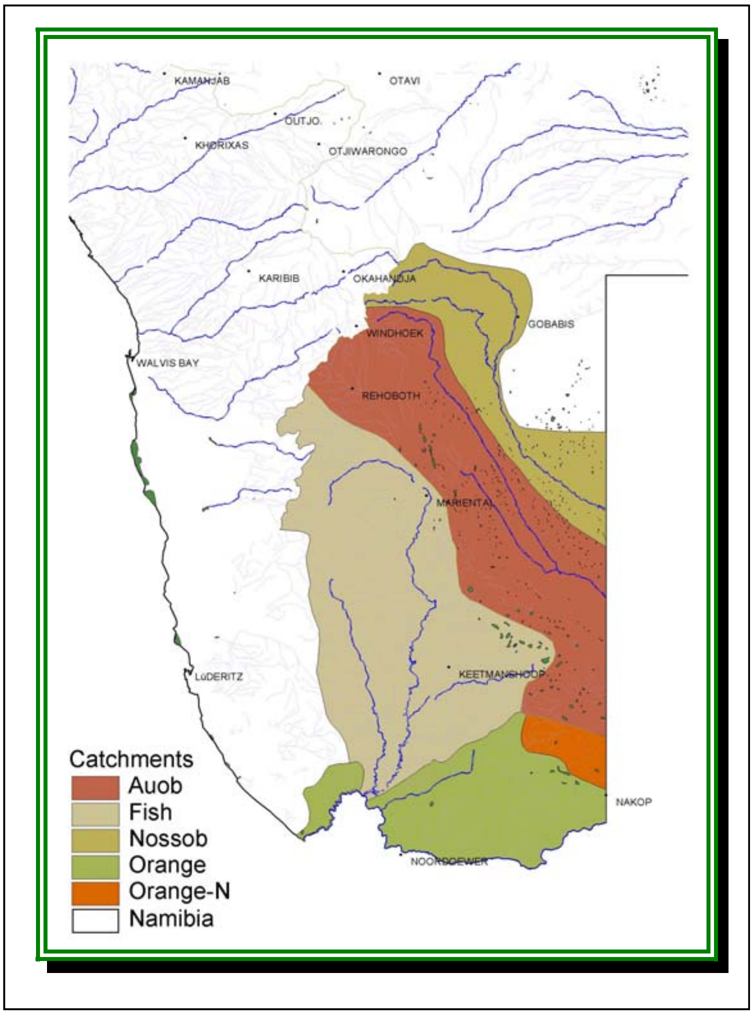

Figure 5-1: The five catchments recognized in Namibia

The southern zone of Namibia contains four desert systems, three of which are drained by the catchments of the Orange, (a) the Succulent Karoo in the extreme south west, consisting of the "winter rainfall" area from Luderitz south to the Orange River and on into South Africa, and in fact representing an area where rainfall occurs with almost equal improbability throughout the year; (b) the Nama Karoo, which receive mainly summer rainfall and comprises five different vegetation types in this zone (see Table 5.1); and (c) the Southern Kalahari, consisting of a deep layer of wind-blown sand, with little run-off from rainfall.

Table 5-1: The percentage of vegetation types within the Central-South zone occurring within different land use categories

Biome	Vegetation type	Percentage of vegetation types within different land uses				
		State Protected Areas	Private Nature Reserves	Communal Conservancies	Commercial Conservancies	Total
Namib	Central gravel plains	66.4	0	21.6	0	88.0
	Southern sand sea	87.8	1.4	0	1.0	90.3
Succulent Karoo	Succulent Steppe	90.3	0.1	0	0	90.4
Nama Karoo	West-central Escarpment Transition	15.8	0	33.3	0	49.1
	Desert-Dwarf Shrub Transition	19.6	4.5	0	3.4	27.5
	Dwarf Shrub Savanna	1.8	1.3	12.5	0.2	15.8
	Karas Dwarf Shrubland	0.6	0	8.4	0	9.1
	Dwarf Shrub-Southern Kalahari Transition	0	0	0	0	0
Acacia Tree-and-Shrub Savanna	Southern Kalahari	0	0	0	0.4	0.4
	Highland Shrubland	0.2	0	0	39.5	39.7

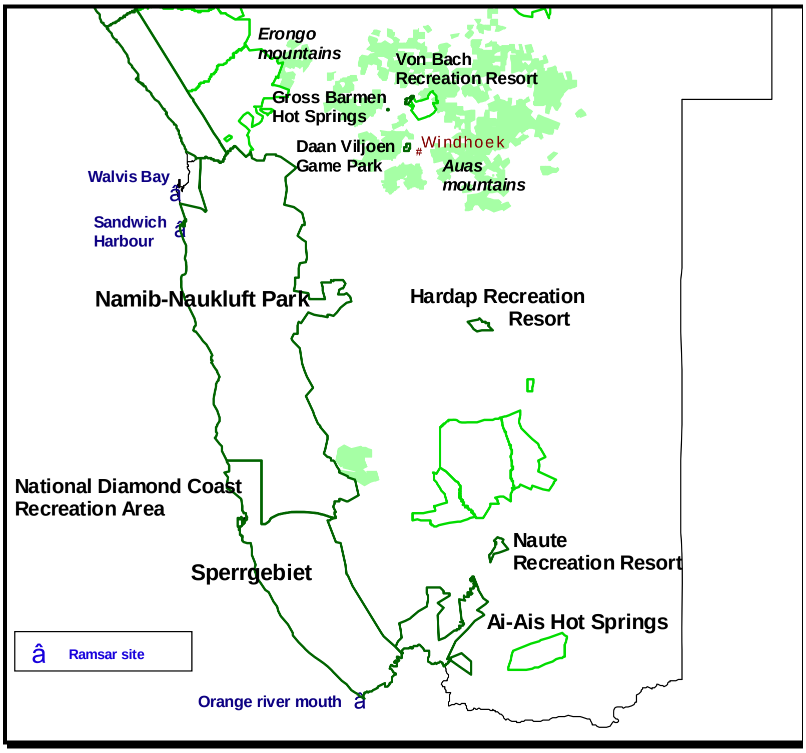

Figure 5-2: National Parks, Recreational areas and Resorts in Western and Southern Namibia

In the northern and eastern parts of the catchments the vegetation is semi-arid Acacia tree-and-shrub Savanna, giving way to Dwarf shrub Savanna southwards. Other relevant components of the landscape include:

- Inland Wetlands – the only perennial one being the Orange River, which forms the international border with South Africa. The Orange River mouth is a Ramsar site registered by both Namibia and South Africa as a wetland of international importance. A number of important ephemeral wetlands occur in the zone, the largest being the south-flowing Fish River. Two main ephemeral river systems – the Nossob and Auob – drain the Kalahari, running south-west into the Botswana/South Africa Kalahari Gemsbok Transfrontier Park. The area from north-east and east of Keetmanshoop, running south mainly within the Karas Dwarf Shrub Karoo vegetation type, is rich is ephemeral pans. And finally, two of the largest impoundments in Namibia occur on the Fish River catchment, being the Hardap and Naute dams. Because of the aridity of the south of Namibia, all wetlands have particular importance;
- Inselbergs and escarpments – important for their increased diversity (at habitat/micro-habitat and species levels), water run-off and refugia for species heavily utilized on the plains. Dominance inselbergs and other topographic features in this zone include the volcanic Brukkaros, the Karas and Small Karas mountains and the Fish River Canyon, the second largest canyon in the world (after the Grand Canyon in the USA).

The human population is generally very small in the Central-South parts of Namibia. Karas and Hardap regions each have less than 70,000 people, with some 20% and 25% respectively being urban. The Khomas region has a higher population of some 250,000, but over 85% are urban, mainly in Windhoek, and fewer than 10,000 people in this region live in the catchments of the Orange River. It is estimated that about 170,000 people live in the various catchments of the Orange River in Namibia, with some 25% of these being urban and about 125,000 people being rural.

Namibia's *average* per capita income of US$ 1,800 (2004) ranks it as a lower middle-income country. This categorization, however, masks the large social and environmental debts that Namibia inherited from 100 years of colonial history and almost half a century of apartheid. Its Human Development Index is 0.65 (0.75 in urban and 0.57 in rural areas), its Human Poverty Index is 25 (17 in urban, 29 in rural areas), and its Gini Coefficient, which provides a measure of equity in society, is 0.67, which is of considerable national concern. In essence, some 0.3% of the population own 40% of the land, and 5% earn almost 70% of the income. High levels of poverty exist. In 2003, the estimated level of literacy was 84% (male: 84.4%; female: 83.7%). life expectancy averaged 43.9 years (male: 44.71 years; female 43.13 years).

Most of the land in the catchments consists of freehold and communal farmland. The communal areas are centered on Aminuis, Bersiba, near Karasburg and Warmbad. Apart from some very limited and intensive crop production under irrigation near Mariental (Hardap Dam), at Naute Dam, along the Orange River and along the ephemeral Auob River near the village of Stampriet, the vast majority of the land is extensive rangeland livestock and wildlife farming within indigenous ecosystems. Cattle predominate in the north around Gobabis, Khomas and Okahandja areas, while mainly sheep and goats are farmed in the more arid south. The mean carrying capacity (stocking biomass) of this zone is low, ranging from about 25 kg/ha in the extreme north and east of the zone to less than 10 kg/ha in the south and west. Because of the low and highly variable rainfall in this zone, the carrying capacity also varies considerably from year to year. As a result, over 75% of the Central-South zone is rated as falling into an area defined as being at “high to very high risk” for conventional farming.

5.2 Conservation Areas

Land under State Protected Areas (National Parks) in this zone is found mainly in the extreme western and southern areas (Figure 5.2). These areas were set aside because they were unsuitable for farming, being too arid and too mountainous. The largest park in the zone and in Namibia, and one of the largest in the world is the Namib-Naukluft Park (5.07 million ha), which falls west of the escarpment and thus just outside the Orange River catchments. Within the catchment area is the Huns Mountains/Ai-Ais/Fish River Canyon Park complex, the extreme southern part of the Sperrgebiet National Park (approved by Namibia’s Cabinet as a protected area of some 2.6 million ha, but still to be formally gazetted), the Naute Dam and Hardap Resort. The Ai-Ais Complex borders onto the Richtersveld Park in South Africa, immediately south of the Orange River, and the governments of South Africa and Namibia have entered into an agreement to develop them into a transfrontier conservation area to promote tourism, job creation and conservation.

In addition to the State Protected area network there are a number of community and private initiatives that enhance biodiversity conservation in the zone. These include conservancies, both on freehold and communal land, and private nature reserves.

There are three registered and one emerging communal conservancies in the Karas region, and a host of freehold conservancies mainly in the Khomas and Gobabis areas. In addition, there is one large private reserve adjacent to the Fish River Canyon, the Gondwana Cañon Park.

5.3 Environmental Challenges

Over the past five years Namibia has undertaken a plethora of consultations, assessments and reviews of the main environmental and sustainable development challenges facing the country, particularly in the semi-arid and arid areas. The results from these consultative processes have been mutually reinforcing, and the views of local land and natural resource owners and managers, support agencies (government and civil society) and various specialists are well known, documented and largely in agreement. These processes have fed into a range of national planning documents, including Namibia's second five-year National Development Plan, the National Poverty Reduction Strategy and Namibia's 30 year Vision 2030. Recent consultative assessments in the Fish River catchment of the Karas and Hardap regions prioritized the following challenges:

- Unsustainable land management practices, particularly
    - Overgrazing
    - "Deforestation" (loss of woody vegetation)
- Limited and limiting water resources, particularly
    - Limited sources
    - Poor management and infrastructure
- Tenure rights over land and natural resources, with the need for full devolution to lowest appropriate level being paramount
- Contradictory policy environment over land and natural resources
- Need for diversification in land use, going hand-in-hand with a need for enhanced entrepreneurial skills
- Limited capacity, skills and access to finances
- HIV/Aids

A clear manifestation of these challenges is poverty and a poor quality of life, and an inability for rural communities to extract themselves from the poverty trap.

5.3.1 Unsustainable land management practices

The following have been distilled and reformulated from the above:

- Ecosystem integrity: Land degradation poses a risk to ecosystem integrity in fragile dryland environments, defined in terms of health, connectivity and stability, biotic and abiotic components of ecosystems and the interconnectedness between them. This is likely to diminish the ability of dryland environments to supply vital ecological goods and services, including climate regulation and water regulation. In particular efforts to stem deforestation (loss of woody vegetation – there are no forests in Namibia, but rather open to sparse woodlands to dwarf shrubs) are likely to reduce the expected increase of surface albedo on cleared land. Such efforts coupled with efforts to reduce the loss of other vegetation cover and soil erosion are further expected to help maintain the capacity of soils to maintain moisture and reduce the release of soil particulates into the atmosphere. This will help to maintain air quality and regulate climate.
- The loss of above- and below-ground biomass as a result of deforestation and the increase of decaying vegetation matter on cleared land contribute to the release of Green House Gases (GHG) and the reduced capacity of savannas to function as a carbon sink. In 1994, Namibia was estimated to be a net sink for carbon due to the large uptake of CO_2 by trees and its contribution of less than 0.05% to global CO_2-equivalent emissions.
- Watershed integrity is severely impaired through deforestation and other forms of degradation. Water harvesting places additional stress on Namibia's few perennial rivers which are all transboundary. In the long-term, uncontrolled abstraction is likely to have serious downstream impacts, with economic and ecological consequences, which are not, limited to Namibia but extend into the southern African region.
- Land degradation is impairing ecological functions and habitat quality in critical ecosystems that contain biological diversity of global importance. One of Namibia's two ecosystems that are internationally recognized as biodiversity "hotspots" due to their high degree of endemnicity with respect to plants and animals, falls partly into the Orange River catchment. This is the Succulent Karoo, which represents the only global arid hotspot.

Overgrazing

Despite the country's severe climatic constraints, a significant percentage of the land is used for agriculture, mainly livestock farming in the south. For a number of reasons, including overstocking, poor management, lack of mobility due to land be divided into farming units, past drought subsidies, poor access to markets, etc. there has been considerable rangeland degradation **Rangeland degradation** manifests itself in two contradictory forms: loss of vegetation cover on the one hand and bush encroachment on the other. In the south of Namibia, the former is by far the dominant expression of degradation. Loss of vegetation cover is perhaps the most obvious indicator of rangeland degradation, ranging from the loss of grass species diversity and perennial grasses, a loss of grass vigor to a loss of ground cover and land productivity, increasing vulnerability to drought and facilitating encroachment of undesirable plants. In Namibia there are two interrelated causes for loss of vegetation cover: overstocking - which describes the situation where more animals are kept on a certain piece of land than there is fodder available to feed them; and overgrazing – which is caused when animals are concentrated in one specific area for too long, resulting in over use of the vegetation with inadequate recovery time. Open access to land and unsuitable distribution of water and boreholes is one major factor for the latter.

Deforestation

Deforestation is the second major form of vegetation degradation in Namibia, and refers to the removal of woody vegetation cover. Its consequences are loss of habitats, changes in hydrological and nutrient cycles, and reduction in carbon sinking capacities. Deforestation in Namibia is most prevalent in the North and North Central regions than in the south, but because of the limited woody resources in the south, and their very slow rates of growth, even modest levels of tree harvesting has a significant impact. The predominant fuel for cooking still remains fuel wood.

Soil degradation

Another set of threats relate to soils: the predominant factors of soil degradation in Namibia are soil erosion due to wind and water factors and declining soil fertility and loss of soil organic matter.

Soil erosion due to wind and water factors occurs when top soil is blown or washed away by wind or water (i.e. heavy rainfalls) mainly in areas of poor rangeland management. It leads to the removal of top soil thus decreasing land productivity. It is widespread given Namibia's naturally thin vegetation cover especially in the central and southern parts of the country.

Declining soil fertility and loss of soil organic matter refers to the deterioration in the quality of soils due to loss of nutrient and water retention capacity and leads to loss of soil fertility and ability to support plant life which in turn exacerbates vulnerability to wind and water erosion. The soils in Namibia generally have low natural fertility, are humus-poor, shallow, sandy and stony and have low water retention capacity. These characteristics impact on the natural soil condition, making it more prone to fertility degradation. Even those areas classified within Namibia as being of "high" soil fertility do not rate highly globally. Small-holder cultivation and large scale irrigated agricultural projects are major causes of soil productivity loss.

Over abstraction of water

In the area of water management, over-abstraction of water has immediate implications for the natural environment given the intricate relation between nutrient and water cycles. Disrupting these cycles through, for example, inappropriate irrigation methods, leads to reduced soil fertility and productivity through loss of nutrients and/or salinisation and water logging. Lowering of groundwater levels hampers the ability of plants to take up water and leads to the desiccation of springs and, consequently, destruction of habitats. Furthermore, it may reduce fluid pressure in confined/artesian aquifers and cause aquifer deformations through the compaction of geological material. An essential basic additional 'use' of water, often not accounted for in water consumption breakdowns, is the ecological reserve of water needed to sustain critical wetland and terrestrial ecosystems. The two major demands on water supply are urban centres and agriculture. Between them these two sectors account for almost 91% of Namibia's water demand. Despite its modest contribution to GDP, agriculture accounts for about 60% of all water used in Namibia. Crop irrigation alone accounts for almost 40% of all water use, and there are plans to expand this use further. One of the most pressing problems is the maintenance of the thousands of boreholes in remote communal areas. Government has not had the resources to maintain all these boreholes and has introduced a Community Based Management programme in which villagers, led by a Water Point Committee, will be expected to pay the recurrent costs of maintaining water point installations in future.

Climate change

The most significant "external factor" to impact of environmental and sustainable development issues in the south of Namibia is likely to be that of **climate change**. The impact of these anthropogenic threats is exacerbated by natural vulnerability in the form of rainfall variability and drought. This natural vulnerability is likely to be aggravated by the effects of human induced global climate change. Based on the initial National Communication to the United Nations Framework Convention of Climate Change (UNFCCC) (July 2002), in the worst case scenario for the year 2100 predicts the range of mean annual temperature increase for the central plateau region to be 4.5-6°C above the 1961-1990 mean temperature, while a more optimistic simulation estimates a rise of 2-3°C. There is less agreement amongst the various models regarding future rainfall. The greatest impact is projected to occur in the central and southern areas. Evaporation rates are also estimated to increase by around 5%. These impacts threaten Namibia's water supply in general and water dependent activities such as agriculture and mining, in particular. Namibia's wetlands have been identified as the ecosystems most vulnerable to climate change. Although Namibia itself is a small contributor to greenhouse gas emissions, it has to be able to adapt to future changes in conditions in order to avoid large economic, social and environmental costs from climate change.

Two specific projects to be undertaken in livestock and crop production within the framework of adaptation to climate change. These include, firstly, development/adaptation and use of agricultural production models for arid-land crops and livestock in hot and arid environments, and secondly, the testing and dissemination of heat, drought and salt tolerant crop cultivars and livestock breeds.

In summary, inappropriate land uses and agricultural practices are the main factors which underlie Namibia's land degradation; however, these causes are only symptoms of actual root problems at a structural level, which as the figure below shows, are tightly interlinked with each other (Figure 5.3). Ultimately, it is poverty mainly on communal lands, linked to the need for agricultural and industrial expansion at a national level, but also diversification away from agriculture in the more arid areas that will alleviate pressure on land and natural resources, combat desertification and start to counteract poverty.

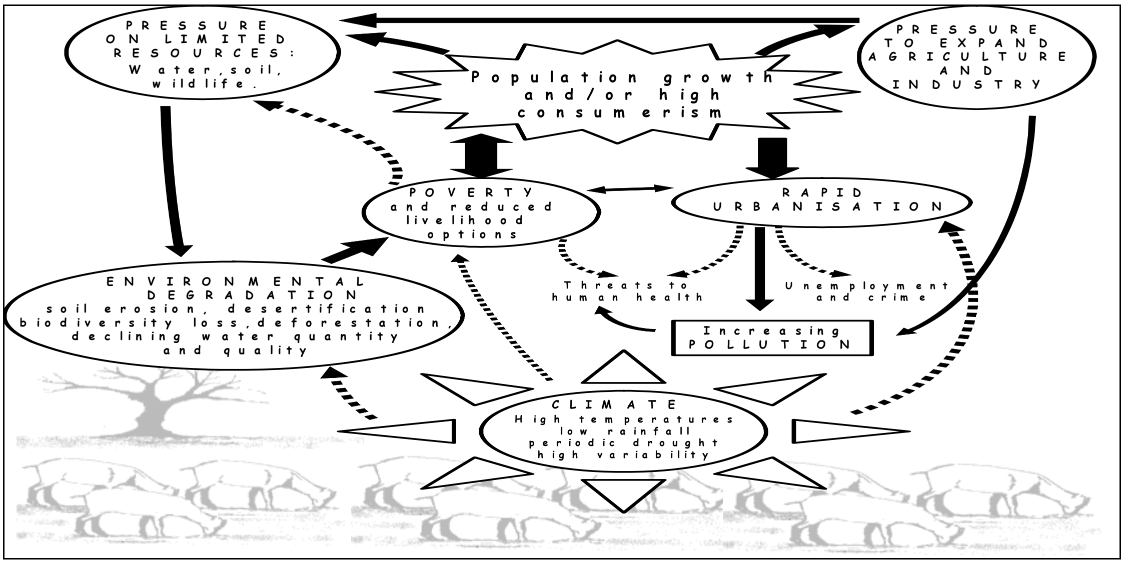

Figure 5-3: Some of the interlinked issues that underpin unsustainable land and natural resource management

5.3.2 Land Degradation on Communal Land

Traditionally, livelihoods have been based on the use of natural resources through livestock husbandry and cultivation of land. Land management practices had evolved to adapt to the physical conditions of Namibia's climate and historically resource use is considered to have been largely sustainable. Today, people on Namibia's communal land still largely lead subsistence lifestyles, due to the absence of employment and other significant monetary incomes. As affordable alternatives are not available, food, fuel, housing materials, and even medicines are extracted directly from the land, in most cases barely covering the needs of the respective resource users. Dependence on the exploitation of natural resources locks residents into a cycle of short-term over-exploitation of resources. Traditional land use practices are increasingly marginalized: rainfall, and therefore the availability of fodder in Namibia are highly variable in terms of time and space. In the past, communities employed a flexible rangeland management system, moving herds to distant pastures to benefit from better rainfall and grazing. Given severe demographic pressures, sedentarisation is now a reality in most of the communal areas of the country, and there is little scope for stock farmers to return to the more nomadic lifestyles of the past.

Currently the capacities of communities to make informed management decisions are limited. An easy to operate, locally based decision-support system providing information on important parameters like rangeland condition, bush densities, carrying capacity, livestock condition and rainfall, is urgently needed. Based on their own information, collected by themselves, resource users should be able to identify problem areas and make appropriate mitigation decisions (e.g. marketing of livestock, movement of livestock to key resource areas, additional fodder supply, etc). Knowledge is necessary but not sufficient for sustainable land management. Especially where sustainable land management involves investments of time and money (even if only initially) favourable (economic) incentives are also required.

Land Tenure

Land tenure issues and ensuing consequences for land management, are pervasive throughout Sub-Saharan Africa. In Namibia, communal land is owned by the State, while its residents have usufruct rights over the land and its resources such as grazing. Heretofore, land use has been governed by traditional leaders. However, group rights and their enforcement have weakened and this undermines the ability of many residents to prevent appropriation of their land by wealthy individuals and settlers and herders from other areas. In the north central regions there are conflicts between residents wishing to expand their croplands and others who wish to maintain extensive grazing areas. As government to this date has refrained from introducing a formal land tenure system for communal lands, previously controlled community management of land has turned into an open-access system. Open access to resources implies that the value of a resource is only secured and internalised by individuals through exploitation, while its preservation or even investment for securing or improving future productivity is not simply an inter-temporal consumption decision, but induces the risk that the investor incurs a loss when the respective returns on this investment are internalised by other resource users - the so called free rider problem. Open access, its ensuing risks to investments and the inability of communities to coordinate land use planning at a larger scale is impeding sustainable development in communal areas.

Apart from land tenure, thin or absent markets in the rural economy lead to coping strategies, which are not often sub-optimal from the perspective of sustainable land management. Markets and market infrastructure for other indigenous products (e.g. reeds, crafts, skins) are little developed if existing at all, and participation of the local communities in these are highly dependent on outside support. Where markets exist they value pure extraction but not sustainable use, thus again leading to overexploitation of the resources. In other words, markets which create a present value to future consumption, i.e. attach a value to the sustainable use of resources and the preservation of ecosystems hardly exist. The absence of these markets limits the opportunities of rural people to diversify their livelihoods away from livestock production or extensive dryland cultivation. At the same time, limited rural financial markets restrict saving and borrowing possibilities. Commercial banks do not provide adequate banking facilities to communal farmers on a regular basis, which leaves farmers with few options other than to re-invest their money in livestock; the absence of insurance markets implies that a strategy of maintaining large livestock numbers is favoured by farmers to minimise risks in times of external shocks. Thus, the absence of credit and insurance markets again leads to overstocking on the one hand, and diminishes the capacity of farmers to invest in their land.

5.3.3 Land Degradation on Commercial Land

Most freehold land is used for livestock farming that was heavily subsidized in the past. Despite an average size of 7,000 ha, many freehold farms are not economically viable because of the semi-arid to arid environmental conditions: it has been estimated that as much as 60% of these farms are not profitable. This is particularly true for the south of Namibia where, in dry periods, over 50% of farmers leave their land to seek employment. Again, a number of (economic) reasons can be identified that lead to the inefficient use of resources (rangeland) on commercial farmland. In the past, livestock subsidies on commercial farms led to overstocking. Although these subsidies have largely been phased out, the legacy (land degradation mainly in the form of bush encroachment and overgrazing) is still apparent. A main challenge is therefore the rehabilitation of farmland to regenerate their productivity. However, again, there are various obstacles to sustainable land management. Farmers expecting to sell land under the Government’s willing buyer willing seller scheme, pursued as part of its land reform initiative may have little incentive to invest in land rehabilitation, perceiving that the benefits accruing to them will not outweigh the costs. Second, technologies to restore degraded land are complex and often require a reduction in stock to allow the veld to recover, thereby reducing short-term income.

5.3.4 Closing the circle: Poverty, land degradation and eroding livelihoods

The actual impacts on livelihoods of land degradation in communal areas are difficult to measure given the complex interactions between the bio-physical environment and socio-economic conditions, and manifold non-monetary goods and services that local communities derive from natural resources, not to speak of non-use values (e.g. cultural / spiritual value of resources). However, one cost estimation of losses of the most basic goods, shows that continuing land degradation severely impacts on rural livelihoods, as depicted in the Table 5.2.

Table 5-2: Some costs of land degradation incurred to households per year

Item	Explanation	Cost per year (N$)
Lost fuelwood supply	Cost of commercially purchased fuelwood 1bundle / day at N $2	720
Lost fencing materials	Cost of purchasing wire and poles for replacing 1/5 of fence around mahangu field	400-640
Lost livestock (lack of access to grazing, drought)	Replacement cost of 2 cattle / 3 goats	480
Lost milk output	Cost of purchasing substitute protein plus loss in income	300-600
Total		1,900-2,440

Source: DEA Research Discussion Paper No 3 (1994)

It has been estimated that land degradation on commercial farms leads to a loss of 34 000 tonnes of beef production per year (worth N$ 102 million in 1994 prices ibid). This loss, of course, has direct national economic impacts regarding the overall level of output, export and tax revenues.

Opportunity costs arising from the loss of foregone benefits that higher value and sustainable land uses could derive, could even be more significant however. At this point these have not been clearly established. Preliminary studies into alternative land use options show that non-agricultural resource use in Namibia’s communal lands has significant potential to contribute to economic growth. The aggregate economic value for four study areas (located in former Damaraland, in the Opuwo District, the Caprivi Region, and former Bushmanland) was N$8.5 million (Barnes (1995)). With the realisation of non-agricultural potential (especially wildlife based tourism), this could increase by 2.5 times. The recently published State of Conservancy Report shows that for the past five years total income from wildlife based conservancies increased from about N$0.6 million in 1998 to over N$ 8 million in 2003, N$14 million in 2004 and a projected N$19 million in 2005, comprising cash income as well as non-cash income derived mainly from wildlife management and wildlife based tourism. Directly and indirectly, the Namibian economy earned about N$ 111 million from community-based natural resource management activities in communal areas in 2003. These incomes are based on wildlife only, while there is more economic potential arising from other resources such as indigenous plants, e.g. *Hoodia* species.

As the above analysis shows, the physical impacts of land degradation occur at local-level while much of the impetus (or root cause policy failures) is derived at the national level. Some of this is a legacy of the past (land tenure and land distribution) others arising from present policy preferences which adhere to an economic development paradigm (agriculture as the engine of growth and poverty eradication to be implemented through initiatives such as the Green Scheme) which is sub-optimal given Namibia's climatic circumstances. At the bottom line however, it clearly shows: poverty at local and resulting economic aspirations at national level lead to land degradation, which in turn erodes livelihoods. Given these inter-linkages, combating land degradation in new and innovative ways must form an integral part of any feasible poverty reduction strategy as well as any sustainable development strategy.

5.3.5 Barriers to Sustainable Land Management

From this range of management issues, five key barriers that impede sustainable land management can be identified.

Systemic capacity

The existence of policies that contradict the objective of sustainable land management and rural development creates adverse incentives that work against SLM. Specific issues that need to be addressed through policy review are the lack of tenure rights over land, management control over natural resources, and rural development/ agriculture policy. However, just as pressing as the review of the current policy set up is the process of implementing policies – moving from paper to practice: while Namibia has taken several important steps on paper, these need to be brought to the ground and strengthened through appropriate enforcement. Finally, where policies are in place, lack of knowledge and awareness as well as frictions between official and customary law at the local-level, where many policies need to be executed, create obstacles.

Institutional capacity

Rural people and communities manage the land and its natural resources. Their decisions and actions will, to a major extent, determine whether land-use options and management will be sustainable and optimal – both for the environment and themselves. Such decisions are taken within various policy settings, knowledge systems and the day to day *modus operandi* of the communities and their support organisations, such as the extension services of government Ministries. The management effectiveness of these institutions regarding sustainable development is impeded at several levels. Centralised management of planning and implementation of activities creates one of the strongest barriers. Land-use planning and natural resource management fall under the jurisdiction of several different Ministries, including Ministry of Lands and Resettlement (MLR); Agriculture, Water and Forestry (MAWF); Regional and Local Government and Housing and Rural Development (MRLGHRD); and Environment and Tourism (MET). There are no mechanisms in place to facilitate integrated multi-sectoral planning, and Ministries often inadvertently undermine one another's initiatives. Also, on the few occasions that ministry's do come together to plan, the resultant approach is usually heavy-handed, top-down and disempowering for local communities. Regional and local authorities have weak institutional mandates and lack the financial resources, skills and equipment necessary to perform their functions. They consequently fail to provide adequate support to their constituencies. At the same time, strong institutional mechanisms at local community level for land and natural resource management are lacking.

Individual Capacity

Namibia has limited human capacity, i.e. skilled individuals capable of turning rhetoric and goodwill into effective action on-the-ground, particularly in the rural and more remote areas. At local and regional level, there is an overwhelming need for general education, while at national level the lack of technical experts such as experienced water and land technicians and scientists, development specialists and natural resource economists was identified as a severe constraint. Across sectors, understanding of the interlinked causes of land and environmental degradation and the principles of integrated land and resource management are lacking. One critical factor that aggravates the low availability of specialists is the *brain drain*, i.e. the loss of motivated and skilled people to better paying international institutions and businesses, with the ensuing consequence that the Namibian government is highly dependent on costly external consultants, donor and NGO expertise. A further barrier to the continuous learning process necessary to maintain a high calibre workforce stems from the access to information and technology, which derives partly from the fact that knowledge is not owned at the level it pertains to but often rather by outsiders and more importantly, that information systems are generally weak where they exist and not easily accessible to managers on the ground.

Knowledge and Technology

Related to the lack of individual capacity is the limited availability of M&E systems that provide information on economically and environmentally efficient land and natural resource use, and guidelines for adaptive resource management. Especially in a climatic environment such as Namibia's where successful sustainable resource management is, to a large extent, dependent on swift adaptation to changes in weather conditions, the ability to monitor and evaluate the risk of desertification is critical, as is knowledge about best management practices. A second element that determines adaptive management is the ability of resource users and managers to track impacts. Namibia in this regard faces a number of barriers: firstly, information for adaptive management is not generated on a reliable basis at any level, be it national or local, scientific or applied; secondly, where information is generated and lessons are learned, these are not communicated and disseminated across the country and beyond to facilitate adaptive management and the diffusion of technology and innovation. Given the uncertainty associated with the impacts of global climate change, information on changes in resource state becomes even more critical.

HIV/AIDS

Lastly, HIV/AIDS is a new factor that creates a barrier to sustaining institutional and individual capacity for land and associated resource management. Namibia is one of the top four countries in the world most affected by HIV/AIDS, with an estimated prevalence rate of 25% of the adult population. This has enormous social implications: there are already an estimated 100,000 AIDS orphans and it is predicted that between 1985 and 2020, 26% of the labour force in Namibia will be lost to HIV/AIDS. For every person lost, traditional knowledge and mechanisms for coping with climatic and general variability are lost. When this knowledge disappears basic subsistence becomes more difficult and the risk to people's livelihoods increases. The loss of skilled and unskilled personnel within the environmental management sector also has devastating effects on sustainable natural resource management, reducing its effectiveness and generally threatening those who rely on natural resources for their livelihoods. Further, losses in time and personnel due to HIV/AIDS are persistent and compounding, not random or isolated. Thus they weaken institutional memory, reducing the long-term integrity of natural resource management.

In environmental terms, the loss in time, skills, experience and finances will result in degradation of the landscape. As the burden of HIV/AIDS increases, people begin to look for short-term solutions that often involve methods that are less well suited to the environment. For example, the loss of labour, and health, means that farmers are less able to spend time to move herds to distant pastures or to take time-consuming anti-erosion measures. Their options to generate income are compromised as they are forced to take emergency action by, for example, selling livestock at sub-optimal times. In short, the dual impacts of HIV/AIDS and environmental degradation lead to a complex self-reinforcing cycle detrimental to livelihoods. Poverty and reduced livelihood options are interlinked factors influencing land degradation.

5.4 A Focus on the Orange River

The estimated natural runoff of the Orange River Basin is in the order of 11 300 Million m^3/a. Much of the runoff originating from the Orange River downstream of the Orange/Vaal confluence is highly erratic and cannot be relied upon to support the downstream water requirements unless regulation is provided. The portion of runoff originating from the Fish River in Namibia can support some of the downstream demands, particularly the environmental demands at the river mouth.

The ecological condition of the river is deemed to be on a negative trajectory. The Orange River Mouth Wetland is designated a RAMSAR site and is on the Montreaux Record. The present Ecological Status of the Estuary is classed as “largely modified”.

In Namibia, the majority of the present and future water demands from the Orange River are for irrigation, with some increase in demands by mining. The availability of water along the Orange River is currently based on the regulation of water from the Vanderkloof Dam and cannot be guaranteed, especially when drought conditions prevail in the upper reaches of the Orange Basin. Water demand in 2002 was 102.3 Mm^3 for irrigation and 23.9 Mm^3 for mining and urban use along the common border of the river.

The Lower Orange common border water demands are likely to increase from 82 to 122 Mm^3/a on the South African side and 60 to 227 Mm^3/a on the Namibian side, by the year 2025.

At 2005-development levels and 2002 irrigation water use, it has been calculated that, to maintain the estuary at its present ecological status, there is currently a surplus yield of some 14 Mm^3/a. To improve the ecological status of the estuary (from a category D to a C) would put the system into a 500 Mm^3/a water deficit.

Hydraulic river modelling indicated that the surplus yield in the system can be increased by 80 Mm^3/a when real time modelling is used to optimise inflows from the Vaal more effectively. An increase in yield of 143 Mm^3/a can be achieved by the utilisation of the lower level storage in Vanderkloof Dam below the minimum operating level defined by the outlets to the irrigation canals. The irrigation sector is the highest consumer of water in the Lower Orange River Management Study area and it also has the biggest potential for savings.

Investigations into a re-regulating dam at Vioolsdrif, Komsberg or a new dam at Boegoeberg, to reduce operating losses and therefore increase the allocatable yield suggests the Vioolsdrif option provides a significantly higher yield and lower unit reference value. Results from the economic analyses indicated that the Vioolsdrif Dam is the better option. This site was recommended as the best site for a large storage dam on the Orange River downstream of Vanderkloof Dam. It should be considered in the context of the whole Orange River Basin and compared with the alternative dam sites in the Upper Orange, which have been considered and provisionally recommended in other studies. A Vioolsdrif Dam would not be in place until 2015 at the earliest. The estimated capital cost of a hydropower station at the dam was R30 Million, the maximum generating capacity 4.2 MW and the total annual power generation was estimated at 21.3 GWh. The estimated income is R 3.4 million/a, based on a selling rate of R 0.12 per kWh and a carbon emission reduction subsidy of R 0.04 per kWh.

5.5 The Ecological Importance and Sensitivity of the Lower Orange River Downstream of 20º Longitude to the Orange-Fish Confluence

In an analysis of the median monthly flows in the previously termed middle Orange River, with Boegoeberg Dam as point of reference, Benade (1993), using data from 1914-01-01 to 1989-04-30, calculated that the natural flow patterns in the system showed an 82% summer (October to May) versus 18% winter (May to October) distribution. Minimum flow occurred during August (Wellington, 1933; Chutter, 1973; Benade, 1993) and maximum flow during February (Tomasson & Allanson, 1983; Benade, 1993), showing erratic flow peaks coupled with high silt loads (To-masson & Allanson, 1983). Statistically the ORS appears to display a one in 10 to 15 year episodic flood cycle (Benade, 1988), but floods can also occur every five to 10 years (Department of Information, 1971).

Biological information mostly involves fish parasites and/or economically important organisms, such as the Simuliidae (Blackflies) and the snail intermediate hosts of Schistosoma (Bilharzia) and Fasciola (Fluke) spp. (Benade, 1993). Ag-new (1965) undertook a once-off survey of the invertebrates of the Orange River as a whole. Dr Rob Palmer documented some recent studies on ORS invertebrates whilst doing Blackfly control research and the Namibian National Museum compiled a checklist of freshwater invertebrates found within the Namibian borders.

The invertebrate populations appear to be rather homogenous throughout the entire length of the Orange River - ascribed to the unpredictable, erratic nature of the system. The occurrence of freshwater fish being infested by parasites, as well as an increase in fish parasite diversity, in the study area had been observed during fish surveys between 1985 and 1989 (Benade, unpublished data). This phenomenon is indicative of water quality deterioration. The Orange River system as a whole is relatively poor in indigenous freshwater fish species diversity. Presently, eight fish families are represented by 22 species.

Dam construction and river regulation usually lead to increases in riparian agricultural activities, especially irrigation (catchment utilisation). This, in turn, will inevitably lead to agricultural pollution resulting in changes to the river oxygen content, pH, turbidity and conductivity.

Riverbed degradation resulting from suspended solid precipitation caused by the combination of low flows (river regulation), high evaporation rates and high mineral content (agricultural and other pollution) leads to aquatic habitat degradation, which could be detrimental to the survival of certain indigenous, including endemic, organisms, while promoting the unwanted establishment of other indigenous, as well as alien, organisms.

Increasing river regulation and catchment utilisation will result in increases in filamentous Phycophytes and blue-green alga (algal blooms), and will also promote habitat changes suitable for the encroachment and colonisation of plant species. It can be expected that further river regulation will enhance habitat possibilities for economically important invertebrates such as Blackflies, the snail intermediate hosts of Bilharzia and Fluke spp., mosquito's, etc.

Five of the six endemic Orange River fish species occur in this lower river section, of which one, *Barbus hospes*, is unique to the Orange River section between Aughrabies Falls and the Orange River Mouth. Three of the five endemic species, *B. hospes*, *B. kimberleyensis* and *Austroglanis sclateri* are Red Data listed. Although the other two endemics, *B. aeneus* and *Labeo capensis*, are fairly abundant and thus appear not to be threatened, they remain of concern because of their endemic status.

5.6 Orange River Mouth Development Plan

The Orange River mouth is one of very few areas of sheltered shallow water along southern Africa's arid Atlantic coastline, and a site considered important primarily for sustaining substantial numbers of waterbirds, including an appreciable number of Red

Data-listed species such as the Cape Cormorant, Damara Tern and Hartlaub's Gull. In recognition of this exceptional ecological significance, the Orange River mouth was designated a Wetland of International Importance in terms of the Ramsar Convention on Wetlands in 1991. When Namibia designated its portion of the Orange River mouth a Ramsar site in 1995, it created the potential for this wetland to become the first jointly managed transfrontier Ramsar site in southern Africa. As a result of severe deterioration of the mouth's general condition, and especially the salt-marsh component, the wetland has continued to deteriorate subsequent to its designation as a Ramsar site. This has resulted in the South African portion being placed on the Ramsar Convention's Montreux Record, which lists wetlands in need of urgent conservation action.

5.7 Heritage Sensitivity

Any dam site within the region between 20 degrees longitude and the Fish River confluence will cause some heritage impacts. The Richtersveld is archaeologically rich. Any inundation of the river valley will constitute a loss to the National Estate. The construction of the Vioolsdrif dam option will affect between 219 and 286 archaeological sites. None of these are know to be unique or exceptional, and are thought to be representative of much of the lower Orange River.

5.8 Sendelingsdrif Proposed Irrigation Scheme

A 300 ha irrigation project proposed for the cultivation of table grapes and Barhee dates. The proposed site is located 15 km south east of the mining settlement of Rosh Pinah and 5 km north west of the Orange River at Sendelingsdrif.

Expected impacts include:

- Increased human settlement and harvesting within the riparian zone. The Rosh Pinah population has grown from 2,000 to 7,300 by June 2004. Apart from the mine, the population is also increasing due to in-migration from all over the country because of the real and perceived work opportunities offered by agriculture and, increasingly, tourism ventures in this south western corner of the country.
- Potential conflict in land use between the proposed irrigation development and the Transfrontier Conservation Initiative.
- Threats to biodiversity, particularly to endemic vegetation and endemic invertebrates known to occur in the project area.

- Cumulative impacts as a result of this and other existing and new developments with respect to water abstraction
- The contribution of saline irrigation return flows to a deterioration in the water quality of the Orange River, in the absence of mitigation.

5.9 Land Capability and Alternative Options

In areas of low rainfall in Namibia significantly greater financial and economic returns can generally be earned from land uses and enterprises based on indigenous biodiversity than from conventional farming. Much of the Central-South lends itself to (a) tourism, based on scenic landscapes, wildlife, cultures and rural lifestyles, and (b) wildlife production, based on a suite of species and sometimes integrated with domestic stock farming. The area is predisposed to expand rapidly in these areas because:

- national policy supports investment in, and land-use conversion to, wildlife and tourism, and there is now sufficient confidence in the sector that a critical mass of land owners/managers have embarked on these changes to good effect;
- the tourism sector is growing (it is now the second most important contributor to the national economy, after mining) and so are the associated market opportunities;
- government shows commitment to expand and open up the protected area network, which provides the anchor points for tourism and wildlife conservation and acts as a catalyst and engine for local and national development;
- government shows strong support to conservancies and community-based initiatives in the wildlife and tourism sector, as foci for sustainable rural development.

<u>Special natural features</u>

The Central-South zone has a number of special features which, if linked together in intelligent and effective ways, would predispose the zone to rapid growth based on its tourism potential:

- four deserts – the Namib, the Succulent Karoo, the Nama Karoo and the Kalahari, each with a number of diverse vegetation types;
- the most plant-diverse desert in the world – the Succulent Karoo;

- large and linked protected areas, containing a large component of the most dramatic and diverse landscapes of the zone, including the Namib gravel plains, the Namib sand sea, the Sperrgebiet, and over 700 km of coastline;
- Transboundary links with the Richtersveld in South Africa, and links via a continuous set of large coastal Parks into Angola – thereby being part of a three national protected landscape;
- three Ramsar sites, being wetlands of international importance, at the Orange River mouth (a site proclaimed in partnership with South Africa), Sandwich Harbour and Walvis Bay, the last two being the richest coastal lagoons on the southern African coast based on wetland bird counts;
- the world's second largest canyon – the Fish River Canyon;
- the mystic Sperrgebiet, closed for almost a century, with its diamonds, dramatic coastline, historic buildings and mining history, and vast untouched wilderness areas;
- the Orange River, cutting through deep gorges, on its way from the Lesotho highlands to the Atlantic Ocean – the next perennial river to the north being the Kunene 1,400 km away;
- the largest area of sand dunes south of the Sahara stretching over some 350 km and covering over 3.5 million ha;
- spectacular and diverse open landscapes with rich topography, much of it readily accessible.

The Orange River catchments in Namibia overlay a large part of the area described above, and the management and development of these catchments should be aligned with the larger Vision for the area. In addition, the focal area is particularly well equipped with respect to the following:

- communications - an extremely good road network, linking to South Africa and Botswana, as well as to other destinations in Namibia and to the trans-Caprivi highway, good air links - international, within the country and within the zone, and good telecommunications and internet links;
- services - ready access to car hire and travel agents, good banking, foreign exchange and credit card services, and good medical support and back-up;
- established tourism routes and facilities – the main tourism attractions in the area including the Fish River Canyon, and the Sperrgebiet shortly to become

a very sought-after destination. There are a large number of guest and hunting farms in the area, and Luderitz is growing in popularity;

- conservancies (both communal and freehold) and private game parks are expanding and proliferating, which creates opportunities for further tourism and conservation growth and partnership.

The southern regions of Namibia have only relatively recently started attracting tourists in significant numbers, mainly to Sossusvlei and the Fish River Canyon. This can be seen in the nature of the developments in the south, particularly the fact that access to the parks is very limited, and there are relatively few tourism facilities in many areas. Some of the main challenges in the area, linked to the opportunities that addressing these challenges will create, include:

<u>Creating linkages – existing initiatives</u>

There are a number of reasons for linking different regions – some ecological, others economic and market related. The main ecological reasons are:

- to cover adequate components of the biomass, habitats, micro-habitats, species and genetic variations, both in terms of diversity as well as in sufficient numbers to ensure that both ecosystems (in space) and evosystems (evolutionary systems – over time) function effectively;
- to create space for movement. One of the most important adaptations to arid and unpredictable environments is the ability to move - far and fast. Most wildlife, particularly larger mammals and birds, are highly mobile and nomadic. Large open systems allow for such responses. Even in one of the largest parks in the world, the Namib-Naukluft park (over 5 million ha), large ungulates are restricted from moving eastwards in dry times, and die along the park boundary fence;
- to accommodate wide-ranging species with large home ranges. The endangered Lappet-faced Vulture is at its highest density in the Namib-Naukluft Park. Yet this 5 million ha park does not contain the entire home range of a single pair. Birds expose themselves to the risk of persecution and poisoning on adjacent farmlands when they leave the park;
- to make provision for climate change. The best response we have at this stage is to manage for open systems, create linkages and "corridors" for

plants and animals to move, disperse and colonize new areas as conditions shift.

The main economic reasons are to create a diversity of marketing opportunities, to cater for a wide range of interests that are environmentally and socially acceptable (e.g. spectacular landscapes, geology, archaeology, flora – including specialist interests such as succulents, birding, wildlife, hiking, horse-riding, wilderness, off-road 4x4 driving, photography, hunting, fishing, etc.), and to keep tourists gainfully occupied in the area for as long as possible, thereby creating wealth, the opportunity for further services and support industries and generating employment in the zone.

The following linkages within the zone are important:

- the Sperrgebiet National Park must work seamlessly with the Namib-Naukluft Park and the Huns Mountain/Ai-Ais/Fish River Canyon Park complex;
- these parks should all seek linkages through partnership and mutual incentives with neighbouring private land owners, and take down fences to allow wildlife to move eastwards during dry periods;
- the Fish River Canyon Park must work seamlessly with the Richtersveld Park in South Africa, and tourists should be able to move easily across the border from one side to another.

<u>New initiatives</u>

Most of the protected areas of Namibia were established prior to the science of biodiversity conservation. Indeed, most protected areas were established more because the land was deemed unsuitable for farming than for conservation imperatives. As a result, many vegetation types are very poorly represented, or entirely unrepresented in the protected area network (Table 5.1). In some cases, private nature reserves and conservancies make significant contributions to the percent of land held under conservation-friendly management, and this approach is in line with government's call for "innovative approaches" to securing adequate coverage of all habitats for conservation.

The Central-South zone contains the entire ranges of eight of the vegetation types that occur there.

Five vegetation types in two biomass have less than 2% representation in the state protected area network in this zone, with two of them being totally unrepresented. When taking into account the other forms of biodiversity-friendly land management such as private nature reserves and conservancies, one vegetation type remains totally unprotected (Dwarf Shrub – Southern Kalahari Transition), one is at just 0.4% (Southern Kalahari) and one is at 9.1% (Karas Dwarf Shrubland).

In addition to vegetation types, there are some areas outside the protected network that are relatively rich in biodiversity and endemic species. The Karas Mountains south-east of Keetmanshoop has high plant diversity and endemism, as does the northern side of the Orange river from Noordoewer eastwards. This latter area is also rich in mammal endemics. The entire escarpment and transition zone is a rich zone of endemism.

With these two aspects in mind it is clear that it would be highly desirable to secure representative components of the under-represented vegetation types in the areas with high diversity importance.

Table 5-3: The priority vegetation types and recommended actions and targets to adequately protect biodiversity

Biome	Vegetation type	Recommended actions
Nama Karoo	Dwarf Shrub Savanna	1.8% in PAN (small parts of Fish River Canyon, Hardap & Naute). A further 1.8% receives high level of protection in a private nature reserve, and 12.5% in two emerging communal conservancies (Berseba & Behanie). An initial target of 4% of this vegetation type would be appropriate within the national Parks estate – through linkages of existing areas. This vegetation type is quite diverse across both north-south and east-west gradients. It would thus be beneficial to acquire land in a number of different places within the vegetation type. Options include: (a) north of the Fish Fiver Canyon Park, linking this to Naute; (b) land to the south (linking to Naute), west and north of the Berseba/Behanie communal conservancies; (c) land to the east of the Naukluft, creating an east-west landscape covering three vegetation types; and (d) land adjacent and to the west of Hardap. Options (a), (c) & (d) would be the preferred priorities - all three. Both the existing and future parks should be used to lever (through incentives and co-management options) compatible and biodiversity friendly land uses on adjacent land.

Biome	Vegetation type	Recommended actions
	Karas Dwarf Shrubland	0.6% in PAN and a further 8.4% within communal conservancies (mainly !Khob!Naub). See recommendations under “Dwarf Shrub – Southern Kalahari Transition” to target Karas mountain and adjacent areas, thus linking this and next vegetation types. In addition to the Karas Mountain and adjacent area, the southernmost area in this vegetation type along the Orange River, is high in both diversity and endemics – plant and animal. The most strategic area to target is the Blydeverwacht Plateau and south to the Orange River, in the extreme south-eastern corner of Namibia. This would include a diversity of habitats including wetlands and riparian belt along the Orange River, and link to Augrabies National Park in South Africa, thereby creating a transboundary protected area. In addition, the area is close to the Araimsvlei and Onseepkans border posts and highways, making it ideally located for tourism purposes and lodge developments. Could be a good “joint venture” between public and private sectors, for land acquisition, tourism development and park management. In addition to about 2-3% of this vegetation type linked to the Karas Mountain area (see next vegetation type), an additional 2% should be acquired in the extreme south-eastern corner of Namibia and bordering on the Orange River
	Dwarf Shrub – Southern Kalahari Transition	0% in PAN, and 0% under any other form of protection. Currently the only vegetation type in Namibia that enjoys absolutely no form of protection. Apart from some small ephemeral pans, there are no distinguishing features to this vegetation type and no significant routes, infrastructure, etc. At its north-western side it approaches the base of the Karas Mountains (Groot Karasberge). This small mountain range (inselberg) is a site high in plant diversity and endemism, and falls within the Karas Dwarf Shrubland, of which only some 0.6% occurs within the PAN. It is thus recommended that the Karas mountains and surrounding areas – to east and west - be the focal point for land acquisition, so that both vegetation types are represented and linked. An initial target of some 3-4% in the Dwarf Shrub – Kalahari Transition would be appropriate (and 2-3% at this linked site in the Karas Dwarf Shrubland – which together with part of the Karas mountain will made a highly diverse and interesting Karoo park. Incentives for neighbours to practice biodiversity friendly land uses and co-management approaches should be explored and implemented.
Salt Pans	Pans	95.8% of the surface area of pans in Namibia are contained within the PAN. While this seems impressive, it is heavily biased towards the Etosha and other large pans in the north-central parts of the country within the Etosha National Park. There are a series of smaller pans, particularly in the Karas Dwarf Shrubland north-east of Keetmanshoop and in the Southern Kalahari and its transition zones that are unprotected. It is not suggested that these areas should be targeted for inclusion in the PAN exclusively on the presence of ephemeral pans. However, it is recommended that pans should be one of the positive contributing factors considered when looking to acquire land in the underrepresented vegetation types of the Central-South zone. It is also recommended that the pans in this area should gain higher priority within the wetlands portfolio of the relevant MET staff and the Wetlands Working Group, to understand their role better and to develop, in partnership with land owners, appropriate management approaches.

Biome	Vegetation type	Recommended actions
Acacia Tree-and-Shrub Savanna	Southern Kalahari	0% in PAN, 0.4% in freehold conservancies. One of the least protected vegetation types in Namibia. Well protected in South Africa and Botswana within the Kalahari Gemsbok Transboundary Park. With the opening of the Mata Mata gate and the flow of tourism traffic, there is considerable potential to link tourism and wildlife management in this area. The primary focus should be for public and private sector partners to acquire land in this area, and along the national border, with a future vision to incorporating a state/private sector land partnership within the current transboundary park, turning it into a three-nation initiative, and lifting the fence between Namibia and SA. By linking land in Namibia to the very large Kalahari Park, a 3-4% representation of this vegetation type in Namibia would be ecologically viable. In isolation, it would not. The linkage would also hugely promote its marketability and thus is economic viability.

5.10 Conclusion

Land and water management are the key challenges in the semi-arid and arid regions of southern Namibia. There is considerable evidence of environmental degradation. The symptoms, such as overgrazing, loss of biodiversity and woody vegetation, have root causes that generally are to be found in the socio-economic sectors and in policy failures. These range from tenure over land and resources to pricing and economic incentives to policy harmonization between sectors.

In general terms, conventional agriculture has not been conducive to achieving sustainable rural development in the southern arid and semi-arid regions of Namibia. New land uses are becoming preferable, from a number of different perspectives. Wildlife and tourism is being seen as one of the most viable alternatives. It generates more income per hectare, it creates more and higher paying jobs, it allows for diversification and a range of capacity-building directions, it facilitates entrepreneurial skills and small and medium enterprises, and it is generally more environmentally friendly and sustainable. It also uses far less water than does agriculture, and adds considerable value to each cubic meter of water used – generally in the order of 5-15 times more than in all but the highest end of the agricultural sector, e.g. grape production.

6 COMMON ENVIRONMENTAL ISSUES

A synthesis of the environmental issues from Chapters 2 to 5 is indicated in Table 6.1.

The main issues can be divided up into System Drivers and Habitat Response (Figure 6.1).

The major drivers in the Orange River Basin are as follows:

- Altered flow regime or hydrology (dams. Interbasin transfers, Hydro-electrical flow releases, irrigation and mining abstraction)
- Water quality (salanisation due to mines and irrigation diffuse return flows, nutrient build up due to agricultural use of fertilizers and irrigation diffuse return flows)
- Geomorphology (river channel not being scoured due to reduced flood regime and changed seasonal flows)

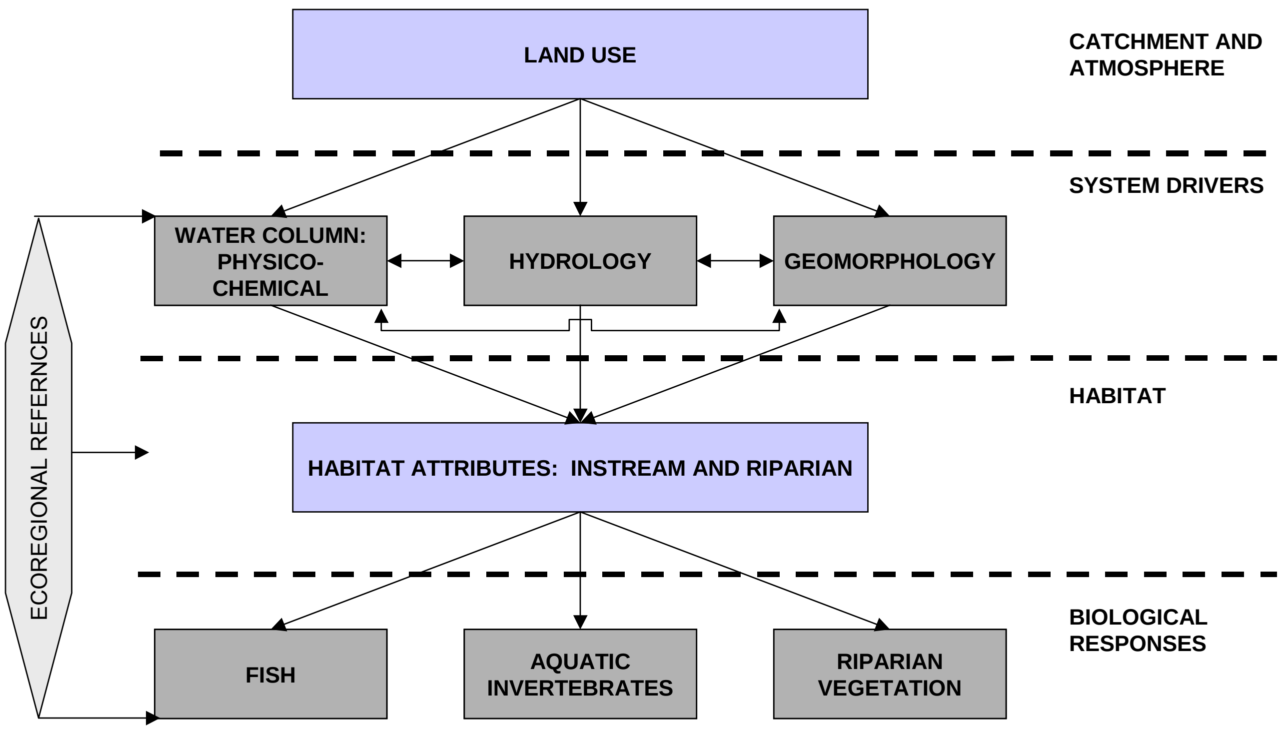

Figure 6-1: Typical habitat drivers and biological response for rivers.

Table 6-1: Major environmental aspects within the different counties of the Orange River basin

Country	Drivers					Response	
	Hydrology			Geomorphology	Water quality	Species diversity	Increased pests
	Flow changes	Flow modifications	Abstractions	Flow modifications			
Lesotho	Interbasin transfers for drinking water supply	Dams for water supply and hydropower		Dams trapping sediments		Habitat inundation by dams	
South Africa	Interbasin transfers for drinking and irrigation water supply	Dams for water storage and hydropower, unseasonable winter flows, reduction in annual volumes, wet and dry seasons reduced, lack of flow variability	Irrigation and mining abstractions	Floods masked by dams reduce scouring and sediment transfer, islands due to sediment deposits, reeds in river, channel encroachment, flood attenuation capacity reduced	Nutrient, temperatures changes, enrichment Salinisation Pesticides	Artificial flows, species threatened, salt marsh lost RAMSAR status	Water hyacinth, blackflies
Botswana			Irrigation abstractions				
Namibia		Unseasonable winter flows, reduction in annual volumes, wet and dry seasons reduced, lack of flow variability		Irrigation and mining abstractions	Nutrient enrichment Salinisation Pesticides	Salt marsh lost RAMSAR status	Blackflies

The major habitat changes are:

- Salt marsh at Orange River Mouth no longer being inundated and consequently RAMSAR status being lost
- Reduced breeding ground or birds
- River channel becoming narrower due to less floods (being captured by dams)
- More reed encroachment into river channel and on islands due to sediment deposition and less flood and high flows

The major biological responses are:

- Greater occurrence of nuisance black flies due to altered flow and greater available habitat for fly breeding
- Greater growth of water hyacinth due to less turbid water and greater nutrients

7 ENVIRONMENTAL FLOWS

7.1 Background to Environmental Flows

International law and regional agreements give these countries a say in whatever developments take place that will impact the flow of shared rivers. South Africa has recently implemented the Ecological Reserve (South African National Water Act, Act 36 of 1998) and Namibia is also in the process of incorporating environmental flows into its river management procedures. Thus, there may exist the need for harmonization of environmental flow procedures and allocations between the countries that share the Orange River (and possibly other river) basins.

An environmental flow is a flow in a river (or wetland) that maintains the ecosystem in a negotiated ecological condition. This condition is decided by society and is normally a compromise between economic, social and ecological values of the water for various uses.

Water is essential to support the Earth's ecosystems. Aquatic ecosystems such as rivers and wetlands are important to people because they provide fish, floodplain grazing land, timber, reeds, wild vegetables, medicine and other goods. They also provide services such as flood protection and water quality improvement, and much of what we call quality of life. In particular, many of the world's poorest people depend directly on the natural resources and services of aquatic ecosystems. For instance, in the case of the Lesotho Highlands Water Project (LHWP), contrary to the expectation of local experts, the affected rivers were found to be central to the lives of 150 000 riparian people in Lesotho alone (Metsi Consultants 2000).

Water is also required for all other human endeavors, and water resource developments invariably impact on the natural flow regime of aquatic ecosystems, with concomitant impacts on the goods and services provided by the ecosystems themselves. Experience has shown, however, that such impacts can be partially mitigated through the implementation of environmental flow releases .

Sustaining Rivers and Livelihoods

The World Commission on Dams recognized the role of environmental flow releases in mitigating the potential negative environmental effects of water resources developments, and recommended that "*large dams provide for releasing environmental flows to help maintain downstream ecosystem integrity and community* *livelihoods and are designed, modified, and operated accordingly*" (Policy Principle 4.5, Strategic Priority 4 - Sustaining Rivers and Livelihoods).

Even the most successful environmental flow programme will only partially mitigate against the effects of a water-resource development. Nothing is gained at no cost – if flow regimes are manipulated, the targeted rivers will change. Society decides, pro-actively or through neglect, the extent of that change (Brown and King 2002a).

Environmental flow assessments links between flow and ecosystem condition are referred to as environmental flow assessments. Such assessments can be done at several levels of detail, from a simple statement of water depth to provide wetted habitat for a valued fish species, to a comprehensive description of a flow regime with intra-annual and inter-annual variability of low flows and floods in order to maintain whole river systems. Early EFAs concentrated on one or more biophysical aspects of river condition, but some more recent EFAs in areas such as SADC, where many people depend on rivers for subsistence, have included socio-economic aspects.

For rivers, environmental flow assessments most often concentrate on representative sites or reaches, where a team of specialists assess the relationships between various aspects of the riverine ecosystem and flow.

There are essentially two approaches to flow assessments: prescriptive and interactive. Methods based on the prescriptive approach usually address a narrow and specific objective and result in a recommendation for a single flow value or flow regime. Interactive approaches, on the other hand, focus on the relationships between changes in river flow and one or more aspects of the river. Once these relationships are established, the outcome is no longer restricted to a single interpretation of what the resulting river condition would be, and the flow assessment team is able to produce a range of possible scenarios, linking the volume and timing of flows to river condition and the provision of various goods and services (Brown and King 2002a). These scenarios provide the decision maker with the impacts and benefits of each scenario, which can be used in deciding water allocations where tradeoffs need to be made between ecosystem protection, protection of resources used by riparian people, and a variety of other off-channel uses of the water, such as irrigation, rural and urban domestic supply and water from industry.

Increasingly, flow assessments are seen as tools in water-resource management that display the wider costs as well as the benefits of developments, allowing more informed trade-offs to be made.

The analysis of environmental flow requirements is based on the premise that river flow is the primary determinant of a number of physical and biological parameters in aquatic and riparian ecosystems. A crucial relationship exists between river flow or discharge (analyzed as a number of components, notably base flows and floods), hydraulics and geomorphology. The volume of flow determines the depth and size of the river and a number of ecological processes are linked to this.

An instream flow requirement (IFR) or Ecological Flow Requirement (EFR) is a description of a modified flow regime, invariably due to the presence of a control structure in the river, such as a dam or weir that is linked to a description of the condition or health of the river that this flow might be expected to produce. Furthermore, because the characteristics of a river change as one moves downstream, flow-ecology relationships change too. One must, therefore, establish different relationships for each affected river reach. Thus, IFR studies focus their analyses on carefully selected IFR Sites, representative of particular river reaches.

It is worth considering the implications of environmental flow releases not only on yield but also on operation costs and expertise required. Information obtained from elsewhere in the world suggests that environmental flows are becoming central aspects of water resource developments and a universal tool for managing water resources. They can be accommodated most cost-effectively through consideration of the following options (after Bird *et al*. 2002):

- EFRs should be brought into consideration early on in the decision making process for proposed water-resource developments (i.e. as early as master planning and pre-feasibility).
- Where possible, dams should be located off the main river channels.
- Dam sites should be located upstream of major tributaries to protect natural flow variability and reduce the onus on the dam to provide EFRs.
- Certain rivers or river reaches should be designated as either sacrificial (can be heavily utilized) and others as sacrosanct (very little water abstraction)
- Dams should allow for the release of large floods, unless situated upstream of large tributaries.
- There should be a provision for EFRs during the filling and construction of dams.
- Real time daily hydrological data should be collected at the inflow into the dam and downstream of it.

- Multiple vertical releases (draw offs) at dams are essential to implement comprehensive environmental flow releases.
- The various water releases from dams should be integrated into an overall environmental flow management strategy that includes water quality.
- Harmonisation of environmental flow procedures and allocations between the countries that share the river basins should be achieved.
- An agreed-on process for decision-making involving parties on a broad basis should be established, where tradeoffs between economics and environmental impacts can be considered and consensus reached on a final environmental flow allocation.
- Procedures for optimisation and implementation of the agreed-on environmental flow allocations should be established.
- Institutional capacity to monitor environmental flows and the resulting river condition, and to practice adaptive management should be established.

7.2 Lesotho and Environmental Flows

All of Lesotho's rivers flow into South Africa and, through the Orange River, onto to Namibia.

The Lesotho Highlands Water Project environmental flow studies were conducted by Metsi Consultants between 1997 and 2002 (see Box 1). These studies used an interactive environmental flow assessment methodology called DRIFT (King *et al*. 2002) and concentrated on six sites each representative of a river reach downstream of the proposed Lesotho Highlands Water Project impoundments, *viz.* (Metsi Consultants 2000):

IFR Site 1 On the Matsoku River near the village of Seshote, representing the Matsoku River from the site of the proposed Matsoku Weir to the confluence with the Malibamats'o River;

IFR Site 2 On the Malibamats'o River downstream of the Katse Bridge, representing the Malibamats'o River from Katse Bridge to the confluence with the Matsoku River;

IFR Site 3 On the Malibamats'o River at Paray, representing the Malibamats'o River from the confluence with the Matsoku River to the confluence with the Senqu River;

IFR Site 4 On the Senqu River at Sehonghong, representing the Senqu River from the confluence with the Malibamats'o River to the confluence with the Tsoelike River;

IFR Site 5 On the Senqu River at Whitehills, representing the Senqu River from the confluence with the Tsoelike River to the confluence with the Senqunyane River;

IFR Site 6 On the Senqu River at Seaka Bridge, representing the Senqu River from the confluence with the Senqunyane River to the Lesotho/South Africa border;

IFR Site 7 On the Senqunyane River at Marakabei), representing the Senqunyane River from the site of the proposed Mohale Dam to the confluence with the Lesobeng River ;

IFR Site 8 On the Senqunyane River upstream of the confluence with the Senqu River representing the Senqunyane River from the confluence with the Lesobeng River to the confluence with the Senqu River

Box 1 Key Statistics of the LHWP Environmental Flow Assessment* (from Brown and King 2002b)

Client: Lesotho Highlands Development Authority

Consultant: Metsi Consultants (Joint Venture: Southern Waters ER& C and SMEC International).

Study area: 5980 km^2 (a 10-km wide corridor along 568 km of river).

Study rivers: Senqu, Malibamatso, Matsoku and Senqunyane Rivers.

Rural population using the study rivers for subsistence: 150 000 people.

Number of reports produced: 22

The dataset of consequences of flow change for the study rivers and for the people reliant on the resources provided by the rivers allowed for the initial development of four scenarios ranging from Minimum Degradation (c. 60% of the mean annual runoff remaining in the river) to Treaty releases (c. 3-5% of the mean annual runoff remaining in the river). An additional set of scenarios (based on the original dataset), and more detailed information on compensation and mitigation of possible impacts on riparian people were compiled as part of a second phase study, LHDA No. 678.

The environmental flows finally agreed on for the Lesotho Highlands Water Project followed a prolonged period of negotiation between the Lesotho Highlands Development Authority, the Governments of Lesotho, South Africa and Namibia, various other interested and affected parties and the World Bank. The agreed-on environmental flows concentrated on the river reaches immediately downstream of Phase 1 structures, *viz.* IFR sites 1, 2, 3 and 7, and represented between 10 and 40 % of the mean annual runoff at those sites.

The reports for the Lesotho Highlands Water Project study (LHDA 648 & 678) have been made available to the public and can be obtained from LHDA in Maseru, the LHDA website or the Southern Waters website.

7.2.1 The potential implications of environmental flow requirements for further Lesotho water projects?

It is almost certain that some form of environmental flow requirements assessment will be required for the Lesotho Lowlands Study once specific options have been chosen and for Phase II of the Lesotho Highlands Project (if either of these studies take place). However, it is also likely that some of the information already generated for the Lesotho Highlands Water Project could be used to good effect, particularly that for the sites situated on the middle and lower Senqu River. Indeed, for any water resource developments on the mainstem of the Senqu, Senqunyane or Malibamatso Rivers, relevant environmental flow studies have been completed and, provided permission to use the data were forthcoming from LHDA, they would require relatively little updating and adjustment for use in the Lesotho Lowlands study.

Should other aquatic ecosystems be targeted for proposed water resource developments as part of further phases of the Lesotho Water Projects, then they will also require environmental flow assessment.

7.3 South Africa and Environmental Flows.

The Water Law Principles of South Africa (1996) clearly set the direction of the future of water resources management. The twin threads of sustainability and equity run through the Principles, the National Water Policy of 1997 and the National Water Act (NWA, Act 36 of 1998). The key to balancing sustainability and equity lies in the provisions for the Reserve, and in our ability to quantify a Reserve, as well as to manage water uses so as to meet the Reserve.

The NWA is founded on the principle that National Government has overall responsibility for and authority over water resource management for the benefit of the public without seriously affecting the functioning of the natural environment. In order to achieve this objective, Chapter 3 of the NWA provides for the protection of water resources through the Reserve for water resources.

The move to integrated management of water resources, on an ecosystem basis, requires the introduction of a new set of tools for resource management, tools that are flexible, protective and can take account of extreme differences within South Africa, both in socio-economic conditions, and in natural variability of aquatic ecosystems. The move to resource management has been a gradual one over the last ten years, driven by need, as South Africa approached the limits of new development of water resources and was forced to begin a shift to careful management of existing available resources. To support this change, new tools and new ways of making decisions have been under development within the Department of Water Affairs and Forestry (DWAF) and within other agencies responsible for natural resource management. In response to requirements for environmental impact assessment, and as a result of the Department's commitment to follow the Integrated Environmental Management procedure in planning and implementation of major water resources developments, a considerable amount of effort within the South African scientific community was focused on finding ways to assess the water requirements of aquatic ecosystems (Ecological Water Requirements (EWR) and Estuarine Flow Requirements (EFR).

Since 1998, the Department of Water Affairs and Forestry (DWAF) has investigated the development of methods to determine the Ecological Reserve for rivers.

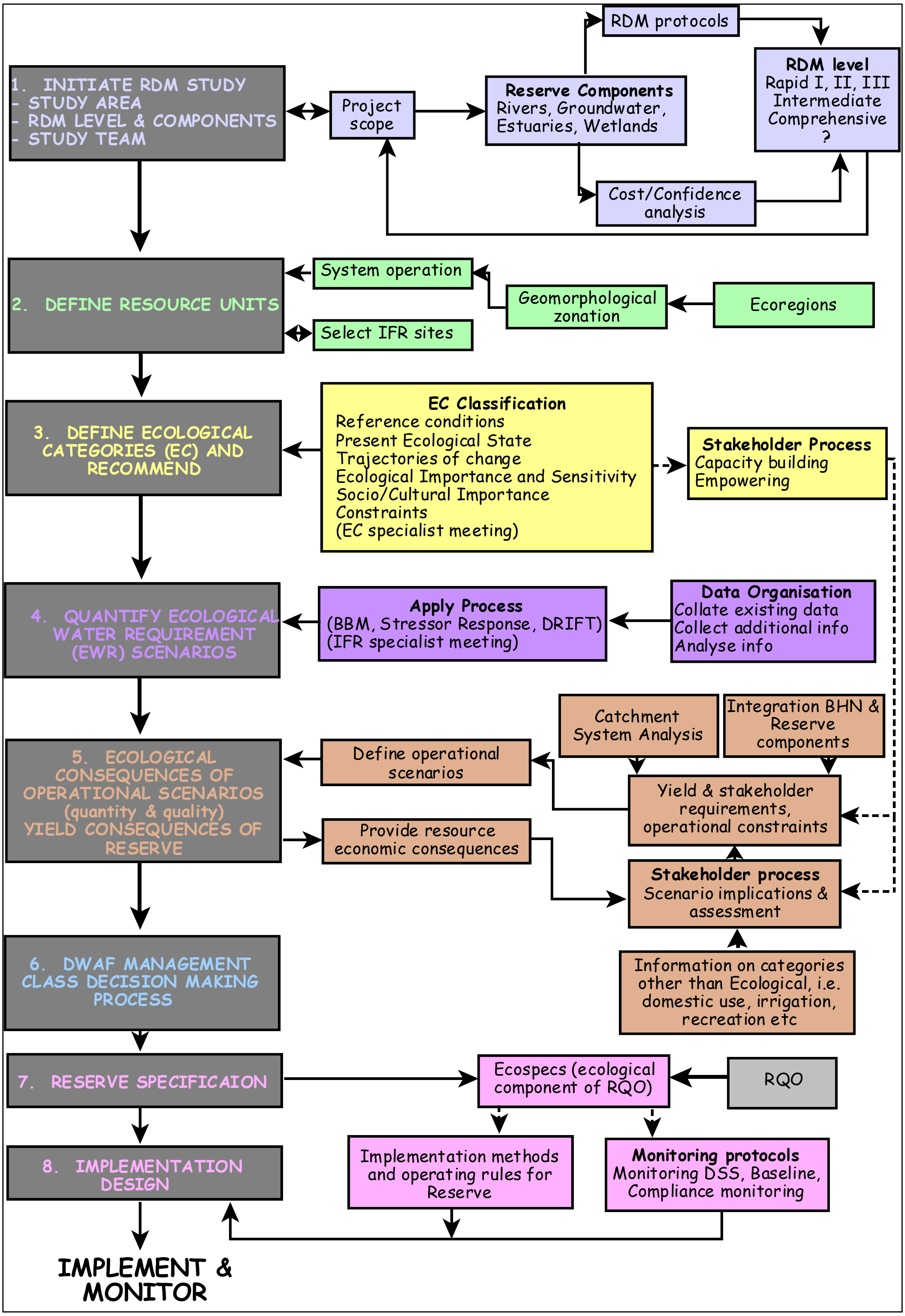

Figure 7-1: The 8-step Reserve process as used in South Africa

The Directorate: Resource Directed Measures (D: RDM) of DWAF is tasked with the responsibility of ensuring that the Reserve requirements, which have priority over other uses in terms of the NWA, are determined before license applications are to be processed. There are several stressed catchments where applications for licensing have been received by the D: RDM. The available water resources cannot meet all the water requirements of the users in these catchments, without trade-off among water user sectors. DWAF has identified these stressed catchments where it will be desirable in the near future to undertake compulsory licensing.

It is important to note that in the South African context the following key RDM component need to be addressed:

- Ecological Water Requirement Scenarios. In order to provide EWR scenarios, an ecological classification process must be applied. This will provide a range of Ecological Categories for which flow scenarios can be developed as well as a recommended Ecological Category.
- Resource Quality Objectives includes various aspects other than ecological.
- Basic Human Needs Reserve (amount of water required within a catchment for basic human needs)
- Socio-economic assessment (place a value on water usage so as to compare different water usages in terms of economic contribution to the catchment).

7.3.1 Process for Reserve studies

Ecological Water Requirement (EWR) methods have been designed and tested for South African circumstances since the late 1980s. With the inclusion of EWRs in the form of the Reserve in the National Water Act (No 36 of 1998), specific developments were initiated to tailor-make existing tools to conform to Reserve requirements as well as to develop new methods/tolls where necessary.

EWR methods consist of the application of various tools. To comply with the requirements for determining the Reserve, this work must be undertaken within the context of a Reserve determination process. The Reserve determination process consists of an 8-step procedure (Figure 7.1). (Louw & Hughes, 2002).

The following process (Figure 7.1 modify DWAF 2002) is used to undertake Ecological Flow Requirement studies in South Africa:

- A set of Ecological Water Requirement (EWR) scenarios is generated to test through the application of a yield model. Each scenario represents a possible flow regime, intended to have specific outcomes linked to the Reserve. Scenarios specify how much water is required, where and when, and take cognizance of the likely water quality consequences.
- Based on the impacts of the EWR scenarios a set of flow scenarios, called Operational Scenarios, is generated and tested. These scenarios are realistic scenarios as impacts on users and constraints such as outlet sizes of dams are considered. Decision makers will select one of these scenarios as the Reserve.
- The likely impact of the Operational Scenarios on the available yield is determined.
- The likely impact of the Operational Scenarios on the aquatic ecology is determined.
- The likely economic impact of selected Operational Scenarios is determined.

The likely impact of selected Operational Scenarios on the Goods and Services provided by the riverine system is determined.

7.3.2 South African Environmental flows studies to date

The Orange River catchment within South Africa covers many Water Management Areas (WMA's, Figure 7.2) and quaternary catchments (Figure 7.3).

To date, in order to process licence applications many desktop and rapid (low confidence) as well as some intermediate Reserve determinations have been undertaken in the Orange River catchment within South Africa (Table 7.1). None of these studies have been undertaken on a broad river reach and they have mainly been undertaken on a quaternary basis. No comprehensive or high resolution (high confidence) Reserve has been undertaken with the Orange River catchment to date.

The roll out of DWAF policies as part of the National Water Act (Act 36 of 1998) should ultimately enable the Orange River Basin to be optimally managed and water allocated on a more ecologically sustainable manner. Further pressure will be brought to bear on the management of the Orange River Basin (and especially the Upper Orange River) by the continued requirements of the international obligations of neighboring states.

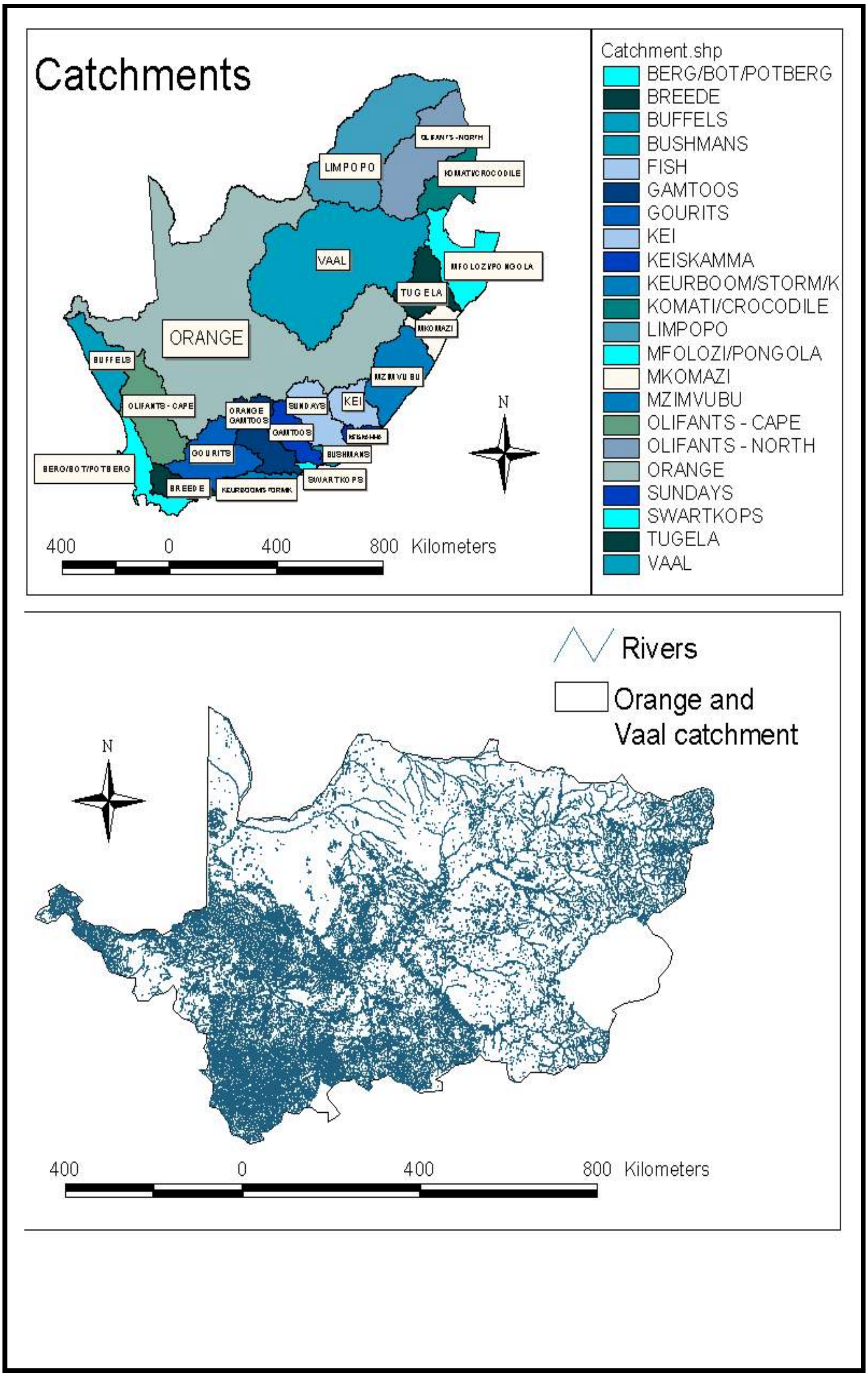

Figure 7-2: Water Management Areas and the river systems in the Orange River catchment area

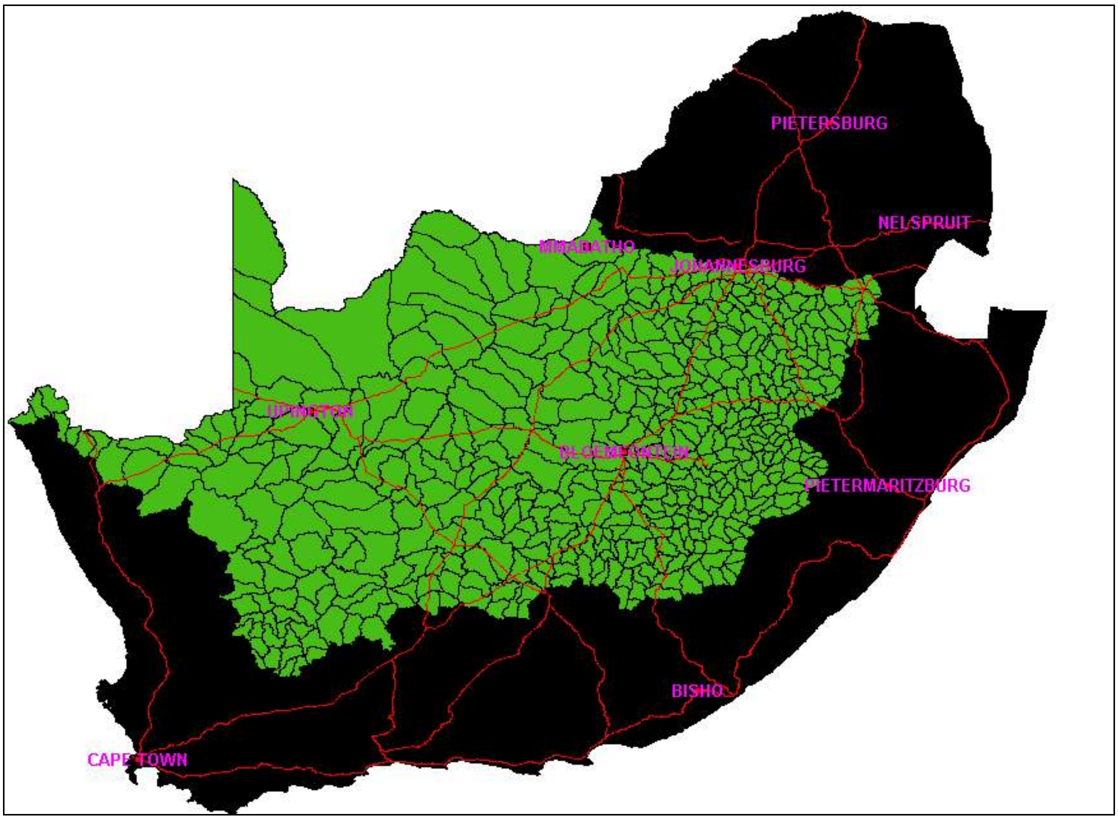

Figure 7-3: Orange and Vaal River quaternary catchments

Table 7-1: List of all DWAF reserve studies that have been undertaken on the Vaal and Orange River catchments

Quat	ID	Compartment	WMA_Description	SurfaceWaterResource	GWaterResour	QuantityLevel	QualityLvl	ECQualit	ECQuant	LinkQuats	PESC	RDApproved	TERTIARY	SECONDARY
C11E	147	River	Lower Vaal	Vaal River		Rapid 1	Desktop				C	12-Mar-02	C11	C1
C11F	148	River	Upper Vaal	Brummerspruit		Desktop					C	31-Aug-01	C11	C1
C21E	164	Groundwater	Lower Vaal		River	Rapid 1						14-Feb-03	C21	C2
C22B	164	Groundwater	Middle Vaal		River	Rapid 1						25-Mar-04	C22	C2
C22C	166	River	Middle Vaal	Vaal River		Rapid 1					D	27-Feb-02	C22	C2
C22D	170	River	Lower Vaal	Vaal River		Rapid 1					D	28-Mar-01	C22	C2
C22F	138	River	Lower Orange	Orange River		Desktop						12-Apr-01	C22	C2
C22H	230	River	Upper Vaal								C	16-Oct-00	C22	C2
C23E	232	River	Lower Vaal	Vaal River		Rapid 1					C	16-Oct-00	C23	C2
C24C	60	River	Upper Vaal	Suikerbosrand River									C24	C2
C24F	227	Groundwater	Upper Vaal		Vaal River	Rapid 1			C		C	14-Dec-01	C24	C2
C24F	228	River	Lower Orange	Riet River		Rapid 1					B	31-Aug-01	C24	C2
C24J	237	River	Lower Orange									31-Aug-01	C24	C2
C25D	239	River	Lower Orange									31-Aug-01	C25	C2
C25E	241	River	Middle Vaal	Vaal River		Rapid 1					D	05-Jun-01	C25	C2
C25E	249	Groundwater	Middle Vaal		Vaal River							06-Jul-01	C25	C2
C31A	251	River	Middle Vaal	Makwassiespruit		Desktop	Desktop				C	21-Nov-01	C31	C3
C31F	257	River	Lower Vaal									31-Aug-01	C31	C3
C42E	259	River	Lower Vaal									31-Aug-01	C42	C4
C42H	260	River	Upper Vaal	Vaal River		Rapid 1			D		D	14-Dec-01	C42	C4
C42K	260	Groundwater	Upper Vaal	Vaal River		Rapid 1	Rapid 1					31-Aug-01	C42	C4
C42L	262	River	Upper Vaal	Blesbokspruit River		Desktop				C21F	C	25-May-01	C42	C4
C51E	271	Groundwater	Upper Vaal			Desktop						31-Aug-01	C51	C5
C51G	265	River	Lower Orange	Orange River		Rapid 1					A/B	21-May-01	C51	C5
C52C	270	River	Lower Orange	Orange River		Intermediate	te				D		C52	C5
C52D	272	River	Lower Orange			Intermediate	te					31-Aug-01	C52	C5
C91A	313	River	Upper Vaal	Klipspruit River	Klipspruit River	Rapid 1	Rapid 1				D	01-Jul-01	C91	C9
D12F	82	River	Upper Vaal	Waterval River		Desktop	Desktop				C	05-Feb-02	D12	D1
D13M	70	Groundwater	Middle Vaal			Desktop						23-Jul-04	D13	D1
D14H	102	River	Lower Orange	Annis River		Rapid 1					D	31-Aug-01	D14	D1
D18B	79	River	Lower Orange										D18	D1
D18E	82	River	Upper Vaal	Waterval River		Desktop	Desktop				C	05-Feb-02	D18	D1
D22A	102	River	Lower Orange	Orange River		Rapid 2	Rapid 2				D	31-Aug-01	D22	D2
D23D	343	River	Upper Vaal	Blesbokspruit River									D23	D2
D31E	352	River	Lower Vaal			Intermediate	te				D	31-Aug-01	D31	D3
D32K	352	River	Lower Orange	Orange River		Rapid 2					D	31-Aug-01	D32	D3
D34G	358	River	Lower Vaal							C91E		12-Mar-02	D34	D3
D35G	359	River	Lower Vaal							C91E		12-Mar-02	D35	D3
D35H	360	River	Lower Vaal							C91D		12-Mar-02	D35	D3
D41C	364	River	Lower Orange	Orange River						D73B		31-Aug-01	D41	D4
D41D	364	River	Lower Orange							D73B		31-Aug-01	D41	D4
D41D	364	River	Lower Orange	Orange River						D73B		31-Aug-01	D41	D4
D41G	365	River	Lower Orange	Vaal River		Desktop					C/D	31-Aug-01	D41	D4
D41J	369	River	Upper Orange	Kraai River		Desktop					B/C	14-Sep-01	D41	D4
D42C	366	River	Lower Orange	Vaal River		Desktop						31-Aug-01	D42	D4
D56A	374	River	Lower Orange	Orange River		Rapid 1	Rapid 1					31-Aug-01	D56	D5
D56B	375	River	Lower Orange	Orange River		Desktop					D	31-Aug-01	D56	D5
D57E	375	River	Lower Orange	Orange River		Desktop					D	31-Aug-01	D57	D5
D58A	376	River	Lower Orange	Orange River		Desktop					D	31-Aug-01	D58	D5

7.3.3 The Lower Orange River Management Study (LORMS)

A study focussed on the river reach of the Orange River between Augrabies and Onseepkans, was undertaken in 2005 known as the Lower Orange River Management Study (LORMS) (DWAF 2005). Specialists also contextualized their information within the wider LORMS study area (i.e., from the confluence of the Vaal to the mouth of the Orange River). The text in this section is a summary of some of the findings of the LORMS study (DWAF 2005).

Social/Environmental Demands provided the outcome of the comparison between the 1996 estimates for the instream flow requirements for the Orange River (DWAF 2005) and those obtained from the Desktop Model using the latest hydrology. If the Ecological Flow Requirements (EFR) had to be supplied from which Vanderkloof Dam (the last major structure on the Orange River main stem), then implementing the EFR would be problematic. Using the river as a conduit for irrigation water creates ecological problems related to unnaturally high and stable flows in the river. Using the environmental flow estimates of either the Orange River Replanning Study (ORRS) or the Desktop for planning purposes in LORMS may not be appropriate or feasible, and it was recommended that the relationship between the current flow regime in the river and the EFR recommended by the Desktop Model be examined, and that where appropriate, recommended flows be revised.

Table 7.2 is a summary of the Present Ecological Status (PES) for each of the disciplines considered for the river in the environmental flow tasks. In general, the ecological condition of the river is deemed to be on a negative trajectory, with all disciplines expecting a one-category deterioration in condition in the next twenty years. River systems function as an integrated whole, and changes made in one part of a system will inevitably lead to changes in another part, and so it is unsurprising that the disciplines predict similar trends.

Table 7-2: Summary of the Present Ecological Status (PES) for each of the disciplines considered, their predicted trajectory of change for 20 years and an indication of whether these changes documented/expected are related to changes in the flow regime of the Orange River. Colour codes are provided in the key (DWAF 2005).

Discipline	PES	Trajectory	20-year prediction	Flow-related	Non flow-related
Water quality	B/C - Category	Negative	C/D - Category	No	Yes
Geomorphology	C- Category	Negative	D - Category	Largely	Channel manipulation - levees
Algae	D - Category	Negative	E/F - Category	Partly - not flushed	Partly - imported from u/s
Vegetation	D - Category	Negative	E - Category	Some	Predominately
Macroinvertebrates	D - Category	Negative	D/E-Category	Some	Predominately
Fish	D - Category	Negative	D/E-Category	Partly	WQ also
Overall	D - Category	Negative	D/E-Category	ONLY PARTLY	Predominately

Category	A	B	C	D	E/F
Colour used					

The most important aspects of the flow regime for maintaining or improving the current ecological condition are reinstating the winter low flows (i.e., reducing current flows) and the November freshet. The flow-related contribution factors identified were:

- unseasonable winter releases;
- lack of very low flow periods;
- lack of the November freshet;
- reduction in water volume;
- reduction in wet and dry season inter-annual floods; and
- lack of flow variability.

The extent to which the negative trajectory can be halted will depend on the degree of variability that can be managed in the system, as well as issues other than flow, and cannot be assessed in this task. This variability will include:

- reinstatement of year-on-year variability;

- provision of intra-annual floods; and
- capping of winter releases.

The recommended category for a Comprehensive Reserve Determination would most likely be a C-Category.

The main reasons for this negative trajectory are the deviation from the natural flow and deterioration in water quality. Flow changes, as a result of river regulation, are considered to be the major culprit. The aspects of the flow regime causing a decline in the river's condition include:

- the absence of seasonal natural flow patterns;
- the absence of minor to medium maintenance floods; and
- higher winter volumes for hydropower generation.
- It should be kept in mind that ±98% of the Orange River's runoff, including the bigger bulk of these maintenance floods, is generated in the system's upper catchment, above the major dams within the SA borders.

Table 7-3: Summary of the Present Ecological Status (PES), The Predicted Trajectory of Change for 20 Years and an Indication of whether These Changes Documented/Expected are Related to Changes in the Flow Regime of the Orange River.

Discipline	PES	Trajectory	20-year prediction	Flow-related	Non flow-related
Water quality	B/C - Category	Negative	C/D - Category	No	Yes
Geomorphology	C- Category	Negative	D - Category	Largely	Channel manipulation - levees
Algae	D - Category	Negative	E/F - Category	Partly - not flushed	Partly - imported from u/s
Vegetation	D - Category	Negative	E - Category	Some	Predominately
Macroinvertebrates	D - Category	Negative	D/E-Category	Some	Predominately
Fish	D - Category	Negative	D/E-Category	Partly	WQ also
Overall	D - Category	Negative	D/E-Category	ONLY PARTLY	Predominately

Category	A	B	C	D	E/F
Colour used					

The changes to the Flow Regime Most Likely to have contributed to Present Ecological Status are as follows:

There has been a reduction in the volume of water flowing down the Orange River, *viz.* natural Mean Annual Runoff (nMAR) = *c.* 10 587.30 MCM (median *c.* 5 100 MCM) and 2005 Mean Annual Runoff (2005MAR) = *c.* 4 382.12 MCM (40% nMAR). In general, relationships between reductions in nMAR from elsewhere in South Africa and ecological condition of the affected riverine ecosystem show strong correlations, particularly when this is accompanied by a change in the natural distribution of flows. However, much of the reduction in ecological condition in the LOR can be attributed to mechanical manipulation of the riverbanks and floodplain.

The most important aspects of the flow regime for maintaining or improving the current ecological condition are reinstating the winter low flows (i.e., reducing current flows) and the November freshet. In summary, the flow related contribution factors identified were:

- unseasonable winter releases;
- lack of very low flow periods;
- lack of the November freshet;
- reduction in volume;
- reduction in wet and dry season inter-annual floods; and
- lack of variability.

It was the consensus opinion of the LORMS study (DWAF 2005) that a **Comprehensive Reserve/EFR Determination on the LOR** should be undertaken as a matter of priority.

Furthermore, the Study Team stressed the importance of controlling mechanical manipulation of the river bed, banks and floodplain, as these factors are major contributors towards the decline in the condition of the riverine ecosystem and, together with changes to the flow regime, will eventually lead to its complete collapse

7.4 Botswana

The Molopo River Basin (Nossop River Basin included), which forms part of the northern portion of the Orange-Senqu River Basin, is located in the southern part of Botswana with an area of approximately 71,000 square kilometers (Figure 4.1). The Molopo and Nossop are the major rivers in the Basin and they form part of the international boundary with the Republic of South Africa. These rivers are highly season and their flow is dependant on good summer rains. In general there are no longer flows in the rivers of the Basin.

The Botswana Water Act (Act 34.01) intends to define ownership of any rights to the use of water and to provide for grant of water rights and servitude. Water in rivers, streams, lakes, pans, swamps or beneath a watercourse or underground water and in works such as canals, reservoirs and dams is public water. The use of such water can only be with permission granted by the Water Apportionment Board in the Department of Water Affairs. Application for the water user rights to the Board is done through the Water Registrar who shall issue a certificate. The Act bars pollution of public water with any matter derived from such use likely to cause injury either directly or indirectly to public health, livestock, animal life, fish, crops, orchards or gardens which are irrigated by such water or to any product in the processing of which such water is used. The holder of a water right is obligated to take precautions to prevent accumulations in any river, stream or watercourse of silt, sand, gravel, stones, sawdust, refuse, sewage, waste or any other substance likely to affect injuriously the use of such water. A holder of water right who contravenes the Act shall be guilty of an offence and liable to a penalty under the Act.

Environmental flows are not a high priority for the highly seasonal rivers of Botswana that flow into the Orange River.

7.5 Namibia

Namibia is also in the process of incorporating environmental flows into its river management procedures. Namibian scientists and conservationists were observers on the LORMS study (DWAF 2005) and concurred with the consensus opinion that a Comprehensive Reserve/EFR Determination on the LOR should be undertaken as a matter of priority.

7.6 Possible international implications related to environmental flows

South Africa and Namibia are situated downstream of the Lesotho and Botswana. Southern Africa has recently implemented the Ecological Reserve (SA Water Act 1998) and Namibia is also in the process of incorporating environmental flows into its river management procedures. Thus, there may exist the need for harmonisation of environmental flow procedures and allocations between the countries that share the Orange River (and possibly other river) basins.

At this stage no transboundary or international studies using this methodology have been undertaken within the Orange River basin. The principles of environmental flows have been exhaustively applied in Lesotho for Phase 1 dams and rivers (Brown and King 2002) and South Africa. No detailed or comprehensive Reserve studies have been undertaken on the Orange River or Vaal River to date in South Africa. DWAF is in the process of commissioning a comprehensive Reserve for the Vaal River system which should begin in 2006.

The Orange River Environmental Flow Requirements should be undertaken as a matter of priority at a comprehensive or detailed level. This study should be undertaken under the banner of ORASECOM and must include all of the countries. Despite the different water legislation in the Orange River Basin countries the basic principles of environmental flows are internationally accepted and can be applied across shared water courses. It is important that this study include the following aspects at the onset of the study:

- Agreement on the Environmental Flows methods to be used
- Full participation of all countries and their scientists and regulators in the process
- A inclusive public participation process throughout the study (including public education and awareness)
- Socio-cultural and socio-economic assessments to run concurrently with the EFR study

In conclusion, cultural and ecological issues are now globally taking the same level of importance as engineering and economic issues, with cost implications for projects. Many schemes might become far less viable than originally assumed with these new aspects included.

8 DATA AVAILABLE AND GAPS

A list of the data available, including Geographical data, is in Appendix B. **The following is a list of information gaps**

It is difficult to put together a definitive list of information gaps on any subject, because there are different perspectives, different degrees of detail and different information needs at different times. The task is, essentially, as long as a piece of string. However, the following list identifies some of the more important information gaps based on recent socio-economic and biophysical participatory assessments, LORMS study (DWAF 2005) and literature reviews.

- **Holistic management of the Orange River Basin:** the flows that go to sea at the Orange River mouth should be managed in an integrated manner starting with environmental flow releases from Lesotho, the Vaal River system as well as in stream dams along the length of the Orange River. The Orange River mouth salt marsh losing its RAMSAR status is mainly due to the altered flows due to dams in the system. The ORASECOM initiative is an excellent starting point for the holoitic management of the Orange River Basin's flows.
- **Environmental flows method to be confirmed for the Orange River Basin**: at present there is not agreed upon environmental flow assessment method for the Orange River basin. Lesotho and South Africa have applied slightly different methods for environmental flows but these methods are not fundamentally different and recent research has shown that the results from these methods are statistical. In addition, a single methodology should be applied to both the river and the estuary. Currently, two different methodologies are used, but the interface between the two is now improving. It is critically important that a comprehensive or high level of confidence Environmental flows study is undertaken for the Orange River Basin. This full assessment requires better data (including low flow information). Thus, a focused monitoring system should be established to provide the necessary information, for a period of two years. It is planned that the Vaal River system will undergo a comprehensive Reserve (environmental flows) study from 2006 to 2008. This study needs to be extended to include the whole Orange River basin.
- **Water flow monitoring in the lower Orange River**: the flow gauging system in this section of the basin is inadequate. This is particularly true for low flows,

where existing data is unreliable. This information is needed (and low flow info is particularly important) for environmental flow management. Good flow gauging stations need to be established that provide reliable data during low flow periods. These gauging stations need to be monitored. Historic data needs (as far as possible) to be adjusted, based on the results from the new gauges.

- **Environmental needs of the lower Orange River**: a preliminary environmental flow requirement assessment of the lower Orange River and estuary (river mouth) has been done. A comprehensive assessment is now needed. This full assessment requires better data (including low flow information). Thus, a focused monitoring system should be established to provide the necessary information, over a period of two years. In addition, a single methodology should be applied to both the river and the estuary. Currently, two different methodologies are used, which do not interface particularly well, and the client is often left having to manage the interfacing.
- **Environmental economics data for the whole Orange River**: a preliminary set of environmental accounts have been developed for the Orange River some 5 years ago. These need to be updated and refined. Of particular relevance is a good understanding of the value of water and its use, including (a) basic human needs and ecological needs, particularly with regard to the ecological services that water provides; and (b) value-adding for different water uses. This exercise should go further, to investigate how a “water stock exchange” could be established, so that water quotas could be traded, thereby creating a mechanism that would, at the same time (i) create optimal value for water, so that it became (over time) used for the most value-adding and strategically important activities, and (ii) it became viewed as a high value commodity and was not wasted (i.e. creating policy incentives for “water demand management”).
- **Environmental water flow requirements of the Fish and other ephemeral rivers**: while there are methodologies in place (which have been well tested) to determine environmental flow requirements of perennial river basins, there are no clear mechanisms to determine environmental flows for ephemeral systems. It is important that this issue be addressed, for the Fish River (because of its periodically significant contribution to the Orange River mouth, as well as for the optimal management and development of the Fish River system), as well as for some other, more arid systems which contribute little of

nothing to the Orange (e.g. Nossob / Auob), but which have important groundwater aquifers used for domestic and agricultural purposes. A current Water Research Commission Project is being funded in South Africa to address the issue of how to determine environmental flows for ephemeral rivers. Similarly the Department of Water Affairs and Forestry in South Africa has developed a prototype method for a groundwater reserve determination.

- **Agricultural return flows, and more efficient irrigation**: the environmental flow work done to date on the lower Orange river and on the mouth have shown that the degraded condition of the system is only partly a result of the severely altered hydrology of the system. A large contributing factor results from out-of-river management. One of the more immediate concerns is the poor management practices of some of the irrigated cultivation in the Orange River valley. Cultivation is too close to river banks. Excessive irrigation occurs, resulting in return flows carrying pesticides and fertilizers into the river. Improved farming methods and management practices need to be implemented, and closer monitoring and regulation is required.
- **Socio-economic conditions around informal settlements**: new projects along the lower Orange River, e.g. prospecting and mining, grape and other farming, have resulted in informal settlements becoming established. People arrive with the hope of work, and/or people are employed on a highly seasonal basis (e.g., grape picking) and remain in the area, in informal settlements, throughout the remainder of the year with no formal income. This results in high pressure on local resources (e.g. riparian woodlands stripped for timber for building informal houses and for energy; fishing in river, using fine mesh nets (even mosquito nets) and thus stripping the fish resources), and uncontrolled domestic stock entering protected areas and overgrazing the river banks and floodplains – all leading to severe environmental degradation. It also results in social degeneration, with poor housing, no adequate schooling and medical care, escalating poverty, illegal border crossings and transfer of goods, prostitutions, escalating incidents of HIV/Aids, etc. There is little information available on this rapidly changing and expanding situation, and even less decisive action. It is important that the situation be properly understood, and that some clear development plan is implemented to address the situation before it spirals out of control.
- **Better understanding of a dam at Vioolsdrif**: the lower Orange River management study recommended that a storage come re-regulating dam

should be considered at Vioolsdrif. The impacts (both positive and negative) need to be better understood, so that these may be optimized and mitigated for, respectively. Some of the information needs would include:

- The likely water quality profile of the proposed dam option, particularly with regard to the potential for algal growth, which will affect the reservoir itself and the downstream environment;
- Changes in the thermal stratification and its likely effects on the downstream aquatic biota: fish spawning and growth; flowering times, growth rates and size at maturity of riparian vegetation;
- The extent of riverine habitat (including the riparian zone) likely to be inundated, and its availability outside of the various inundation zones;
- Movement of fish past the barrier;
- Invasive aliens, e.g. black fly;
- As yet unidentified impacts such as water quality effects linked to the underlying geology;
- Extent to which large floods will flush pollution from existing and proposed operations, including mining operations, into the dam
- Detailed archaeological impacts;
- Socio-economic impacts (e.g. informal settlements, potential impact of disease, such as bilharzias, and possibly expansion of malaria linked to climate change) and economic opportunities (e.g. fish farming, tourism), etc.

Impact of climate change on security of water supply and hydrology of the system. The impacts of climate change need to be monitored and the security of water supply needs to be planned for The common management of the Orange River Basin across international boundaries will go along way to improving the understanding and water needs of the countries and regions.

9 RECOMMENDATIONS AND CONCLUSIONS

The Orange River originates in the Lesotho Highlands and flows in a westerly direction 2 200 km to the west coast where the river discharges into the Atlantic Ocean. Four countries share the Orange River Basin. Each of these countries have different rain falls with Lesotho the main supplier of water to the Orange River, followed by South Africa. Botswana and Namibia's rivers are highly seasonal (if at all) and consequently have a small contribution to the MAR of the Orange River basin.

Each country within the Orange River Basin has its own water management legislation as well as their own water demands or stressors. It is therefore pressures or drivers that contribute to the environmental issues within the Orange River.

The environmental issues associated with the Orange River are directly related to the anthropogenic use of the water. The major impact is due to the altered flows of the Orange River due to man reallocating this water for uses outside the catchment, for hydro-power, agricultural and mining use. As a result the river's ecological integrity has been compromised to such an extent that the current flow regime has resulted in the loss of biodiversity, nutrient enrichment, increasing salt loads and nuisance plants and animals.

In order to manage the Orange River basin's environmental aspects in a holistic manner the ORASECOM initiative must continue to promote the use of environmental flow requirements. A comprehensive environmental flow study should be undertaken for the Orange River. This will include the existing study that has been undertaken in Lesotho for Phase 1 as well as the comprehensive study to be undertaken for the Vaal River system (2006 to 2008). It is important that all the countries within the Orange River basin are part of this study and that the appropriate socio-economic assessments and public participation takes place concurrently with the environmental flows study.

The following **recommendations** are suggested:

- The holistic management of the Orange River Basin (source to sea) should be promoted through ORASECOM;
- The data collected in each country (water quality, flow, GIS etc) should be collated and stored in a standardized format that will allow way easy exchange between countries;

- ORASECOM initiative must continue to promote the use of environmental flow requirements (and appropriate methods for all countries and rivers);
- Environmental water flow requirements of the Fish and other ephemeral rivers should be determined;
- Appropriate socio-economic assessments and public participation takes place concurrently with the environmental flows study;
- The flow monitoring in the lower Orange River is inadequate and should be addressed; and
- Agricultural return flows, and more efficient irrigation should be studied as results to date have shown that the degraded condition of the Lower Orange River is only partially as a result of the severely altered hydrology of the system.

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LHDA-F-09). See item 154.609.

S. Ferreira, N. Jacobsen. *Specialist report - volume 1: wildlife and birds; volume 2: herpetofauna.* (November 1999), xii + 87pp.; viii + 31pp. (Report no. LHDA-F-19). See items 223.603, 163.334 (Ferreira) and 165.360 (Jacobsen).

S. Yance, H. Sabet. *Specialist report - water supply.* (November 1999), vii + 42pp. (Report no. LHDA-F-11). See item 236.598.

678 Contract 678: Additional Scenarios and Production of a New Final Report to Augment Consulting Services for the Establishment and Monitoring of the Instream Flow Requirements for River Courses Downstream of LHWP Dams.

[Maseru]: Metsi Consultants (June 2000), 5 different bound volumes, of which 4 volumes belong to a single numbered report.

The Contract for Additional Scenarios and Production of a New Final Report to Augment Consultancy Services for Establishing and Monitoring Instream Flow Requirements Downstream from LHWP Dams was awarded to Metsi Consultants, a joint venture of Southern Waters Ecological Research and Consulting Pty Ltd (South Africa); and Snowy Mountains Engineering Company (SMEC) International Pty Ltd (Australia). The contract is essentially a continuation of Contract 648, and it produced two numbered reports as follows:

H. Sabet, C. Brown, S. Hirst. *Final report: summary of main findings for Phase 1 Development.* (June 2000), viii + 44pp. + annexes totalling 8pp. (Report no. LHDA 678-F-01). See item 233.608.

H. Sabet, S. Yance, C. Brown, P. Martel, M. Majoro. *Analysis of the Minimum Degradation, Treaty, Design Limitation and Fourth Scenarios for Phase 1 Development.* (June 2000), 4 vols. (Report no. LHDA 678-F-02). See item 233.609.

Environmental flows Lesotho

Contract 648: Consulting Services for the Establishment and Monitoring of the Instream Flow Requirements for River Courses Downstream of LHWP Dams.

[Maseru]: Metsi Consultants (November 1999, June 2000), 28 different bound volumes, of which 5 volumes comprise 2 ‘volumes’ bound together as a single report.

The Contract for Consultancy Services for Establishing and Monitoring Instream Flow Requirements Downstream from LHWP Dams was awarded to Metsi Consultants, a joint venture of Southern Waters Ecological Research and Consulting Pty Ltd (South Africa); and Snowy Mountains Engineering Company (SMEC) International Pty Ltd (Australia). For this project, reports are numbered LHDA 648-F-XX, where XX runs from 02 to 23. Some of these reports (notably 03, 12, 14, 16, 19) contain two volumes on different topics bound together, while report 13 is in 6 separate volumes. The number 01 was apparently allocated for the Inception Report, which has not been seen. Apart from the Inception Report, there are 22 final reports bound in 27 parts, covering 27 topics. The individual reports and the sections in the bibliography where they can be found area as follows:

J. King, H. Sabet, C. Brown, S. Hirst. *Final report: summary of main findings.* (June 2000), x + 74pp. + 5 annexes totalling 15pp. maps. (Report no. LHDA 648-F-02). See item 233.592.

C. Brown, J. King. *Project structure, vol. 1: terms of reference, study area and programme of events; vol. 2: IFR methodology.* (April 2000), vi + 27pp.; x + 180pp. (Report no. LHDA 648-F-03). See item 233.593.

C. Brown, J. King, H. Sabet, S. Yance. *Biophysical consequences of the Minimum Degradation Scenario.* (April 2000), viii + 135pp. maps. (Report no. LHDA 648_F_04). See item 233.594.

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Rose Phillips. *Specialist report - public health.* (June 2000), xix + 62pp. (Report no. LHDA-F-09). See item 154.609.

Daniel Phororo. *Specialist report - animal health.* (November 1999), xii + 52pp. (Report no. LHDA-F-10). See item 95.698.

S. Yance, H. Sabet. *Specialist report - water supply.* (November 1999), vii + 42pp. (Report no. LHDA-F-11). See item 236.598.

A. Birkhead, V. Alavian, J. King, C. Brown. *Specialist report - volume 1: hydraulics; volume 2: aquatic habitat mapping.* (November 1999), vi + 23pp.; vi + 74pp. (Report no. LHDA-F-12). See item 233.598.

H. Sabet, S. Yance. *Specialist report - hydrology.* (November 1999), 6 volumes. (Report no. LHDA-F-13). See item 233.599

Albert Roseboom, Martin Thoms. *Specialist report - volume 1 sedimentology; volume 2 geomorphology.* (November 1999), iv + 37pp.; vi + 58pp. (Report no. LHDA-F-14). See item 233.600

R. Skoroszewski. *Specialist report - water quality.* (November 1999), x + 137pp. Report no. LHDA-F-15). See item 233.601

C. Boucher, S. Tlale. *Specialist report - volume 1: riparian vegetation; volume 2: social vegetation.* (November 1999), x + 98pp.; ii + 20pp. (Report no. LHDA-F-16). See items 233.602, 223.140 (Boucher) and 227.830 (Tlale).

R. Skoroszewski, F. de Moor. *Specialist report - macroinvertebrates.* (November 1999), xii + 146pp. (Report no. LHDA-F-17). See item 163.813.

A. H. Arthington, J. L. Rall, M. J. Kennard. *Specialist report - fish.* (November 1999), viii + 80pp. Report no. LHDA-F-18). See item 164.040.

S. Ferreira, N. Jacobsen. *Specialist report - volume 1: wildlife and birds; volume 2: herpetofauna.* (November 1999), xii + 87pp.; viii + 31pp. (Report no. LHDA-F-19). See items 223.603, 163.334 (Ferreira) and 165.360 (Jacobsen).

H. Sabet, S. Yance. *Specialist report - yield analysis.* (June 2000), viii + irreg. pag. totalling 22pp. + 10pp. of figs. + 5 appendices totalling 41pp. (Report no. LHDA-F-20). See item 233.604.

Hossein Sabet. *Sociological report of the four scenarios.* (June 2000), xii + 181pp. map. (Report no. LHDA-F-21). See item 233.605.

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Cate Brown, Jackie King, Hossein Sabet. *Monitoring protocol.* (June 2000), xiv + 69pp. map. (Report no. LHDA-F-23). See item 233.607.

678 Contract 678: Additional Scenarios and Production of a New Final Report to Augment Consulting Services for the Establishment and Monitoring of the Instream Flow Requirements for River Courses Downstream of LHWP Dams.

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H. Sabet, S. Yance, C. Brown, P. Martel, M. Majoro. *Analysis of the Minimum Degradation, Treaty, Design Limitation and Fourth Scenarios for Phase 1 Development.* (June 2000), 4 vols. (Report no. LHDA 678-F-02). See item 233.609.

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ECOLOGY

300 **The South African Land-cover Characteristics Database: a synopsis of the landscape.**

D. H. K. Fairbanks, M. W. Thompson, D. E. Vink, T. S. Newby, H. M. vand den Berg, D. A. Everard. *South African Journal of Science* (ZA), vol. 96, no. 2 (February 2000), pp. 69-82. maps.

The land-cover data base described here covers Lesotho, South Africa and Swaziland, within which area the largest surface type (34.1%) is shrubland and low fynbos, followed by 21.3% grassland, 17.6% thicket and bushland; and 12.2% cultivated land.

As far as Lesotho is concerned, most land is unimproved grassland (37.2%) or degraded unimproved grassland (26.8%), followed by dryland cultivation (mainly in the lowlands) (22.6%), shrubland and low fynbos (mainly at very high altitude) (9.7%), and thicket and bushland (mainly in the foothills) (2.6%). All other areas are under 1% and these include urban and residential land (0.33%), barren rock (0.25%) and wetlands (0.21%). Commercial dryland and forest plantations are each calculated at 0.06%, while all three of waterbodies, irrigated areas, and dongas (and sheet erosion scars) are all calculated at 0.03%. The area of actual forest is given at 144 ha, less than 0.005% of the total area.

Although the article states that 'the research results reported here are definitive', it is clear that for Lesotho some areas have been underrestimated, including residential land (which seems to include urban but not rural residential use); and also the area of dongas and sheet erosion scars. Forest at 144 ha must also be underestimated.

The database was designed and produced as a joint venture between a number of South African bodies including the Centre for Scientific and Industrial research (CSIR). A range of methods was used including satellite imagery. A coloured map across the front and back covers of the same issue of the *SAJR* shows the land-cover classification for the three country region.

Agriculture; Forest; Grassland; Land claasifiation; Satellite imagery; Vegetation types; Wetlands.

584 Manual for a plant community ecology and field taxonomy training course for extension and technical officers of the Range Managment Division, Lesotho.

C. D. Morris, J. B. M. Browning, N. M. Tainton, R. F. Buzzard. [S. I.]: [s. n.] (December 1994), iv + 183pp. map. illus.

The exact provenance of this publication is not clear from internal evidence, but three authors work in Pietermaritzburg, and Buzzard was at the time working in the Community Natural Resources Management Project of USAID in Maseru.

The emphasis in the manual is on the high altitude flora, divided here (following Killick (1963) and Jacot Guillarmod, *Flora of Lesotho* (1971)) into a Montane Belt (2000 - 2400 m), Subalpine Belt (2400 - 2900 m) and an Alpine Belt above 2900 m. Despite its atypical features, many of the examples are taken from the Sehlabathebe National Park.

The book is divided into four chapters, beginning with ‘An introduction to the vegetation of Lesotho’, well illustrated with photographs and diagrams. It is surprising to read here however that *Aloe polyphylla* is ***not*** a Lesotho endemic (surely an error). An appendix to this chapter at page 70 is the paper Morris, Tainton & Boleme (1993).

A short chapter describes ‘Introduction to plant collection and storage procedures’, and shows examples of labelled herbarium specimens.

Chapter 3 deals particularly with identification of grasses and similar plants, and includes a list of some 72 common grasses found in the Maloti in the Mokhotlong area, as well as 11 sedges and 4 rushes.

The last chapter is by R. F. Buzzard, and is ‘An introduction to ecological monitoring’, and deals with the seetting up of monitoring sites and the making of transects. Key indicators of range condition are parameters which include total canopy cover, basal cover, bare soil, litter, average plant distance, soil condition, percentage of palatable (to livestock!) grasses, and the range condition index. An example of transect data is given for the Phororong Basin in the Pelaneng/Bokong Range Management Area. [E. D. May]

***Aloe polyphylla*; Ecological monitoring; Grasses; Grassland ecology; Herbarium technique; Mokhotlong; Plant collecting; Range Management; Sehlabathebe National Park; Soil condition; Transects.**

586 **A threatened resource: Lesotho's alpine wetlands, unique in many ways, are facing a complexity of threats.**

Craig Morris, Stefan Grab. *African Wildlife* (ZA), vol. 51, no. 3 (May/June 1997), pp. 14-16. illus.

This article makes a distinction between *bogs* with a high water table and submerged inter-hummock areas; and *fens* which have their water table below the vegetated surface. Mention is also made of *flarks* defined as water-filled depressions.

There is a general description of Lesotho's high altitude wetlands of the ecology with mention of selected typical plant and animal species. The Sehlabathebe water lily, *Aponogeton ranunculiflorus* is mentioned as having been found recently (1989) growing in wetland pools along the Drakensberg escarpment (more details are not given).

Attention is drawn to the impact of the recent Mokhotlong tarred road construction, which has bulldozed its way through several wetlands. The problems of overgrazing are also discussed. [9]

***Aponogeton ranunculiflorus*; Bogs; Ecology; Fens; Mokhotlong; Road construction; Wetlands.**

588 **Classification of the eastern alpine vegetation of Lesotho.**

C. D. Morris, N. M. Tainton, S. Boleme. *African Journal of Range and Forage Science* (??), vol. 10 (1993), pp. 47-53. map.

This paper derives from the Maloti/Drakensberg Catchment Conservation Programme. The study in the extreme east of Lesotho identified five particular vegetation communities occupying particular topographical positions. These are described in some detail, three of them occupying the Alpine Belt (above 2900 m) and two occupying the Subalpine Belt (2400 to 2900 m). Proportions of plants in each of the communities is tabulated, and in particular certain grass types classified according to photosynthetic pathway (C_3 or C_4).

This paper can also be found reproduced at page 70 of C. D. Morris, J. B. M. Browning, N. M. Tainton & R. F. Buzzard (1994). [E. D. May]

Alpine vegetation; **Maloti/Drakensberg Catchment Conservation Programme**; **Photosynthetic pathways; Vegetation communities.**

900 **Primary divisions of the biomes of South Africa.**

R. H. Westfall, J. M. van Staden. *South African Journal of Science*, vol. 92, no. 8 (August 1996), pp. 373-375. maps.

This article describes a mapping of biomes in Lesotho, South Africa, and Swaziland by means of mean annual rainfall in relation to the existing Acocks Veld Type map. 16 subdivisions of biomes were determined in this way and are mapped in colour. From these a biome map is derived showing six biomes, the desert biome being omitted. The biome map shows most of Lesotho in the Grassland Biome, but also, rather anomalously and without comment, assigns the summit plateau to the Nama-Karoo Biome.

Biomes.

GUIDES

450 **Identification guide to the basaltic flora of Lesotho.**

H. P. Linder, C. Mokuku. [S. l.]: [s. n.] [2000], 45pp. illus.

Although publication details are missing from this item, the senior author is Keeper of the Bolus Herbarium at the University of Cape Town and it seems that the book was published from there, but with assistance from the Lesotho Highlands Development Authority and the Foundation for Reseach Development.

The booklet is intended to assist both amateurs and professionals to identify plant species. It contains descriptions of 382 plant species, apparently mainly collected in the Mohale and Katse catchments. The species are described and where there is a voucher specimen in the Bolus Herbarium (eventually to be transferred to Lesotho), the details are given. The species are arranged under families, the main characteristics of which are also described. Of the described species there are new species (yet to be scientifically described and published) in the genera *Crassula*, *Delosperma*, *Heliochrysum*, *Heliophila* and *Kniphofia*.

Colour photographs of 72 of the plant species (six to a page) are provided on unnumbered pages.

The introducation mentions the intention to include Sesotho plant names, but that this edition does not yet have them.

Basalt; Bolus Herbarium; Field guides (plants); Flora of basalt; Katse catchment; Mohale catchment; New species; Plant species.

ENVIRONMENTAL LAW

100 **Legal aspects of water resources management.**

David Ambrose, George Radosevich, Norton Tennille. Maseru: Water Resources Management Project (May 1996), 186pp. + 3 tables. (Annex A to Main Report).

The original of this report was published as Annex A (together with Annexes B & C, which deal respectively with *Institutional* and *International aspects of water resources management*) as one of the seven volumes of the *Water resources management: policy and strategies* study. It has also been separately bound for library use.

500 **Environmental Bill 2000.**

Lesotho Parliament. [Maseru]: the Parliament (2000), vii + 77pp.

This Bill was a long time in gestation, and it can be traced back to the framework law proposed in Witzsch & Ambrose (1992) (text in Annex II to Part III of the book). By 1996, the Bill had been largely drafted by the Assistant Parliamentary Secretary, and there is an extensive commentary on this version in appendix B in Ambrose, Radosevich & Tennille (1996).

The Bill proposes the setting up of a set of bureaucratic structures for the management of the environment and natural resources, headed by a **National Environmental Council**, the membership of which is rather similar to the Cabinet augmented with representation from several outside bodies. Its members include the Prime Minister and Deputy Prime Minister as Chairman and Vice-Chairman respectively.

The Council is the supreme body in the formulation of policy, but responsibility for environmental management is vested in a **Lesotho Environment Authority** (LEA), set up as a body corporate and governed by a Board of Directors, of which the Government Secretary is to be Chairman. The Chief Executive of the LEA is appointed by the Minister responsible for the environment on the advice of the Board, and the LEA essentially replaces the existing National Environment Secretariat.

The LEA in turn is advised by a **Technical Advisory Committee** of eight members. Moreover, each Line Ministry (Ministry responsible for a law with environmental implications) is also required to establish an environmental unit.

The Bill also makeS provision for the National Environmental Action Plan (to be revised every five years), District Environmental Action Plans, Environmental Impact Assessments, Environmental Quality Standards, Pollution Control, Environmental Management (including conservation of biological diversity), Environmental Restoration Orders, and Procedures for Environmental Inspection, Analysis and Record Keeping. There are also provisions for environmental information dissemination (including a 'State of the Environment and Environment Management Report' to be published every five years. A National Environment Fund is also established administered by the Chief Executive of the LEA. [IE EN/F112/0006]

Environmental Impact Assessment; Environmental management; Environmental quality standards; *Environment Bill 1990*; Lesotho Environment Authority; National Environmental Action Plan; National Environment Council; Pollution control.

SOIL EROSION

100 **Geomorphic effects of soil erosion.**

Heinrich R. Beckedahl, Tanya A. S. Bowyer-Bower, George F. Dardis, Patricia M. Hanvey. In: *The geomorphology of southern Africa.* Edited by Bernard P. Moon and George F. Dardis. Johannesburg: Southern Book Publishers (1988), pp. 249-276. illus. maps.

The authors provide a concise survey of the factors which determine the extent and intensity of soil erosion in southern Africa. Rainfall impact, infiltration, sheetwash, rill erosion, gully erosion and subsurface erosion (including pipe development) are discussed along with wind erosion. Also discussed are the geomorphic effects of soil erosion, the rate of development of soil erosion features, and erosion hazard assessment. Literature cited includes a number of references to studies on soil erosion in Lesotho.

Erosion hazard assessment; Geomorphology; **Soil erosion**.

520 **On the Follow Up of the International Convention to Combat Desertification and its Urgent Action for Africa: report on the SADC Sub-Regional Planning and Programming Workshop, Pretoria 8_10 March 1995.**

P. S. Maro. Maseru: Southern African Development Community Environment and Land Management Sector (June 1995), 150pp.

The SADC Environment and Land Management Sector (SADC-ELMS) has its secretariat located within the Ministry of Agriculture in Maseru. It has been active in addressing problems of land degradation and desertification. Prior to the Earth Summit in Rio in 1992, it produced a regional report, *Sustaining our common future* which became part of Agenda 21, the action plan to achieve sustainable development in the 21st century.

After Rio, the UN General Assembly established a Committee from whose deliberations was drafted the International Convention to Combat Desertification (CCD) which was finalized in June 1994 and opened for signature in October 1994. In the same year SADC-ELMS prepared a *SADC Sub-Regional Case Study on Drought and Desertification*, the draft of which was approved by SADC member states in June 1994. Pending the CCD coming into force, strategies of an Urgent Action for Africa component of the CCD had become a United Nations Environmental Programme supported action agenda, for which this SADC workshop was arranged.

The workshop includes country reports by eleven of the SADC countries. The Lesotho report is K. Mafura & J. Molapo, *Outline of the Lesotho National Strategy to Combat Desertification and Mitigate Effect of Drought* (Annex 3B, p. 49-62), and was prepared by the National Desertification Steering Committee. The report describes national policies and programmes and the status of key sectoral programmes for combating desertification. There is also a section entitled 'Elements of Lesotho's National Action Programme for Combating Desertification and Effects of Land Degradation' in which objectives, actions required and activities are listed under the headings Accelerated Afforestation, Livestock, Rangeland Resources Management, Land Use Management, Water Resources Management, and Energy Savings and the Using of Alternative Energy Sources. Activities listed under Water Resources Management include measures required (but details not specified) to protect bogs and sponges; and the establishment of 30 additional drought/rainfall reporting and monitoring stations.

There is also a comparative tabular summary of the various National Action Programmes at p. 5-13.

The main report includes issues discussed, general observations and conclusions from National Action Programme presentations, and consideration of Sub-Regional Action

Programmes. There is a section indicating the scheduling of Priority Action Programme Areas and a discussion of potential funding mechanisms and resources.

Amongst other issues is the need to rationalise SADC activities with those of SARCCUS, the Southern African Regional Commission on the Conservation and Utilisation of Soil, which was established in 1948 at a meeting in Goma in Zaire, and has had a permanent secretariat since 1950.

Annex 4 is a SADC-ELMS paper entitled *SADC sub-regional action programmes in combating desertification and mitigating the effects of drought.* This lists the three ELMS Programme Areas of Land Management (four projects and sub-programmes); Water Resources Management (five projects and sub-programmes); and Environment Management, Monitoring and Assessment (five projects and sub-programmes). Detail on most of the projects and sub-programmes is, however, scanty.

For a follow-up report, see item 760. [9]

Convention to Combat Desertification; Desertification; SADC-ELMS; SARCCUS; Soil erosion.

760 **On Sub-Regional Action Programme in the Implementation of the Convention to Combat Desertification and its urgent action for Africa: report on the SADC Consultations and Workshop, Windhoek, Namibia, 16-18 January 1996.**

Southern African Development Community - Environment & Land Management Sector. Maseru: SADC-ELMS (1996), [vii +]147pp.

This report is a follow-up to item 520, and SADC-ELMS is taken as author/editor because there is no identified editor of the publication, although possibly this role was played by Umesh Kumar, who undertook the desktop composition.

The workshop was attended by 78 participants and had as objectives *inter alia* to review key elements for an action programme for the SADC region for implementing the Convention to Combat Desertification; to formulate strategies for public participation; to share experiences by SADC member states on their National Action Programme Process.

The Lesotho Country Report by N. M. ’Mota and Kabelo Mafura is on pp. 52-58, and much of the introductory material is the same as the report in item 520. A number of activities during 1995 are reported on including district workshops to introduce the Convention and workshops for traditional doctors, journalists and herdboys. Eight ongoing national Rural Development Porjects are listed with descriptions and capital investment.

It is also noted that Lesotho ratified the Convention to Combat Desertification on 12 September 1995. [9]

Convention to Combat Desertification; Desertification; Soil erosion.

800 **Oral evidence in historical environmental impact assessment: soil conservation in Lesotho in the 1930s and 1940s.**

Kate B. Showers, Gwendolyn M. Malahleha. *Journal of Southern African Studies* (GB), vol. 18, no. 2 (June 1992), p. 276-296.

This paper derives from hypotheses developed in Kate Showers' 1982 Cornell University PhD thesis, where it was suggested that the colonial soil conservation scheme using contour ridges may in fact have exacerbated soil erosion by creating new erosion gullies. The authors discuss evidence from a small sample of oral informants (3 in Quthin and 6 in 'Mobu' [Ha Tšilo]) about the nature and impact of the soil conservation campaigns in the 1930s and 1940s. The applicability of oral methodologies in 'historical environmental impact assessment' is also discussed. [9]

Environmental impact assessment; Oral history; Soil conservation; Soil erosion.

SENSITIVE AREAS

200 **Nationally significant natural areas of Lesotho.**

Alan C. Beverly. [Sehlabathebe, Lesotho]: [the author] (June 1977), 4pp. mimeo.

The author identifies a number of areas of special significance (particularly from the botanical point of view), including the Likolobeng tributary of the Makhaleng; the Quthing Valley; the Tsoelike Valley; Sehlabathebe National Park; the area adjoining the Drakensberg Escarpment; an area SE of Mantšonyane; the Maphotong Gorge; and Qiloane Falls. The author travelled extensively through Lesotho while carrying out a Spiral Aloe survey in 1976-7. [9]

Drakensberg Escarpment; Likolobeng; Mantšonyane; Maphotong Gorge; Qiloane Falls; Quthing Valley; Sehlabathebe National Park; Tsoelike Valley.

301 **Peace parks: the dream & the facts.**

Ross Douglas. *Keeping Track* (ZA), (October/November 1997), p. 44-49. illus. maps.

The peace park movement encourages the creation of Transfrontier Conservation Areas (TFCAs) straddling international boundaries. Seven such TFCAs are proposed for areas bordering South Africa, of which one, the Drakensberg/Maloti TFCA straddles South Africa's border with Lesotho. This TFCA is envisaged as covering 5000 km^2 of land, approximately half of it in north-eastern Lesotho. At present the land on the South African side of the border is mainly managed by the Natal Parks Board, although there is a portion which is 'communally owned'. On the Lesotho side of the border all the land is 'communally owned'.

The concept of Peace Parks originated from a 1988 Commission of the International Union for the Conservation of Nature (IUCN), from which a Southern African Peace Parks Foundation took its cue after a 1990 meeting between Anton Rupert, President of the South African World Wildlife Fund and President Joaquim Chissano of Mozmbique. The Foundation's original aims were linked to cross-border projects between South Africa and Mozambique, in particular linking Kruger Park with areas on the Mozambique side of the border. The geographical scop of the aims has expanded to cover other areas, using the more inclusive TFCA model where formal national parks are not appropriate.

Drakensberg/Maloti Park; Peace parks.

Pollution and Degradation Control

500 **Is it the rich or the poor, the rural or the urban that contribute more in environmental degradation?**

M. P. Nkuatsana. [Maseru]: [Paper given at LEINET (Lesotho Environmental Network) Seminar held at the British Council, Maseru (14 October 1997)], 7pp.

This paper is by a representative of the Lesotho Youth Federation. It points out the difficulties of quantifying relative impact, and that population increase and population distribution are of major importance in environmental degradation. [9]

Environmental degradation; LEINET; Lesotho Youth Federation; Population;

700 **Encouraging regional sustainable development: a role for South Africa as a “JI Intermediary”.**

Ian H. Rowlands. *Africa Insight* (ZA), vol. 27, no. 3 (1997), pp. 200-206. illus.

This article is concerned with the obligations of countries to keep greenhouse gases in the year 2000 no higher than in 1990 levels, with more stringent future targets. Within this context, the concept of 'joint impleentation '(JI) is being discussed by which a country could meet its reduction obligations in another country. The author assesses the possible role of South Africa as a 'JI intermediary' with its SADC neighbours.

Tables show Lesotho as receiving the 9th largest foreign investment development amongst the 12 SADC countries ($13 million average for th period 1991-5); and also show Lesotho as having the 5th lowest financial risk ranking amongst the twelve countries (this data being quoted from *Euromoney* of March 1997). [9]

FORESTRY

Community forestry in Lesotho: the people's perspective; a report on the Social Forestry Study prepared for a Community Forestry Programme for the Kingdom of Lesotho.

David Hall, Thuso Green. [Maseru]: Overseas Development Administration of the United Kingdom [for Lesotho Government Ministry of Agriculture Forestry Division] (December 1989, reprinted 1996), [xiii +] 233pp. illus.

This publication is the most important source of information on the attitudes of people in Lesotho to tree planting. The report is based on both existing literature (including Sesotho literature) and research undertaken by a team of participant-observers who stayed in villages in nine widely dispersed parts of Lesotho.

Traditional knowledge about trees is widespread in villages, and the management of indigenous woodland and certain plantations fall under the chieftainship. The Woodlot Project, on the other hand, although establishing substantial new plantations throughout Lesotho has had the disadvantage of creating a dependency syndrome. Trees were only planted when woodlots were established or maintained through 'food for work' schemes. Moreover, the types of trees planted were determined by the project, not by villagers who (at least for personal household ownership) preferred to have access to good quality fruit trees, not timber trees.

Land acquired for woodlots became forestry reserves, acquired by the state and beyond village control, and the only obligation to the village was to make available 20% of revenue generated by the woodlots. Acquisition of land for woodlots was generally initiated through a traditional village pitso. but the authors point out that pitsos are highly defective as democratic institutions, being easily dominated by one group or another.

Once established, woodlots are extremely inefficient in terms of the amount of time of foresters needed to manage such matters as the sale of wood, which villagers feel free to steal, since they see the woodlots as government rather than community owned. Woodlots also acquire bad reputations as harbouring criminals, and since they were seen as established by the government of the day (which until 1993 was undemocratic and unpopular) were sometimes subjected to acts of vandalism or arson.

Community forestry is used in the report to mean non-governmental tree cultivation by entire villages for the benefit of all in the village. The Report advocates a model for Community Forestry in which Village Tree Committees are established along the lines of the existing successful Village Water Committees. The Forestry Division's future role would then become one of advice and training as well as provision of seedlings.

The report includes an extensive bibliography, and four Appendices, one of which is a somewhat inaccurate list of Sesotho and Latin names of Lesotho indigenous tree species. The photographic supplement ('Appendix 5'**)** does not appear in the published version of the report, even though mention of it on page 28 might expect the reader to think otherwise.

For a perceptive and lively review of the book by F. C. Brideswater, see *Journal of Dendrology*, no. 13 (1991), p. 66-67.

Community development; Community forestry; Indigenous trees; Trees, indigenous; Participant research; Village Tree Committees; Woodlot Project.

RANGE

614 **Grassland degradation and livestock rearing in Lesotho.**

Tim Quinlan. *Journal of Southern African Studies* (GB), vol. 21, no. 3 (September 1995), p. 491-507.

Quinlan's work is based on extensive observation of livestock practices in the late 1980s in Mokhotlong District. He reviews the history of transhumance and settlement in the Maloti, and colonial and post-colonial interventions. However, despite major donor-supported projects, there remains a 'blindness of current 'development/conservation' projects in Lesotho to the character of local stock-rearing characteristics'. He notes that despite official judgments of 'overstocking', the size of the national herd has oscillated around the current figure for the past 50 years. He takes issue on some of James Ferguson's findings in his 1990 book, *The anti-politics* *machine*. Sheep and goats and the labour of herd boys are cash commodities in a different way from cattle and horses.

Amongst details given in the paper are survival rates per annum for livestock, the recent innovation of 'winter' cattle posts in mountain valleys; and the way in which stover, formerly a communal resource, is now taken by farmers as fodder, reflecting perhaps increased ownership rights over land.

In relation to the problem of degradation of mountain catchments, Quinlan states: 'If we accept that Basotho have developed sophisticated stock-rearing practices, we must acknowledge that they have been relatively successful in minimising grassland degradation, even if there is legitimate concern that their efforts are no longer adequate'. By contrast, he is critical of the Range Management Areas created as a result of a USAID-supported project, these areas ignoring existing boundaries between jurisdictions.

Conservation of catchments has current topicality, both as a means to reduce siltation of Lesotho Highlands Water project dams, and as part of a conservation strategy for the Drakensberg/Maloti Catchment Conservation Programme, funded by South Africa and initiated in 1987.

Catchment protection; Cattle; Cattle posts; Donkeys; Drakensberg/Maloti Catchment Protection Project; Ferguson, J.; Goats; Grassland degradation; Herdboys; Horses; Mokhotlong; Mules; Range Management Areas; Sheep; Transhumance; USAID.

Land tenure issues in livestock development and range management.

Steven W. Lawry. In: *Proceedings Land Act Policy Seminar, Quthing, Lesotho, March 18-22, 1984*. Lesotho Government Ministry of Agriculture. [Maseru]: the Ministry (March 1984), pp. 95-110.

Describes how various factors, particularly herd size and ownership patterns interact with range ecology, household income strategies, administrative resources and economic forces to constrain land tenure options.

The grasses and pastures of South Africa.

Lucy K. A. Chippindall and others. [S. l.]: Central News Agency for the Trustees of 'The grasses and Pastures of South Africa Book Fund' (1955), xvi + 771pp. illus. maps.

This standard work on the grasses of southern Africa is well illustrated in black and white with some colour plates. For some species distribution maps are included which show Lesotho records. In other cases, Lesotho is included in verbal description of distributions.

Grasses include bamboos (including the wild bamboo of Lesotho); and the book also includes grasses (many of them introduced) which are food plants. Thus maize, wheat, barley, oats etc are described. There is also information on lawn grasses including Kikuyu grass introduced from East Africa, and the cosmopolitan *Cynodon dactylon* (couch-grass) which in Lesotho quickly colonizes and saves bare patches of soil from erosion.

Part 1 (pp. 1-528) by Lucy K. A. Chippindall is 'A guide to the identification of grasses in South Africa'.

Part 2 (pp. 529-752) consists of 14 chapters by 17 authors on 'Pasture management in South Africa'. Part 2 is wide-ranging including statistics of livestock (including some 1951 figures for Lesotho), and material on the ecology of grasslands; on rotational grazing; and on virtually every economic use of grasses including the grasses used for airstrips.

Three coloured maps, based on the work of J. P. H. Acocks, are tip-ins at the end of the book. One shows the vegetation in A.D. 1950, a second the possible vegetation in A.D. 2050 if prevailing tendencies continue, and a third the possible vegetation pattern under scientific management. Without scientific management, Lesotho is seen as almost totally invaded by the Karoo and by Karroid Bushveld. Under scientific management, sweet grassveld could be restored to much of the country.

Final report: baseline biological survey, fauna and flora, Lesotho Highlands Water Project Phase 1A, Contract no. 75, vol. 2 - flora.

Loxton, Venn & Associates. Johannesburg: Loxton, Venn & Associates [for] Lesotho Highlands Development Authority (September 1993), iv+111pp. +3 appendices totalling 40pp. illus. maps.

This report includes an overview of previous ecological studies and also describes the grazing system in some detail together with the utilization of the vegetation by livestock. A chapter discusses the dynamics of the vegetation under different disturbance regimes, with an extensive discussion of the impact of grazing and the plants that increase, decrease or invade. Carrying capacities in livestock units per hectare (LSU/ha) are calculated for each vegetation community type, and it is concluded that there will be a surfeit of 2078 LSU after impoundment, leading to livestock exceeding the ecological carrying capacity. A wide range of appropriate recommendations are made in relation to managing the stocking rate and grazing pressure.

Anti-erosion policies in the mountain areas of Lesotho: the South African connection.

Thackwray Driver. *Environment and History* (UK), vol. 5, no. 1 (1999), pp. 1-25.

This paper looks at the political pressure placed on the colonial administration by South Africa in the late 1940s and early 1950s to impose policies such as grazing control. Soil erosion at the time became an important element in the debate about the transfer of the High Commission Territories to South African control.

The paper, using Lesotho and South African archival sources, provides an historical account of concern about soil erosion in the Maloti, beginning with the forestry report of A. W. Heywood in 1908. Heywood proposed that trees might regulate the flow of water in the rivers, and this was taken up soon afterwards by Carlson (item 94.009) who advocated South Africa paying for the whole Maloti to be afforested. However, the colonial administration became mainly concerned about overgrazing and its impact on the livestock sector, as set out in a 1931 unpublished report of R. W. Thornton.

After the Second World War, soil erosion in Lesotho became a live issue in relations between the colonial administration and South Africa, while the public was made aware of the problems by articles in *Veld Trust News*. Initially the colonial administration reacted by closing some mountain grazing areas, but culling schemes were opposed in the Basutoland National Council and elsewhere, the more so after a South Africa culling in Witzie's Hoek led to unrest and loss of human lives.

The story of interaction between Lesotho and South Africa is continued up until the 1950s with shifting perceptions on the South African side of Lesotho's future in terms of its apartheid policies.

The article is largely based on the author's PhD thesis (see item 670).

Pastoral utilization and land cover change: a case study from the Sanqebethu valley, eastern Lesotho.

Marcus Nüsser. *Erdkunde: Archive für Wissenshaftliche Geographie* (DE), vol. 56 (2002), pp. 207-221. illus. maps.

This thorough study, which maps cattle posts and makes studies of changes using coloured satellite images, analyses recent developments of pastoral resource utilization and subsequent vegetation changes in the Sanqebethu valley east of Mokhotlong. High altitude grasslands showed a slight reduction of vegetation cover in the period 1989 to 1999.

Land degradation and soil erosion in the eastern Highlands of Lesotho, southern Africa.

Marcus Nüsser, Stefan Grab. *Beitrag zur Physischen Geographie* (DE), vol. 133 (2002), pp. 291-311. illus. maps.

This study looks particularly at human and animal interventions which have resulted in the transformation of high-altitude grasslands and wetlands in eastern Lesotho, looking at factors such as fire, overgrazing, and natural frost-induced processes. Case histories are presented of the Sanqebethu valley and the Sani Plateau region. Vegetation was sampled by transects and moderate to heavy grazing impact was found. In wetlands, hoof pressure of livestock was found to ply a role in gully development. Accelerated soil erosion was found to be partly related to fire, combined with wind, and repeat photography following a fire below Hodgson's Peak illustrates this.

Towards an integrated research approach for the Drakensberg and Lesotho mountain environments: a case study from the Sani Pass region.

Stefan Grab, Marcus Nüsser. *South African Geographical Journal* (ZA), vol. 83 (2001), pp. 64-68. illus. map.

This article makes reference to an intra-disciplinary research programme by geographers from the University of Bonn in Germany and the University of the Witwatersrand in South Africa whereby social and ecological investigations are being used for resource management. The Sani Top plateau area is taken as a case study region, where the writers found that the interactions between the natural and social systems in Lesotho are complex. Reference is made to the palatable grasses and scrubs and to transhumance practices. A map of the Sani Top area shows cattle posts classified by whether they are permanent, seasonal or deserted.

Report on a vegetation survey in pilot area of Mokhotlong District.

Marcus Nüsser. Freiburg, Germany: PARTICIP Gmbh Consultants for Development & Environment [for] Maseru: National Environment Secretariat Drakensberg/Maloti Mountains Conservation Programme (1999?), ??pp.; rev. ed. (March 2001), vi + 33pp.

This vegetation survey, preceded by a training course, was undertaken in the Alpine Belt of eastern Mokhotlong District from 6 to 21 April 1999. The report also includes the main findings from two winter surveys, one in the upper Sanqebethu valley, 11 - 18 August 1999, and the other in the Sani area 28 August - 5 September 1999.

The survey team carried out the range inventory using the metric belt transect method. Appendix D (pp. 22-28) provides the transect data and floristic composition of the transects. Appendix E lists the cattle population in summer and winter at various cattle posts and each records the months when the cattle post was occupied. There is, however, no map showing the location of the listed cattle posts.

The writer advocates a human-ecological approach for monitoring changes in the alpine belt. He advocates repeat photography at different seasons, and notes the damage caused by seasonal illegal grassland burning.

For closely related literature by Marcus Nüsser, see items 216.525 and 216.526.

Grassland degradation and livestock rearing in Lesotho.

Tim Quinlan. *Journal of Southern African Studies* (GB), vol. 21, no. 3 (September 1995), p. 491-507.

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Catchment protection; Cattle; Cattle posts; Donkeys; Drakensberg/Maloti Catchment Protection Project; Ferguson, J.; Goats; Grassland degradation; Herdboys; Horses; Mokhotlong; Mules; Range Management Areas; Sheep; Transhumance; USAID.

11 APPENDIX A

Fish in lower Orange River (extracted from DWAF 2005)

Although situated in the driest part of the country, the freshwater fish species diversity of the LOR (Augrabies Falls to Orange River Mouth), listed in **Table A.**1, is the highest of any of the Orange River System, with 13 of the Orange River Systems' total of 15 indigenous freshwater fish species, naturally distributed in this river stretch. Of the fish species listed in Table 1:

□*Oreochromis mossambicus*, is an introduced indigenous species; and□*Cyprinus carpio* is an alien species.

Table A1: Checklist of the Freshwater Fish Species found between Augrabies Falls and the Orange River Mouth (Skelton 1993; Benade 1993). (L = Large; M = Medium; S = Small; E - Endemic; I = Indigenous; V = Vulnerable; R = Red Data; In = Introduced; A = Alien)

FAMILY	SPECIES			STATUS					
	Scientific Name	Common Name		E	I	V	R	In	A
ANGUILLIDAE	*Anguilla mossambica*	Longfin Eel	L		X				
CYPRINIDAE	*Mesobola brevianalis*	River Sardine	S		X				
	Barbus trimaculatus	Threespot Barb	S		X	X			
	B. hospes	Namaqua Barb	S	X			X		
	B. paludinosus	Straightfin Barb	S		X	X			
	B. kimberleyensis	Largemouth Yellowfish	L	X			X		
	B. aeneus	Smallmouth Yellowfish	L	X					
	L. capensis	Orange River Mudfish	L	X					
	Cyprinus carpio	Carp	L						X
AUSTROGLANIDIDAE	*Austroglanis sclateri*	Rock Catfish	M	X			X		
CLARIIDAE	*Clarias gariepinus*	Sharptooth Catfish	L		X				
CICHLIDAE	*Pseudocrenilabrus philander*	Southern Mouthbrooder	S		X				
	Tilapia sparrmanii	Banded Tilapia	S		X				
	Oreochromis mossambicus	Mozambique Tilapia	M					X	

Mesobola brevianalis (River Sardine) is restricted to the LOR (Jubb, 1967), where it is the most common and abundant fish species (Skelton and Cambray 1981; Cambray 1984; Benade 1993), found in the open water habitats of the mainstream, quiet backwaters, as well as flowing channels and rapids (Skelton and Cambray 1981; Benade 1993).

Barbus paludinosus (Straightfin Barb) prefers quiet to slow flowing, moderately vegetated bays, shores, backwaters, pools and impounded areas, although its numbers are rather low (Skelton and Cambray, 1981).

The three cichlids, *Pseudocrenilabrus philander* (Southern Mouthbrooder), *Tilapia sparrmanii* (Banded Tilapia) and *Oreochromis mossambicus* (Mozambique Tilapia) prefer quiet, well-vegetated water for breeding purposes. *Pseudocrenilabrus philander* and *Tilapia sparrmanii* are the most abundant species in the well-vegetated, (extremely) slow flowing Vaal River section within the Northern Cape Province.

Clarias gariepinus (Sharptooth Catfish), an omnivorous scavenger (Jubb 1967), which does not occur in large quantities under riverine conditions (Skelton and Cambray, 1981; Cambray 1984; Benade 1993) is equipped with suprabranchial organs (pseudo lungs) with which it can survive in water of low oxygen content, and spawns in grassy places inundated by floodwaters of high oxygen content (Jubb, 1967). *Barbus trimaculatus*’ (Threespot Barb) habitat preference is rapid areas and its breeding is triggered by flow (Benade, 1993).

Barbus hospes (Namaqua Barb) is endemic to the Orange River stretch between Augrabies Falls and the Orange River Mouth (Jubb, 1967), being most abundant downstream from Goodhouse (Cambray 1984; Benade 1993) and is Red Data listed (Skelton, 1987), favouring open flowing water, a sandy substrate and little vegetation (Cambray, 1984) in and around rapids (Benade, 1993), and appears to be a stream spawner (Benade, 1993).

Barbus kimberleyensis (Largemouth Yellowfish) is a Red Data listed endemic (Jubb, 1967) Orange River System predator (Jubb and Farquharson 1965; Mulder 1973), preferring clear, fast-flowing water with a sandy to gravel substrate (Mulder, 1973). It takes approximately seven years to mature sexually (Benade, 1993) and breeds in and below rapids (Skelton and Cambray, 1981) during the first post-winter floods (Tomasson and Allanson, 1983).

Barbus aeneus (Smallmouth Yellowfish) is the most abundant large fish species in the LOR (Benade, 1993), and is an endemic (Jubb, 1967) opportunistic omnivore (Tomasson, 1983) preferring clear, fast-flowing water and a sandy to gravel substrate (Mulder, 1973; Skelton and Cambray 1981), for spawning (Jubb, 1967) during the first post-winter floods (Tomasson and Allanson, 1983).

Labeo capensis (Orange River Mudfish), the dominant large Orange River System fish species (Mulder 1973b; Skelton and Cambray 1981) (although its numbers are declining towards the LOR [Benade, 1993]). It is an endemic (Jubb, 1967) detritivore Groenewald,1957; Jubb 1967), which appears to be utilizing all aquatic habitat types

(Mulder 1973b; Cambray 1984), breeding in floodplains, main streams and rapids (Cambray, 1985).

Austroglanis sclateri (Rock Catfish) is an endemic Red Data listed (Skelton, 1987) omnivore (Jubb, 1967), which is not common, even in its preferred habitat (Skelton and Cambray, 1981), and appears to be highly specialised regarding its habitat requirements consisting basically of a rock/sand/gravel substrate, and ranging from bedrock with/without scattered rocks and sandy to gravel substrates, to rocky pools, rapids (Skelton and Cambray 1981; Cambray 1984; Benade 1993) and riffles, with the surrounding aquatic environment adhering to specific water quality standards (Benade, 1993). The river stretch below Muggie Falls appears to be ideal *A. sclateri* habitat.