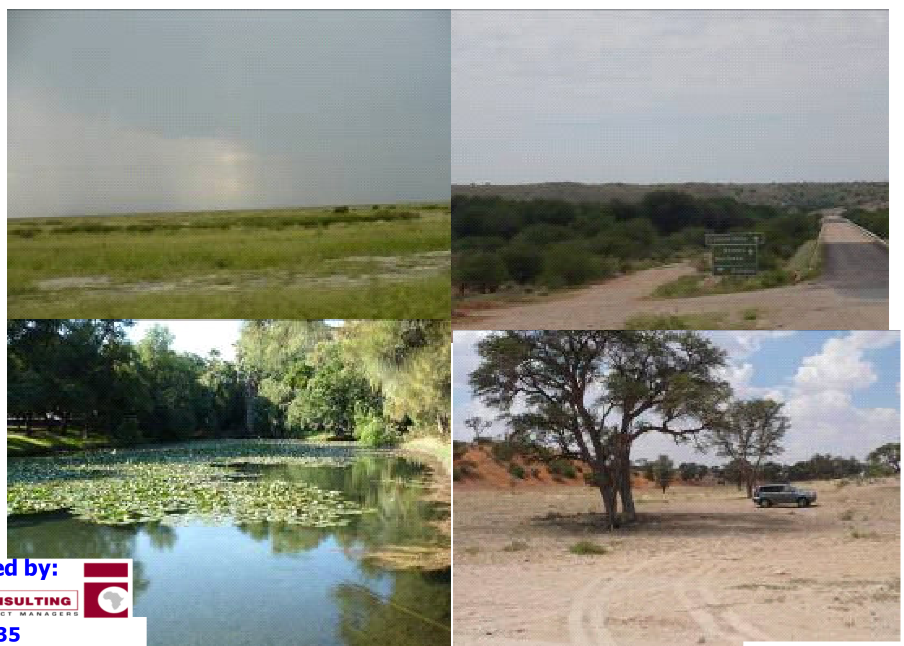
Sharing the Water Resources
Of the Orange-Senqu River Basin

Report No: 007/2009

Feasibility Study of the Potential for Sustainable Water Resources Development in the Molopo-Nossob Watercourse

Main Report
Final



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LIST OF STUDY REPORTS IN FEASIBILITY STUDY OF THE POTENTIAL FOR SUSTAINABLE WATER RESOURCES DEVELOPMENT IN THE MOLOPO-NOSSOB WATERCOURSE PROJECT:

This report forms part of a series of reports done for the Molopo-Nossob Feasibility Study, all reports are listed below:

Report Number	Name of Report
002/2008	Hydrology Report
003/2008	Catchment Status Inventory Report
006/2009	Ground water Study
007/2009	Main Report

FEASIBILITY STUDY OF THE POTENTIAL FOR SUSTAINABLE WATER RESOURCES DEVELOPMENT IN THE MOLOPO NOSSOB WATERCOURSE: MAIN REPORT

EXECUTIVE SUMMARY

The Molopo River receives most of its flow from tributaries in the Republic of South Africa, most of which have now been dammed for irrigation in agriculture. As a result, inflow from these sources to the Molopo River, which forms the boundary between Botswana and South Africa, has become reduced and even non-existent in some years. The Nossob River originates in Namibia and some dams have been constructed in the upper reaches. It later forms the south-western boundary between Botswana and South Africa down to its confluence with the Molopo River. There is no record of the Molopo River surface flows ever reaching the main stem of the Orange River. The reduction of flows in these sub-basins has placed a strain on the sustainability of rural activities in the south-western corner of Botswana and some parts of South Africa along the Molopo and Nossob Rivers.

As an attempt to remedy the situation, the ORASECOM countries has appointed ILISO Consulting, in association with Ninham Shand Incorporated, Schoeman and Partners and Conningarth Economists to study the feasibility of the potential for the sustainable water resources development in the Molopo Nossob Sub River Basin.

The objective of the project was to assess and evaluate the water resources of the Molopo-Nossob catchment to formulate a method to improve the management of the area that will be environmentally sound, economically viable and financially achievable. The possibility of restoring flows to the river system was also investigated, as well as the identification and assessment of sustainable surface water development options. In doing so the catchment was studied as an interrelated system, even though it falls within the political area of three different countries (Namibia, Botswana and South Africa).

Hydrological modelling has been undertaken to provide first order estimates of typical surface water runoff volumes in the main rivers in the Molopo-Nossob catchment. The modelling was done by means of the Pitman rainfall-runoff model, local observed rainfall records and current land use information. Estimates of natural and present day surface water runoff have been calibrated based on observed flow records where available as well as on historical records of floods in the Molopo-Nossob catchment.

The modelling results have shown that the total natural runoff from the Molopo-Nossob catchment, without any channel losses, equals 164 Mm3/a. However, once losses are taken into account, the total cumulative runoff for each of the main subcatchments reduces to zero, except in the case of the Kuruman catchment where the average net outflow equals 4.1 Mm3/a under natural conditions and 4.0 Mm3/a under present day conditions

First order estimates of typical gross storage-yield characteristics for the upper parts of the Molopo, Kuruman and Nossob catchments have shown that significant storage is required to provide yield at an acceptable level of assurance. An assessment of the central parts of the Molopo-Nossob catchment, situated within the drier, central Kalahari Desert, has indicated that it is not feasible for dams to be constructed in this area due to the lack of reliable runoff.

The Molopo-Nossob system does not function in the same way as more conventional rivers, where groundwater discharge provides a baseflow during dry conditions. In the case of the Molopo-Nossob system, the occasional floods are totally absorbed along the river bed and recharge the ground water aquifers along the course of the river. From the investigation it is clear that surplus water is only generated at a recurrence interval of less than 20 years. For the rest of the time, floods are entirely absorbed as ground water recharge along the course of the river.

As the water along the course of the river is needed for small communities and stock watering, there is little sense in building storage dams. It is far more financially and economically viable to abstract the water from boreholes and wells at the point of use, as this will not only cut out the evaporation losses from the surface of a reservoir, but also the necessity of an expensive distribution network.

The study has conclusively shown that there is no surplus water in the Molopo-Nossob catchment that can be economically exploited. It was also shown that the occasional floods serve to recharge the ground water aquifers along the river course, and that any storage that is created will therefore reduce the availability of ground water along the course of the river.

It is therefore recommended that no further surface water development in the form of dams is considered in the study area, and that the development of ground water sources is investigated in more detail.

However, the development of ground water should be undertaken with some caution, as making more water available may lead to overgrazing and the destruction of the natural vegetation, especially where subsistence farming is practised.

FEASIBILITY STUDY OF THE POTENTIAL FOR SUSTAINABLE WATER RESOURCES DEVELOPMENT IN MOLOPO-NOSSOB WATERCOURSE : MAIN REPORT

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ACRONYMS

BEE	Black Economic Empowerment
CASP	Comprehensive Agricultural Support
CBNRM	Community Based Natural Resource Management
CHA	Controlled Hunting Areas
DM	District Municipality
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWNP	Department of Wildlife National Parks
IDP	Integrated Development Plan
ISARM	Internationally Shared Aquifer Resources Management
ISRDS	Integrated Sustainable Rural Development Strategy
LM	Local Municipality
LSU	Large Stock Units
MAE	Mean Annual Evaporation
MDG	Millennium Development Goal
ORASECOM	Orange-Senqu River Commission
RADP	Remote Area Development Policy
RADS	Remote Area Dwellers
RDP	Reconstruction and Development Programme
RSA	Republic of South Africa
SES	Socio-Economic Status
TDS	Total Dissolved Solids
TGLP	Tribal Grazing Land Policy
UMK	United Manganese of Kalahari
WARD	Women in Agriculture and Rural Development
WMA	Wildlife Management Area

FEASIBILITY STUDY OF THE POTENTIAL FOR SUSTAINABLE WATER RESOURCES DEVELOPMENT IN MOLOPO – NOSSOB WATERCOURSE:

MAIN REPORT

1. INTRODUCTION

1.1 BACKGROUND

The Molopo River is an ephemeral tributary of the Orange – Senqu system which is an international river basin shared by the Kingdom of Lesotho, the Republic of Namibia, the Republic of Botswana and the Republic of South Africa. The Orange-Senqu River Agreement signed by the governments of the four countries established the Orange-Senqu River Commission (ORASECOM) to advise the parties on water related issues.

The Molopo River receives most of its flow from tributaries in the Republic of South Africa, most of which have now been dammed for irrigation and urban water supply. As a result, inflow from these sources to the Molopo River, which forms the boundary between Botswana and South Africa, has become reduced and even non-existent in some years. The Nossob River originates in Namibia and some dams have been constructed in the upper reaches. It later forms the south-western boundary between Botswana and South Africa down to its confluence with the Molopo River. There is no record of the Molopo River surface flows ever reaching the main stem of the Orange River. The reduction of flows in these sub-basins has placed a strain on the sustainability of rural activities in the south-western corner of Botswana and some parts of South Africa along the Molopo and Nossob Rivers.

1.2 PURPOSE OF STUDY

As an attempt to remedy the situation, ORASECOM has appointed ILISO Consulting, in association with Ninham Shand Incorporated, Schoeman and Partners and Conningarth Economists, to study the feasibility of the potential for the sustainable water resources development in the Molopo-Nossob Sub River Basin.

The objective of the project was to assess and evaluate the water resources of the Molopo-Nossob catchment to formulate a method to improve the management of the area that will be environmentally sound, economically viable and financially achievable. The possibility of restoring flows to the river system was also investigated, as well as the identification and assessment of sustainable surface water development options. In doing so the catchment was studied as an interrelated system, even though it falls within the political area of three different countries (Namibia, Botswana and South Africa).

The Terms of Reference originally included the identification, feasibility and prioritisation of possible surface water development schemes. The surface water investigations undertaken in the second stage of the study (the catchment status inventory) revealed that the surface water resources of the study area have largely been developed and there is very little scope for further development. At the same time the catchment seems to have reached a saturation point as far as development is concerned. The real need for water that was identified lies in providing water at the household level and as the population lives dispersed and in small communities, ground water offers the only viable source of water.

The exploitation of the dolomitic aquifer in South Africa has had a significant influence on ground water levels, and thereby affected the flow in the upper reaches of the Molopo River. It was therefore agreed that the third stage of the study would consider the availability of ground water in more detail, and focus on the development of this resource, rather than surface water.

1.3 PURPOSE OF REPORT

The purpose of this report is to present the findings and recommendations of the study.

1.4 REPORT STRUCTURE

The physical aspects of the study area are described in **Chapter 2** and the social and economic **in Chapter 3.** The availability of water is presented in **Chapter 4** and the water requirements in the study area in **Chapter 5**. The impact of groundwater use on river flows in presented in **Chapter 6**. **Chapter 7** is a discussion of the findings and **Chapter 8** presents the conclusion and recommendations.

2. DESCRIPTION OF STUDY AREA

2.1 LOCATION

The Molopo-Nossob system forms part of the Orange-Senqu system and is shared by the countries of Namibia, the Republic of Botswana and the Republic of South Africa (RSA). A significant portion of the catchment falls within the Kalahari Desert. The system is an ephemeral system and consists of four main subcatchments viz. the Molopo, Kuruman, Nossob and Aoub catchments. The locations of these catchments are shown in, **Figure 2-1** while the catchment areas per country are presented in **Table 2-1.**

Table 2-1: Main Subcatchments within the Molopo-Nossob System

	Catchment Area (km^2)			
	RSA	**Namibia**	**Botswana**	**Total**
Molopo	61 882	18 120	112 583	**192 585**
Kuruman	41 194	0	0	**41 194**
Nossob	4 704	46 928	17 426	**69 058**
Aoub	5 589	34 601	0	**40 190**
Total	**113 369**	**99 649**	**130 009**	**343 027**

2.2 TOPOGRAPHY

There are no distinct topographic features in the study area, with the majority of the area being relatively flat with no climatic barriers. The upper tributaries of the Nossob and Aoub rivers, in the mountainous areas surrounding Windhoek, are characterised by higher elevations (1 700 to 2 000 masl), while high-lying areas to the east and south of Mafikeng (1 500 masl) and Kuruman (1 336 masl) form the watershed divide between the Molopo-Kuruman system to the north and the Vaal-Orange system to the south.

The Nossob and Aoub catchments gradually fall towards the south, while the Molopo and Kuruman catchments display a gradual decline in elevation towards the west.

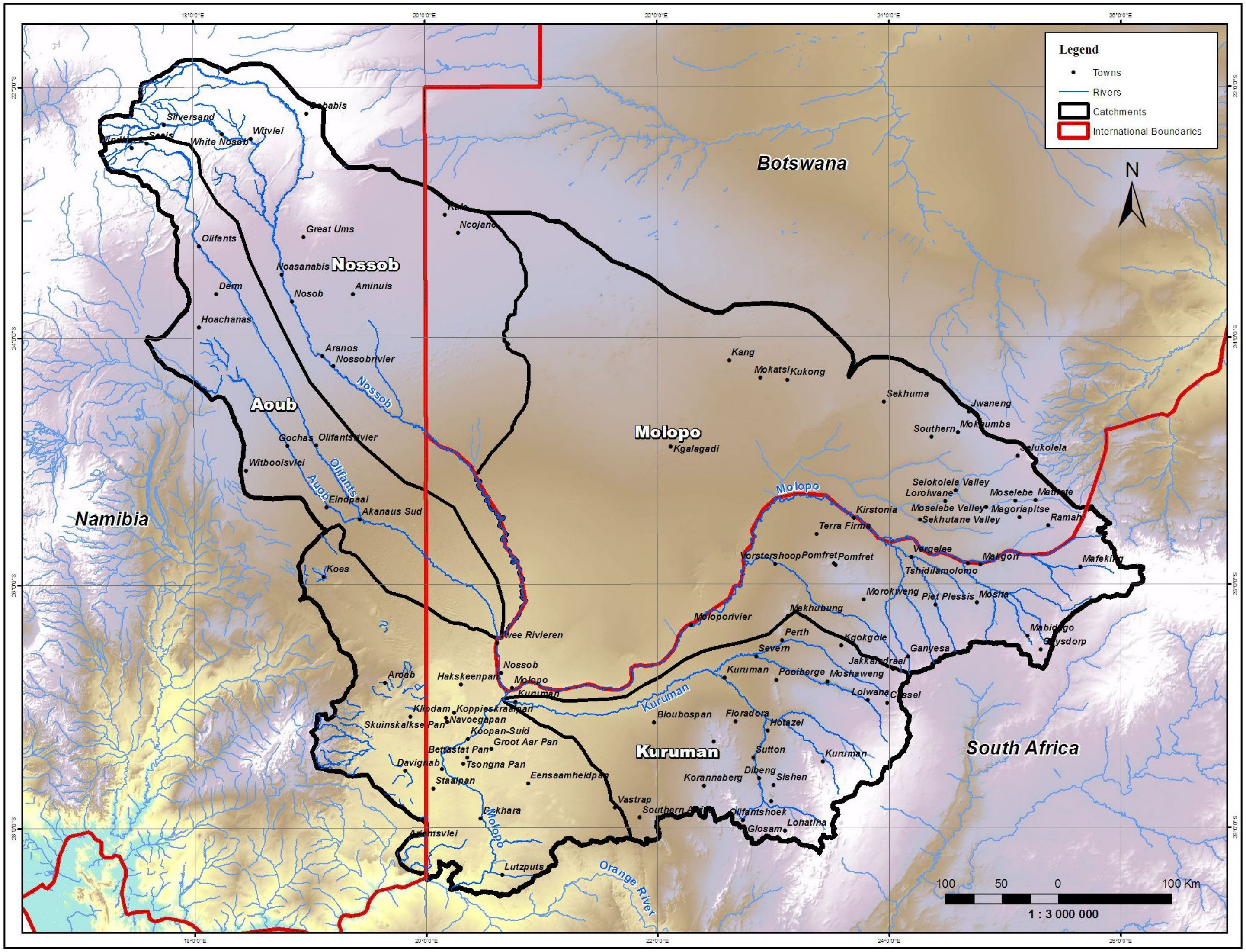

Figure 2.1: Study Catchment

After the confluence of these rivers, to the south of the Kgalagadi Transfrontier Park, the Molopo River continues southwards until its confluence with the Orange River in the vicinity of the Augrabies Falls in the RSA (**Figure 2-2**).

2.3 DRAINAGE

As a result of the low rainfall, flat topography and the occurrence of pans, dunes and sandy soils over much of the study area, specifically where the rivers flow through the Kgalagadi, little surface runoff is generated. Although occasional runoff occurs in the upper parts of the various subcatchments, evaporation and seepage losses, in conjunction with relatively large storage dams, specifically in the upper Molopo and Nossob catchments, prevent this runoff from reaching the lower reaches except during extreme events. Although there is anecdotal evidence of occasional flow along the lower Kuruman, Molopo, Nossob and Aoub rivers, linked to specific flood events, there is no record of flows in the Molopo River ever having reached the Orange River and the Molopo-Nossob catchment is therefore classified as an endoreic area. Previous recordings of flow in the lower reaches of the Molopo and/or Kuruman rivers were in 1933, 1974/5 and 1975/76. Flow along the lower reaches of the Nossob and Aoub rivers has been recorded in 1934, 1963, 1974 and 1999/2000. A recent event of flow in the Aoub River in the Kagalagadi Transfronteir Park was reported in the press

The occurrence of pans in the study area, which are common in the Botswana and Namibian parts of the catchment, also has a significant impact on local drainage patterns and further reduces runoff. Schoeman and Partners, as part of the landuse task of this study, calculated that the water retaining capacity of all 2 607 the pans in the study area equaled some 1 900 million m^3. The number, area and volume of pans in the study area are summarised in **Table 2-2**.

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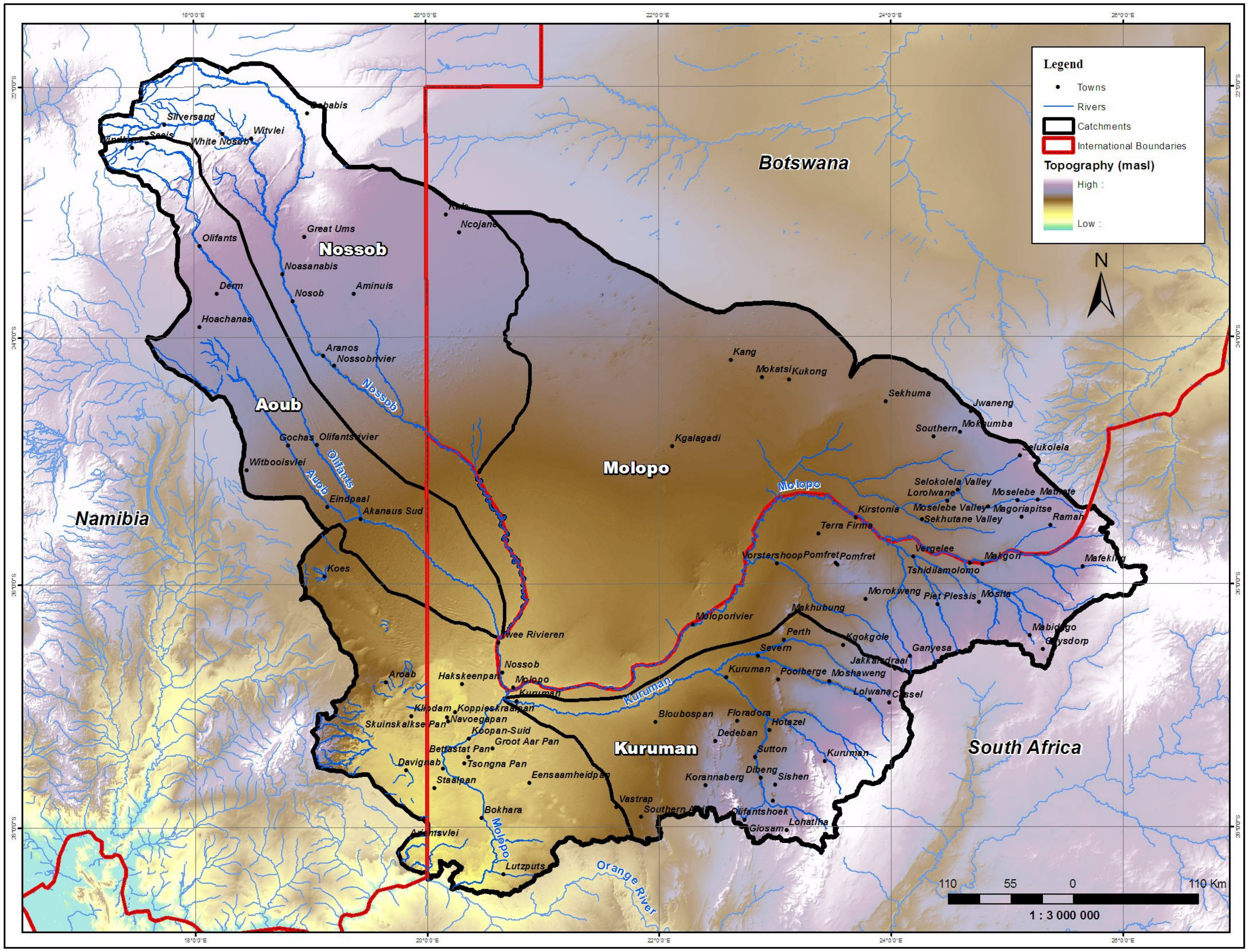

Figure 2.2: Catchment Topography

Table 2-2: Details of Pans in the study catchment

Subcatchment	No. Pans	Volume (Mm^3)	Area (km^2)
Molopo	1 179	1 406	972
Kuruman	226	71	54
Nossob	676	279	167
Aoub	526	230	141
TOTAL	**2 607**	**1 986**	**1 334**

2.3.1 Nossob River

The Nossob River originates in the mountainous area to the north-east of Windhoek and its upper reaches are characterised by two main tributaries viz. the Black Nossob and the White Nossob. These tributaries originally drain in an easterly direction towards Gobabis, where they turn south until their confluence at the town of Hoaseb, approximately 70 km south of Gobabis. From Hoaseb, the Nossob River flows in a south-easterly direction and eventually constitutes the border between the Republic of Botswana and the Republic of South Africa. The Nossob River has its confluence with the Aoub River at Twee Rivieren in the Kgalagadi Transfrontier Park and with the Molopo River at the town of Bokspits, 60 km south of the Aoub confluence.

2.3.2 Aoub River

The Aoub River has its origin in the Karubeam Mountains in Namibia north east of Mariental, from where it flows in a south-easterly direction towards the Republic of South Africa. Approximately 80 km upstream of the Namibian/South African border, the Aoub River is joined, from the north, by its main tributary, the Olifants River. The Olifants River originates in the mountainous areas surrounding Windhoek and flows parallel to the Aoub River until their point of confluence. The Aoub River joins the Nossob River at Twee Rivieren in the Kgalagadi Transfrontier Park (**Figure 2-1**).

2.3.3 Kuruman River

The Kuruman River originates south east of Kuruman, where it is fed by various springs, most notably the Great Koning Eye, Little Koning Eye and the Kuruman Eye. Originally, the river flows in a north-westerly direction over a distance of approximately 140 km, after which it turns west and flows parallel to the Molopo River, until it has its confluence with the Molopo River at Andriesvale, in close proximity to the Nossob/Molopo confluence. Various tributaries join the Kuruman River along its upper reaches, including the Ga-Mogara, Moshaweng, Mathlawareng and Kgokgole rivers. The Kuruman catchment is the only subcatchment within the Molopo-Nossob system which falls completely within the Republic of South Africa (RSA).

2.3.4 Molopo River

The Molopo River emanates from the area to the east of Mafikeng, where it is fed by various springs, most notably the Molopo Eye and the Grootfontein Eye. From here it flows in a westerly direction and essentially constitutes the border between South Africa and Botswana until its confluence with the Nossob. Several dry-bed, ephemeral streams join the Molopo stem along its upper reaches. These include localised tributaries from the south (South Africa) e.g. Setklagole, Phepane and Disipi rivers, which drain north-westwards towards the Molopo River, and tributaries from Botswana e.g. Ramatlabama and Melatswane, which drain westwards before joining the main stem of the Molopo River. The Molopo River is joined by the Nossob River at Bokspits and the Kuruman River at Andriesvale, immediately south of the Kgalagadi Transfrontier Park, from where it flows southwards before joining the Orange River about 300 km downstream.

2.4 LANDUSE

Most of the land in the study catchment is under natural vegetation and a large portion of the catchment falls within the Kagalagadi. Areas of cultivation are found in the Upper Nossob and Olifants catchments, where irrigation is predominantly from ground water sources, and the south-eastern parts of the Molopo catchment near Mafikeng where the demand is satisfied from farm dams. No afforestation or large-scale infestations of invasive alien vegetation occur in the study area, although land-invasion by *Prosopis* species is on the increase in Namibia. There is large-scale mining activity in the vicinity of Sishen and Hotazel in the upper Kuruman catchment where manganese ore, iron ore, tiger's eye and crocidolite (blue asbestos) are mined. The towns of Mafikeng, Kuruman, Gobabis and part of Windhoek represent the only significant urban areas in the study catchment, while scattered rural settlements and small towns supporting mining activities abound.

2.5 GEOLOGY AND SOIL

2.5.1 Namibia

At the Omaheke, the sandveld constitutes mainly an Aeolian sand mantle about 50 m thick. It has a low relief of vegetated ancient longitudinal sand dunes and windblown sand. Those sandy soils together with the flat topography have produced the poorly developed drainage lines of the region all of which rise in the west. The harder surfaces of the landscapes to the west, together with the more gentle relief, result in better-defined drainage lines.

The common base material of the Kalahari is remarkably uniform, relatively unweathered medium-textured sand. The clay content is very low and the soils are in general weakly developed, shallow and calcareous. Closer to the drainage lines the soils contain deposits of limestone and quartzite while sandstone and shale also occur. The sandy nature of the soil accounts for the very low water-retaining capacity.

The high clay content of the soil in the Hardap Region limits water penetration which results in a nearly total absence of vegetation. The western border of the Kalk plateau is characterised by isolated drainage systems and many pans. To the north the Kalk plateau changes gradually to the rocky landscape surrounding Rehoboth.

2.5.2 South Africa

Dunes are associated with the arid environment of the Kalahari occur in the far western region. It also has an interesting and ancient geological heritage, rich in minerals and palaeontological artefacts. The north-eastern and north-central regions of the Province are largely dominated by igneous rock formations, as a result of the intrusion of the Bushveld Complex. Ancient igneous volcanic rocks dating back to the Ventersdorp age (more than 2 000 million years) appear to be the dominant formations in the western, eastern and southern regions of the Province.

The sub river basin area in the Northern Cape is considered to be of medium-low ecological sensitivity.The Northern Cape's landscape is characterised by the Kalahari Desert, wavy hills, sand plains, red sand dunes. The rocky soil type of the Richtersveld are more suited to crop production than the soils of the rest of the Namaqua District Municipality (DM), but their relatively shallow depth and adverse climate conditions as well as the steep mountainous topography makes crop production non-viable. The southern part of the district has granite-derived loam soils in the valleys. Alluvial soils with high loam contents result in relatively highly fertile soils.

Due to the dynamic nature of soils of the North West Province, they are constantly evolving and degrading by means of natural and man-induced processes. The weathering of rocks in deserts and semi-arid areas tends to be superficial and hence these soils tend to be shallow and stony. Erosion and deposition by the agents of wind and water are responsible for the transportation of soils from one location to another.

Due to the low rainfall, soils only slightly leached over much of the western region. With high evaporation rates, there is a predominance of upward movement of moisture in the soils. This often leads to high concentrations of salts such as calcium and silica in soils, which sometimes lead to the formation of hard pans or surface duricusts. As a result, high levels of salinity or alkalinity may develop in these areas. Levels of organic matter tend to be low, governing the vegetation types which are able to grow there.

The central region has areas covered by red or brown non-shifting sands with rock. This region also has weakly developed lime soils associated with the dolomite limestone formations. The south-western region also has areas characterised by undifferentiated rock and lithosols. Lithosols are shallow soils containing coarse fragments and solid rock at depths less than 30 cm. The southern and central regions have black and red clays as well as ferrisiallitic soils of sands, loams and clays. The drier western region is characterised by red and yellow arenosols while the south west has calcareous sands and loams and arenaceous lithosols.

2.5.3 Botswana

Botswana is characterised by the Kgalagadi (Kalahari) sanda, a mantle of sand covering the Kalahari Basin, and vast flat, semi-arid and comparative featureless landscape, except for occasional rocky outcrops. The mean altitude above sea level is 1 000 m.

2.6 VEGETATION

2.6.1 Namibia

The vegetation can be classified as dry, medium tall savannah associated areas with good edible grass cover, dominated by acacia thorn bush over the western and central areas, but do not always form dense stands. To the east it changes gradually to the Camelthorn (*Acacia eroloba*) savannah, characterised by dense edible grass stands with lone standing trees and mixed stands of shrubs. To the north east it changes to forest savannah and dry woodland, becoming denser to the north as taller trees appear.

Tall trees and denser stands of the mixed shrubs are confined to watercourses between the slopes. Over the extreme eastern and southern part lone standing Camelthorn (*Acacia erioloba*) trees are more prominent. Low shrub trees and bushes of varying density become sparser towards the west and the vegetation changes to a semi-desert dwarf shrub savannah.

Desertification is an issue throughout the region, but especially in the western areas due to human activity and the injudicious utilisation of the veld. Since years of drought always predominate over wetter years in an arid environment, the degeneration of vegetation cannot be stopped by a period of high rainfall. In the delicately balanced ecosystem of the arid environment over-utilisation of vegetation, particularly by feeders such as small stock, could lead to total destruction of the habitat.

2.6.2 South Africa

Only savannah and grassland biomes occur in the North West Province. The western part of the province falls within the Grassland Biome comprising a wide variety of grasses typical of arid areas. Given the arid and semi-arid conditions of the western half of the North West Province, the vegetation of this region largely comprises plants that are adapted to these conditions (known as xerophytes). As a result, low biomass, productivity and species richness of plants tend to prevail in this region. With the east-west variation in climate and rainfall, there is a corresponding gradation in the vegetation types from xerophytic in the west to open grassland and savannah in the central region.

There is a predominance of Kalahari deciduous Acacia thornveld (open savannah of *Acacia erioloba* and *A. haematoxylin* as well as desert grasses) and shrub bushveld in the dry western half of the province. The rocky soil is conducive to Tarchonanthus veld on the dolomite Ghaap Plateau.

The northern and eastern regions reflect the greatest variability of vegetation types in the province. Vegetation types include sourish mixed bushveld (open savannah dominated by *Acacia caffra* and grasses of the Cymbopogon and Themeda types), turf thornveld and isolated pockets of Kalahari thornveld and shrub bushveld.

The Northern Cape has unique vegetation consisting of the orange scattered field and the Kalahari-Dune field, with a large bio-diversity of plants and animals' species, which are endemic to the respective field types.

The primary threats to biodiversity, ecosystem goods and services are habitat transformation and degradation, and invasive alien species. Many invasive species are well established and cause substantial damage, including: *Atriplex lindleyi* (Sponge-fruit saltbush); *Nummularia* (old-man saltbush); *Nicotiana gluaca* (wild tobacco); *Opuntia ficus-indica* (sweet prickly pear) and *torreyana/velutina* (honey mesquite). These alien invasive species cause threats of massive economic and social threats, in terms of our water security, the productive use of land, intensity of fires and floods, and ultimately the ecological integrity of the natural system.

2.6.3 Botswana

The vegetation of the south-western parts of Botswana is the Kalahari Acacia wooded grassland and deciduous bushland, shrub savanna, dominated by Acacia species (mainly *A. haematoxylin, A. mellifera*, and *A. erioloba*), *Terminalia sericea* and same *Bascia albitrunca*.

2.7 CLIMATE

2.7.1 Rainfall

Rainfall within the study area is highly seasonal with most rain occurring during the summer period (October to April). The peak rainfall months are February and March. Rainfall generally occurs as convective thunderstorms and is sometimes accompanied by hail. The mean annual rainfall over the Molopo and Kuruman catchments decreases fairly uniformly from more than 500 mm in the east (upper Molopo catchment) to approximately 150 mm in the vicinity of the Orange River confluence. In the Nossob and Aoub catchments, mean annual rainfall decreases in a southerly direction and varies from about 400 mm in the upper Nossob catchment to less than 200 mm at the confluence with the Molopo River.

Figure 2.3 shows the typical seasonal distribution of rainfall within the study area, while **Figure 2-4** depicts the variation in mean annual precipitation over the study area.

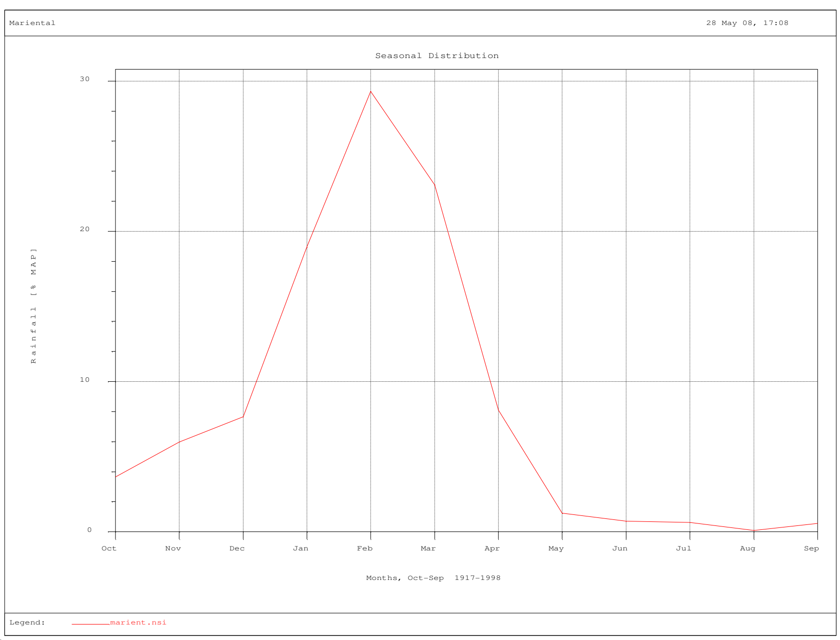

Figure 2.3: Typical Seasonal Rainfall Distribution in Study Catchment

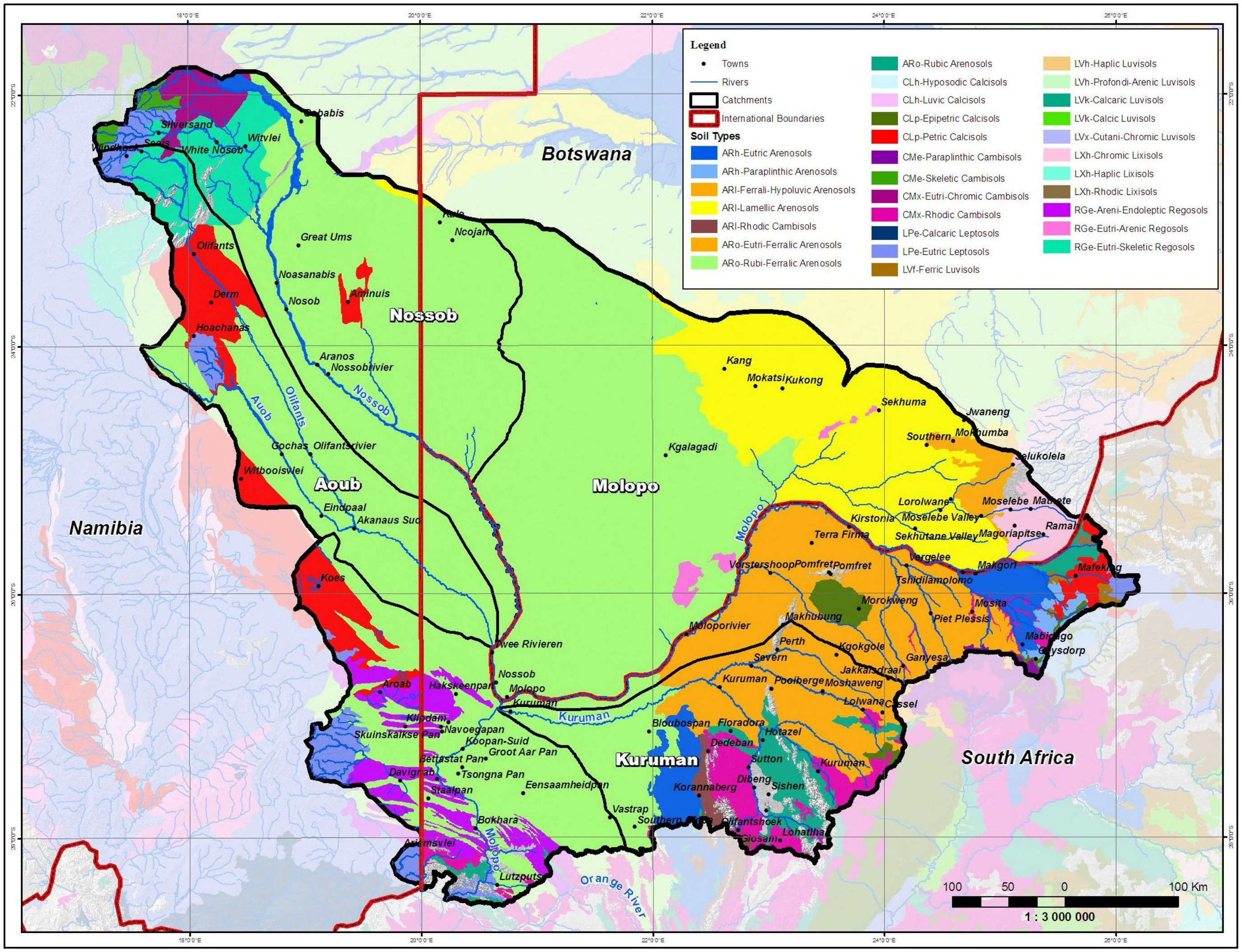

Figure 2-4: Major Soil Types

2.7.2 Evaporation

Evaporation in the Molopo-Nossob catchment is significant with Mean Annual Evaporation (MAE) generally increasing in a north-westerly direction. MAE (S-Pan) varies from about 1 900 mm in the upper Molopo catchment to more than 2 600 mm in the Kalahari Desert. Similar to rainfall, evaporation in the study area is highly seasonal, with evaporation in the summer months more than twice as high as during the winter

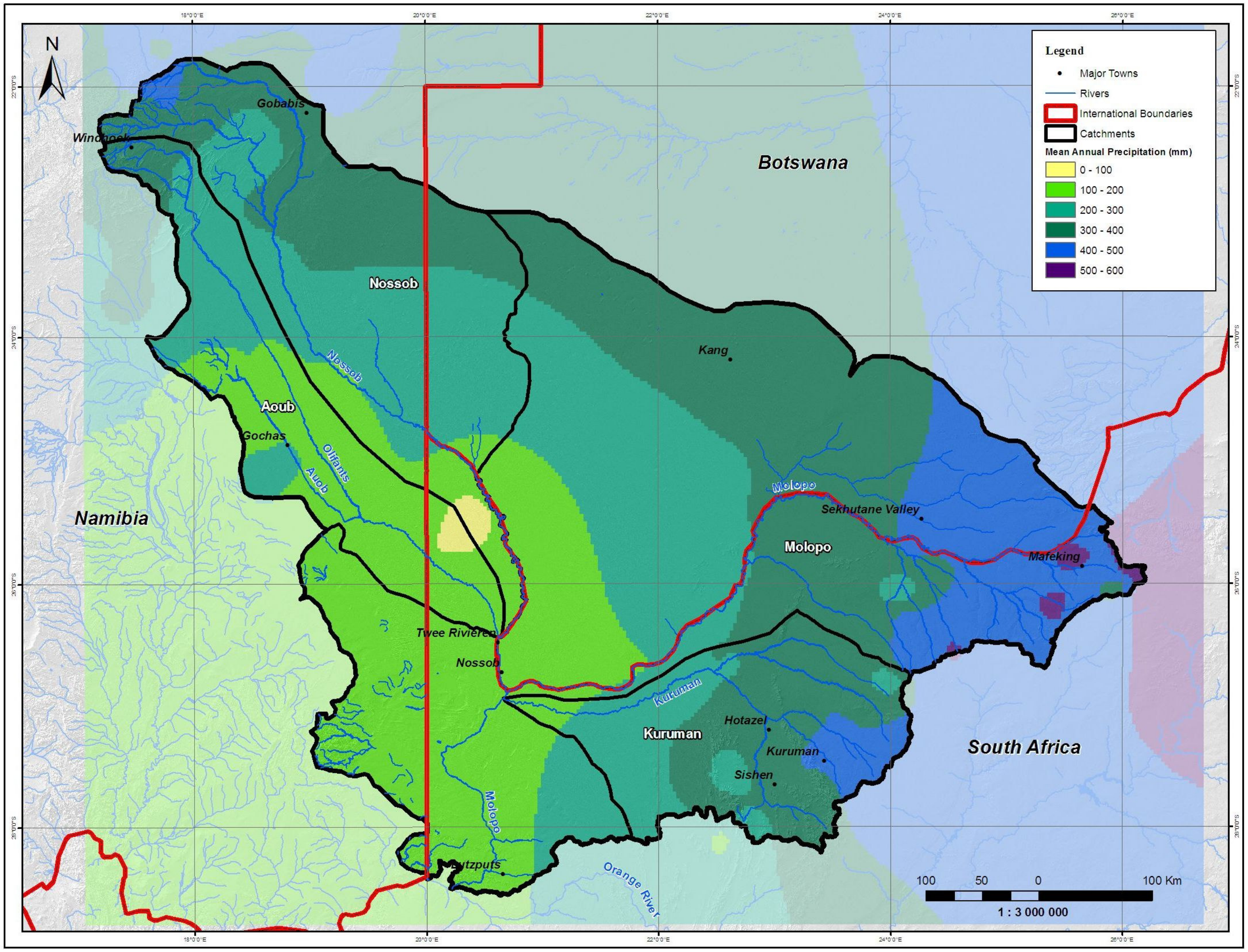

Figure 2-5: Mean Annual Precipitation

3. SOCIO-ECONOMICS

3.1 CATCHMENT ADMINISTRATIVE DISTRICTS

The Molopo River forms the border between South Africa and Botswana for most of its length to the confluence of the Nossob River, while the Nossob River forms the border between South Africa and Botswana from where it crosses the border between Namibia and Botswana to the confluence with the Molopo River. The three countries have a common border and the point where the Nossob River crosses the Namibia/Botswana border.

3.1.1 Botswana

The Molopo-Nossob catchment area in Botswana covers the Kgalagadi and Southern Districts (**Figure 3-1**). The Kgalagadi District is sub-divided into Kgalagadi North and South Sub-Districts. The Southern District is sub-divided into three Sub-regional centers of Good hope, Mabutsane and Moshupa. The district headquarters is Kanye Village. The Good hope sub-regional center represents the Barolong region, the Mabutsane sub-regional center represents the Ngwaketse West region and the Moshupa sub-regional and Kanye regional centers represent the Ngwaketse region.

3.1.2 Namibia

The administrative regions in Namibia that fall in the Molopo-Nossob catchment are Omaheke, Komas, Hardap and Karas. More specifically, for Karas, parts of Keetmanshoop rural and Karasburg constituencies are included; for Hardap mainly the Mariental rural constituency is included; for Khomas mainly the Windhoek rural constituency is included; for Omaheke the Aminuis, Gobabis and Kalahari constituencies are included (**Figure 3-1** and **Table 3-2**).

Table 3-1: Namibian Regions and Constituencies

Region	Constituency	Some Villages in Region
Hardap	Mariental rural	Stampriet, Hoachanas, Bernafy, Aranos, Gotchas
Karas	Keetmanshoop rural Karasburg	Koes, Aroab Ariamsvlei
Khomas	Windhoek rural	Seeis
Omaheke	Aminuis Gobabis Kalahari	Aminius, Leonardville Gobabis

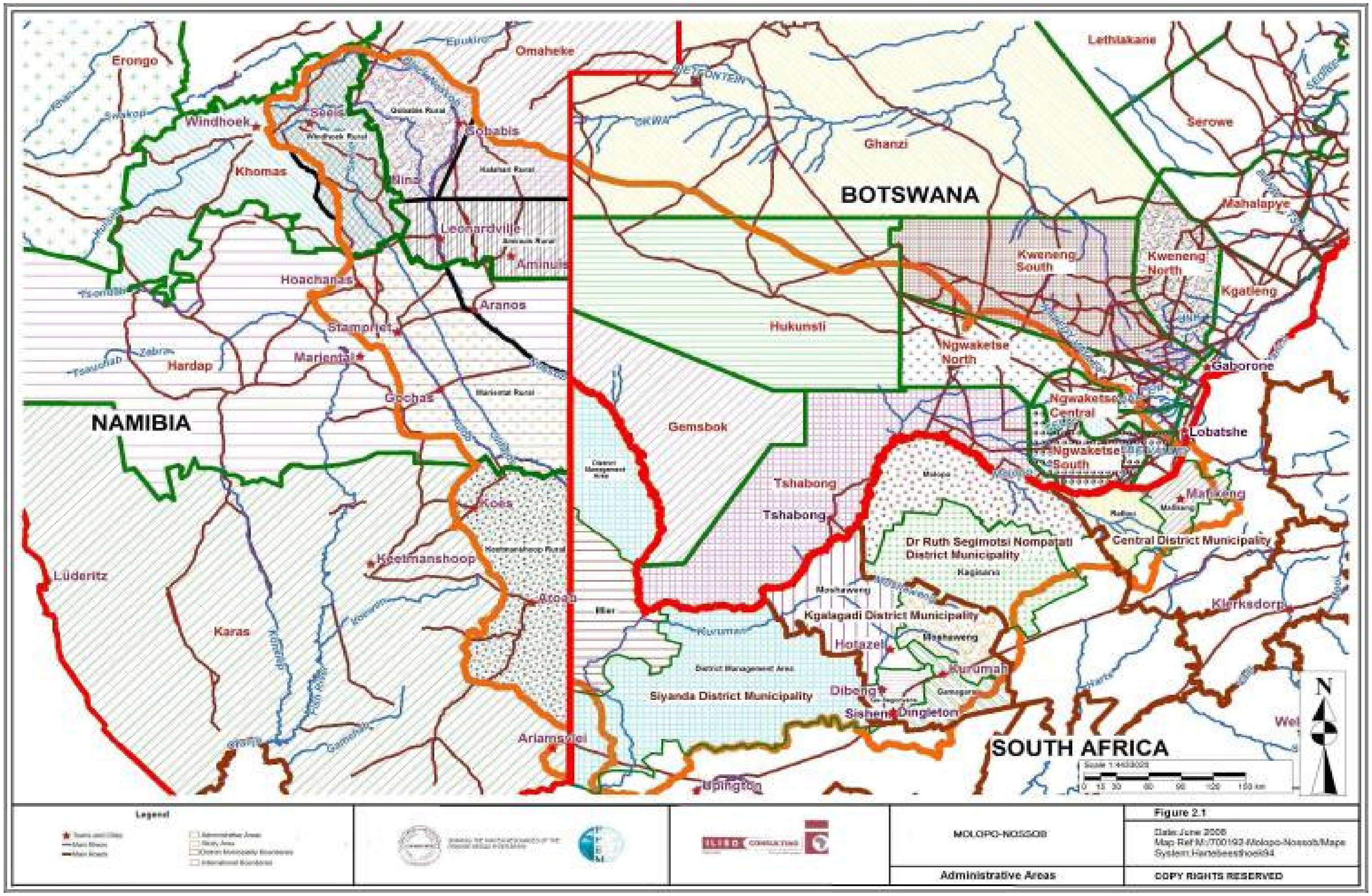

Figure 3-1: Locality of the Molopo Nossob River Catchment

3.1.3 South Africa

In South Africa, the Molopo-Nossob sub river basin covers a northern section of the Northern Cape Province and the north-western section of the North West Province. It covers the area between Mafikeng and the South African-Namibian border, north of the N14. Mafikeng and Kuruman are included in this catchment, and Upington is excluded. The local municipalities of three district municipalities fall in the sub river basin (**Figure 3-1**).

3.2 LANDUSE

3.2.1 Botswana

There are four main types of land use in the Botswana part of the study area (**Figure 3-2**) namely:

- *Communal Area* - In this area all the major villages are situated and traditional livestock rearing is the most important land use. Apart from livestock rearing a number of arable fields, especially around the villages are found in this land use zone.
- *Commercial grazing (tribal lease)* - In accordance with the Tribal Grazing Land Policy (TGLP), ranches have been established. TGLP ranches were created to relieve grazing pressure on communal grazing land. In the Kgalagadi District there are 6 blocks of TGLP ranches being, the Bokspits Block, the Middlepits Block, Tsabong Block, Makopong Block, Werda Block and Hukuntsi Block.
- *Commercial grazing (freehold, state land leased)* - this land use zone is entirely taken by the freehold and leasehold farms of the Molopo Block. Since these farms are not situated in the Kgalagadi Tribal Territory, they are administered by the Department of Surveys and Lands. Generally these farms are developed, well managed and commercially run.
- *Wildlife Management Area (WMAs)* - the Wildlife Conservation Policy of 1986 converted stretches of land that were formerly designated as "reserved" under the Tribal Grazing Land Policy of 1975 into WMAs. According to NDP 9 2003/04 to 2008/09 (MFDP, 2003, p. 246), WMAs were established by the Department of Wildlife National Parks and Division of Land Use Planning to serve as migratory corridors for wildlife between the protected areas as they allowed for movement that is essential for the survival of Botswana's wildlife in the arid environment. The WMAs were further sub-divided by DWNP and Division of Land Use Planning into Controlled Hunting Areas (CHAs), and these CHAs were subsequently earmarked for various kinds of management and utilization, and

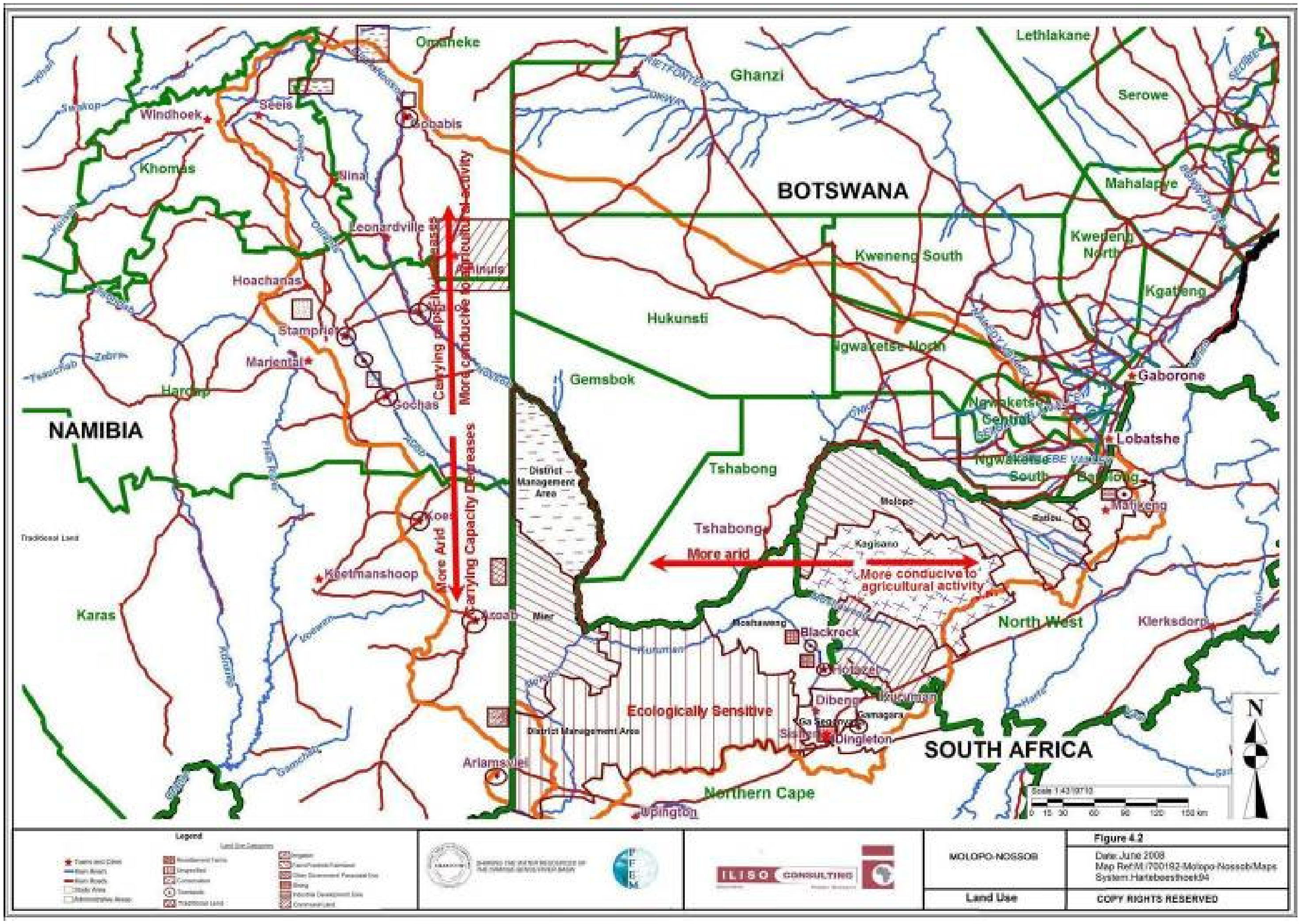

Figure 3.2: Landuse in the catchment

3.2.2 Namibia

In Namibia, the area in the sub river basin consists of *farms/freeholds farmlands* on which large scale commercial agriculture takes place (**Figure 3-2**).

Pockets of *communal land* on which subsistence agricultural activities take place exist north of Aranos and Ariamsvlei. Where grazing for subsistence purposes occur in this area, the carrying capacity of the land tends to be overloaded.

The carrying capacity of the land decreases from the northern part of the sub basin to the southern part, from 30-39 kg/ha to 4-9 kg/ha. The cattle density reduces from 5-12/ha to 0-4/ha (Atlas of Namibia Project, 2002).

Information about the suitability of soil in the affected area in Namibia for *crop production* could not be sourced. However, the fact that mostly grazing occurs in this area indicates that crop farming is not considered to be suitable.

In general, where crop farming occurs, dry land farming is practiced because of lack of water which is required for effective irrigation. Crop farming and some irrigation was observed between Gobabis and Windhoek. The Gobabis area where crop farming with irrigation was observed was in close proximity to the Tilda and Daan Viljoen Dams in Namibia. The water supply from the dams proved to be inadequate to provide for the users, and the Gobabis Water Supply Scheme was implemented to supplement water from the dams.

At Bernatey in the Mariental rural constituency, irrigation of crop fields, mainly vegetables for subsistence and citrus for the commercial market, occurs. Bernatey is on the southern end of the Stampriet artesan aquifer on the Auob River.

Mining is not a significant land use in the Namibian sub river basin. Planned mining developments in the sub basin in Namibia could not be determined.

As far as could be established, no major industries operate in the Namibian sections of the sub river basin.

3.2.3 South Africa

The land in the sub river basin is mainly private land, with some state/tribal land in the North West Province and Moshaweng LM in the Northern Cape **(Figure 3-2)**. These are also the areas where most of the subsistence farming occurs.

Irrigation occurs along the Orange River, which does not fall in the sub-basin. However, water usage along this river might affect the water availability in the sub basin.

More than 80 % of the land in the Northern Cape is used for natural grazing to feed an array of animal's mostly cattle, but also sheep, and goats, game and ostriches (Northern Cape Provincial Government, 2007).

The eastern part is more conducive to agricultural activities. The land south of the Kgalagadi Transfrontier Park is considered to be of high ecological sensitivity.

Mining does occur, mainly in Kgalagadi District Municipality. The active mining takes place at Sishen (meaning "new place") and Hotazel. Sishen Iron Ore Mine, a subsidiary of Kumba Resources, is located south of Kathu ("town under the trees") in the Gamagara Local Municipality. This mine intends to further expand, which will have implications for job creation, economic activity, and service delivery.

Almost all of the estimated 12 billion tonnes of manganese in South Africa are located in the Kalahari (Kgalagadi Nodal Economic Profiling Project, 2007). Samancor Manganese at Hotazel also plans to expand.

Assmang is situated in Blackrock, and it is not expected to increase (Kgalagadi Nodal Economic Profiling Project, 2007). Assmang operates three divisions: manganese ore, iron ore, and chrome ore. The manganese and iron ore operations are in Nchwaning and Beeshoek in the Northern Cape.

As far as could be established, no other economically viable mineral resources have been found in the sub river basin, except for recent findings in the Rietfontein (Mier Municipality) area. According to the Kgalagadi DM's Integrated Development Plan (IDP) (2004) there are small pockets of various minerals. The largest are copper and zinc of Areachap north of Upington. Various small concentrations of calcite, lead, fluorspar, barite, wolfram and amethyst have been mapped but not at a notable scale.

Currently, salt is being mined at two pans, namely Groot Witpan, 95 km northwest of Upington and at Witpan, 115 km northwest of Upington. If one takes into account that there are 110 saltpans in the interior (69 coastal saltpans, as well as sea salt plants where salt is produced), the importance of the two pans north of Upington is clear. It might seem as if South Africa has inexhaustible reserves because of the great number of pans, but available information indicates that the production at most pans is small and uncertain. Rain is not conducive to salt production. Some pans have to stop production for years after a good rainy season (Kgalagadi DM IDP, 2002).

As far as could be established, except for the Mafikeng area, no major industries operate in the South African and Namibian sections of the sub river basin. An Industrial Development Zone is planned for Mafikeng.

3.3 POPULATION

3.3.1 Botswana

The population figures for the census years 1971, 1981, 1991 and 2001 are presented in **Tables 3-2** to **3-6**. The data on the tables also shows population changes between the census years. Overall, there was a population increase.

Table 3-2: Population by District

District	1971	1981	% Change 1971-1981	1991	% Change 1981 - 1991	2001	% Change 1991-2001
Kgalagadi District							
Kgalagadi North	3699	6707	81	11 340	69	16 111	42
Kgalagadi South	15 137	24 059	59	19 794	-18	25 938	31
Southern District							
Ngwaketse	70 558	104 182	48	128 989	24	124 175	-4
Barolong	10 973	15 471	41	18 400	19	47 477	158
Total	**100 367**	**150 419**	**50**	**178 523**	**19**	**213 701**	**20**

Table 3-3: Population of towns in District

Town	1971	1981	% Change 1971-1981	1991	% Change 1981 - 1991	2001	% Change 1991-2001
Towns							
Lobatse	12 920	19 034	47	26 052	37	29 689	14
Jwaneng	-	5 567	-	11 188	101	15 179	36

Table 3-4: Kgalagadi District Population by Village/Locality

Village/Locality	1971	1981	% Change 1971-1981	1991	% Change 1981 - 1991	2001	% Change 1991-2001
Hukuntsi Sub District (Kgalagadi North)							
Hukuntsi	1 116	2 009	73	2 562	28	3 807	49
Hukuntsi area	-	256	-	306	20	4 131	1 250
Kang	1 110	1 684	52	2 657	58	4 124	55
Phuduhudu	-	629	-	322	-49	621	93
Lokgwabe	300	866	189	1 037	20	1 304	26
Lokgwabe area	-	538	-	233	57	1 435	516
Lehututu	448	713	59	1 304	83	1 719	32
Lehututu area	-	753	-	231	-69	1 778	670
Tshane	604	637	5	706	11	858	22
Hunhukwe/Ohe	42	424	910	356	-16	579	63
Ohe	Same as above	Same as above	Same as above	77	-	Part of Hunhukwe	-
Manong (RAD)	4	100	2 400	232	132	172	26
Ukhwi (RAD)	31	274	784	313	14	454	45
Ngwatle (RAD)	-	-	-	92	-	206	124
Zutshwa (RAD)	-	-	-	203	-	525	159
Ncaang	-	-	-	-	-	175	-
Maake (RAD)	-	-	-	182	-	366	101
Lokgware (RAD)	-	-	-	307	-	-	-
Caa Cattle-post	-	-	-	100	-	(Part of Zutshwa)	-
Cawane	-	-	-	34	-	(Part of Kang)	-
Shobowe	-	-	-	340	-	-	-
Inalegolo	-	-	-	-	-	558	-
Other settlements				93	-	129	39
Totals	3 699	6 707	81	11 340	69	16 111	42
Kgalagadi South							
Tsabong	647	1 732	168	4 585	165	7 228	58
Werda	706	1 109	57	1 974	78	2 237	13
Makopong	519	824	59	1 270	54	1 635	29
Phepheng/Draaihoek	337	569	69	826	45	998	21
Omaweneno	330	491	49	974	98	1 134	16
Khuis	213	490	130	696	42	851	22
Kolonkwane	240	415	73	751	81	762	2
Gakhibana	221	376	70	659	75	797	21
Middlepits	212	369	74	454	23	657	45
Bokspits	250	312	25	395	27	575	46
Maubelo	110	271	146	395	46	453	25
Bogogobo	191	225	18	368	64	341	-7
Kisa	352	197	44	1 021	418	545	-47
Kokotsha (RAD)	-	-	-	874	-	1 333	53
Vaal-hoek	-	185	-	224	21	346	55
Struizendum	136	182	34	289	59	313	8
Rappelspan	82	151	84	306	103	458	50
Bray	135	269	99	768	186	899	17
Maralaleng	164	186	13	Associated with Kisa	-	487	-
Khawa	-	-	-	424	-	623	47
Maleshe	-	-	-	-	-	455	-

Village/Locality	1971	1981	% Change 1971-1981	1991	% Change 1981 - 1991	2001	% Change 1991-2001
Other settlements (RADs)	-	-	-	1 743	-	2 811	61
Totals	15 137	24 059	59	19 794	-18	25 938	31

Table 3-5: Ngwaketse and Ngwaketse West population by Village/Locality

Village/Locality	1971	1981	% Change 1971-1981	1991	% Change 1981 - 1991	2001	% Change 1991-2001
Ngwaketse							
Kanye	10 664	20 215	90	44 520	120	48 143	8
Ranaka	1 470	1 914	30	3 176	66	3 124	-2
Lotlhakane West	213 (Lotlhakane East & West)	884 (Lotlhakane East & West)	315	906	2.5	1 192	32
Gasita	84	137	62	-	-	2 046	-
Lorolwana	60	115	30	574	399	1 090	90
Tsonyane	-	304	-	-	-	609	-
Kgomokasitwa	299	838	180	1 518	81	1 447	-5
Pitseng/Ralekgetho	149	226	-	-	-	850	-
Mokhoma	-	295	-	-	-	839	-
Lekgolobotlo	204	389	91	1 075	176	1 193	11
Seherelela	-	-	-	-	-	536	-
Lotlhakane	Considered under Lotlhakane West	Considered under Lotlhakane West	Considered under Lotlhakane West	2 581	-	4 692	82
Sese	37	370	900	-	-	1 725	-
Sesung	181	695	284	-	-	440	-
Mogotlhwane	272	661	143	1 039	57	1 131	9
Segwagwa	32	278	760	-	-	1 062	-
Manyana	964	2 004	108	2 943	47	3 488	19
Maokane	140	653	366	1 344	106	1 629	21
Dipotsana	696	-	-	-	-	124	-
Diabo	65	283	337	-	-	272	-
Molapowabojang	346	778	125	4 371	462	7 499	72
Moshaneng	589	716	22	1 732	142	1 637	6
Moshupa	3 114	6 612	112	22 429	239	22 811	2
Ntlhantlhe	421	936	122	2 412	158	2 172	-10
Tshwaane	654	-	-	-	-	204	-
Samane	117	274	134	1 219	345	886	-27
Tlhankane	-	-	-	-	-	503	-
Selokolela	384	512	33	3 028	491	1 825	40
Mogonye	186	362	94	496	37	535	8
Totals	70 558 (for Ngwaketse and Ngwaketse West combined)	104 182 (for Ngwaketse and Ngwaketse West combined)	48	128 989 (for Ngwaketse and Ngwaketse West	24	113 704	-

Village/Locality	1971	1981	% Change 1971-1981	1991	% Change 1981 - 1991	2001	% Change 1991-2001
				combined)			
Ngwaketse West							
Mabutsane	459	928	102	1 178	27	1 805	53
Morwamosu	180	398	121	648	63	671	4
Sekoma	150	490	227	1 277	161	1 327	4
Khonkhwa	-	204	-	-	-	525	-
Keng	78	387	396	893	131	1 095	23
Khakhea	480	1 273	165	2.330	83	2 529	9
Kokong	374	548	47	800	46	989	24
Kanaku	-	-	-	-	-	149	-
Mahotshwane	-	-	-	-	-	775	-
Itholoke	-	-	-	-	-	343	-
Other settlements	-	-	-	-	-	263	-
Totals	Considered under Ngwaketse	Considered under Ngwaketse	Considered under Ngwaketse	Considered under Ngwaketse	Considered under Ngwaketse	10 471	-

Table 3-6: Barolong population by village/locality

Village/Locality	1971	1981	% Change 1971-1981	1991	% Change 1981 - 1991	2001	% Change 1991-2001
Barolong							
Pitsane Siding	-	-	-	2 212	-	2 959	34
Tlhareseleele	628	634	1	713	13	767	8
Pitsana-Potokwe	393	556	41	827	49	860	4
Rakhuna	660	866	31	1 417	64	1 246	-12
Malokaganyane	273	315	15	366	16	321	-12
Bethel	275	295	7	351	19	440	25
Dinatshana	110	278	153	373	34	480	29
Ngwatsau	356	333	-6	327	-2	338	3
Ramatlhabama	610	1 025	68	1 150	12	1 421	24
Good Hope	472	841	78	2 003	138	2 972	48
Mokatako	418	743	78	1 223	65	1 427	17
Tswanyaneng	220	292	33	842	188	518	-39
Metlojane	276	335	21	926	176	919	-1
Borobadilepe	250	305	22	373	22	310	-17
Hebron	257	576	124	711	23	776	9
Logagane	238	271	14	371	37	390	5
Tswagare/Lothoje/Lokalana	172	282	64	391	39	347	-11
Makokwe	191	203	6	165	-19	128	-22
Marojane	327	267	-18	272	2	263	3
Papatlo	278	466	68	429	-8	390	9
Phihitshwane	396	506	28	672	33	560	-17
Molete	-	-	-	313	-	320	2
Ditlharapa	286	296	4	274	-7	682	149
Madingwana	115	250	117	323	29	334	3
Kgoro	523	658	26	726	10	782	8
Sheep Farm	279	272	-3	312	15	313	0.3
Motsentshe	144	215	49	-	-	375	-

Village/Locality	1971	1981	% Change 1971-1981	1991	% Change 1981 - 1991	2001	% Change 1991-2001
Mogwalale	212	367	73	-	-	281	-
Gathwane	347	711	105	2 215	212	1 292	42
Digawana	949	1 780	88	2 156	21	2 675	24
Magoriapitse	272	348	28	1 080	210	1 110	3
Lejwana	210	298	42	379	27	557	47
Mogojogojo	155	358	131	1 533	328	1 910	25
Mmathethe	1 100	1 990	81	6 728	238	6 692	-0.5
Mokgomane	96	359	274	1 735	384	1 309	-25
Pitshane Molopo	768	1 036	35	1 731	67	1 660	-4
Sedibeng	55	139	153	365	163	636	74
Musi	-	-	-	-	-	244	-
Tshwaaneng	144	191	33	625	227	740	18
Gamajalela	-	-	-	-	-	566	-
Dikhukhung	128	156	22	340	118	309	-9
Leporung	276	461	67	708	54	703	-0.7
Mmakgori	220	320	45	435	36	808	86
Mabule	654	1 054	61	2 091	98	1 628	-22
Tshidilamolomo	241	549	128	715	30	702	-2
Metlobo	133	341	156	1 207	254	1 244	3
Lorwana	388	503	30	834	66	725	-13
Kangwe	179	310	73	-	-	166	-
Sekhutlane	-	-	-	-	-	796	-
Other settlements	-	-	-	-	-	86	-
Totals	10 973	15 471	41	18 400	19	47 477	158

3.3.2 Namibia

Despite rapid urbanisation, Namibia is still a mainly rural society. This is anticipated to change considerably and by 2010 it is expected that 50% of the population will be urbanised (43 % in 2006).

Namibia's population was 1.8 million in 2001 and the growth rate is estimated at 2.6 % (Namibia Household Income and Expenditure Survey, 2003-2004). However, aaccording to UNICEF, the HIV prevalence rate in Namibia amongst the population aged 14-64 was estimated at approximately 19.6 % at the end of 2005. To temper growth-related expectations, these figures as well as decreasing fertility (UNDP, 2008) has to be factored into the population growth rate figures, which are projected at 2.61 million by 2011 (4.27 by 2030) (high variants of the projection model) (Office of the President, 2004).

Overall, the sub river basin is sparsely populated, mainly because the area is too dry for extensive human settlement (**Table 3-7**). For Namibia, the majority of the population (60 %) live in the northern regions that do not fall in the basin. Khomas is home to 14 % of the Namibian population, and is the most populated area in

Namibia. The annual growth rate is 4 % per annum. The least populated area in Namibia also falls in the sub river basin. This is the Omaheke Region, which is home to 3 % of the Namibian population. Omaheke Region's annual growth rate is 2.5 % per annum. The annual growth rate for Karas is 1.3 % and for Hardap 0.3 % per annum (Karas and Hardap Regional Poverty Profile, 2005).

The population density (**Figure 3-3**) in the sub river basin is mainly 0.01 to 1.1 people per km^2, and it increases to 1 - 5 people per km^2 in the villages such as Nina, 10 - 25 people per km^2 in Mariental and surrounding villages, and 50 - 100 people per km^2 in Gobabis (Namibia Vision 2030).

All the areas in Namibia showed a positive population growth rate. Whilst 33 % of the population lived in urban centres in 2001, the urban population is currently growing at a much higher rate (over 5 % per annum), than the rural population. The vision is for Namibia to be a "*highly urbanised country with 75 % of the population residing in the designated urban areas"* (Office of the President, 2004: Vision 2030 page 49).

Table 3-7: Namibian Population Growth

Region	Population (2001)	Population (2007)	Population Growth
Karas	***69 321***	***71 701***	***3.4%***
Keetmanshoop Rural	6 349		
Karasburg	14 693		
Omaheke	***68 041***	***75 620***	***11.1%***
Aminuis	12 343		
Gobabis			
Kalahari			
Hardap	***68 246***	***70 584***	***3.4%***
Mariental Rural	13 596		
Khomas	***250 260***	***304 341***	***21.6%***
Windhoek Rural	19 908		

Source: Central Bureau of Statistics

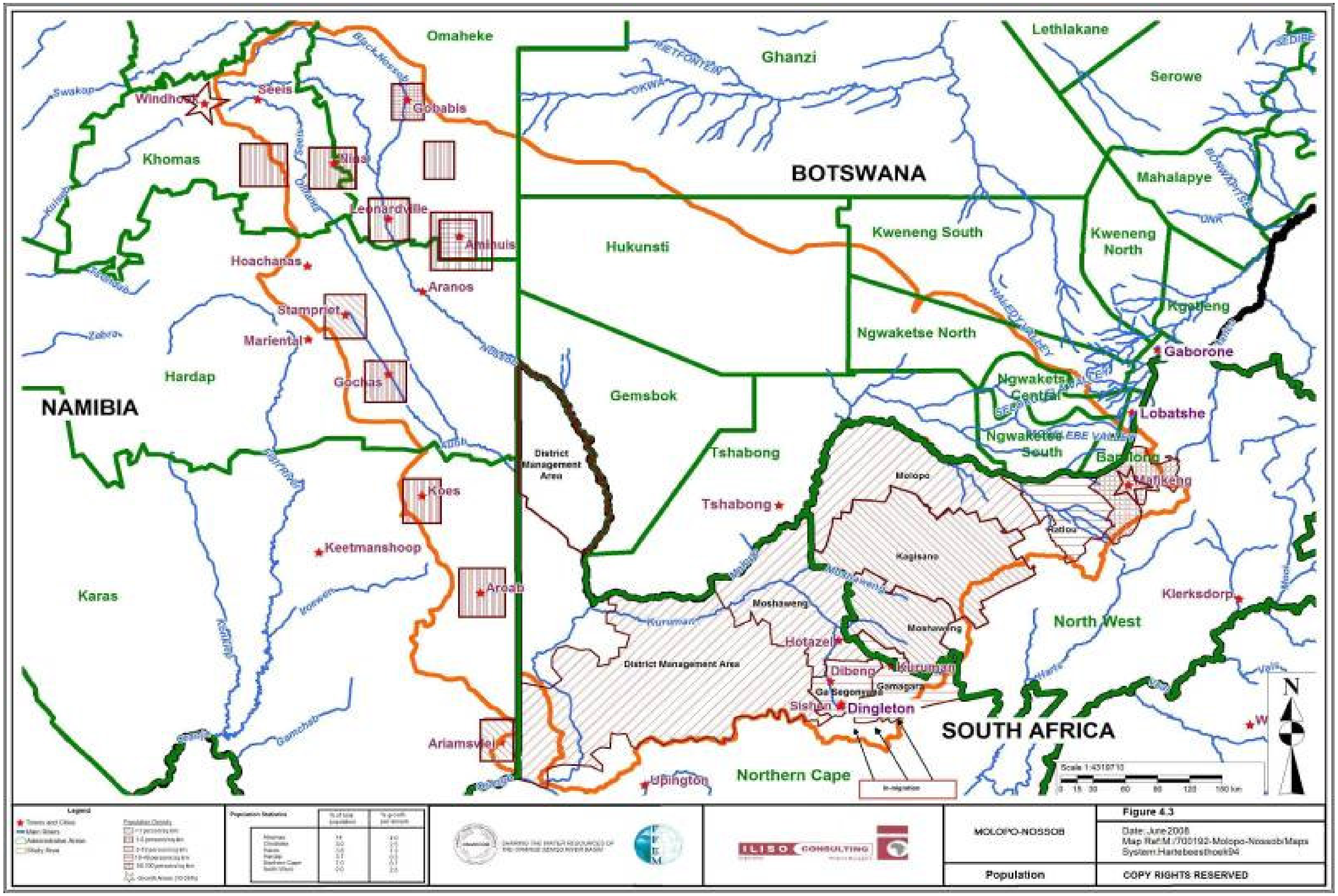

Figure 3.3: Population distribution in the catchment area

The household size in rural areas is larger than in urban areas, 5.4 compared to 4.2 persons. In Namibia, the population in rural areas is generally younger than the population in urban areas, but urban areas have a larger population of 15-59 year olds, the working ages. In urban areas, there are more males than females in the 15 - 49 year old age group, which is a reflection of the migration of males to urban areas in search for jobs. Senior citizens represent 6 % of the urban population. A large percentage (45 %) of Namibia's households is female-headed. These households are often worse off than male-headed households (Namibia Vision 2030). See **Table 3-8** for a summary.

In terms of educational attainment, there are large differences between those living in urban areas, and those living in rural areas. In Namibia, the proportion of those without formal education is 23 % in rural areas, compared to 7 % in urban areas. In Omaheke, 37 % of the population has no formal education, whereas in Hardap, Karas, and Khomas the percentage is below twenty. A higher proportion of households where heads have no formal education own poultry, goats, pigs and donkeys/mules compared to households where the head has attained tertiary education. For households where the head has a tertiary education, the proportion owning grazing land and sheep is relatively high (Namibia Household Income and Expenditure Survey, 2003/2004).

Table 3-8: Differences in Urban and Rural Populations

Urban	Rural
more 15-49 year olds	generally younger
more males	more females
7% without formal education	23% without formal education
Population growth over 5% per annum	Slow population growth

Remote Area Dwellers (Botswana) have a similar profile to the profile depicted in **Table 3-8**.

3.3.3 South Africa

The census results showed that the population of South Africa increased from 40.5 million in 1996 to 44.8 million in 2001, showing an overall increase of 8.2 % since 2001 (Community Survey, 2007).

The distinction between rural and urban areas in South Africa is difficult to make as rural poverty in South Africa differs from other developing countries. South Africa is unique in that migration is circulatory, and households that form part of the migratory cycle are affected by economic, social and health issues of the rural as well as the urban areas. Income generated by and food consumed from agriculture therefore form a small part of the rural household's resources (Northern Cape State of the Environment Report, updated 2005). Considering the 2001 census data, and the State of the Cities Report, the area in the basin may still be considered rural. The Kgalagadi DM was identified as 94 % rural in 2001.

The population of the North West Province has increased by 2.5 % from 2001 to 2007 with the total population estimated at 3.3 million (more than the total Namibian population), and for Northern Cape has increased by 6.7 % with the total population estimated at 1.1 million (below the total Namibian population). Northern Cape is home to approximately 2 % of the South African population, and North West Province to approximately 7 % (**Figure 3-3**).

The population density in the Northern Cape is 2 people per km^2 and for Northwest 21 per km^2. The population density in the Northwest areas that fall in the sub-basin is approximately 8 people per km^2 except for Mafikeng LM with approximately 70 people per km^2; Molopo LM with approximately 0.8 people per km^2; and Ratlou LM with approximately 22 people per km^2. Because most of the land is invaded by bush, the actual figure for density is considered to be much higher.

Table 3-9 shows the growth rate. The pattern that emerges is that the growth in urban areas / close to urban areas, are occurring at a higher rate.

Half of the affected areas in the basin within South Africa showed a negative growth rate between 2001 and 2007. These negative growth rates ranged from as little as -0.9 % to as high as - 44.3 %. It is however unclear what the reasons are for these negative growth rates, i.e. whether it can be ascribed to factors such as high mortality rates and low birth rates, migration, urbanisation, etc.

Table 3-9: South African Population Growth

Region	Population (2001)	Population (2007)	Population Growth
Projected annual population growth rates 2001-2021 (2005 provincial boundaries): 0.73%			
North West Province	***3 193 676***	***3 271 948***	***2.5%***
Bophirima District Municipality	*432 069*	*354 554*	*-17.9%*
- Kagisano Local Municipality	88 780	75 946	-14.5%
- Molopo Local Municipality	11 688	6 516	-44.3%
Central District Municipality	*762 999*	*798 783*	*4.7%*
- Ratlou Local Municipality	104 324	98 104	-6.0%
- Mafikeng Local Municipality	259 478	290 229	11.9%
Projected annual population growth rates 2001-2021 (2005 provincial boundaries): 0.43%			
Northern Cape Province	***991 919***	***1 058 060***	***6.7%***
Siyanda District Municipality	*202 160*	*238 063*	*17.8%*
- Mier Local Municipality	6 844	7 337	7.2%
Kgalagadi District Municipality	*191 539*	*173 454*	*-9.4%*
- Ga-Segonyana Local Municipality	70 392	69 791	-0.9%
- Moshaweng Local Municipality	91 708	70 012	-23.7%
- Gamagara Local Municipality	23 202	28 054	20.9%

Source: http://www.unisa.ac.za/contents/faculties/ems/docs/Press364.pdf

The average household size in South Africa is 3.9, as per the Community Survey (2007). This survey no longer distinguishes between rural and urban communities, and a comparison between urban and rural household sizes can therefore not be drawn. According to the State of the Cities Report (2006) the average city household size decreased from 3.7 to 3.6 between 1996 and 2001, and the average city household size was estimated at 3.31 in 2005. When looking at the difference between the average South African household size and the average city household size, it follows that the household size in areas other than the major cities in South Africa should generally be larger.

According to the State of the Cities Report (2006), there has been a consistent increase between 1996 and 2005 of South African city residents between the ages of 15-34 years, with a proportional decrease of residents aged 65 years and older. Although the population growth in the cities is decreasing, the Gauteng metropolitan centres showed a higher than average growth rate between 1996 and 2005, below 2 % compared to above 2 %. In urban areas, similar to that of Namibia, there are more males than females in the 15-49 year old age group, which is also a reflection of the migration of males to urban areas in search for jobs.

Part of the negative growth rate might be ascribed to the HIV prevalence rate within these two provinces. A report released by the National Department of Health (2006) stated that the HIV prevalence rate within the North West Province is estimated at 29.0 % and within the Northern Cape at 15.6 %.

Another reason might be migration from Moshaweng to the western part of the district municipality where mining occurs. The Moshaweng LM houses about 60 % of the Kgalagadi DM population in 165 villages, job opportunities are scarce, poverty levels are high, and migration of a number of people is therefore a constant occurrence in this municipality.

The South African section in the basin has a similar educational profile to that of rural Namibia, where and an average of 20 % of the adult population have completed grade 12. For Kagisano, Ratlou and Molopo (North West Province) as well as Mier (Northern Cape Province) Local Municipalities, less than 10 % have completed an education equivalent to grade 12. In Kgalagadi DM (Northern Cape), Moshaweng LM has the lowest percentage of adults who passed matric, estimated at 8 %, with Gamagara LM at 23 % and Ga-Segonyana at about 18 % (census 2001; Kgalagadi Nodal Economic Profile Project, 2007). Mafikeng LM (North West Province) equals Gamagara at 23 %. Refer to **Table 3-15** to see the comparison between urban and rural people in this regard.

3.4 ECONOMY

3.4.1 Botswana

3.4.1.1 Kgalagadi District

The Kgalagadi District (**Figure 3-4**) is largely a ranching region. However, traditional livestock rearing remains the most important means of living for most households.

Livestock ownership in the district is skewed. As the economy of the region is primarily based on cattle rearing for meat production, most food, domestic supplies and production inputs to the region come from suppliers based in Lobatse, Jwaneng and Gaborone. No manufacturing activities of a significant scale are currently taking place within the district. As with manufacturing, commercial development within the district is largely constrained by the small, scattered and poor population and undeveloped district infrastructure. Small general dealers, restaurants, bottle stores and other commercial establishments are the predominant retail businesses located in most villages. Informal sector activities provide income for many households.

3.4.1.2 Southern District

The dominant sector in terms of employment is agriculture as most people in the rural areas earn their living from farming. Activities are diverse and cover crop production, cattle rearing, horticulture, poultry and small stock farming. Crop production is more concentrated in the eastern hardveld, while cattle farming is practiced in the western part of the District. Industrial production in the District is limited mainly to the Jwaneng mine, although industrial production is also promoted by servicing industrial areas in Kanye, Pitsane and Moshupa. Small general dealers, restaurants, bottle stores and other commercial establishments are the predominant retail businesses located in almost all the villages. Informal sector activities provide income for many households.

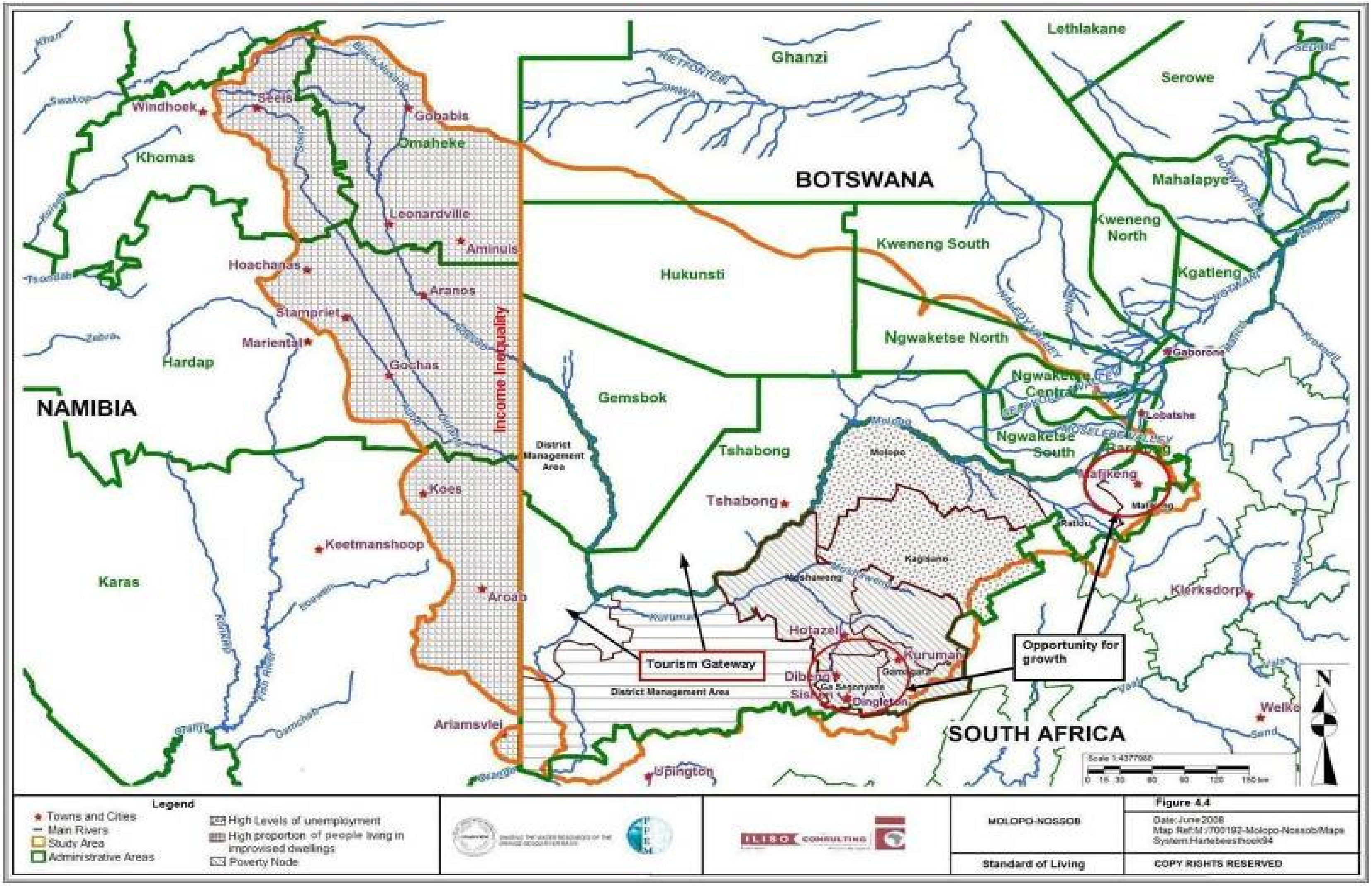

Figure 3.4: Map representing the standard of living in the catchment area

In both Kgalagadi and Southern District are settlements classified as remote area settlements. To address development challenges in remote area settlements, the Government of Botswana introduced the Remote Area Development Policy (RADP). RADP aims to assist people of Basarwa and Balala origin, and other ethnic minorities of non-stock holding origin. RADP is a government welfare programme. Remote Area Dwellers (RADS) are defined as people who:

- Live outside villages (i.e. in communities of less than 300 people).
- Have no or inadequate cash income.
- Have no or inadequate land.
- Have no or inadequate water rights.
- Depend to some extent or another on gathered veld foods, usually to a lesser extent, on wildlife.
- Have to date been out-of-reach in terms of distance from generally, available services (schools, health posts, extension staff etc.).
- Seldom own stock.
- Are in a dependant position socio-economically to wealthier (usually livestock owning families).
- Are seldom literate.
- Are politically for the most part a “silent” sector.
- Tend to live in small scattered settlements (5-100 people) and are sometimes mobile over specified areas of land.

3.4.2 Namibia

In Namibia, the main source of income is derived from salaries and wages (46 %). The per capita income is low and declining; income inequality is high and unemployment stands at 33.8 % and is rising, with poverty being widespread (Namibia Vision 2030).

In rural areas, subsistence farming was reported as the main income by half of the households, and salaries and wages are the main income for only a quarter. According to Vision 2030, 85 % of consumption poor households are located in rural areas, making their living from subsistence. Poverty pockets are found in the southern regions (scope of this study), where income inequality is higher than in other regions. This is in contrast to the households in urban areas, for whom the main source of income is salaries and wages (three quarters). The economic situation of people living in rural areas enhances their vulnerability (Namibia Household Income and Expenditure Survey 2003/2004).

For Karas and Khomas, salaries and wages were the main income for over 70 % (seven in ten) of households, whilst for Omaheke only half (five in ten) derived their income from salaries and wages and four in ten households derived their income from subsistence farming. For Hardap, approximately six in ten households derived their income form salaries and wages, whilst four in ten households derived their income from pensions. Hardap and Omaheke are therefore areas with less job opportunities. However, Omaheke, Hardap, Karas and Khomas regions reported the highest proportions of households living in improvised dwellings (42 %, 38 %, 29 % and 29 % respectively).

Of those surveyed (Namibia Household Income and Expenditure Survey 2003/2004) large proportions of female headed households in rural areas reported subsistence farming and pensions as their main source of income. Those dependent on subsistence farming for an income tended to have no formal education or some primary education (82 %). Job opportunities for people with this level of education seem scarce.

3.4.3 South Africa

In the Northern Cape, 42.8 % of the people have an income below the poverty breadline of R800 per month (Northern Cape Provincial Growth and Development Strategy 2004-2014).

According to the Siyanda Regional Development Plan (2007), approximately 60 % of its population earns an income between R 0-800 per month. The Siyanda Regional Development Plan (2007) reports that only 46 % of its population is employed, and that the primary sector (specifically agriculture), plays an important role in employment provision.

Kgalagadi DM was identified as a poverty node in 2001, and Moshaweng LM represents the real poverty node in this DM. In Kgalagadi DM, over 70 % of the households live below the poverty line (under R20 000 per household per annum). Gamagara LM represents the developed part of the DM, because of the job opportunities the mines present, and about 50 % of households live below the poverty line.

The situation in the more urban Mafikeng LM is similar to Gamagara LM, where one and a half in five households have no income with 30 % of households living on an income equal or above the acceptable standards. Just under half (43.0 %) of the remaining households therefore earn less than R20 000 annually.

Nearly two in five households (37.9 %) in Ratlou LM have no income and 10 % of households live on an income equal or above the acceptable standards. More than half (52.2 %) of the remaining households therefore earn less than R20 000 annually, which is below acceptable standards.
For the Bophirima District Municipality 83 % of the households have an income of equal to or less than R19 200 per year, meaning that about 15 % of households in the District Municipality live above the acceptable standard. Molopo and Kagisano LMs in this DM show similar profiles.

The levels of income correlate with the employment levels. For example, in Ratlou LM 70 % of the population is not economically active, compared to 43 % in the Mafikeng LM.

Gamagara LM is the only municipality in the sub river basin of which mining and quarrying are the main form of employment. Of the iron ore, 30 % is sold locally, and the remaining 70 % is exported to 36 clients in 16 countries through the port of Saldannah, north of Cape Town. The mine is seen as one of the seven largest open cast mines in the world (Kgalagadi Nodal Economic Profiling Project, 2007).

The income profile of the population in this municipality compares favourably to the other municipalities. For this DM, mining was identified as the sector with the highest potential growth, followed by catering and accommodation (Kgalagadi Nodal Economic Profiling Project, 2007). Although there is a ready supply of unskilled labour for the mines, there is a lack of skilled labour for technical and managerial positions.

An opportunity to use high quality clay (an estimate of 167 million tonnes) in the manufacture of ceramics has been identified by Kumba Resources, which could potentially provide an economic boost to the area (Kgalagadi Nodal Economic Profiling Project, 2007), and further stimulate other beneficiation activities.

The towns Kathu, Dingleton (previously known as Sishen) and Sesheng were established because of the mining activities at Sishen, which started in the 1950s. Kathu is considered the biggest mining town in the Kalahari Region. The towns depend on the mine for water and other services. It seems as if access to services is generally better in this municipality compared to others in the sub river basin. The mine creates approximately 3 000 permanent jobs and 1 500 contracts, which might increase pending the new developments.

The Hotazel mine employs approximately 1 200 people, with a static growth of approximately 0.5 % per year, as per 2003 (Nodal Economic Profiling Project, 2007). Assmang is situated in Blackrock, employs approximately 1 000 people, and it is not expected to increase (Kgalagadi Nodal Economic Profiling Project, 2007).

3.5 TOURISM

3.5.1 Botswana

Tourism opportunities within the district are virtually untapped largely due to poor state of the district's infrastructure and other supporting facilities. Wildlife is an important renewable resource in Kgalagadi District with wildlife areas accounting for about 48.8 % of the District. The District's potential for tourism has improved since the merging of Gemsbok National Park and Kalahari Gemsbok National Park. The introduction of community based natural resource management (CBNRM) policy has also contributed to improved tourism and incomes in the district. There are five areas earmarked for CBNRM activities and these are, KD 1, Ukhwi, Ncaang and Ngwatle, KD 2 Zutshwa, KD 11 & 12 Kokotsha, Inalegolo, Phuduhudu, KD 15 for Khawa. Community mobilization to engage in CBNRM projects commenced in 1998 in the Kgalagadi District. The aim of CBNRM is to give the communities an opportunity to manage natural resources especially wildlife in their respective areas.

3.5.2 Namibia

The sub river basin in Namibia does not have any protected or conservation areas. Between Windhoek and Gobabis conservancies on freehold land occur in the sub-basin. A need to co-ordinate the establishment of these conservancies was identified. The area in the sub river basin does have a number of private game farms.

3.5.3 South Africa

North West and Northern Cape's share of foreign arrivals decreased, with North West's decreasing from 7.1 % in Q3 2006 to 6.2 % in Q3 2007, and with Northern Cape's decreasing from 4.1 % in Q3 2006 to 2.7 % in Q3 2007 (SA Tourism Index, Quarterly report Q3, July to September 2007).

For the Northern Cape the main purposes of foreign tourist visits were (SA Tourism Index, Quarterly report Q3, July to September 2007):

- Holiday 42 %;
- Visit friends and family 30 %; and
- Business traveller 12 %.

For North West Province the main purposes of foreign tourist visits were:

- Holiday 21 %;
- Visit friends and family 36 %; and
- Business tourist 14 %.

In the Northern Cape in South Africa, the sub river basin is in close proximity to the Augrabies Waterfall, and Spitskop Nature Reserve.

In Kgalagadi DM the Moffat Mission, the Raptor Rehabilitation Centre, the Wonderwork Caves, and the Kuruman Eye are tourist attractions. The Kuruman Eye is a natural underground fountain delivering 20 - 30 million litres of clear water daily, and apparently it is the biggest natural fountain in the southern hemisphere. It was proclaimed a national monument in 1992. The Wonderwerk Caves were formed by gas and water, close to Kuruman. However, most of the B&Bs in Kuruman accommodate contractors/long term renters (Kgalagadi Nodal Economic Profiling Project, 2007). Accommodation facilities include McCarthy's Rest, Soetvlakte Guest Farm, Amaziah Guesthouse, Tswalu Kalahari Reserve, Oude Werf Lodge, Legaeng Guesthouse, the Guesthouse on Main, the Tuscany Guesthouse, Riverfield Guesthouse, Sishen Airport B&B.

The whole area serves as a stop over on the way to Namibia, The Kgalagadi Transfrontier Park and Botswana. Some Germans, Belgians and British second comers specifically come to visit this area. The niche market is eco-tourism, adventure routes, historical/archaeological sites, and business people (Kgalagadi Nodal Economic Profiling Project, 2007).

The Khomani San received farms adjacent the Kgalagadi Transfrontier Park with game that can be used commercially for hunting (Department of Land Affairs, 2002). The Department recommended that a serious effort should be made to capacitate the community members responsible for the management of these game camps in the tourism industry, financial management and marketing.

3.6 WATER AND SANITATION

3.6.1 Botswana

3.6.1.1 Kgalagadi District

The district lacks surface hydrological features except for seasonal shallow pans and the Molopo and Nossob fossil valleys (**Figure 3-5**). The generally low rainfall and sandy soils results in a total lack of permanent surface water in the district, although water collects on pans for some periods during and sometime into the rainy season that occurs between November and April. The underground water though available in large quantities is often found in isolated perched aquifers and extremely saline.

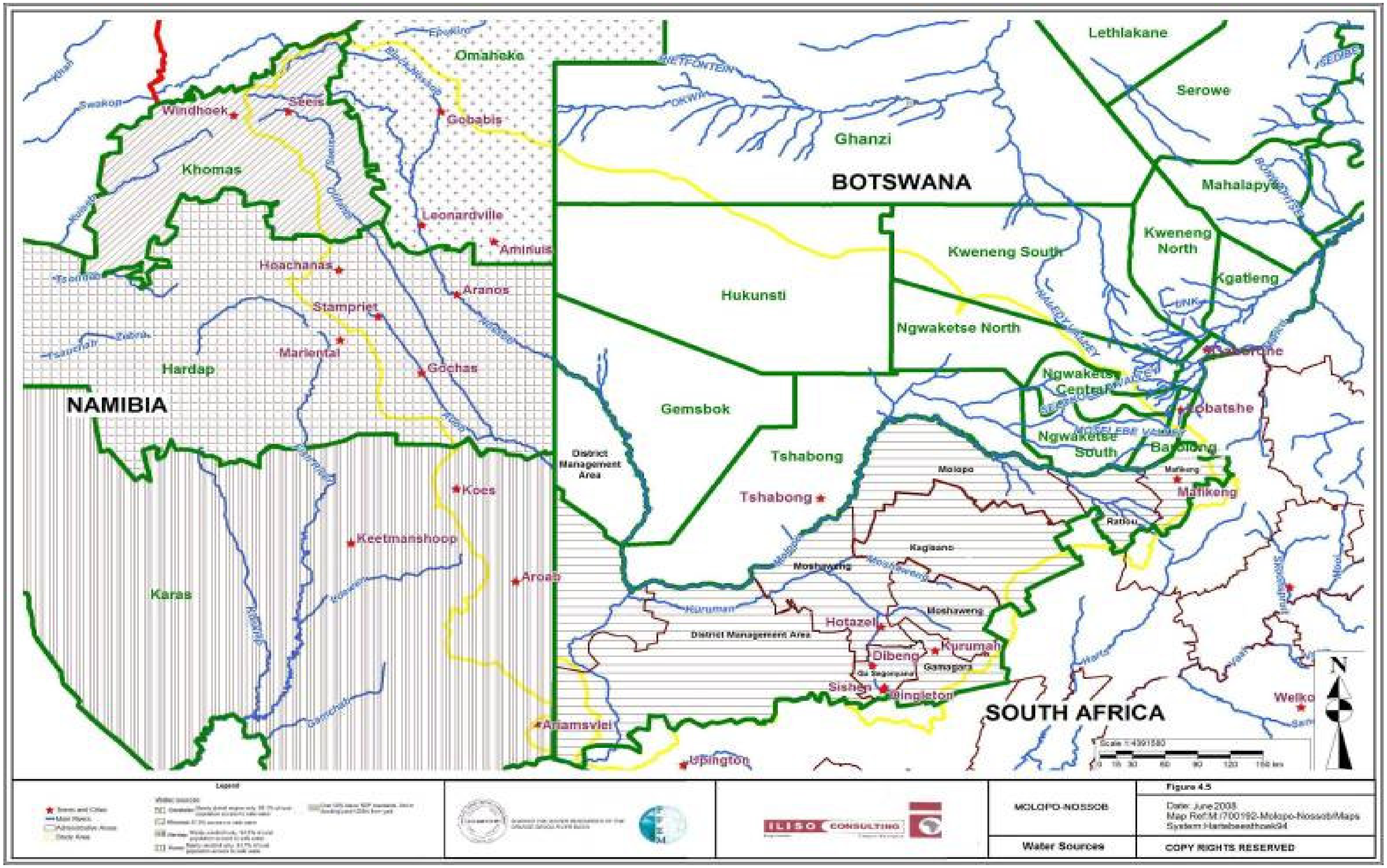

Figure 3-5: Water sources

Table 3-10: Water Supply Data for Settlements under Department of Water Affairs in Kgalagadi District

Settlement	Water source	No. of boreholes	Yield (m/day)	Demand (m/day)	No. of standpipes	No. of private connections	Water quality
Tsabong	Borehole	5	1 027	864	30	1 500	Good
Struizendum	Borehole				5	10	Saline
Inversnaid					3	9	Saline
Rapplespan					3	9	Saline
Vaalhoek	Borehole				3	9	Saline
Bokspits	Borehole	3	83	76	9	89	Saline
Gakhibana	Borehole				7	23	Fair
Khuis	Borehole				12	23	Fair
Bogogobo	Borehole				8	12	Fair
Kolonkwaneng	Borehole				11	12	Fair
Middlepits	Borehole	4	56	201	7	56	Poor
Khawa	Borehole	1	11	14	5	8	Saline
Omaweneno	Borehole		112	89	9	84	Good
Maralaleng	Borehole				7	18	Good
Maleshe	Borehole						
Kisa	Borehole	2	41	27	6	43	Good
Draaihoek	Borehole	2	53	51	9	71	Good
Makopong	Borehole	2	83	72	132	141	Good
Werda	Borehole	3	227	107	15	139	Good
Hereford	Borehole	2	137		4		
Khokhotsha	Borehole	1	36	28	9	31	Good
Inalegolo	Borehole	2	77	21		12	Good
Phuduhudu	Borehole	1	50	42	5	7	Good
Kang	Borehole	3	387	264	22	138	Good
Hukuntsi	Borehole	1	26	240	25	241	Fair
Lehututu	Borehole	5	400	92	18	58	Poor
Lokgwabe	Borehole	2	62	63	12	42	Good
Tshane	Borehole	1	22	68	12	47	Poor

Source: Department of Water Affairs, Botswana.

3.6.1.2 Southern District

The provision of water for domestic use is the responsibility of the Council, assisted by the Department of Water Affairs (DWA). Between 1983–1986 a total of 14 boreholes were successfully drilled and handed over to Council by DWA for operation and maintenance. Most of the boreholes in the district show a low yield as the ground water is not recharged. The expansion of the bigger villages, has called for the expansion of the existing water network. The Southern District operates 60 domestic boreholes and has 83 syndicate boreholes. Council continues to distribute water (by bowser) to areas and schools where there is no permanent water supply. According to National Development Plan 6, major villages are those having a population over 5,000.

These villages are serviced by DWA and in the district are mostly the district centres. However, the growth in some villages, which are presently under district council control, might lead to a request to DWA to operate these water schemes for them. The Council Water Unit continues to service the village water schemes under its responsibility.

The District relies on ground water for human and livestock consumption. There are few dams in the district that are able to hold water throughout the year, such as the Moshupa and Mmakgodumo Dams. The western part of the district is experiencing a water shortage and poor quality water problem.

3.6.2 Namibia

In Namibia, three quarters of households reported piped water as their main source of drinking water. Of the urban households, 99 % reported to use piped water as their main source of water, and in rural areas only 58 %. For Hardap, Karas, Khomas and Omaheke, the main source of drinking water is piped water (for over 80 %). In Omaheke, the only other source is boreholes/protected wells. Khomas has the highest percentage of households with access to piped water (Namibia Vision 2030).

The urbanised region of Khomas stands out as a region where the households have relatively short distances to cover to services. Among urban households, 96 % have a distance of less than 1 km to cover to the source of drinking water, whereas 56 % of rural households have 1 or more kms and 11 % have more than 3 kms to cover. For Hardap, Khomas, Karas and Omaheke, more than 90 % of households are at a distance of 1 km and less from their drinking water sources.

The number of active water points by technology by 2003 and access to safe water by 2001 per region are listed in **Table 3-11**. Although 94 % of the households in Karas have access to safe water according to the Population and Housing Census of 2001, "*due to contamination with nitrates in some areas and high fluoride contents in other areas, some of the underground sources are only marginally potable*" (Karas Regional Poverty Profile, page 48).

Table 3-11: Namibia Number of Active Water Points

Water point source driven by	Hardap	Karas	Omaheke
diesel engine only	77	32	**407**
windmill only	**300**	**405**	5
diesel and windmill	0	0	0
hand pump	4	5	3
solar power	4	1	1
pipeline	10	3	62
Total	395	446	478
Access to safe water % of rural population	94.6	93.7	89.1

Source: Central Bureau of Statistics

In Namibia, just over a third (37 %) reported flush toilets as the main toilet facility used by a household. In the Omaheke Region, just under two thirds do no have a toilet/use the bush, and a third of households have a flush toilet. Hardap Region is also an area of concern where just below half the households have a flush toilet whilst a third used the bush. The number of households without a flush toilet is on the increase in urban areas, which gives an indication of the increase in informal settlements in the area. In the Khomas Region, for example, one in five households have no toilet and in the Karas Region one in four (Namibia Household Income and Expenditure Survey 2003/2004).

There is a link between dwelling type and reticulation (water and sanitation). Informal/improvised houses usually do not have adequate access to water. The most common dwelling in Namibia is traditional dwellings, and these mostly occur in the rural areas. For Khomas, Hardap and Karas Regions, on average a third of households live in improvised (informal) houses. For Omaheke, nearly half (41 %) live in improvised houses. Traditional dwellings do not form a significant part of the landscape in the sub river basin. Those living in traditional dwellings and improvised houses tend to have no formal education or primary school education only, which impacts on their level of income. An estimate of 1 500 houses needs to be built each year, assuming a housing backlog of 37 000 houses, by projecting in 5 year intervals to the year 2030. This has implications for the provision of reticulation – more so in the Omaheke Region.

3.6.3 South Africa

In South Africa, the majority of households have access to water below Reconstruction and Development Programme (RDP) standard. In terms of the delivery of basic water services, as at March 2006, there are still an estimated 8.22 million people who do not have access to a safe potable water supply to the standards set in the RDP. Below RDP standard is a river, stream, piped water more than 200 m away from the household, a water vendor, borehole, and dam or water tank. Therefore the current targeted delivery rate for water services (1.5 million people per year) needs to be increased to ensure that all South Africans have access to safe potable water to RDP standards by 2008, which is the national target (National Water Sector Plan, 2007/08 to 2011/12).

Table 3-12 shows that provision in the Northern Cape and North West Provinces need to be targeted in terms of water delivery at acceptable standard. The deduction is that ground water is of vital importance in the North-West and Northern Cape Provinces. Ground water is in many instances the only source of drinking water and water for stock for many rural people, particularly in the arid western region of the Province. More than 80 % of rural communities in the Province depend on ground water as a sole source of domestic water. Nineteen (19 %) percent of the total population has no water supply services or has services below basic standards. A lot of progress has been made with regard to the targets and the country has achieved the Millennium Development Goals (MDGs) of halving the backlog of access to basic sanitation and water by 2015. Areas most affected are rural villages, farm settlements and informal/peri-urban settlements which form part of new developments (National Water Sector Plan, 2007/08 to 2011/12).

The provision of consistent quality water is on the priority list of all the affected municipalities. The bulk water supply system is not sufficient to meet everyone's needs.

The number of households with toilets below RDP standard is listed in **Table 3-19**, and more households in the North West Province are below RDP standard. Toilets below RDP standard are pit latrines without ventilation, buckets, or nothing. The RDP standard is a flush toilet, a septic tank, a chemical toilet or a pit latrine with ventilation.

Table 3-12: Northwest and Northern Cape Provinces Water and Sanitation (2001 census)

Region	Sanitation pit latrine without ventilation/bucket latrine	Water not in dwelling/yard/<200 m from yard
North West Province	***39%***	***64%***
Bophirima District Municipality	*33%*	*69%*
- Kagisano Local Municipality	40%	79%
- Molopo Local Municipality	7%	60%
Central District Municipality	*47%*	*69%*
- Ratlou Local Municipality	67%	83%
- Mafikeng Local Municipality	46%	71%
Northern Cape Province	***20%***	***58%***
Siyanda District Municipality	*12%*	*56%*
- Mier Local Municipality	20%	58%
Kgalagadi District Municipality	*37%*	*73%*
- Ga-Segonyana Local Municipality	30%	73%
- Moshaweng Local Municipality	54%	81%
- Gamagara Local Municipality	3%	52%

Source: Municipal Demarcation Board

Apart from farming land, the sub basin in Namibia and South Africa is characterised by scattered villages. These settlements have developed in a formal manner, except for some in Ratlou LM in the North West Province. The Ratlou settlements have developed in an informal manner, the properties are large, and it was doubted in 2002 (Central DM IDP, 2002) if geo-technical investigations were undertaken for any area in the municipality to determine the suitability of the land for example for the installation of services or the establishment of cemeteries.

Although the number of informal houses in Kagisano LM is on the increase, the number is still low at 5 %. Moshaweng LMs informal housing is below 5 %. The informal houses in Mafikeng, Molopo and Mier Local Municipalities have increased

(15 % increase on average). Although Gamagara LM has shown a decrease, the percentage of informal houses is still in the order of 14 % (Community Survey, 2007).

A study done by the Department of Land Affairs (2002) amongst the Mier and Khomani San in the Northern Cape, found that for the Khomani San, those living in the municipal area had sufficient water, and that the main source of water was from taps – either in the house or on the stand. This water was used for all household needs.

The main concern that was voiced by the community members was the water need on farms. Those living on farms depended on the farmers, the police station at Witdraai and the local store for all their water needs.

Of those respondents who lived on farms, 80 % lived in shacks or traditional huts. No formal houses have been constructed on the farms and this was a major problem for the farm residents. At that time (2002) there was no project for the provisioning of housing planned, but the intention was to address this as part of the second phase of the development plan.

Community members living in the town areas all took part in the Local Authority housing project and did not pay for the construction of their houses. The dwelling type was brick houses. These respondents indicated that housing was not a problem, but 60 % of the respondents indicated that they would like to return to the farms, but could not because of the lack of housing.

3.7 ECONOMIC ACTIVITIES

3.7.1 Irrigation agriculture

Agriculture is one of the major economic activities in the area and although the region is arid and water scarce, irrigation activities covers around 20 692 ha. It is estimated that approximately 16 657 ha or 80.5 % of this utilises ground water and 4 040 ha or 19.5 % surface water. The top six crops cultivated are groundnuts, lucerne, maize, potatoes, wheat and vegetables.

3.7.2 Livestock farming

Due to the semi–arid and dry climatic conditions of the area, livestock farming is a very important farming activity. It provides both an income and a livelihood to a large number of households in the area. Livestock farming in the area has been divided into two categories, namely; commercial and communal/subsistence livestock farming, with the former mainly as a business venture.

3.7.3 Mining

There are several mining operations in the area, especially on the South African side. The major minerals being mined are diamonds, iron ore and manganese. On the South African side mining has grown at a hectic pace in the last three years and the current number of mineworkers involved is estimated to be around 7 500 permanent and 3 100 contract workers. Information from the area also indicates that further growth is due to take place in the immediate future.

3.7.4 Tourism

Tourism is also an important activity in the area, especially on the South African side. Two specific categories of tourists have been identified, eco-tourists and business tourists, and the extent of the tourism activity in the catchment was estimated based on these two categories.

3.8 IRRIGATION AGRICULTURE

3.8.1 Methodology

In order to calculate the value of water used for agricultural activities, crop budgets were compiled and analysed based on the Combud Enterprise Budget frameworks developed by the Department of Agriculture in South Africa for each of the six major crops.

Table 3-13 shows the crops analysed as well as their respective yield per ha in tonnes. Given that there is currently no irrigation taking place in the catchment on the Botswana side, no provision was made for Botswana.

Table 3-13: Crops Analyzed

Namibia		South Africa	
Crop	**Maximum yield per hectare (tons)**	**Crop**	**Maximum yield per hectare (tons)**
Maize	10	Maize	10
Lucerne	12.5	Wheat	7.1
Vegetables	70.2	Lucerne	12.5
		Ground nuts	4.5
		Potatoes	34

Table 3-13 shows that three major crops dominate Namibian's irrigation activities in the catchment area while five crops dominate irrigation on the South African side.

Table 3-14 also provides a summary of the main crop types, total ha currently under irrigation for each crop and the total water usage per crop.

Table 3-14: Irrigated Crops, Hectares and Water Use (2007)

Namibia				South Africa			
Crop	**Total hectares**	**Water use (m^3/ha)**	**Total water use (Mm^3)**	**Crop**	**Total hectares**	**Water use (m^3/ha)**	**Total water use (Mm^3)**
Maize	435.4	5 700	2.48	Maize	12 483	5 700	71.16
Lucerne	64.2	12 850	0.82	Wheat	1 271	6 070	7.71
Vegetables	162.7	3 680	0.65	Lucerne	1 748	12 850	22.46
				Ground nuts	2 292	4 410	10.11
				Potatoes	2 234	3 870	8.64

3.8.2 Country Discussion: - Irrigation Farming

Namibia

The total area cultivated and irrigated is relatively small, only ± 660 ha with maize being the dominant crop in terms of ha and total water use.

Republic of South Africa

Table 3-14 shows that maize is produced on more than 60 % of the total hectares irrigated (12 483 ha) and also uses the bulk of the total water (71 16 million m^3) reserved for irrigation in the area. The demand for water use per ha is high for lucerne irrigation and low for potato irrigation. In terms of maximum yield per ha, **Table 3-3** indicates that 34 tonnes was used as the yield per ha of potatoes, while groundnuts being the lowest, with 4,5 tonnes per ha.

3.9 LIVESTOCK FARMING

3.9.1 Methodology

The total area used for livestock by each country, was used to calculate the number of Large Stock Units (LSU), based on the average grazing norm per country, as determined by the team. An average annual weight gain per LSU was used to calculate the total weight gain per country, a value per kilogram live weight was used to calculate the value of livestock farming per country. The annual weight gain per country was set at a conservative level to accommodate losses and the value was established at a net farm gate price.

In **Table 3-15,** the results per country are presented. The tabulated results are given in Rands for comparison purposes, and for the individual countries the results have been converted to the local currency.

Table 3-15: Livestock Calculations

Item	Botswana	Namibia	South Africa
Total Catchment Area -hectares	13 847 369	9 231 579	11 346 735
Total Game Parks - hectares	2 641 000		959 000
Livestock Area	11 206 369	9 231 579	10 387 735
Average Grazing Norm (ha/LSU)	33.1	33.1	31.45
Estimated Number of LSU	338 561	278 900	330 294
Average Annual Weight Gain (kg/LSU)	120	120	319
Average Price (R/kg)	7.88	7.71	8.23
Average LSU value increase (Rand)	946	925	1 296
Value of Activity (Rand million)	320.3	258.0	326.4
Estimated Number of LSU per Labourer	100	100	100
Estimated Number of Employees	3 385	2 789	3 303

3.9.2 Country Discussion: - Livestock Farming

Botswana

The total value of the livestock activity in the Botswana part of the catchment is estimated at about P266.9 million (R320.3mil.). It is divided between commercial and communal farmers. According to the division between commercial and communal area is roughly 75 % to 25 %. Also according to the same source the average number of cattle per communal farmer converts to 30 LSU, with an average annual take-off of 6 animals. With the assumption that 50 % is for own consumption and that three animals are sold, the estimated cash revenue per farmer is around P7 400. The estimated number of employees in livestock farming is estimated to be 3 385.

Namibia

The value of livestock farming in the Molopo-Nossob is estimated to be around N$258 million annually. Very little if any communal farming takes place in the Namibian section of the catchment.

The estimated number of employees in livestock farming is estimated at 2 789.

Republic of South Africa

In the South African section of the catchment the value of livestock farming is estimated at R326.4 million annually. It might, however, be an under estimation because it appears that large tracts of land is being converted to game farming and according to a number of sources this type of farming is much more profitable.

Also, in the South African a large area of land is occupied by communal farmers, according to estimates around 27 % of the land. No literature could be traced that specifically referred to the number of animals kept by the average communal farmer in the project area.

About 64 % of rural families own cattle and a slightly higher number own goats. This percentage is in line with other estimates, specifically in the Transkei region. According to the survey the average number of cattle kept by the communal farmer is 20 which converts to 17 LSU units, less than the 30 in Botswana. If the same assumptions are applied as applied in the case of Botswana, it appears as if the average cattle owner has an annual cash income of around R7 000 pa. It must however, be borne in mind that only 64 % of the rural households are actually cattle owners and that the number of cattle vary from 1 to 67.

The estimated number of employees in livestock farming is estimated at 3 303.

3.9.3 Conclusion

Livestock farming occupies the largest part of the catchment and plays a very important role in the lives of the inhabitants of this very arid and rural region. It is estimated that the total annual monetary value is R886 million (N$886 million, P768.4 million) and, with a conservative estimate, 9 478 people are directly employed.

3.10 MINING

3.10.1 Methodology

The compilation of this section relied on published reports and other information of mining companies operating in the respective areas. Most of the information was taken from these reports and some data figures were verified by means of telephone calls to the companies concerned. In some cases companies refused to give specific financial data and it was necessary to use the actual volume of ore mined multiplied with the average price, to arrive at an annual turnover.

Water use by the mining companies in South Africa was obtained from the DWAF offices in Kimberley.

3.10.2 Country Discussion: - Mining

Botswana

In Botswana, presently one diamond mine could be identified in the area employing around 120 people with an annual turnover of P76.6 million (R92 mil.).

Namibia

In Namibia at present one copper mine could be identified in the area employing around 375 people with an annual turnover of N$267 million.

Republic of South Africa

In South Africa a number of mines operate, the most important activity is however, taking place at the Kathu – Hotazel hub with the expansion, due to the worldwide demand for these commodities, at the iron ore and manganese pits. At present the total number of people employed in the mining appears to be around 10 600 of which around 7 500 are fulltime and the rest part time or on contract. All indications are that this will further increase in the next 2 to 3 years. The present annual monetary turnover is estimated at R11.5 billion.

3.10.3 Conclusion

From the above analysis it appears that, especially in South Africa, mining activity is growing dramatically and is an important employment and income generator which appears to have further potential to expand.

A summary of the activities is presented in **Table 3-16**.

Table 3-16: Mining in the Molopo – Nossob Catchment (2007 prices)

Country	Mineral	Total sales: R million	Direct Labour employment
Botswana	Diamond	92	124
Namibia	Copper	267	375
Republic of South Africa	Diamond	12 400	248
	Iron Ore	9 687	7 859
	Manganese	1 700	2510

3.11 TOURISM

3.11.1 Botswana

In the case of Botswana one tourism facility was identified in the Kgalagadi Transfrontier Park and four others outside the park. The total number of available beds identified is 66 with an average tariff which varies between P170 to P3 400 per person per night. The average bed occupation was established at 35 % converting to an annual turnover of P7.8 million (R9.3 million).

Namibia

In the case of Namibia 493 beds was identified with an average overnight rate of N$583 and an occupancy rate of around 35 % with the estimated turnover at N$36.7 million.

Republic of South Africa

In South Africa two areas were identified as growth points for tourism, the Mmbatho/Mafikeng area hosting the capital of the North West Province and a casino complex. Then the more rural establishments which also target the eco-tourists and holiday makers in the Molopo area towards the Kgalagadi Transfrontier Park have been identified. A number of farms have also switched from livestock to game farming, with the accompanying tourist or hunting facilities and attractions.

The total number of beds identified is 2 544 with an occupancy rate which varies from 65 % in the Kgalagadi Transfrontier Park to 25 % in some of the other areas. The estimated annual turnover is established at R179, 9 million.

3.11.2 Conclusion

From data in **Table 3-17** it is appears that although over 430 000 bed nights are sold annually the low occupation rates indicate that considerable scope exists for further expansion.

Table 3-17: Tourism Activity in the Molopo – Nossob Catchment (2007 estimates)

Country	Total annual bed nights sold	Total Available Beds	Total Income per year: R million
Botswana	8 432	66	9.33
Namibia	62 981	493	36.71
Republic of South Africa	362 226	2 544	179.93

3.12 MACRO ECONOMIC IMPACTS

In **Table 3-18** a summary of the Direct and Total Macro-economic indictors of the main economic activities in the catchment, as detailed in the Catchment Inventory Report are compared.

Table 3-18: - Direct and Total Macro Economic Indicators of the Different Activities for the Molopo – Nossob Catchment (2007 prices)

Activity	GDP (R Million)		Employment (Numbers)		Household Income (R Million)	
	Direct	**Total**	**Direct**	**Total**	**Low**	**Total**
Irrigation Agriculture	274.3	435.6	3 450	4 127	65.2	239.2
Livestock (LSU)	518.3	956.7	8 071	10 547	172.2	632.2
Mining	6 390.4	13 345.3	9 999	33 620	2 485.8	9 937.9
Tourism	127.1	251.3	1 034	1 556	48.4	185.2
Total	**7 310.0**	**14 988.8**	**22 554**	**49 851**	**2 771.6**	**10 94.5**

The Macro Economic Impact Model (MEIM) takes the form of a dynamic computerised model and is used to quantify the macro-economic impacts when curtailing water availability or changing the scenario to any irrigated farming enterprise in the study area or any other water policy impacts. It does this by generating appropriate socio-economic multipliers from a Social Accounting Matrix applicable to the study area, and estimating the following indicators:

- Economic growth (i.e. the impact on GDP)
- Job creation (i.e. the impact on labour requirements)
- **Income distribution (i.e. the impact on low-income, poor households and the total income of households)'**

In this instance low-income household is the "poor" households as defined by the appropriate country definition of "poverty". In South Africa it would be the level 1 to 3 households, with medium income 4 to 6 , and high income 7 to 10.

Mining is by far the largest activity followed by livestock farming. The indirect and induced factor of mining is also much larger than that for irrigation and livestock farming. The percentage of household income directed at Low Income Households expressed as a percentage of Total Household Income varies from 25.0 % for mining, the lowest to 27.3 % for irrigation. Although agriculture creates more direct employment opportunities than mining, at present, the extended number for mining is considerably larger than the number for agriculture.

In **Table 3-19** the macro-economic multipliers expressed as a function of water use is presented as it can be used in possible scenarios to calculate possible policy interventions.

Table 3-19: - Water Based Macro Economic Multipliers Applicable in the Molopo- Nossob Catchment (2007 Prices)

Activity	GDP (R/m^3)		Employment (No/Mm^3)		Household Income (R/m^3)	
	Direct	Total	Direct	Total	Low	Total
Irrigation Agriculture (Weighted)	2.2	3.5	27.8	33.3	0.5	1.9
Livestock (LSU)	35.2	65.0	547.9	716.1	11.7	42.9
Mining	635.9	1 327.9	994.9	3 345.3	247.3	988.8
Tourism	1 465.0	2 897.1	11 926.2	17 943.8	558.2	2 135.9

The multipliers expressed in **Table 3-19** in terms of efficient water use, show that the highest multiplier effect in the Molopo-Nossob Catchment is tourism followed by mining. Livestock farming also has a large water efficient multiplier. Irrigation, although economically of strategic value, is not a very efficient user of water.

4. AVAILABILITY OF WATER

4.1 SURFACE WATER

Hydrological modelling was undertaken to provide first order estimates of typical surface water runoff volumes in the main rivers in the study catchments. For this purpose, the Pitman rainfall-runoff model was configured for the main subcatchments in the study area.

Model subcatchments were originally based on existing quaternary catchment boundaries. However, to facilitate the analysis of scheme development options at a finer resolution (to be undertaken during subsequent phases of the study), the quaternary catchments were further delineated based on major tributaries, the location of existing major dams and international boundaries.

The configured Molopo-Nossob catchment model was calibrated wherever possible on observed flow records. However, due to the paucity of accurate and reliable streamflow records within the study catchment, a conventional calibration approach was only possible in the upper Nossob and Olifants rivers as well as on the upper Molopo River and some of its tributaries. Once the Pitman model had been calibrated, the calibrated Pitman parameters were transferred to similar subcatchments in the remainder of the study catchment.

A further, large-scale calibration of the Pitman model for the main subcatchments was undertaken, based on historical extreme events and anecdotal evidence of flows along certain parts of the lower river reaches. This was mainly achieved by means of adjustments to the soil moisture and the channel loss function in the WRSM2000 model. The historical flood events in the 1970s are simulated, as well as two small events in the mid-1950s and the late-1980s, while no flows occur during the rest of the simulation period, which is consistent with anecdotal evidence about the occurrence or lack of flows along the lower reaches of these rivers.

4.1.1 Quantity

Table 4-1 shows that the total incremental natural runoff from the Molopo-Nossob catchment equals 161 million m^3/a, while the present day runoff equals

85.1 million m^3/a. However, it is important to note that not all of this runoff is available for use, due to excessive losses (infiltration and evaporation) in the system. For example, the results of the hydrological modelling have shown that the effect of channel loss on cumulative runoff is such that flow along the downstream reaches of the main rivers only occurs during extreme events and that channel losses along the respective main river systems are in the order of 80 % to 90 %. It should however be recognised that most of the losses constitute a recharge of the groundwater along the river course.

The flows in the Kuruman River are mainly the result of discharge from the various fountains or 'eyes' in the dolomitic area. Very little of this water is therefore runoff in the true sense of the word, but it should be seen as ground water. However, since the flows from the fountains are reported as surface flow in the South African hydrological data base, it has been included as such. Again, this flow does not reach the lower reaches of the river.

Table 4-1: Total Incremental MAR per main subcatchment

River	Quaternary	Incremental MAR (no channel losses) Natural	Incremental MAR including local channel losses per quaternary		
			Natural	Present-Day	Percentage
Molopo	D41A	35.99	9.85	6.22	
	D41B	12.76	4.75	4.01	
	D41C	9.65	2.77	2.50	
	D41D	5.99	1.22	1.19	
	Z10D	3.57	1.11	1.11	
	Z10C	16.84	3.23	3.23	
	D41E	0.67	0.00	0.00	
	D41F	1.94	0.00	0.00	
	D41H*	0.85	0.00	0.00	
	Z10F	0.64	0.02	0.02	
	D42C*	0.10	0.00	0.00	
	TOTAL MOLOPO	**89.00**	**22.95**	**18.28**	**80%**
Kuruman	D41G	7.13	1.42	1.40	
	D41H*	1.58	0.18	0.17	

River	Quaternary	Incremental MAR (no channel losses) Natural	Incremental MAR including local channel losses per quaternary		
			Natural	Present-Day	Percentage
	D41J	3.66	0.72	0.71	
	D41K	4.53	1.08	1.08	
	D41L	30.05	6.43	6.14	
	D41M	0.89	0.00	0.00	
	D42C*	1.05	0.00	0.00	
	TOTAL KURUMAN	**48.89**	**9.83**	**9.50**	**97%**
Nossob	Z10A	2.30	2.30	1.47	
	Z10A	15.83	4.13	4.13	
	D42A*	0.22	0.00	0.00	
	TOTAL NOSSOB	**18.35**	**6.43**	**5.60**	**87%**
Auob	Z10A	1.47	0.42	0.33	
	Z10A	6.27	4.21	4.21	
	D42A*	0.01	0.00	0.00	
	D42B	0.01	0.00	0.00	
	TOTAL AUOB	**7.76**	**4.63**	**4.54**	**98%**
TOTAL		**164**	**43.8**	**37.9**	**87%**

If it is considered that most of the channel losses are in actual fact a recharge of ground water aquifers along the rivers, it is clear that the flow in the rivers constitutes an important part of the availability of water along the lower reaches. It is also clear that, apart from the Molopo and Nossob Rivers, current was use practices have had little impact on the flow of water in the different rivers.

4.1.2 Assurance of Supply

Table 4-2 and **Table 4-3** present first order estimates of typical gross storage-yield characteristics for the upper parts of the Molopo and Kuruman catchments, which display similar hydro-meteorological characteristics, as well as the upper Nossob catchment. The tables provide an indication of the storage that is required to meet certain yields at different levels of assurance and show that, even in the upper part of the Molopo and Kuruman catchments, significant storage is required to provide yield at an acceptable level of assurance. An assessment of the central parts of the Molopo-Nossob catchment, situated within the drier, central Kalahari Desert, has indicated that it is not feasible for dams to be constructed in this area due to the lack of reliable runoff.

Table 4-2: Typical yield-reliability characteristics (upper Molopo/Kuruman)

	(1)Gross Yield (% MAR)		
Live Storage (% MAR)	**1:100 RI**	**1:20 RI**	**1:10 RI**
50	16	25	32
100	26	41	52
200	34	53	71

(1): Based on WR90 storage-draft frequency curves

Table 4-3: Typical yield-reliability characteristics (upper Nossob)

	(1)Gross Yield (% MAR)		
Live Storage (% MAR)	**1:100 RI**	**1:20 RI**	**1:10 RI**
50	3	4	4
100	6	8	9
200	12	15	16

(1): Based on results of this study

4.1.3 Water Quality

The surface water quality is generally good. In the upper reaches of the Molopo and Kuruman Rivers where the water emanates from the dolomitic aquifer, the salinity is in the order of 450 mg/ℓ, which means that the water is fit for all uses. A minor problem is that the water tends to be hard and can cause scaling of pipelines and hot water appliances.

The surface water runoff is fresh and of good quality. Even water that collects on the pans is usable for domestic purposes and stock watering, although in some cases it tends to become saline after a few months.

4.2 GROUND WATER

The Molopo-Nossob sub river basin covers a wide area, from Windhoek in Namibia to Lobatse in Botswana and Mmabatho in South Africa. Landsat imagery and aerial photographs show that the Kalahari sand cover obscures most of the solid rock geology. Aeolian sand deposits have produced a landscape characterized by WNW to NW trending longitudinal sand dunes in Botswana. Some rock exposures are found along the Molopo River in the Khuis, Werda and Phitshane Molopo. The Molopo-Nossob sub river basin constitutes most of the rock types from Archaean Basement Complex to recent Kalahari deposits and ground water occurs in most of rock units and water quality is fresh to hyper saline.

4.2.1 Aquifers

In the Molopo Nossob Sub river basin four main aquifer types were identified namely, fractured, fractured porous, porous, and karstic. The fractured aquifers, where the matrix has limited porosity due to the solid rock structure the ground water is associated with secondary interstices such as fractures, fissures and/or joints. The fractured aquifer includes Archaean Basement complex, Protoerzoic, and Karoo Basalts. Fractured porous aquifers are dual porosity systems whereby water is released from a porous matrix via a series of transmissive interconnected fractures. These aquifers are represented by the Karoo sandstones. The porous aquifers, that store and transmit water via the interstitial pore space in the sedimentary formations represented by alluvial and Kalahari Bed aquifers. The karstic fractured aquifers are carbonate rocks where solution weathering along joints, fractures, and bedding has enhanced the water-bearing capabilities of the rock. This aquifer is very limited in aerial extent and located eastern and southern part of the study area and represented by dolomites.

4.2.2 Basement Aquifers

Generally, the Basement aquifers offer poor prospects of securing ground water in the study area. Ground water occurrence in these rocks can be wholly attributed to secondary porosity (i.e.: water contained in fractures and fissures). As such the resource is controlled by the size of fractures and their interconnectivity.

The Molopo River used to receives most of its flow from tributaries in the Republic of South Africa, most of which have now been dammed for irrigation. As a result, inflow from these sources to the Molopo River has become heavily reduced and even non-existent in some years. The Archaean and proterozic rocks occupy most of the southern part of the Molopo-Nossob sub river basin. The Unnamed Swazian Granite and Gneiss extend from west of Mmabatho in the east to Morokweng in the west up to Cassel in the south. The ability of these granite and gneisses to host ground water is enhanced by the presence of fractures and dykes. The aquifers can be subdivided into a weathered (regolith), intermediate (weathered and bedrock) and a fractured bedrock zone. The grade and depth of weathering is function of climate and mineralogy. The result is that borehole yields vary considerably over the study area.

The Basement aquifers are restricted mainly to the east of the study area in Botswana and this area is classified as having a poor ground water potential by the National hydro geological reconnaissance maps. The existing borehole data in the area also indicates that most of the boreholes were unsuccessful. The most significant aquifer is at Sedibeng where 10 boreholes have been drilled and have an average yield of 5 m^3/hr (DWA, 2000). Over period of time the boreholes yields have reduced and some boreholes have become dry.

Several boreholes were drilled in the Olifantshoek Supergroup rocks of Protoerzoic age between Khuis and Kolonkwaneng in Botswana for village water supply to Khuis, Middlepits, Bogogobo and Kolonkwaneng villages. The quartzite generally outcrop in the area but can be overlain by Kalahari Beds and river alluvial. Water strikes in the fractured quartzite range from as shallow as 10 m to as deep as 199 m. Yields of boreholes are highly variable and range from dry to 40 m^3/hr. The static water levels of boreholes range from 5 m to 100 m, indicating that ground water in the fractures occurs under unconfined to semi-unconfined conditions. Borehole 5898 in Bogogobo encountered overflowing artesian conditions when it was drilled indicating some degree of confinement in the fractured quartzite's. Tsabong is the only major supply wellfield within the Molopo River Basin catchment area in Botswana exploiting the Transvaal and Waterberg Aquifers.

In South Africa, Archaean and Protoerzoic rocks occupy most of the Molopo-Nossob sub river basin. The borehole yields vary considerably over the study area. Towards the west where the sand covers increase, low yields up to 0.36 m^3/hr (0.1 ℓ/s) prevail and numerous dry boreholes are drilled. At Coetzersdam, and to the east of this where the local geology includes pegmatite, high yielding boreholes are encountered (Vryburg, 2006).

The Volop Group and Postmasterburg Group are the other important rock formations in the study area. The Volop Group consists of predominantly meta - arenaceous rocks (Quartzite). The borehole yields are generally low. The Hydro geological map (sheet 2722 9Kimberly) shows that the borehole yields range from 0.36 m^3/hr to 1.80 m^3/hr (0.1-0.5 ℓ/s). Near Olifantshoek the borehole yields are up to 7.20 m^3/hr (2.0 ℓ/s). The Postmasterburg Group consists of basic and intermediate extrusive rocks (basalt, andesite). Almost 40 % of the boreholes are dry. Of the 60 % of the boreholes analysed, the yield frequency is highest for the range 0.36 m^3/hr to 1.80 m^3/hr (0.1 to 0.5 ℓ/s). Boreholes in excess of 7.20 m^3/hr (2.0 ℓ/s) are less than 5 % (Kimberly 2003).

4.2.3 Karst Aquifers

The karstified fractured aquifers are represented by Transvaal dolomite units in Botswana and Ghaap Group in South Africa. In Botswana, ground water occurs in the dolomite sequence of Taupone Group of Transvaal Supergroup and are well developed as a Chert Breccia aquifer in Kgwakgwe area and as a Dolomite aquifer in the Ramonnedi area. The clusters of boreholes in these aquifers are broadly grouped as Kgwakgwe and Ramonnedi Wellfields.

Water strike depths and yields of boreholes in these aquifers vary widely. Water strikes in Chert breccia aquifer of Kgwakgwe area are generally at 50 to 110 mbg with yields ranging from 20 to 70 m^3/h. In Ramonnedi and Taupone areas water strikes are shallow at 31 to 50 m within karstic dolomite aquifer and the yields range from <10 to 90 m^3/h (DWA, 2006).

The dolomites of the Ghaap Group in South Africa has generally good ground water potential and yields in excess of 7.20 m^3/hr (2.0 ℓ/s) are common. Ground water occurs along the fractures, joints, and solution cavities commonly associated with faults and diabase dykes. An explanation on the General Hydrogeological Map Vryburg 2522 (2006) indicates that more than 25 % of the boreholes analysed yielded from 1.80 m^3/hr to 7.20 m^3/hr (0.5 to 2.0 ℓ/s) and 13 % of the boreholes analysed yielded more than 18 m^3/hr (5 ℓ/s). Boreholes with these higher yields are used for large volume needs like municipal and irrigation.

4.2.4 Karoo Aquifers

4.2.4.1 Dwyka Formation Aquifers

In Botswana, the Dwyka Formation does not constitute an important aquifer as indicated by boreholes near Gakhibana. The borehole yields in this aquifer are generally low, showing little confining head and poor quality water. Three boreholes in Gakhibana show water strikes ranging from 24 m to 74 m and yields ranging from less than 1 m^3/hr to 6 m^3/hr. Two exploration boreholes drilled during the Bokspits TGLP Ground water Survey Project (DGS, 2002) also confirms the poor yields in this aquifer.

In South Africa the Dwyka Formation is classified fractured aquifer consists predominantly diamictite (tillites). The Hydrogeological map (Sheet 2714 – Upington/Alexander Bay) shows that the Dwyka Formation extends from north of Upington to Inkbospan and the borehole yields range from 0.36 m^3/hr to 7.20 m^3/hr (0.1-2.0 ℓ/s).

4.2.4.2 Ecca Group Aquifers

In Botswana the Ecca Group sediments cover most of the area and majority of boreholes have been drilled in these sediments. The Ecca sediments occur under varying thickness of Kalahari beds ranging from 10 m to 55 m (ORASECOM, 2007). The Otshe (Auob) sandstone of the Ecca Group forms an important aquifer in the area with localized areas of potable ground water. It consists of a complex succession of canalized fluvial and deltaic sediments. The sediments consist of multiple interbedded layers of fine to coarse-grained sandstone, shale, mudstone, carbonaceous shale and poor coal (DGS, 1994). Argillaceous units within the formation confine the individual water bearing sandstone units.

The Otshe (Auob) sandstone generally provides sufficient yields (2 – 3 m^3/h) for livestock watering in both confined and unconfined conditions. The confined sandstone generally yielded very saline water while semi-confined sandstone yield usable brackish water and is some places the confined Otshe sandstone contains water too saline for any agricultural use. Depths to first water strike in the Ecca sediments are highly variable and range from 30 m to 196 m. Multiple water strikes have been recorded on several boreholes tapping the Ecca aquifer(s) with the deepest water strike at 301 m. Yields of boreholes are highly variable and range from dry to 60 m^3/hr.

The Otse Formation in Ncojane Block constitute main aquifer unit within the Ecca Group occurs beneath relatively thin Kalahari Beds and Lebung/Beaufort Group rocks and the water strikes are generally between 145 m and 290 m (DWA, 2008). The borehole yields are varying from 20 m^3/hr to over 100 m^3/hr. The ground water quality is portable (TDS is about 500 mg/ℓ) in a broad area in the western and northern part of the Ncojane Block. The TDS values tend to increase significantly (> 6 000 mg/ℓ) to the south and southeast (DWA, 2008).

The Nossob sandstone formation occurs at the base of the Ecca Group and forms a thin confined aquifer near the north-eastern boundary of the Kgalagadi Transfrontier Park yielding saline water under very high pressure head conditions. The Nossob sandstone was encountered in boreholes 7246, 7243, and 7192 (DGS, 1994). The Nossob sandstone was encountered at 212m depth in borehole 7243 and at 360 m depth in borehole 7246 and the water is very saline with TDS value of >25 000 mg/ℓ. This formation is, however, very deep and has very saline water and thus does not constitute an important aquifer.

One of the Internationally Shared Aquifer Resources Management (ISARM) Programme case studies was carried out on the Stampriet Artesian Basin an aquifer shared by Namibia, Botswana, and South Africa, which is part of the current study area. In Namibia, the Auob aquifer has the highest potential while the Nossob aquifer shows the lowest potential.

The Ecca Group sediments in South Africa are not productive. Boreholes drilled in massive shale beds in the Ecca Group yielded very little water less than 0.36

m^3/hr (0.1 ℓ/s) and generally not potable for human or livestock. Boreholes drilled in the Auob and Nossob sandstone formations yielded up to 7.20 m^3/hr (2.0 ℓ/s) and the water quality varies from 3000 – 20000 mS/cm.

4.2.5 Kalahari Group Aquifers

The Kalahari aquifer(s) constitute an important water supply source in the region, along the Molopo and Nossob Rivers, for both human and livestock populations. The water strikes range from 12 m to 72 m with yields ranging from <1.0 m^3/hr to 8.6 m^3/hr. Broadly the Kalahari Group consists of a layer of aeolian sand up to 20 m thick, which may display relict dune structures. The sand is generally underlain by a duricrust layer of silcrete and calcrete which must represent an unconformity within the succession. The duricrust is underlain by poorly consolidated sandstones which are often calcareous. Where a full succession is present, red marls and a basal clayey gravel of undoubted fluvial origin underlie the sandstones. The thickness of the Kalahari succession is largely a function of pre-Kalahari Group topography, with the gravels being largely confined to palaeo-valleys.

The basal Kalahari gravels can constitute a useful aquifer. The Kalahari Group sediment thickness around Bray in Botswana and Vryburg in South Africa indicate a broad 15-30 km wide trough of these sediments (in excess of 180 m thickness) forming a palaeo-valley. Steep gradients are observed on the northern and southern flanks of the palaeo-valley. The northern flank shows several tributaries, which drain southwards into the palaeo-valley. The palaeo-valley crosses the international border and passes into the Molopo Farms area.

There is high borehole density on the South African side indicating extensive abstraction of ground water resource on this aquifer. Thus the Kalahari aquifer(s) constitute an important water supply source in the region, along the Molopo and Nossob Rivers, for both human and livestock populations. The water strikes range from 12 m to 72 m with yields ranging from <1.0 m^3/hr to 8.6 m^3/hr. The Kalahari Beds aquifer in Namibia is highly developed and account for greater abstraction (10 MCM/yr) than the underlying Ecca Aquifer (DWA, 2008).

4.2.5.1 Recharge in the Molopo and Kuruman catchments

The recharge in the areas covered by Kalahari sediments is negligible in areas with less that 300 mm/year and the quality of the groundwater is poor. The isolated areas of higher recharge e.g. in the vicinity of Van Zylsrust, at Keesi and Fullifeesand in close proximity to the Kuruman river are directly linked to recharge that occurs infrequently at times when floodwater reaches as far as the confluence of the Nossob-Molopo Rivers. The groundwater exploitation from dolomitic aquifers is good even in the low rainfall areas like Tosca/Vergelee, as this aquifer is periodically being recharged by floods occurring in the Molopo River and it has sufficient storage to be exploited excessively during periods of low rainfall. Replenishment could occur in one year of high rainfall that has caused floods to reach the aquifer. Similarly the Louwna-Coetzersdam granite aquifer is regularly being recharged in view of higher local rainfall and a thin overburden of unsaturated material overlying the granite aquifer. In areas overlain by thick Kalahari sediments, representing about 70 % of the investigated drainage area, the recharge will be small as a result of the retention of potential recharge in the unsaturated zone, from where it is lost by evapotranspiration. This is the case in Jwaneng aquifer which receives most of its recharge from the outcropping area of the aquifer and nothing from infiltration through the Kalahari (Nijsten and Beekman 1997).

The occurrence of groundwater is closely related to the underlying geology and the structural deformation it has been subjected to e.g. faulting, folding, fracturing and intrusion of dolorite dykes. The selection of high-yielding drill sites remains difficult but the use of aero magnetic surveying and satellite imaging could reveal regional structures that are often related to higher-yielding boreholes. In view of the poor quality of the groundwater in the central Kalahari region the prospects of good groundwater supplies are zero. In these areas alternative sources of water e.g. from ‘gatdamme’ might still be viable if local rainfall-harvesting could be applied.

It is most important that the Hydrogeological Sheet of the Vryburg area be completed without delay and that that the information be conveyed to the water managers and water users.

The regional approach to assess the recharge potential of unknown areas is the only viable method that can be applied in a consistent way to derive a quantitative prediction of the rainfall-recharge of any aquifer from the exponential relationship between the recharge and the rainfall. In view of the similarities between larger part of the Kalahari in the RSA, Botswana and Namibia, much of the missing information could be ascertained from the regional models. The outcome indicates that the groundwater potential of the Kalahari areas would inevitably be small and thus requires that alternative resources be found. Such possibilities are almost non-existent but the use of 'gatdamme' for the collection of rainwater or by desalinisation of highly saline water, seems to be prospects in some areas.

The monitoring of rainfall, water levels and abstraction from groundwater is essential to derive the aquifer parameters that are required to model specific groundwater system reliably. It would however be rather fruitless to invest in expensive monitoring in the central dry Kalahari region. The hydrodynamic modelling of the large aquifers should be extended to incorporate the change of aquifer storativity with depth that specifically applies to the dolomitic aquifers. An aspect not to be neglected is proper management of the resource and the education of the water users to participate in this respect.

The results obtained from simulations of the flows of dolomitic springs have potential to derive the sustainable exploitation potential of an aquifer as well as determining the reserve of the aquifer in a consistent way.

In view of the rainfall being the primary factor to cause recharge, the exploitation of groundwater will be affected by long-term cyclical recurrences of low and high rainfall, which appears to be synchronized with the sunspot variations. This is particularly important in view of sub-normal rainfall that could be expected in the period 2010 to 2014.

4.3 DAMS

4.3.1 Main Dams

There are a total of nine main dams within the study area, none of which are located in Botswana. **Table 4-4** lists their main characteristics and a brief description of each is provided hereafter. **Figure 4-1** shows their approximate locations.

The Otjivero Dams (Namibia)

These two dams (Otjivero Main Dam and Otjivero Silt Dam) are located on the upper reaches of the White Nossob River in Namibia, approximately 100 km to the to the east of Windhoek. They form the main sources of the bulk water supply scheme known as the *Gobabis Regional State Water Scheme*. This scheme provides water to the town of Gobabis and to some surrounding smaller settlements in the area. The two dams have a combined full supply capacity of 17,8 million m^3. The Silt Dam located about 2,5 km upstream of the Main Dam and is used to reduce sedimentation accumulation in the Main Dam.

The Daan Viljoen Dam and Tilda Viljoen Dam (Namibia)

These two dams are located at Gobabis and also form part of the *Gobabis Regional State Water Scheme*. The Daan Viljoen Dam is an in-channel dam on the Black Nossob River, which impounds flood waters. The water is then pumped into the larger Tilda Viljoen Dam (off-channel), located nearby. Water is also transferred from the Otjivero Main Dam into the Tilda Viljoen Dam via a 110 km pumped pipeline.

Lotlamoreng Dam (RSA)

This small dam is located in the Lotlamoreng Dam Cultural Reserve on the Molopo River and is used for recreational purposes only. It has a capacity of 0,5 million m^3.

Setumo (Modimolo) Dam

This dam is located on the Molopo River near Mafikeng and has a capacity 21.5 million m^3. It supplies bulk water for treatment at the Setumo Waterworks (formally Mmbatho Waterworks). The treated water from the works is blended with treated water from the Mafikeng Waterworks (supplied from ground water), and supplied to the urban and peri-urban areas of Mafikeng.

Disaneng Dam

This dam is also located on the Molopo River, approximately 35 km downstream of Mafikeng. It provides water for irrigation of about 100 ha at the Disaneng WUA (former Disaneng Irrigation Board).

Koedoesrand and Blackheath Dams

According to the South African DWAF, these small dams are used for irrigation purposes. Information available is as shown in **Table 4-4.**

Table 4-4: Features of the Main Dams in the Molopo-Nossob Catchment

DAM NAME	RIVER	NEAREST TOWN	COUNTRY	LOCATION		DATE COMPLETED	FULL SUPPLY CAPACITY (million m^3)	YIELD (million m3/a)	WALL HEIGHT (m)	DAM TYPE
				Lat	Long					
Otjivero Main	White Nossob	Windhoek	Namibia	22°17'	17°58'	1984	9,808	1,65 (95% assurance	16	Concrete Buttress
Otjivero Silt	White Nossob	Windhoek	Namibia	22°17'	17°57'	1984	7,795		17	Embankment
Daan Viljoen	Black Nossob	Gobabis	Namibia	22°13'	18°50'	1958	0,429	0,36 (95% assurance	6,6	Concrete Arch
Tilda Viljoen	Off-channel	Gobabis	Namibia			1958	1,224		12.5	Embankment
Lotlamoreng	Molopo	Mafikeng	RSA	25°52'	25°36'	1958	0,5		7	Embankment
Modimola	Molopo	Mafikeng	RSA	25°51'	25°31'	1995	21,5	13,2	-	Embankment
Disaneng	Molopo	Mafikeng	RSA	25°46'	25°16'	1980	17,4	1,0	17	Embankment
Koedoesrand	Koedoe	Mafikeng	RSA	26°14'	25°13'	1989	0,75	Unknown	9	Embankment
Blackheath	Molopo	Vryburg	RSA	25°41'	24°15'	1971	0,124	Unknown	5	Embankment
Leeubos	Swartbas	Twee Rivieren	RSA	26° 44'	20°06'	1948	1,071		4	Embankment
Abiekwasputspan	Molopo	Twee Rivieren	RSA	27°18'	20°06	1963	-	Unknown	5	Pan

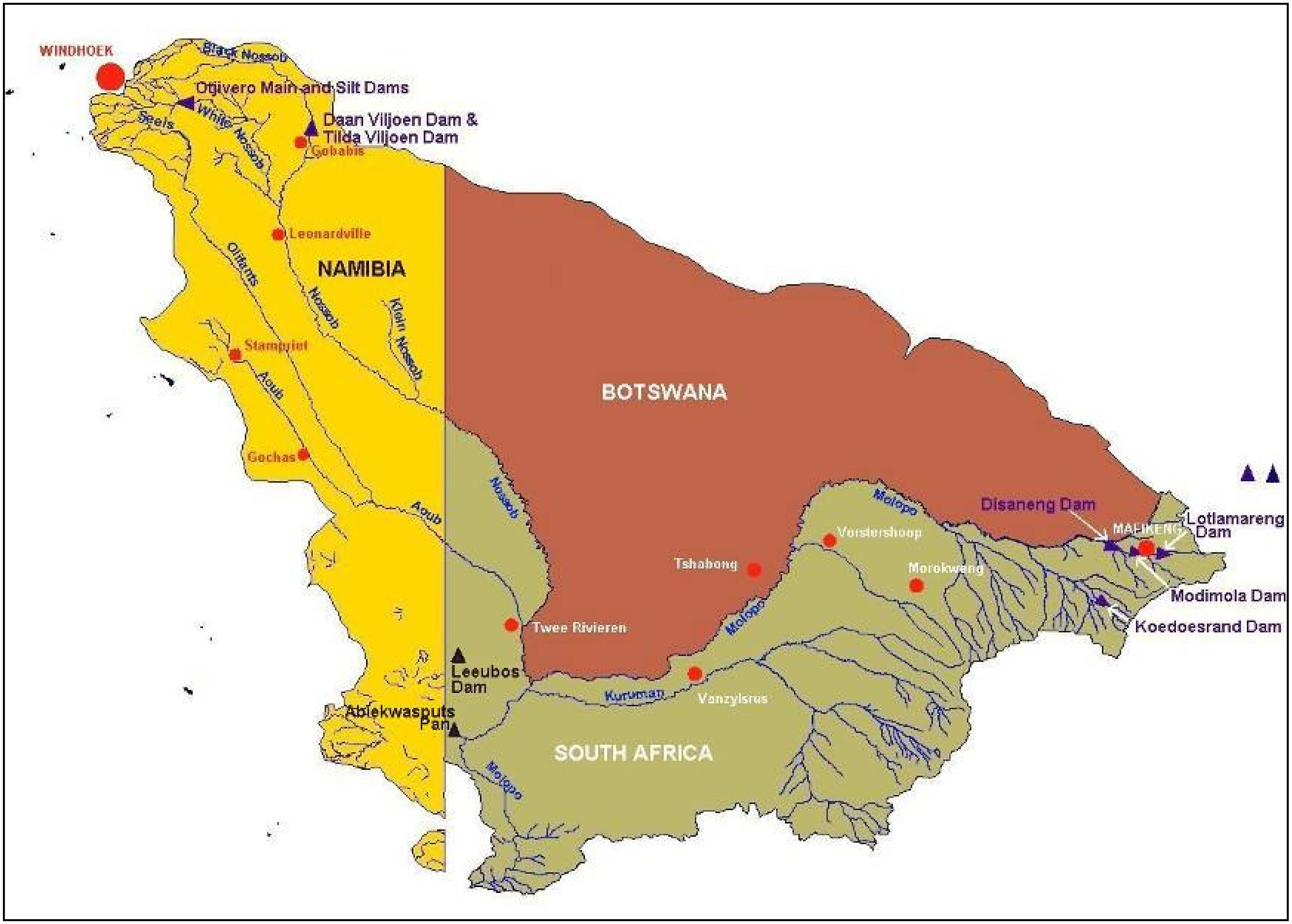

Figure 4.1: Location of Main Dams in the Molopo-Nossob Catchment Area

4.3.2 Farm Dams

From the GIS database developed for the study, the information on the extent of farm dams within the total study area is summarised in **Table 4-5.**

Table 4-5: Features of the Farm Dams in the Molopo-Nossob Catchment

DEPTH RANGE (m)	No. of FARM DAMS	TOTAL CAPACITY (million m^3)	TOTAL SURFACE AREA (ha)
0 - 0,5	75	0,44	80
0,5 – 0,8	5	0,01	3
0,8 – 1,0	126	1,95	214
1,0 – 1,5	42	0,67	84
1,5 – 2,0	49	0,82	110
2,0 - 2,5	12	0,13	20
2,5 – 3,0	5	0,71	50
3,0 – 4,0	3	0,12	13
4,0 – 5,0	1	0,19	16
TOTAL	**318**	**5,04**	**590**

4.3.3 Pans

From the GIS database developed for the study, the information on the extent of natural occurring pans within the total study area is summarised in **Table 4-6**.

Table 4-6: Features of the Pans in the Molopo-Nossob Catchment

DEPTH RANGE (m)	No. of PANS	TOTAL CAPACITY (million m^3)	TOTAL SURFACE AREA (ha)
0 - 0,5	1 150	17,44	6 977
0,5 – 1,0	596	52,52	10 504
1,0 – 1,5	234	35,69	4 759
1,5 – 2,0	265	256,71	25 671
2,0 – 2,5	64	401,54	32 123
2,5 – 3,0	105	174,28	11 618
3,0 – 3,5	4	4,74	271
3,5 – 4,0	74	183,88	9 194
4,0 – 5,0	84	754,03	30 161
5,0 – 6,0	8	21,66	722
6,0 – 7,5	10	44,68	1 192
7,5 -10	9	37,38	748
TOTAL	**2 603**	**1 984,55**	**133 940**

Table 4-7: Summary of run-off, storage and yield

River	Quaternary	MAR(1) (Mm^3)		EXISTING MAJOR DAMS			
		Natural	Present Day	Dam name	River	Storage (Mm^3)	Yield (Mm^3/a)
Molopo	D41A	32.9	6.4	Lotlamoreng	Molopo	0.50	0
				Modimolo	Molopo	21.50	13.2
				Disaneng	Molopo	17.40	1
	SUB-TOTAL	**32.9**	**6.4**			**39.40**	**14.20**
	D41B	12.8	4.0	Koedoesrand	Koedoe	0.75	Unknown
	D41C	9.7	2.5	Blackheath	Molopo	0.12	Unknown
	D41D	6.0	1.1	-	-	-	-
	Z10D	3.6	1.1	-	-	-	-
	Z10C	21.3	8.7	-	-	-	-
	D41E	0.7	0.8	-	-	-	-
	D41F	1.9	2.4	-	-	-	-
	D41H*	0.9	0.9	-	-	-	-
	Z10F	0.6	0.0	-	-	-	-
	D42C*	0.1	0.1	-	-	-	-
	TOTAL	**90.3**	**28.0**	**-**	**-**	**40.27**	**14.20**
Kuruman	D41G	7.1	6.9	-	-	-	-
	D41H*	1.6	1.4	-	-	-	-
	D41J	3.7	3.4	-	-	-	-
	D41K	4.5	4.5	-	-	-	-
	D41L	25.2	16.9	-	-	-	-
	D41M	0.9	0.9	-	-	-	-
	D42C*	1.1	1.0	-	-	-	-
	TOTAL	**44.1**	**35.0**	-	-	-	-
Nossob	Z10A	18.1	17.3	Otjivero Main	White Nossob	9.81	1.65
				Otjivero Silt	White Nossob	7.80	
				Daan Viljoen	Black Nossob	0.43	0.36
				Tilda Viljoen	Off-channel	1.22	
	SUB-TOTAL	**18.1**	**17.3**			**19.26**	**2.01**
	D42A	0.2	0.2	Leeubos	Swartbas	1.07	Unknown
	TOTAL	**18.4**	**17.5**	**-**	**-**	**20.33**	**2.01**
Auob	Z10A	7.7	4.5	-	-	-	-
	D42A	0.0	0.0	-	-	-	-
	D42B	0.0	0.0	-	-	-	-
	TOTAL	**7.8**	**4.5**	-	-	-	-

(1) Based on catchment model results

5. WATER REQUIREMENTS

5.1 SURFACE WATER

5.1.1 Urban and Rural Water Requirements

The largest urban areas within the study catchment are Mafikeng and Kuruman in South Africa and Gobabis and part of Windhoek in Namibia. The Botswana part of the catchment includes no major urban areas. Data on urban water requirements within the study area were obtained from DWAF in South Africa, DWA in Botswana and NamWater in Namibia.

The urban demands for Mafikeng are approximately 11 million m^3/a (Dube, Pers.com). Approximately 65 % of this demand is sourced from the Molopo and Grootfontein Eyes and the remaining 35 % from the Modimolo Dam. Kuruman supplies almost all of its municipal demand of approximately 9 million m^3/a from the Kuruman Eye which is abstracted directly at the source, which is equivalent to 94 % of its total demand. Only approximately 6 % of the total supply is contributed by surface water. Some of the rural demands in the lower Molopo-Nossob catchment is supplied via the Kalahari Water Supply Transfer Schemes (refer to **Section 5.1.4**). Gobabis' municipal supply of about 1 million m^3/a is provided from the Otjivero Dam with the shortfall being supplemented by ground water during periods of drought. Most rural water requirements are met from localised ground water abstractions.

5.1.2 Mining Water Requirements

In the upper Molopo catchment, mining and industrial water requirements are approximately 5 million m^3/a and in the upper Kuruman catchment, approximately 6 million m^3/a (DWAF, 2003). Most water requirements for mining are satisfied by ground water sources in conjunction with transfers from outside the study catchment.

5.1.3 Return Flows

Urban and mining return flows from the upper Molopo (larger Mafikeng area) are approximately 7 million m^3/a, contributing to the total available water for use in Mafikeng (Crocodile West WMA, DWAF, 2003). Urban and mining return flows in the upper Kuruman catchment equal less than 2 million m^3/a. Irrigation return flows, based on information provided by Schoeman and Partners are estimated to be 10 % of the irrigation supply.

5.1.4 Water Transfers

Due to the scarcity of water within most of the Molopo-Nossob catchment, no water is transferred out of the catchment. However, schemes transferring water into the Molopo-Nossob catchment include the Vaal-Gamagara Regional Water Supply Scheme and the Kalahari Rural Water Supply Schemes:

Vaal-Gamagara Scheme

The Vaal-Gamagara Regional Water Supply Scheme was initiated in 1964 to mainly supply water to the mines in the Gamagara Valley in the vicinity of Postmasburg and further north. The scheme abstracts water from the Vaal River near Delportshoop, immediately downstream of its confluence with the Harts River, from where the water is pumped to a water purification works next to the river. From the purification works, water is pumped via a 99 km double rising main to reservoirs in the Vaal/Molopo watershed near Clifton, from where water is gravity fed over a distance of 182 km along a route which serves Postmasburg, Sishen, Hotazel and Black Rock. Branch pipelines of 24 km and 5 km respectively supply water to the town of Olifantshoek and a reservoir at Beesthoek. The design capacity of the scheme is 36.4 Mℓ/d (13.3 million m^3/a), with allowance having been made to increase this capacity by means of additional booster pumps and reservoirs. In 1995, the actual abstraction by this scheme was 8.4 million m^3/a (this include the water use by the Kalahari East Rural Water Supply Scheme – see next paragraph).

Kalahari West Rural Water Supply Scheme

The Kalahari West Rural water Supply Scheme was constructed in 1982 to supply farmers north of Upington with water for stock watering and domestic use. The scheme serves a total of 74 farms covering an area of 633 000 ha, which extends into the Molopo catchment. The scheme was implemented as an emergency scheme during a period when ground water sources in the region started to fail and was designed to serve that part of the Kalahari experiencing the worst water shortages. The scheme sources water from Upington's municipal system, from where it is pumped via a number of balancing reservoirs and small booster pumpstations. The scheme's peak design capacity is 1,99 Mℓ/d. In 1995, the actual water abstraction via the scheme was estimated to be 0,42 million m^3/a, which, taking peak factor requirements into account, implies that the scheme is being operated at or near capacity.

Kalahari East Rural Water Supply Scheme

The Kalahari East Rural Water Supply Scheme was constructed in the early nineties to supply water to farmers in the Kalahari north of Upington (including parts of the Molopo catchment) with water for stock watering and domestic use. The scheme sources its water from the Vaal-Gamagara pipeline, which is currently underutilised. Water is abstracted from the Vaal-Gamagara pipeline at Kathu, north-east of Olifantshoek, from where water is distributed via a 32 km long rising main, a 4.3 Mℓ reservoir and an extensive gravity pipe network to serve an area of approximately 14 000 km^2. The scheme was designed to deliver a peak flow of 6.18 Mℓ/d, with provision having been made to increase this to 8.52 Mℓ/d. The actual water that was supplied by the scheme in 1995 equalled 1.3 million m^3/a.

Based on the assumption that return flows from the above transfer schemes are negligible, the above transfers have not been included in the hydrological model.

5.1.5 Ecological Reserve Requirements

The ecological Reserve in the Upper Molopo River is estimated to be 5 Mm^3/a (Crocodile West & Marico WMA) (DWAF, 2003) and in the lower Molopo River is estimated to be 29 Mm^3/a (Lower Vaal WMA) (DWAF, 2003).

5.2 GROUND WATER

The ground water is extensively used in the study area for domestic, livestock, and irrigation purposes. Ground water abstraction increased dramatically in the last 25 years due to improved technology in developing ground water resources.

In Botswana, the Department of Water Affairs: Department of Geological Survey carried out various major ground water exploration projects, TGLP Projects and Rural Village Water Supply projects to develop ground water potential to supply to various major centres, villages and settlements for domestic and livestock purposes. In Botswana large volume of water consumption is for the domestic use followed by Livestock watering (BNWMP, 1991).

In South Africa, agriculture was the largest utiliser of ground water resources and livestock is a minor volumetric consumer. The mining sector and domestic water supply are also reliant on ground water resources. The large-scale water use is listed in **Table 5-1** where the total use amounts to almost 111 million m^3/annum. Other smaller scale water use in the area could increase total use in the map area to 115 million m^3/annum (Gawie van Dyk and S.Kisten, 2006).

Table 5-1: Locality and amount of large scale ground water abstraction (million m^3/a)

Locality/Area	Source	Municipal	Agricultural Irrigation	Mining	Info source
Louwna/Coetzersdam	Fractured and weathered granite		40		Botha (DWAF 1996)
Tosca	Karst dolomite		18		Van Dyk (DWAF 2005)
Stella	Fractured and weathered granite	0.2	1		Nel (DWAF 1998)
Mmabatho/ Mafikeng Grootfontein compartment	Karst dolomite	8	8		Nel (DWAF 1997)
Vryburg	Fractured quartzites	5			Louw (Africon 2002
Delareyville	Fractured sediments	5	13		Louw (Africon 2002) Van Dyk DWAF est 2003)
Sannieshof	Fractured lava	0.9	2.5		Louw (Africon 2002) Van Dyk DWAF est 2003
Ottosdal	Fractured sediments	3	3		Louw (Africon 2002) Van Dyk DWAF est 2003
Pomfret	Karst dolomite	1			Van Dyk (DWAF 1994)
Kalahari gold mine Mareetsane	Fractured and weathered granite			2.4	Louw (Africon 2002)
Total		**23.1**	**82.5**	**2.4**	

The estimated water consumption in the Stampriet Artesian Basin in Namibia, which is part of the current study area, is also indicates that large volume (46.1 %) of water consumption is for the irrigation purpose followed by livestock watering. **Table 5.2** shows the estimates of water usage in the Stampriet Artesian Basin area for March 2000 (JICA, 2002).

Table 5-2: Estimates of Water Usage in the Stampriet Artesian Basin area

Sectors	Water Usage (million m^3/year)	Proportion (%)
1. Domestic water		
1.1 Village centres	0.635	4.26
1.2 Commercial farms	1.594	10.69
1.3 Communal land	0.127	0.85
Sub-total	2.356	15.80
2. Industries	0.000	0.00
3. Tourism	0.004	0.03
4. Stock watering	5.678	38.07
5. Irrigation	6.876	46.10
Total	**14.914**	**100.00**

5.2.1 Available Water

In the semi-arid areas with limited precipitation and recurring droughts the long term sustainable use of ground water resources is always be a challenge. Most of the villages and settlements are situated along the Molopo and Nossob dry valleys where they rely on the shallow alluvial aquifers for their water supply. All the cattle posts and ranches in the area rely entirely on ground water sources. The ground water sources have proven over time to be unreliable and saline in most areas. The quantification of water availability for the whole Molopo-Nossob sub river basin is not available. The ground water is already over exploited in the region and the water levels are declining. Continued good management of ground water resources in the project area is essential.

In Botswana, major ground water exploration studies namely, Tsabong Ground water Investigations, Assessment and Development, Bokspits TGPL Areas Ground water Potential Survey, Werda – Mabutsane - Sekoma TGLP Ground water Potential Survey, and Matsheng Ground water Development Project were carried out in the Molopo River Basin area to provide the water for domestic and livestock.

The Tsabong wellfield, which extracts from the quartzites of the Olifantshoek Group, is over exploited. It is unlikely that any more resource is available in this area. The sustainable yield of the Tsabong wellfield is around 300 m^3/day but the abstraction is more than double (750 m^3/day). The Bokspits TGLP ground water potential survey project (DGS, 2002) covering an area of 7 435 km^2 and is bound to the south and west by the Molopo and Nossob rivers, respectively. 95 % of the project area underlies the Otshe (Auob) sandstone of Ecca Group and forms an important aquifer. The calculated available water sources of 1 515 m^3/d are from the project boreholes in addition to existing pumping. However the exploitable is only 943 m^3/d. The Werda-Mabutsane-Sekoma TGLP ground water survey project covering an area of 12.000km^2 in the three administrative districts (Kgalagadi, Southern, and Kweneng) with the Molopo River bordering the south of the project area predominantly quartzites and shale's of the Transvaal Supergroup and concluded that the ground water potential is poor to very poor for provision of portable water supply. The Ecca aquifer in the Ncojane Block situated northern side of the study area was explored during the Matsheng Ground water Development Project (DWA, 2008). The total calculated reserve in the Ncojane Block is 158 MCM in storage of which the exploitable reserve is 32 MCM. The Kalahari Group sediments are along the Molopo River is productive. The thickness is of Kalahari sediments are around 200 m at Bray (NWMP, 2006). Boreholes drilled around Hereford/Bray yields' vary up to 6.0 m^3/hr and the Total Dissolved Solids (TDS) is generally below 1 000 mg/ℓ, but occasionally saline water is also present.

In the South African part of the basin, extensive ground water abstraction by commercial and communal farmers, domestic and other purpose, there is very limited potential for future exploration of the ground water resources in the study area. The productive aquifer is mainly along the Molopo and Nossob rivers in the Kalahari Group.

In Namibia there is a comparatively good understanding of the geology and hydrogeology of the aquifer in the Stampriet Artesian Basin. Water occurs in the Auob and Nossob sandstones of the Ecca Group as well as the overlying Kalahari Group sediments. The strata dip approximately 30 towards the southeast and the water quality deteriorates in that direction. Construction of a numerical model of the aquifer was being undertaken by the Department of Water Affairs in Namibia. The storage of ground water in each of the aquifer in the Stampriet Artesian Basin is estimated during the ground water potential evaluation and management plan study (JICA, 2002).

Table 5-3: Ground water Storage of each aquifer

Aquifer	Thickness (m)	Area (m^2)	Volume (m^3)	Effective Porosity (%)	Ground water Storage (m^3)
Kalahari (Saturated)	0-250	52.6E+9	2.36E+12	5	**120E+9**
Auob Aquifer	0-150	50.7E+9	3.60E+12	5	**180E+9**
Nossob Aquifer	0-60	9.98E+9	1.24E+12	5	**57E+9**

The **Table 5-3** indicates that the Auob Aquifer contains more ground water than the Kalahari and the Nossob Aquifer. However, it should be noted that a very little of ground water within the aquifers is virtually available for the extraction.

5.2.2 Water Quality

Water quality is the major constraint on ground water utilisation in the Molopo-Nossob Sub river basin area. The water quality in the study area varies from fresh to hyper saline. The most important ions contributing to the ground water salinity are chloride, sulphate and sodium. In Botswana, the ground water over much of the southern and western Kgalagadi District is excessively saline and large areas of the Otshe (Auob) Formation sandstone aquifers and Kalahari Group aquifers are quite unusable.

The quality of water in the different aquifers is discussed below.

Basement Aquifers

The quality in the Kraaipan Group of rocks near Pitsane-Molopo indicated that the water quality for the few yielding boreholes is generally acceptable with TDS values below 500 mg/ℓ. Nitrate and fluoride registered marginal limits in BH 1218, varying between 2.0 mg/ℓ to 29 mg/ℓ for Nitrate and 0.16 mg/ℓ to 0.37 mg/ℓ for fluoride. The water was described as Ca-Mg-HCO_3 type (DWA, 2007).

The water quality data of the Vryburg map area in South Africa collected from the DWAF indicates that elevated magnesium concentration in some of the boreholes are not suitable for drinking purposes. Aquifers in the Kraaipan Group and Unnamed Swazian rocks can be used marginally but only in the short term (Gawie van Dyk and S.Kisten, 2006).

The fractured rock aquifers display four types of water, (HCO_3+CO_3) -Mg – Ca; Mg – (Cl+NO_3) – SO_4; Mg – (HCO_3+CO_3) – (Cl+NO_3); and Mg – SO_4 - (HCO_3+CO_3). Aquifers of the Dominion Group Bothaville Formation, Vryburg, and Black Reef Formation display recently recharged ground water (Gawie van Dyk and S.Kisten, 2006).

The quality of ground water in the quartzites in Botswana is generally potable with TDS values of less than 2.000 mg/ℓ. However, two borehole drilled near Middlepits during the Bokspits TGLP ground water survey project (DGS, 2002) indicates that the TDS varies between 10.540 mg/ℓ (BH 9421) to 29.550 mg/ℓ (BH 9420) indicating that the quartzite north of Middlepits has poor quality water. The Olifantshoek quartzite has a variety of water types ranging from Na-Cl, SO4 to Na-HCO_3, Cl and Ca, Mg, Na-Cl, SO4 (DGS, 2002).

Karst Aquifers

The Ghaap Group of aquifer in the South Africa displays a HCO_3+CO_3 – Mg – Cl + NO_3 water type. The bicarbonates and magnesium rich waters indicate recently recharged aquifers. However there is a presence of the Cl + NO_3 anions that could possibly infer contamination from surface from agricultural practices (Gawie van Dyk and S.Kisten, 2006).

Dwyka Formation Aquifers

The quality of ground water from the few boreholes that tap the Dwyka Formation in Botswana varies from brackish to saline with TDS ranging from 2.300 mg/ℓ to 7.170mg/ℓ. The Dwyka Formation water is mainly of the Na-Cl type. In South Africa, more than 66 % of the boreholes drilled in the Dwyka Group of rocks are dry. The Dwyka Group aquifer display mixed water type (Mg – (HCO_3+CO_3) – (Cl+NO_3)). The Mg^{2+} cation and the bicarbonate/carbonate anions reflect recently recharged waters. The Cl+NO_3 ratio is strongly influenced by the nitrate content (Gawie van Dyk and S.Kisten, 2006).

Ecca Group Aquifers

The quality of ground water in the Ecca aquifer(s) in Botswana varies from fresh, brackish to very saline with TDS ranging from 780 mg/ℓ (BH Z5853) to 129,930 mg/ℓ (BH 8467). The confined sandstone units contain generally very saline waters with yields up to 60 m^3/hr (DGS, 1994) whilst the semi-confined sandstone(s) may yield brackish usable water with yields up to 25 m^3/hr. Several boreholes in the project area also show increasing TDS with depth, e.g. boreholes 7245, 7425, 7475, 7476, 9426, 9427 9430 and 9433. Otshe (Auob) sandstone waters are mainly of the Na-Cl, SO4 and Ca, Mg, Na-Cl, SO4 type. High concentrations of TDS are observed around Twee Rivier area in Namibia. The maximum value of TDS concentration was 6.754 mg/ℓ.

Kalahari Beds

The quality of water in this aquifer is also highly variable and ranges from fresh to hyper-saline. The fresh water aquifer units of the Kalahari beds (alluvial sediments) are localised and very limited in extent and mainly occur along the Molopo and Nossob Rivers. Other potential freshwater/brackish water aquifers of the Kalahari Group are those associated with pans e.g. Tshane-Tshane borehole (BH Z2905). These occur as isolated perched aquifers developed around pans. The Kalahari aquifer has waters dominated by Na-Cl, SO4 type.

6. RIVER FLOWS

6.1 HISTORICAL EXTREME EVENTS

Figure 6.1 shows typical runoff volumes at three locations along the Molopo River as simulated by the Pitman model. These represent runoff volumes associated with the three most extreme rainfall events since 1920 viz. in 1943, 1973 and 1975.

6.2 DESIGN FLOOD VOLUMES

In order to verify the above estimates of historical runoff volumes, typical estimates of design rainfall (Smithers and Schulze, 2002), areal reduction factors (Alexander, 1990), temporal storm distributions (Adamson, 1981) and storm losses (HRU, 1972) were used to provide first order estimates of storm runoff volumes at locations which coincide with those shown in **Figure 6.1**. Design runoff volumes for different return periods, as well as channel losses as 'calibrated' in the Pitman model, are summarised in **Table 6.1**.

Table 6.1 shows that only in the case of floods with return periods in excess of 20 years, will flood water propagate down to the Nossob confluence. Furthermore, based on the 'historical' flood volumes as depicted in **Figure 6.1**, **Table 6.1** implies that the most extreme historical event (1975) represented a storm with a return period of between 20 and 50 years.

Table 6-1: Design storm runoff volumes in the Molopo River (Mm^3)

Sub-catchment		**Return Period (a)**			
		100	**50**	**20**	**10**
Upper Molopo	Runoff	492	406	283	223
	Losses	120	120	120	120
	Balance	372	286	163	103
Middle Molopo	Runoff (1)	499	390	236	161
	Losses	135	135	135	135
	Balance	364	255	100	26
Lower Molopo	Runoff (1)	364	255	100	26
	Losses	100	100	100	100
(Nossob confluence)	Balance	264	155	0	0

Note (1): Includes runoff balance from upstream and runoff from incremental catchment

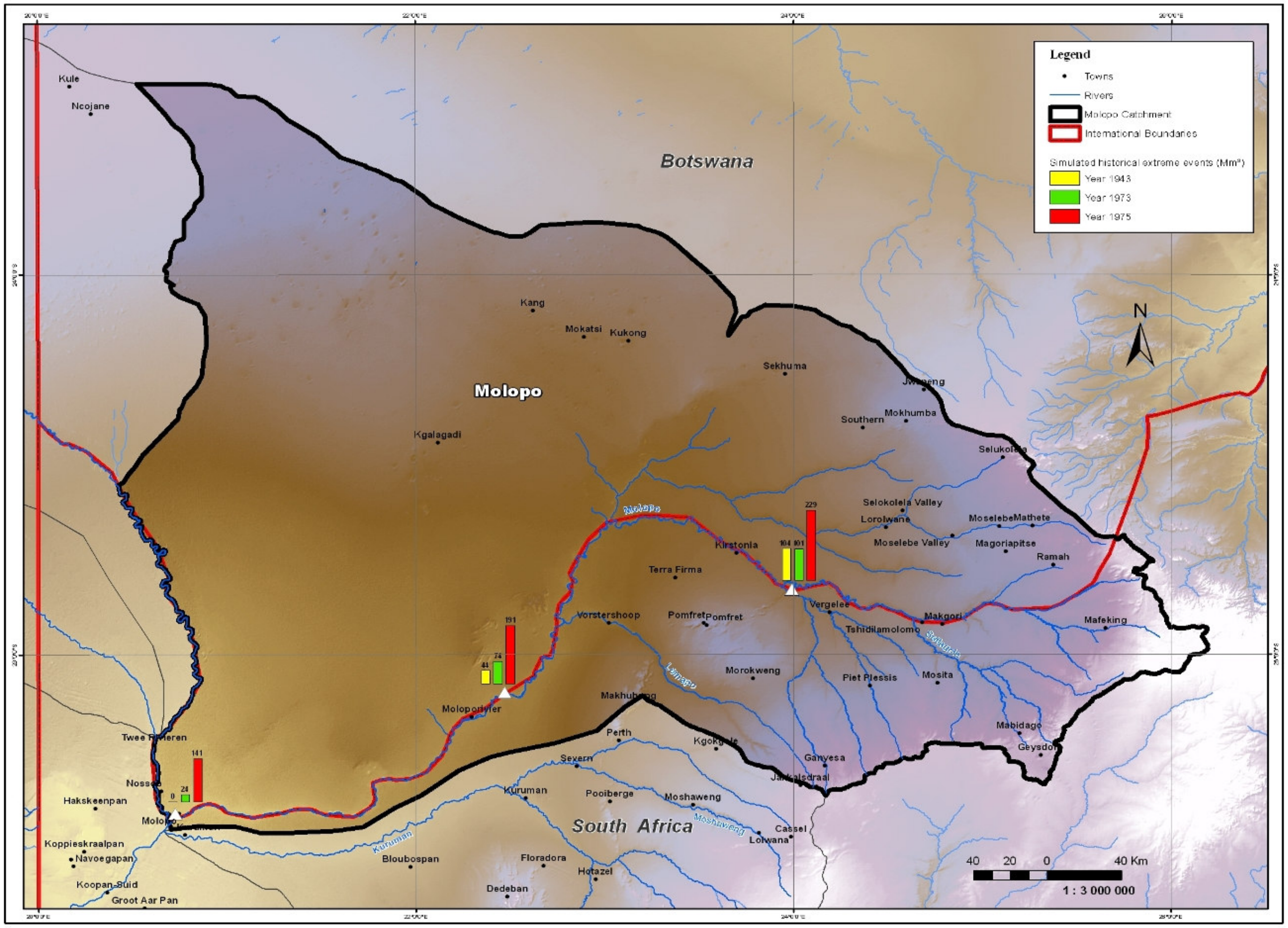

Figure 6.1: Simulated extreme historical runoff events

During discussions with the stakeholders from Botswana, a concern was voiced that the construction of the dams in the catchment of the Upper Molopo River has reduced the occurrence of floods reaching the lower reaches of the river, and that this has reduced the recharge of the aquifers along the river. In order to investigate this, the volume of the floods was calculated, and taking into account the river losses, to determine how far down the river the flows would reach. This exercise was done for a no-dam (natural) scenario (**Table 6.2**), as well as a with-dam scenario (**Table 6.3**).

Table 6-2: Design storm runoff volumes in the Molopo River (Mm^3): Natural conditions

Subcatchment		**Return Period (a)**					
		100	**50**	**20**	**10**	**5**	**2**
Upper Molopo	Incremental Runoff	492	406	283	223	160	105
(250 km)	Losses	120	120	120	120	120	120
	Runoff Balance	372	286	163	103	40	0
Middle Molopo	Incremental Runoff	127	105	73	58	41	27
(265 km)	Total Runoff	499	390	236	161	81	12
	Losses	135	135	135	135	135	135
	Runoff Balance	364	255	100	26	0	0
Lower Molopo	Incremental Runoff	0	0	0	0	0	0
(270 km)	Total Runoff	364	255	100	26	0	0
	Losses	100	100	100	100	100	100
(Nossob confluence)	Runoff Balance	264	155	0	0	0	0

Table 6-3: Present day conditions (Mm^3) (assuming maximum interception of floods by major and farm dams)

Subcatchment		**Return Period (a)**					
		100	**50**	**20**	**10**	**5**	**2**
Upper Molopo	Incremental Runoff	492	406	283	223	160	105
	Losses	120	120	120	120	120	120
	Interception by Dams	63	63	63	63	63	63
	Runoff Balance	309	223	100	40	0	0
Middle Molopo	Incremental Runoff	127	105	73	58	41	27
	Total Runoff	436	327	173	98	18	0
	Losses	135	135	135	135	135	135
	Runoff Balance	301	192	38	0	0	0
Lower Molopo	Incremental Runoff	0	0	0	0	0	0
	Total Runoff	301	192	38	0	0	0
	Losses	100	100	100	100	100	100
(Nossob	Runoff Balance	201	92	0	0	0	0

confluence)							

The construction of the dams in the Upper Molopo River has resulted in a reduction in the frequency of floods reaching the lower reaches of the river. The effect is a reduction from 1 in 2 years to 1 in 5 years for the Upper Molopo, while for the Middle and Lower Molopo it was from 1 in 5 to 1 in 10. It is unlikely that a recharge with a frequency of more than two years will have a significant effect on the long term yield of the aquifer, and it can safely be stated that the effect of the dam is limited to the Upper Molopo, and that the effect further downstream is not significant.

At this point in time it is not possible to quantify the effect of the dams on the yield of the aquifer along the Upper Molopo River, and exactly how far down the river the effect lasts. A rough estimate is that the effect stretches for about 50 km downstream of the dams, and that the reduction in groundwater yield is about 5 Mm^3/a. This will be spread evenly along the river, along both sides.

A rainfall trend analysis was conducted, and no statistical significant trend was observed based on the available rainfall data in the catchment.

7. DISCUSSION

Hydrological modelling has been undertaken to provide first order estimates of typical surface water runoff volumes in the main rivers in the Molopo-Nossob catchment. The modelling was done by means of the Pitman rainfall-runoff model, local observed rainfall records and current land use information. Estimates of natural and present day surface water runoff have been calibrated based on observed flow records where available as well as on historical records of floods in the Molopo-Nossob catchment.

The modelling results have shown that the total natural runoff from the Molopo-Nossob catchment, without any channel losses, equals 164 Mm3/a. However, once losses are taken into account, the total cumulative runoff for each of the main subcatchments reduces to zero, except in the case of the Kuruman catchment where the average net outflow equals 4.1 Mm3/a under natural conditions and 4.0 Mm^3/a under present day conditions

First order estimates of typical gross storage-yield characteristics for the upper parts of the Molopo, Kuruman and Nossob catchments have shown that significant storage is required to provide yield at an acceptable level of assurance. An assessment of the central parts of the Molopo-Nossob catchment, situated within the drier, central Kalahari Desert, has indicated that it is not feasible for dams to be constructed in this area due to the lack of reliable runoff.

The Molopo-Nossob system does not function in the same way as more conventional rivers, where groundwater discharge provides a baseflow during dry conditions. In the case of the Molopo-Nossob system, the occasional floods are totally absorbed along the river bed and recharge the ground water aquifers along the course of the river. From the investigation it is clear that surplus water is only generated at a recurrence interval of less than 20 years. For the rest of the time, floods are entirely absorbed as ground water recharge along the course of the river.

As the water along the course of the river is needed for small communities and stock watering, there is little sense in building storage dams. It is far more financially and economically viable to abstract the water from boreholes and wells at the point of use, as this will not only cut out the evaporation losses from the surface of a reservoir, but also the necessity of an expensive distribution network.

The construction of the dams in the Upper Molopo River has resulted in a reduction in the frequency of floods reaching the lower reaches of the river. The effect stretches for about 50 km downstream of the dams in the Upper Molopo, and the reduction in ground water is estimated at 5 Mm^3/a.

8. CONCLUSIONS AND RECOMMENDATIONS

The study has conclusively shown that there is no surplus water in the Molopo-Nossob catchment that can be economically exploited. It was also shown that the occasional floods serve to recharge the ground water aquifers along the river course, and that any storage that is created will therefore reduce the availability of ground water along the course of the river.

It is therefore recommended that no further surface water development in the form of dams is considered in the study area, and that the development of ground water sources is investigated in more detail.

However, the development of ground water should be undertaken with some caution, as making more water available may lead to overgrazing and the destruction of the natural vegetation, especially where subsistence farming is practised.

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