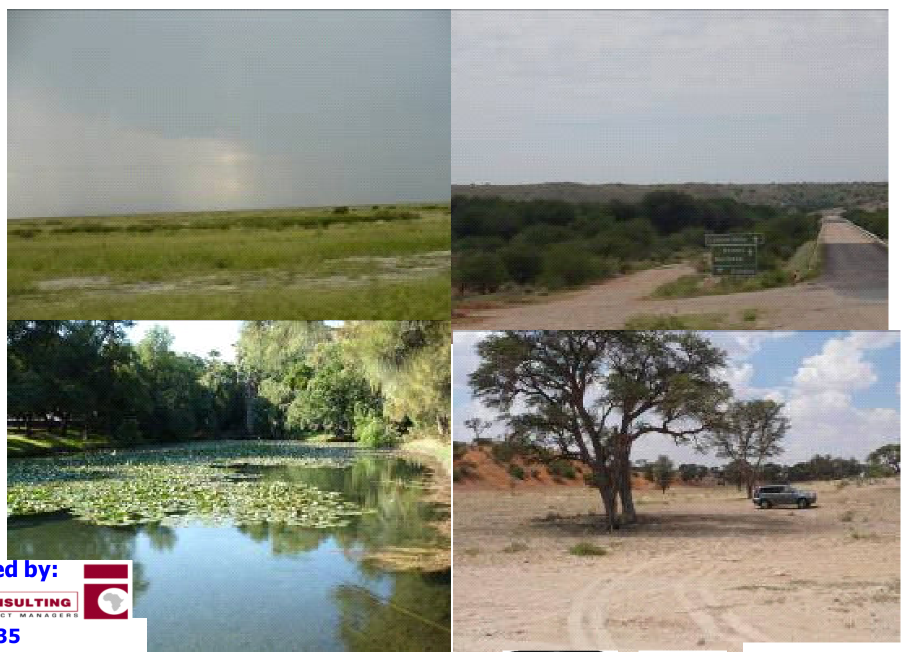
Sharing the Water Resources
Of the Orange-Senqu River Basin

Report No: 003/2008

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

Catchment Status Inventory Report
Final



Submitted by:

ILISO CONSULTING
ENGINEERS PROJECT MANAGERS

PO Box 68735
Highveld
0169
Tel: (012) 665 6302
Fax: (012) 665 1886
Contact: Dr M van Veelen

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Title:	***Catchment Status Inventory Report***
Authors:	***Dr M van Veelen, T Baker, K Mulale, A Bron, Dr A Fanta, V Jonker, W Mullins, H Schoeman***
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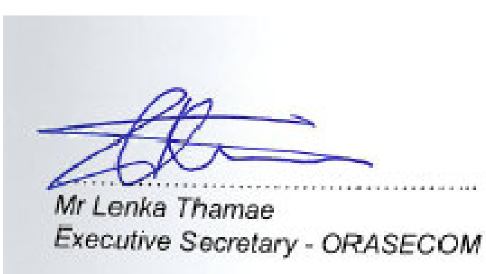
ILISO Consulting (PTY) LTD

Approved for and on behalf of ILISO Consulting (Pty) Ltd, Ninham Shand Incorporated, Schoeman and Partners and Conningarth Economists by

2009/05/11
Date

ORANGE SENQU RIVER COMMISSION

Approved on behalf of ORESECOM by



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LIST OF STUDY REPORTS IN FEASIBILITY STUDY OF THE POTENTIAL FOR SUSTAINABLE WATER RESOURCES DEVELOPMENT IN 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
CATCHMENT STATUS INVENTORY

EXECUTIVE SUMMARY

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 in agriculture. As a result, inflow from these sources to the Molopo River, which forms the boundary between Botswana and South Africa, has become heavily 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 objective of this study is 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 should also be investigated, as well as the identification and assessment of sustainable development options. In doing so the catchment should be studied as an interrelated system, even though it falls within the political area of three different countries (Namibia, Botswana and South Africa). The management plan should therefore also consider the institutional framework that will be required to realise the plan.

The purpose of this report is to document the results of phase two of the study, the Catchment Status Inventory Stage. The objective of this stage is to conduct an in-depth investigation of the status of the catchment, specifically with respect to water requirements vis-à-vis the availability of water, but also with respect to the demographic profile, land-use and other related matters.

The Molopo-Nossob Catchment is predominantly an arid, flat area. In Botswana the catchment is characterised by the Kalahari sands, a vast flat semi-arid area and comparatively featureless landscape that has no rivers or streams. The only areas that receive significant rainfall are found to the north of Gobabis (Namibia), and to the south of Mafikeng in South Africa. As a consequence the drainage pattern is poorly developed and very few tributaries join the main rivers. Dams have been constructed in the areas that drain the high rainfall areas, and most of the available yield has been taken up, the water being used for domestic water supply. The exception is the Seeis River where some yield can still be developed, but this is limited.

Activities in the study area centre around farming (predominantly stock farming), mining (mainly in South Africa), conservation and tourism.

Stock farming is limited by the availability of water. Boreholes have been extensively used to open up areas for grazing, but in many cases the quality of the ground water is such that it affects the health of the animals. As a consequence some innovative ideas have been implemented in the past to overcome this problem, such as the holes that were dug in the middle of some pans in South Africa (so-called gatdamme) to conserve rain water. This had limited success, and this method of rain water harvesting has largely been replaced by the Kalahari West Rural Water Supply Scheme that brings water from the Orange River to the area.

The commercial farmers generally apply sound farming practises, but subsistence farmers tend to allow overgrazing which has affected the condition of the veld and consequently the condition of their stock. The rangeland in the immediate vicinity of boreholes has been irreversibly damaged. Providing more water will exacerbate the situation and may in the long run destroy the rangeland to the extent where it can no longer sustain any form of pastoralisation.

The situation is further exacerbated by invasive alien species, specifically persopia, that outperform the indigenous vegetation and deplete the ground water.

Extensive irrigation has been developed in the dolomitic area in South Africa, which has led to extensive over-utilisation of the ground water. As a consequence springs that fed the rivers in this area only flow intermittently after sustained good rainfall. This has affected the upper reaches of the Molopo River specifically, and the nature of the river has been altered significantly.

Mining provides about half of the direct employment opportunities in the study area, but generates 8,7% of the GDP. Up to the present dewatering of the mines provided sufficient water for their own purposes, but imports via the Vaal-Gamagara Scheme will be needed in the near future to augment their own supplies.

Conservation and tourism do not yet play a significant role in the study area, although there is some scope and many farmers are changing from cattle to game farming.

The study area is sparsely populated, and only a few relatively small towns occur. No significant growth in population is foreseen. Most of the young people migrate to urban areas outside the study areas in order to find job opportunities.

Most of the available surface water is already used. In the Molopo River the remaining available water is equal to the required environmental flow of 29 million m^3*/a and there is therefore no exploitable water left.*

Although there seems to be water available in the Kuruman River, this is in fact ground water that is discharged from various fountains (eyes) that emanates from the dolomitic area. These discharges are measured and recorded as surface water flows in the South African hydrological system, and were therefore included in the catchment model as such. A storage dam on the river will therefore serve very little purpose, as it is more economically to abstract the water at source than to store it in a dam where evaporation losses will lead to a significant reduction in yield. Any scheme to exploit the water in the Kuruman River Catchment should therefore consider ground water exploitation, rather than surface run-off.

The yield that can be obtained from the upper reaches of the Auob is about 0.5 million m^3*/a. This is very small and only viable for domestic purposes. The only user for such water is Windhoek and the distance and therefore associated cost of delivery does not make it a viable source of water. This means that, although there is some water available, there is no user for the water.*

The surface water resources of the study area have therefore 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 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 is therefore recommended that the rest of the study considers the availability of ground water in more detail, and focuses on the development of this resource, rather than surface water.

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

CATCHMENT STATUS INVENTORY

Draft

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

APPENDIX A: Water Demand Tables

LIST OF ACRONYMS

AIDS	Acquired Immune Deficiency Syndrome
BEE	Black Economic Empowerment
B&Bs	Bed and Breakfasts
CASP	Comprehensive Agricultural Support
CBNRM	Community Based Natural Resource Management
CHAs	Controlled Hunting Areas
Combud	Computer Based Budgets
DBSA	Development Bank of Southern Africa
DM	District Municipality
DRWH	Domestic Rainwater Harvesting
DWA	Department of Water Affairs (Botswana)
DWAF	Department of Water Affairs (South Africa)
GDP	Gross Domestic Product
GDPR	Gross Domestic Product of Region
GIS	Geographic Information Systems
HIV	Human Immunodeficiency Virus
IDP	Integrated Development Plan
ISARM	Integrated Shared Aquifer Resource Management
ISRDS	Integrated Sustainable Rural Development Strategy
LM	Local Municipality
LSU	Large Stock Units
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MDG	Millennium Development Goals
MEIM	Macro Economic Impact Model
ORASECOM	Orange-Senqu River Commission
RADP	Remote Area Development Policy
RADS	Remote Area Dwellers
RDP	Reconstruction and Development Goals
RSA	Republic of South Africa
RWH	Rainwater Harvesting
SAM	Social Accounting Matrix
SARAR	self-esteem of mothers, assosciate strengths, responsibility, action planning, resourcefulness.
SMME	Small, Medium and Micro Enterprises

TDS	Total Dissolved Solids
TGLP	Tribal Grazing Land Policy
UNICEF	United Nations Childrens Fund
UNDP	United Nations Development Programme
UMK	United Manganese of Kalahari
WARD	Women in Agricultural and Rural Development
WMAs	Wildlife Management Areas
WSA	Water Services Authority
WUAs	Water Users Assosciation

FEASIBILITY STUDY OF THE POTENTIAL FOR SUSTAINABLE WATER RESOURCES DEVELOPMENT IN THE MOLOPO-NOSSOB WATERCOURSE
CATCHMENT STATUS INVENTORY

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 in agriculture. As a result, inflow from these sources to the Molopo River, which forms the boundary between Botswana and South Africa, has become heavily 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 tremendous 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.

Although the identification and possible water development scenarios is mostly an engineering exercise, elements of social and economic analysis are also present in determining the feasibility of the schemes and helping to prioritise the different proposals.

1.2 DESCRIPTION OF THE STUDY AREA

1.2.1 The characteristics of the Orange River basin

The Orange River drains a significant portion of South Africa and Lesotho, as well as parts of Botswana and Namibia. It flows into the Atlantic Ocean at Alexander Bay (**Figure 1-1**). The basin covers around 1 000 000 km^2 and represents a mean annual runoff around 5 700 mm^3 as compiled from data of the period between 1976 and 1987 (DWAF, RSA). Most of this run-off is generated in the uplands of Lesotho, and at present flows from the Vaal River are managed so that only flood flows reach the Orange River under extreme conditions. The Orange River is extensively utilised, and water from the river is used over a wide area in South Africa.

In its lower reaches, the Orange River receives the flows of the Fish River (Namibia) on its right bank, the confluence being approximately 120 km upstream of the estuary. The confluence of the Molopo River is upstream of the border between South Africa and Namibia. Since flow gauging has commenced in South Africa, there is no record of any flow from the Molopo River reaching the Orange River.

Figure 1-1: The Orange River Basin

The precipitation in the Orange River basin is generally low, particularly in the lower part of the Orange River basin. The Mean Annual Precipitation (MAP) on the Molopo-Nossob subcatchment areas of the Orange River basin are higher compared to the lower reaches of the basin. **Figure 1-2** shows the distribution of MAP over the basin.

The variation of temperature in the basin spatially and temporally is high. For instance, the mean temperature in Alexander Bay is 17.3ºC, ranging from 9ºC in July to 24ºC in January (monthly means). The potential evaporation (A-Pan equivalent) is more than 2 800 mm/a in Vioolsdrift and downstream on the Orange River, with values higher than 2 600 mm/a in Alexander Bay (Schulze et al., 1997). On the Fish River, potential evaporation is higher than 2 950 mm/a (LORMS, 2005b). Consequently, in average terms, the contribution of rainfall to the runoff of the Orange River downstream of Vioolsdrift and of the Fish River downstream of Ai-Ais is negligible (ORASECOM, 2006).

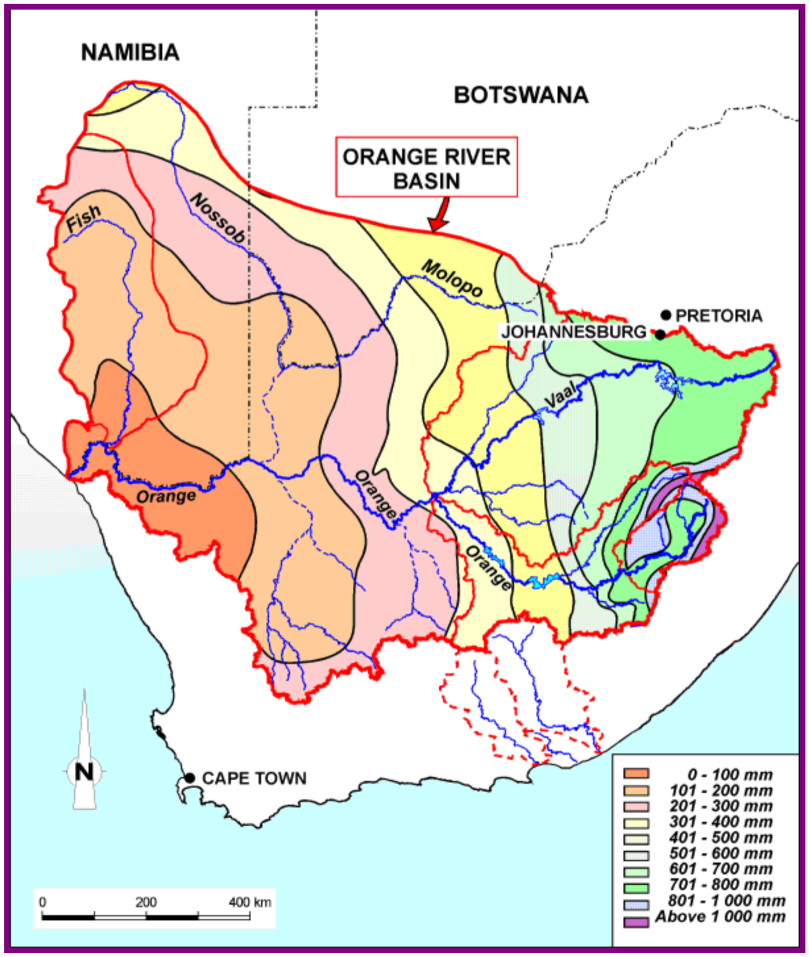

Figure 1-2: Mean annual precipitation on the Orange River Basin (Source: DWAF, RSA)

The sub river basin covers parts of Namibia, South Africa and Botswana. Both the Nossob (meaning dark clay) and the Auob (meaning bitter water) rivers have their sources in the Anas Mountains near Windhoek, Namibia. They flow south-easterly joining in the former Kalahari Gemsbok Park (6 km north of Twee Riviere) and continue as the Nossob River to the Molopo and Kuruman Rivers 60 km to the south. The Molopo River with its origin near Mafikeng, no longer reaches the Orange River as sand dunes near Noeneput have blocked its course for at least the last 100 years (www. kgalagadihistory.co.za).

1.2.2 The Molopo-Nossob Catchment

The Molopo-Nossob Catchment covers a wide area, from Windhoek in Namibia to Lobatse in Botswana and Mmabatho in South Africa (**Figure 1-3**). A significant portion of the catchment falls within the Kalahari Desert and most of the run-off is generated in the headwaters. The natural run-off of the Molopo River is 134.4 million m^3/a, and that of the Nossob 26.2 million m^3/a.

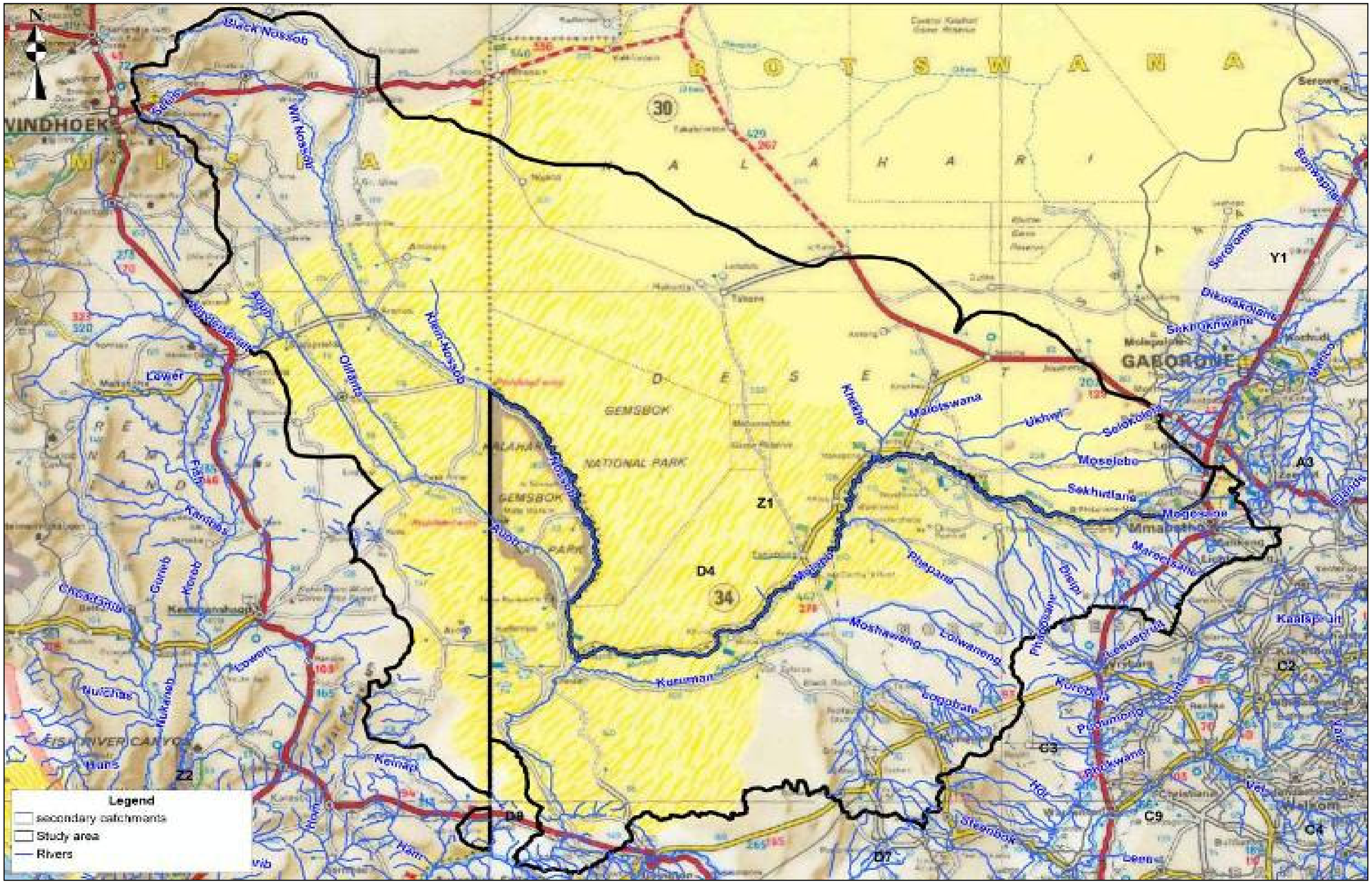

Figure 1-3: Locality of the Molopo Nossob Rivers catchment

The 134.4 million m^3 per annum run-off is the natural mean runoff for the entire Molopo Catchment, including the upper portion of the catchment which falls in Botswana. Large evaporative losses through pans and wide river beds in the lower Molopo River has the effect that limited flow, only in very extreme flood events, reaches the Orange River. However, flows from the Molopo River have not reached the Orange River in recorded history and the Molopo catchment is therefore considered to be an endoergic area.

The Molopo River emanates in South Africa from a spring to the east of Mmabatho and forms the border between South Africa and Botswana up to the confluence with the Nossob. Main tributaries are the Kuruman, Phepane, Disipi and Marocisana Rivers.

The Molopo River within Botswana is formed as clear channels draining from the Good hope, Phitshane Molopo and the Karst-Dolomitic formations around the Kanye area in Southern Botswana. It drains westwards joining Ukhwi River, Motsoye Kopje River that flows south-westerly along the Molopo farms joining the main Molopo River east of Makopong Village. The main Molopo River is formed mainly from a watershed divide around half way between the South African towns of Mafikeng and Zeerust. Several dry-bed ephemeral streams emerge west and south of Mafikeng joining the Molopo River, combined with streams from Botswana and flowing further south-westerly until it is joined by the Nossob River.

The Nossob River emanates from an area to the north-west of Windhoek and flows almost due south. The Auob and Olifants Rivers flow parallel to it until the Auob joins the Nossob River a short distance upstream of its confluence with the Molopo River.

A large part of the Molopo-Nossob Catchment falls within the Kalahari Desert, and there are no tributaries that join any of the rivers from this area.

According to officials from the Namibian Ministry of Water, flow from the Nossob River very seldom reaches the Molopo River. To all intents and purposes the two river systems can therefore be treated as separate systems.

1.3 PURPOSE OF THE STUDY

The objective of the project is 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 should also be investigated, as well as the identification and assessment of sustainable development options. In doing so the catchment should be studied as an interrelated system, even though it falls within the political area of three different countries (Namibia, Botswana and South Africa). The management plan should therefore also consider the institutional framework that will be required to realise the plan.

1.4 APPROACH

The assignment consists of three stages, namely an Inception Stage, a Catchment Status Inventory Stage and a third stage which investigates Development, Management and Restoration Options. The three stages form a logical sequence, and the Consultant intends to follow that sequence.

Stakeholder involvement and consultation forms an important part of the assignment, and the Consultant has performed this task as a parallel task during the execution of the three stages. In essence this means that there will be two parallel but closely associated processes; a technical process and a stakeholder consultation process.

Project management and reporting will also be a cross-cutting activity over the duration of the project

1.5 PURPOSE OF THIS REPORT

The purpose of this report is to document the results of phase two, the Catchment Status Inventory Stage. The objective of this stage is to conduct an in-depth investigation of the status of the catchment, specifically with respect to water requirements viz-a-viz the availability of water, but also with respect to the demographic profile, land-use and other related matters.

This report provides a catchment profile that describes the current situation in the catchment with respect to planned developments and water requirements *viz-a-viz* the availability of water, and also the demographic profile, land-use and other related matters.

1.6 STRUCTURE OF THIS REPORT

The first part of the report deals with the environmental, socio-economic and economic situation in the study area. The second part examines the availability of water, and the third part synthesises the information and proposes a way forward for the study.

2. 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.

2.1 BOTSWANA

The Molopo-Nossob catchment area in Botswana covers two administrative districts. These districts are the Kgalagadi and Southern Districts. 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.

2.1.1 Kgalagadi District

The Kgalagadi District is located in the south-western corner of Botswana, and covers an area of approximately, 110 km^2. Administratively and geographically, the district can be divided into the northern and southern Kgalagadi. The Northern Kgalagadi covers approximately 44 004 km^2 and forms the Hukuntsi Sub-District with its headquarters in Hukuntsi. Southern Kgalagadi covers approximately 66 066 km^2 and forms the Tsabong Sub-District with its headquarters in Tsabong.

Almost all villages and settlements in the district are situated near pans or fossil river valleys, or on rock outcrops that serve as sources of ground water. Most of the settlements in the southern part are linear starting from Kokotsha down to Struizendum. On the other hand, settlements in the north are scattered possibly due to pans. The Kgalagadi District Council grouped the villages in the district into clusters. The villages are clustered around cluster centres. The clusters and their cluster centres are shown in **Table 2-1**.

Table 2-1: Kgalagadi District Village Clusters

Cluster centre	Villages in cluster
Tsabong	Omaweneno, Kisa, Maralaleng, Tsabong and Maubelo
Werda	Werda(Kokotsha), Hereford, Makopong, and Draaihoek
Hukuntsi	Hukuntsi, Lehututu, Tshane, Lokgwabe, and Ohe/Hunhukwe
Kang	Kang
Middlepits	Middlepits, Kolonkwaneng, Bogogobo, Khuis, Gakhibana and Khawa
Bokspits	Bokspits, Vaal-hoek, Rappelspan and Struizendum

2.1.2 Southern District

Southern District is located in the south east of Botswana. It has an area of 26 876 km^2. The major centres in the district are Kanye, Lobatse and Jwaneng. The village of Kanye is the administrative and commercial centre. The town of Lobatse is one of the oldest towns in Botswana and houses the national abattoir, the Botswana Meat Commission. Jwaneng is a fast growing mining town and it is the commercial centre for Ngwaketse West. The district has decentralized some of its administrative functions to the four sub-regional centres of Moshupa, Good Hope, Mabutsane and Moshupa.

There are two distinct physiographic areas that influence settlement pattern in Southern District. These are the hardveld and the sandveld. There are three identifiable settlement patterns in the district namely agro-towns, dispersed homesteads and semi-modern settlements.

The agro-towns are prevalent in the northern hardveld and include settlements like Kanye, Moshupa, Ranaka, Manyana, Mmathethe, Molapowabojang, Kgomokasitwa, Ntlhantlhe, Digawana etc.

The dispersed homestead pattern is found mostly in the Barolong area. These villages owe their establishment from the Molopo River. Such villages include Mokatako, Phitshane-Molopo, Leporung, Dikhukhung and Mabule. The river was a source of water for both livestock and domestic use for a long time. In dry seasons shallow wells can be dug in the riverbed. The dispersed settlements are also evident in the western part of the district in the Ngwaketse West and Mabutsane. The area is predominantly pastoral. Homesteads in these areas are mostly cattle posts and are usually grouped around a water source or with a water source within 8 km. Villages in this area (sandveld) are small with population of approximately 500 people.

The third type of settlement pattern is the modern commercial town. Jwaneng is the only modern commercial town that falls within the boundary of Southern District. There is also the town of Lobatse that also provides services as well as employment to Southern District residents.

2.2 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 2-1** and **Table 2-2**).

Table 2-2: 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

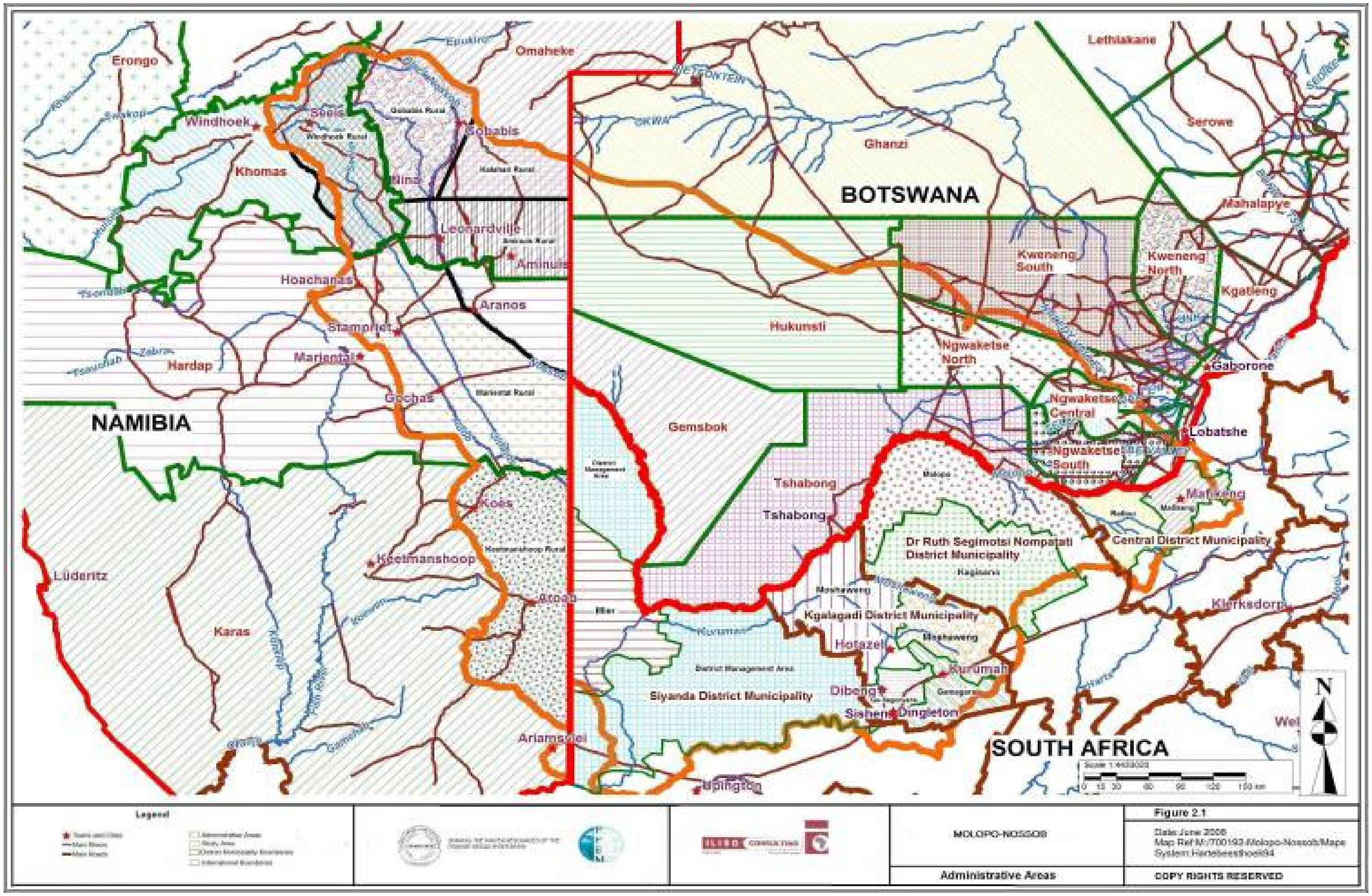

Figure 2-1: Locality of the Molopo Nossob River Catchment

2.3 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 2-1**).

2.3.1 North West Province

In the North West Province, the affected district municipalities are the Central District Municipality or Ngaka Modiri Molema District Municipality, and the Bophirima District Municipality. For the Ngaka Modiri Molema District Municipality, the two relevant local municipalities are the Mafikeng Local Municipality and Ratlou Local Municipality. A small section of the Disobotla and Dinaledi Local Municipalities fall in the catchment, but as not to skew data this municipality was not included in the status quo reporting. For Bophirima District Municipality (recently changed to Dr Ruth Segomotsi Mompatati), the local municipalities are Molopo and Kagisano (**Figure 2-1** and **Table 2-3**).

Table 2-3: Northwest Province Municipalities

District	Local	Villages
Central/Ngaka Modiri Molema	Mafikeng Ratlou Disobotla	Mafikeng
Bophirima/Dr Ruth Segomotsi Mompatati	Molopo Kagisano	Stella

2.3.2 Northern Cape

In the Northern Cape, the main affected district municipalities are Kgalagadi and Siyanda. The affected local municipalities in Kgalagadi are Moshaweng, Gamagara and Gasegonyana. A District Management Area forms part of the District Municipality. For Siyanda District Municipality the affected local municipality is the Mier Local Municipality.

Ga-Segonyana Local Municipality was a cross-border municipality spanning across the provincial border between the North West and Northern Cape Provinces. The hand over process should have been completed by March 2007. This local municipality falls under the Kgalagadi District Municipality of the Northern Cape (**Figure 2-1** and **Table 2-4**).

A small section of the Kara Hais Local Municipality falls in the catchment, but was not included in the Status Quo Reporting so as not to skew data.

Table 2-4: Northern Cape Municipalities

District	Local	Villages
Kgalagadi	Moshaweng Gamagara Ga Segonyana	Hotazel Dibeng, Dingleton/Sishen, Kathu, Kuruman Kuruman
Siyanda	Mier District Management Area	

3. NATURAL ENVIRONMENT

3.1 CLIMATE

3.1.1 Namibia

The climate of the sub river basin in Namibia can be described as mild sub-arid to arid around the Omaheke and Khomas Region, while the Hardap and Karas Region as either desert. Windhoek and its immediate surroundings are the only parts of Namibia that experience a dry steppe climate, because of the high altitude. The rainfall decreases in a south-westerly direction, but overall is quite variable from year to year becoming more variable as the average rainfall decreases.

The mean annual rainfall varies from 710 mm at the northern part of Omaheke Region to below 59 mm at the part adjacent to the coastline at the Hardap Region. The arid climatic condition is not only enhanced by the variability of the rainfall, but also the very high evaporation potential (more than 2 500 mm per year in the Khomas Region, and more than 3 000 mm per year in the Hardap Region) and the wide range between day and night temperatures (20ºC). In the Karas Region the difference between day and night temperatures is about 15ºC, which occurs almost all year round.

The mean annual temperature of the sub river basin ranges between 19°C to 21°C, with a mean maximum temperature range of 30°C to 35°C for summer and mean minimum range of 3°C to 7 °C for the winter months.

The cold Benguela Current has a profound effect on the climate of the coast and Namib Desert. This is enhanced by winds blowing from the sea that cause fog banks that can envelope the coast for about 300 days per year. The humidity is then seldom below 80% and the precipitation of ±130 mm of fog is more than eight times the average of the Namib.

The stretch of the Orange River south of Warmbad and the adjacent areas has the dubious distinction of being the hottest place in Southern Africa. Its maximum summer temperature frequently hovers around 45°C in the shade. This area is also well known for its contract between summer and winter temperature. During winter, minimum temperatures below freezing point are common and frost frequently occurs.

3.1.2 South Africa

The South African sub-river basin ranges from semi-desert, semi-arid to arid. The North West Province is arid (receiving less than 300 mm of rainfall per annum), encompassing the eastern reaches of the Kalahari Desert. The central region of the Province is dominated by semi-arid conditions. The Northern Cape is a semi-desert area with low summer rainfall levels (between 150 to 200 mm per annum). The central, northern and north western parts of the Northern Cape are situated in the area dominated by the Kalahari high-pressure system, which is well developed for most of the year.

The rainfall pattern is highly variable both spatially and temporally and largely mirrors the prevailing climatic conditions of the North. On average, the western region receives less than 300 mm per annum, the central region around 550 mm per annum Western parts of the province typically receive rain in the late summer (peaking in February). Evaporation exceeds precipitation. Hail from convective storms does occur sporadically approximately 1 - 3 times per year in summer. A major source of veld fires are lightning strikes and the typical ground flash density is around 5 - 6 flashes/km^2/year in the central parts and 2 - 3 flashes/km^2/year in the west.

The North West Province is also characterised by great seasonal and daily variations in temperature, being very hot in summer (daily average high temperatures of 32ºC in January) and mild to cold in winter (average daily minimum in July is 0.9ºC). Seasonal fluctuations in mean temperatures between the warmest and the coldest months exceed 15ºC in the western region, while the central experience a range between 12ºC and 15ºC. The mean number of days of frost in the province is 31. Occasional snow has been known to occur in the south and eastern regions. The Northern Cape has an average summer temperature between 18^{o}C and 36^{o}C, with extremes of up to 43^{o}C and winter temperatures are moderate between 3^{o}C and 20^{o}C.

Relative humidity is also typically low throughout the North West Province, being below 28 % in the northern part of the Province in July and between 28-30 % for the central. In February, the month with the highest relative humidity, the eastern and northern parts range between 66 and 68 % and the rest of the province ranges between 64-66 %. This gives rise to high potential evapo-transpiration rates, affecting the flora of the region.

The predominant wind direction is from a northerly direction, and there is a trend for the windiest months to occur between August and November (www.nwpg.gov.za).

3.1.3 Botswana

Botswana is prone to droughts that extend over a number of years. The west region is the driest part with annual rainfall of 400 mm, decreasing to less than 250 mm per year in the extreme southwest of the country.

3.2 GEOLOGY AND SOIL

3.2.1 Namibia

The topography of the sub river basin in Namibia is characterised by variety of landscape, from the escarpment that is 900 to 1100 m above sea level to the mountainous areas west of Windhoek that can rise up to 2 000 m above sea level. The Region of Omaheke flat and forms part of the Kalahari Sandveld. The Karas Region is characterised by a variety of landscape, from a remote desert coastline and Namib dunes to some of the world's wildest, most desolate mountainous scenery.

The interior of the Karas Region north of Keetmanshoop is dominated by the Kalk plateau, a monotonous flat plain about 1 200 m above sea level with almost no gradient.

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 Rehobotho.

3.2.2 South Africa

The North West Province has the most uniform terrain of all the provinces, with an altitude ranging from 920 - 1782 m above sea level. The central and western regions are characterised by flat or gently undulating plains. 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, 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.

3.2.3 Botswana

Botswana is characterised by the Kgalagadi (Kalahari) sanda, a manthle 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.

3.3 VEGETATION

3.3.1 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 a mixed stand 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.

Both the coastline and the Namib dune sea are virtually without vegetation. The seemingly barren plains of the pro-Namib may sprout ephemeral vegetation in the short period following isolated and sporadic rain showers. Over the escarpment, the central interior plains as well as the Kalk plateau, semi-desert dwarf shrub savannah occurs. In the past those areas have been used extensively for karakul farming, but the pro-Namib, however, was and still is almost completely unpopulated. To the east the vegetation is a dry, medium tall savannah, characterised by its dense, edible grass stands on Kalahari sand. Desertification is a result of injudicious utilisation of the veld and overgrazing (especially on communal land).

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.

3.3.2 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 mountainous areas of this region are covered by mixed bushveld. The northern edge of the Magaliesberg is characterised by dense short bushveld trees and grasses.

However, overgrazing and agricultural practices such as maize and sunflower production have transformed much of the natural vegetation of the central and south and south eastern regions of the Province.

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. Furthermore, an interesting blend of hydrous and drought resistant plant species appear, due to the Orange River flowing through a semi-arid area. The northern part of the area consists of Bushveld while the southern parts have Karoo type vegetation, which could be described as desert-like. The Kenhadt areas' vegetation is also Karoo type vegetation with various types if succulent. Various Quiver trees are also found.

The primary threats to biodiversity, ecosystem goods and services are habitat transformation and degradation, and invasive alien species. The five most prevalent invasive alien plants within the Northern Cape are all classified as major invaders. Many invasive species are well established and causes 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 causes 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 which we all depend on.

3.3.3 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*.

4. SOCIO-ECONOMIC

4.1 LAND UTILIZATION

4.1.1 Botswana

There are five main types of land use in the study area (**Figure 4-1**) 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.

- *National Parks and Game Reserves* – this area is entirely used for the protection of wildlife species and non-hunting tourism is the only economic activity taking place.

Land use in the districts is shown in **Table 4-1** and **Table 4-2**. The land is mainly used for communal grazing.

Table 4-1: Land use and size in Kgalagadi District

Land use	Area (square kilometer)	Area (% of district)
Communal grazing	41 300	38.7
Commercial grazing (tribal lease)	2 500	2.5
Commercial grazing (freehold, state land leased)	6 490	6.1
Wildlife Management Area	25 000	23.3
Game Reserve	1 800	1.7
National park (State land)	25 500	23.8

Table 4-2: Land use and size in the Southern District

Land use	Area (square kilometer)	Area (% of district)
Communal grazing	19 733	73.5
Commercial grazing (tribal lease)	4 177	15.5
Commercial grazing (freehold, state land leased)	34	0.1
Wildlife Management Area	2 510	9.3
National park/State land	322	1.2

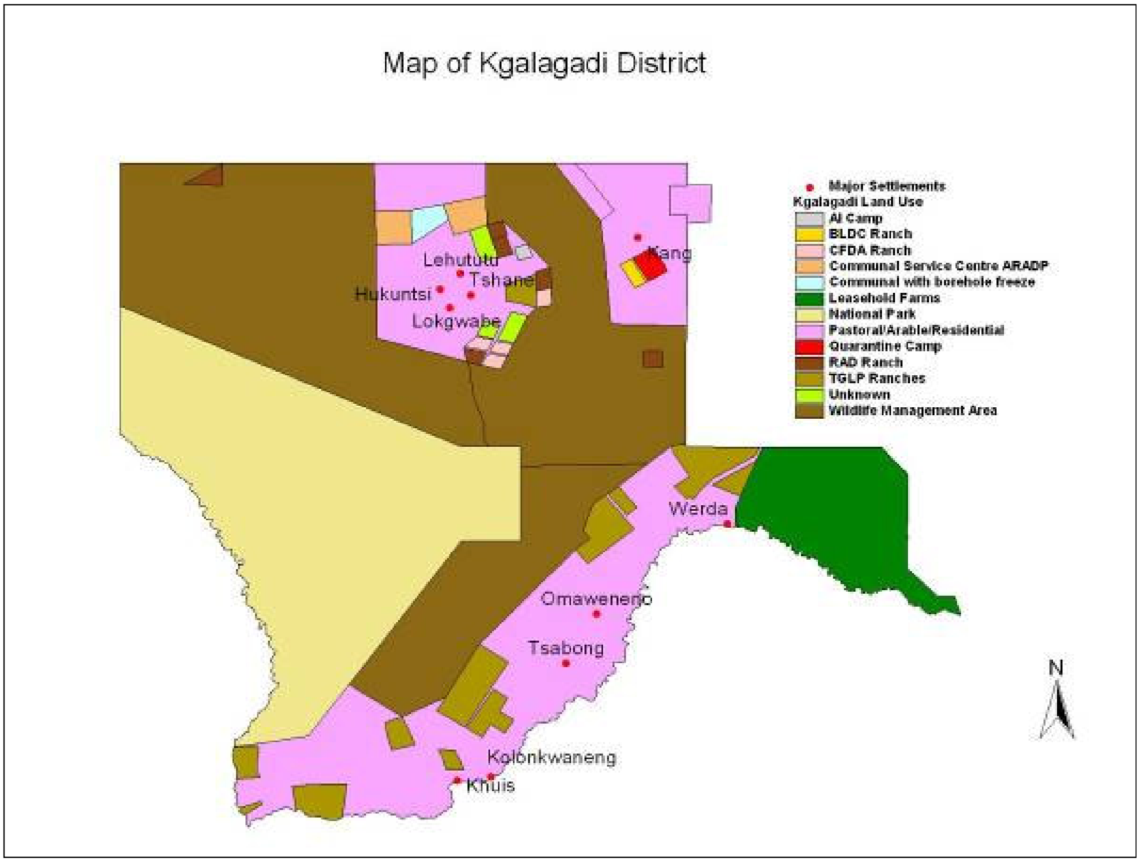

Figure 4-1: Landuse in the Kgalagadi area

4.1.2 Namibia

Land use is depicted in **Figure 4-2** and **Table 4-3**. In Namibia, the area in the sub river basin consists of *farms/freeholds farmlands* on which large scale commercial agriculture takes place.

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 *centre pivot 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.

Irrigation from ground water or the Hardap Dam also occurs in the Mariental area. 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.

Table 4-3: Land use in Namibia

Land use	Cover
Khomas Region	
Private individuals and Companies on freehold land	94.2%
Karas	
Small stock, commercially and subsistence	Mostly
Omaheke	
Private individuals and Companies on freehold land	50%+
Local authorities	Small percentage in Gobabis, Leonardville and Witvlei
Communal farming	Aminius, Eisebblock, Epukiro, Otjinene, Rietfontein
State owned land	Rest
Hardap	
Freehold farms	Majority (mainly 5000-10 000ha)
Namibia	
Private individuals and Companies on freehold land	43.3%
Private individuals on Communal Land	5.9%
Traditional Authorities and Small-scale farmers on Communal land	30.3%

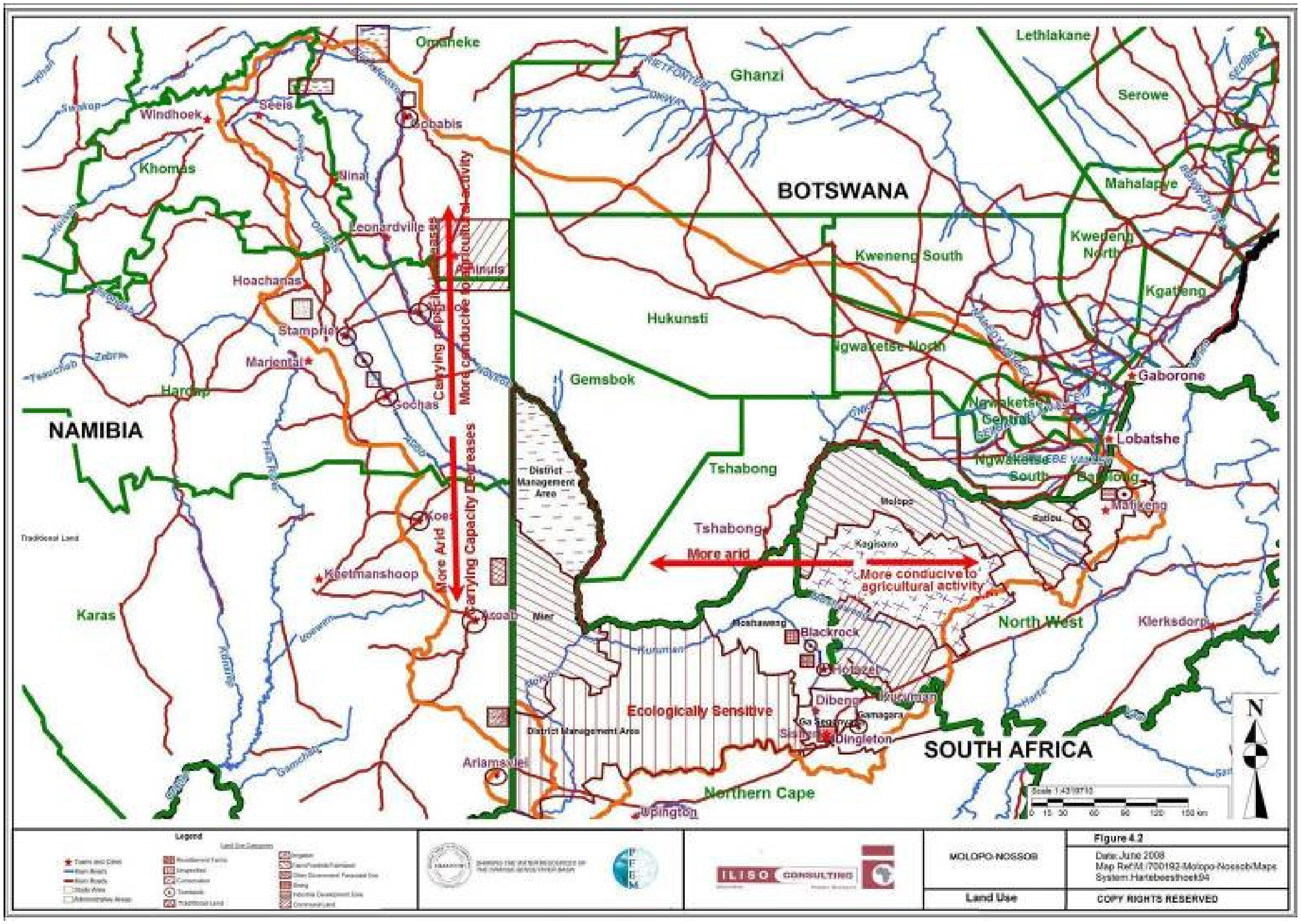

Figure 4-2: Landuse in the catchment

4.1.3 South Africa

Land use is depicted in **Figure 4-2** and **Table 4-4**. The land in the sub river basin is mainly private land, with some state/tribal land in the North West Province and Moshaweng Local Municipality (LM) in the Northern Cape. 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 District Municipality's Integrated Development Plan (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 really 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.

Table 4-4: Land use and cover in South Africa

Land use	Area
Private land, mainly grazing	Majority
Tribal land and communal grazing	Some
Mining	Some (Hotazel, Blackrock, Sishen)
Conservation	North of Mier
Unspecified (high ecological sensitivity)	District Management Area
Industries	Minor (Mafikeng)

4.1.4 Implications

Drivers

Both subsistence and commercial farmers in the sub river basin are severely challenged by their natural and physical environment. The summary of the water situation in the Integrated Development Plan (IDP) of the Siyanda District Municipality (2002) is applicable to the whole sub-basin. To summarise, the IDP states that due to the aridity, the rainfall is unpredictable, and the agricultural production therefore is also unpredictable. Ground water is not available in abundance, and available ground water is not always of good quality. Ground water often dwindles because of over-pumping, and limited rainfall reduces the chances of ground water being replenished.

Surface water is also not available in abundance. For example, the town Dibeng in the Kalahari region is often referred to as the sunflower town, due to the many windmills / windpumps that provide water to the town. "Dibeng" is the Tswana word for "first drinking place" – the name remained despite the fact that the river since dried up (http://www.sa-meanders.co.za/pubphp/town.php?lang=eng&x_town_id=701).

Many rivers flow only after heavy rainfall and water supply is therefore inconsistent. The quality of surface water has also been degrading. The quality of the rain water is good since there is no significant air pollution in the area which could otherwise have resulted in acid rain.

Because of the variable rainfall, limited ground and surface water, and soil conditions, the main farming activity in the sub river basin is therefore stock farming. Stock farming conditions in the area is not ideal, because of the lack of water.

In a report edited by Faurès & Santini (2008), the Namibian and South African (identified as large commercial and smallholder livelihood zone by the study) areas in the catchments were identified as areas with moderate potential for poverty reduction through water interventions. This conclusion was based on the relatively low rural poverty prevalence, water as a limiting factor, and low potential for water intervention. For Botswana (identified as arid livelihood zone by the study), the area in the catchment was identified as an area with low potential for poverty reduction through water interventions. This conclusion was based on the high rural poverty prevalence, water as a limiting factor, and low potential for water intervention.

Pressures and Impacts

Agriculture

Lack of water for grazing affects the condition of the animals. Lack of water for crop farming affects the quality of the crops. This situation is applicable to both commercial and communal farmers. This has an impact on income and farmers have to look for additional sources of income to make a living.

Specifically for communal farmers, crop farming with ground water has many challenges. For example in the Hardap Region farmers depend on ground water for dry land farming, but they generally lack knowledge about ground water reserves and the height of the ground water table or the amount of water they use. Many gardens and potential for income is further curtailed be the labour and time needed to hand carry buckets of water to crops (Hardap Regional Poverty Profile, 2005, page 135).

The lack of communal land for grazing also results in overgrazing, which negatively impacts on sustained livelihoods. Grazing is also focused around areas, such as rivers, pans and boreholes, where water is available. In Botswana, throughout the first half of the 20th century, cattle posts multiplied westwards into the Kalahari sandveld as more wells and boreholes were established. The land use is imbalanced, with no land use activity occurring in areas where water is not readily available.

Lack of water might encourage cattle to always graze close to water sources, again resulting in overgrazing. Although it is preferable, it might not be feasible to move cattle away from these sources to areas where water is scarce.

Borehole grazing techniques opened the Kgalagadi desert up to intense grazing. After the establishment of this technique consequences were observed as more land became barren around the borehole and shrubby thickets established themselves (Perkins 1996). Borehole pastoralism has caused heavy rangeland degradation. Cattle impacts have been described by Perkins (1996), as five overlapping zones including boreholes. In the borehole zone, which extends from the water to 50 m in circumference there is irreversible damage done to the soil by trampling and a build up of an excess amounts of nutrients resulting from dung and urination, causing soil toxicity. The next impact zone occurs extends from 50 to 400 m from the borehole. The vegetation in the zone is also thoroughly destroyed but the soil degradation is primarily due to wind erosion. The previous zone then transfers into a nutritious grass zone existing 200 to 800 m from the borehole. The soil is slightly changed in this area and usually contains a monoculture of palatable grass, often *Digitaria eriantha* or *Cynodon dactylon* (Perkins 1996). The bush encroachment zone fallows from 200 – 2 000 m. This zone consists of an impenetrable thicket unusable to cattle. The zone which extends further is called the grazing reserve. Most grazers do not affect the land further than 2 000 m (Perkins 1996).

Those who have cattle might have to share the water they use for household purposes for their cattle, impacting on the health and livelihoods of people as well the health of the animals (lack of water).

As a result, subsistence farmers tend to get lower prices for their stock due to concerns over animal health, grazing regimens and herd improvement. The situation of subsistence farmers is exacerbated by the lack of proper access to roads, water, electricity and also a lack experience.

Those living in remote areas with limited resources struggle to make a living, more so compared to those living in areas closer to resources.

Productivity is often constrained by land fragmentation.

There is limited long-term investment into farming (people go to places where opportunities are), but people are flexible and tend to take up any income opportunity in farming if it is promising (Faurès & Santini, 2008).

Commercial farmers avoid overgrazing, and in the basin in South Africa commercial farmers generally break even. Farmers in the Kgalagadi DM are close to break even, reflecting an estimated 2 – 4 % return in good years (Kgalagadi Nodal Economic Profiling Project, 2007). There seems to be a long term investment into farming which is not only related to monetary gain, but also to attachment to place.

The increasing numbers of the Persopia were voiced as a concern by a number of farmers (interviews and public meetings), as these trees affect ground water levels, impacting on current and future land use. Climate change might also change water levels, impacting on current and future land use – which will have negative economic impacts. As it stands, agriculture in Namibia accounts for 70 % of water use, yet it contributes little more than 10 % to GDP (N$7.2/m^3).

Improvements in agricultural productivity can provide a pathway out of poverty for rural households in several ways (Faurès & Santini, 2008 pages 8-9):

- For poor households that own land, increases in crop and livestock yields will generate greater output and higher incomes per unit of land and labour.

- For households that do not own land but provide farm labour, improvements in yields will increase the incremental productivity of labour, thus stimulating the demand for farm labour and raising farm wages.
- For households that do not own land or provide farm labour, improvements in yields will generate greater aggregate output, thus increasing the local supply of agricultural products, with consequent reductions in prices.
- Higher agricultural incomes and higher net incomes in non-agricultural households that are net food purchasers will generate greater demand for food and other goods and services that might be provided by local farmers and other non-farm residents.
- Improvements in crop yields made possible by enhancing water management will increase the incremental productivity of complementary inputs, such as labour, fertilizer, chemicals, animal health services, animal traction, and machinery. Greater demand for these inputs might stimulate economic activity that benefits households providing non-farm labour.
- Improvements in the yields of crops and livestock might also stimulate labour demand in local processing and marketing activities, particularly in areas near urban centres.

"*The relative importance of these potential implications of improvements in agricultural productivity will vary among regions with differences in resource endowments, demographic characteristics, marketing opportunities, and labour supply and demand. However, in most cases, the impacts should be such that poor households gain opportunities to improve their livelihoods by generating greater output per unit of owned land and labour, or by earning greater wages for the labour they provide to others. Over time, higher net income will enable poor households to generate savings and invest these funds either in farm-related activities or in efforts to increase the potential return from non-farm and non-rural endeavours."* (Faurès & Santini, 2008 page 9).

Mining

Mining opportunities can provide a pathway out of poverty for people in the area, but it might also impact on water quantity and quality available to them. Mining activities need water, and an expansion of these activities not only means in increase in the water needs for the mine itself, but also for the employees of the mines.

The effect of mining activities and expansion on ground water quality and quantities should be considered. Water is necessary for production and waste products are disposed of into the used water, which is discharged as effluents into rivers and other surface waters. Mining wastes, such as overburden, waste rock or slimes all have a negative impact on the aquatic environment. For safety when underground mining is done, dolomite aquifers are dewatered which might result in the increase of surface water. Dolomite aquifers tend to become depleted in the long run (North West Province State of the Environment Report, 2002).

The pressure is that Kgalagadi DM has one of the world's highest delivery costs and competitors such as Australia, Ghana and Gabon have lower costs. Potential solutions that were identified (Kgalagadi Nodal Economic Profiling Project, 2007) included: develop sufficient processing infrastructure, establish local markets through local processing and beneficiation of raw materials, provide for SMME development within mining, and provide shares to local communities. All of these solutions have implications for water demand, also in light of the fact that other beneficiation activities will be stimulated.

Industries

Industries may put pressure on water quality because of the release of chemicals in the production process. It may also increase water demand.

Response

The Northern Cape Provincial Government, together with the private sector in agriculture, does not focus on the provision of water as the only way to improve the situation. The efficient use of water resources was identified as one of the aspects that will contribute to a growth in the sector in order to increase contribution to GDPR, employment, income generation, and access to resources by previously excluded sections of society (http://www.northern-cape.gov.za/index.asp?inc=docs/papers/discussion.html):

> *"The provincial government seeks to grow the agricultural economy through the promotion of new investments in primary agricultural production, the more efficient use of water resources, by promoting crop diversification, the reduction of levels of risk in agriculture, the development of agro-processing and by stimulating increased export of high value agricultural produce. Government is also committed to promoting transformation in agriculture*

through land reform, the allocation of water rights, transfer of skills and knowledge and the provision of agricultural credit to emerging black farmers."

Opportunities that have been identified to stimulate the agriculture sector in the province include:

- The Northern-Cape government is implementing the Nguni Cattle Project, which involves the reintroduction of indigenous Nguni bloodlines in the communal and rural areas (Stock Betterment Scheme) (Ms Dipuo Peters, Premier, State of the Nation Address, 2007).
- As part of their partnership with the Northern Cape Provincial Government, the Industrial Development Corporation has injected R15.4 million into the Northern Cape Province for the commercialization of the goat industry in South Africa. The plan is to roll out this project to the other provinces, including the North West Province (http://www.idc.co.za/IDC%20News%20and%20Media%20releases.asp?ArticleId=210).
- Investment opportunities that have been identified in the Kgalagadi DM to stimulate the agricultural sector included (Nodal Economic Profiling Project, 2007):
    - Vegetable farming. Phase 1 involved an investment of R5million to construct a dam and water pipeline to transport water from a nearby farm;
    - A poultry abattoir in Maruping;
    - A goat processing plant; and
    - A livestock abattoir.

The Kgalagadi Nodal Economic Profiling Project (2007) reports a number of plans for expansion through new investments and existing companies increasing their production through new operational sites. These are:

- United Manganese of Kalahari (UMK), which is a South African-Russian joint venture between a Black Economic Empowerment company (BEE) and RENOVA (49%). The plan is to open a pit with the annual capacity of 1.5-2.0 million tons. The plan includes building processing facilities.
- Khumani Mine Project. This entails the development of an 8.4 million ton per annum iron ore export mine. The site is in close vicinity to the Sishen mine.

The Namibian government identified equitable access to land and other natural resources and the sustainable use of land and natural resources as one of their key responsibilities. The aim is to achieve this while maximising Namibia's comparative advantages (Namibia Vision 2030). A number of strategies were identified to achieve this, of which the following are considered to be relevant to this study:

- creating an economically and ecologically rational land use plan to ensure that land is used optimally and not just for direct use activities such as agriculture mainstreaming;
- consider the effect of HIV/AIDS in agricultural development programmes;
- promote diversification away form agriculture to promote economic growth;
- aim resettlement and agriculture policies at rural level and serious farmers;
- focus on food security and not food self sufficiency – crops whose production is intensive in the use of water should be imported;
- improve the quality of environmental education.

Whilst the Northern Cape is still emphasising the role of agriculture and high value agricultural produce for export, as per its Agri-BEE strategy, Namibia is intent on focusing on tourism/other services sectors (N$574/$m^3$ of water used) and manufacturing (N$272/$m^3$) as a means to utilise water in the most economically viable and ecologically sound manner.

4.1.5 Future Planning

Overall, agriculture is the main activity that will continue to take place in the basin, because of the existing conditions. Mining will be the main activity on the border between the North West and Northern Cape Provinces. Tourism might further develop. The concern is the availability and management of water to continue these activities in order to ensure livelihoods.

"*Although water seems to be the major limiting factor in production, this is often not the case. Planning interventions by developing irrigation or improving agricultural practices in rain fed areas must also consider the availability of affordable complementary inputs, access to markets, and institutional arrangements that promote farm-level investments in land and water resources. Furthermore, great attention has to be paid to the form in which access to water is increased. There is no 'one size fits all' strategy that can be recommended, and each 'livelihood condition'* *must be considered individually and in its historical and cultural context."* (Faurès & Santini, 2008 page 9).

The fact that an area is classified as one of moderate and low potential for poverty production (Faurès & Santini, 2008) does not imply that water related interventions are not needed. Rather, it suggests that the poverty-reduction impact in terms of agriculture will be minor. In arid zones (the Botswana area in the catchment), "*where there is very limited potential to develop water control, poverty reduction often depends on seasonal or permanent migration to seek employment as labourers in wealthier zones or urban areas. There is a substantial need for alternative livelihood activities to agriculture or livestock husbandry. Over time, increases in off-farm income and exit from agriculture are likely to be at the core of poverty reduction efforts. In many cases, on-farm diversification and increases in off-farm employment will be more helpful than investments in water control in reducing poverty in these areas."* (Faurès & Santini, 2008 page 40)

The following should be considered:

- More water should not be allocated for low value purposes, but should focus on activities that will significantly contribute to the livelihoods of people.
- Potential risks should be reduced, not increased.
- Education and awareness about efficient water and water scarcity form an important part of intervention, not only in terms of household usage, but also in the agricultural and mining sector, and the use of water efficient technology.
- More efficient water use and water re-use and recycling, alternative sources should be considered.
- The effect of increase in water usage on pans in the area should be considered.
- Interventions should be manageable and accepted by those who benefit (ownership, capacity, and training of municipalities).
- A livelihoods approach should be followed in rural water development. A report by the Food and Agricultural Organization of the United Nations (Edited by Faurès & Santini, 2008) shifts to a livelihoods approach in rural water development.

4.2 POPULATION

4.2.1 Botswana

The population figures for the census years 1971, 1981, 1991 and 2001 are presented in **Tables 4-5** to **4-9**. The data on the tables also shows population changes between the census years. Overall, there was a population increase.

Table 4-5: 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 4-6: 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 4-7: 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	-

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

Table 4-8: 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	-

Village/Locality	1971	1981	% Change 1971-1981	1991	% Change 1981 - 1991	2001	% Change 1991-2001
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 combined)	24	113 704	-
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 4-9: 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	-
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

4.2.2 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, according 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 4-10**). 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 4-3**) 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 4-10: 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

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 4-11** 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 4-11: 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 4-11**.

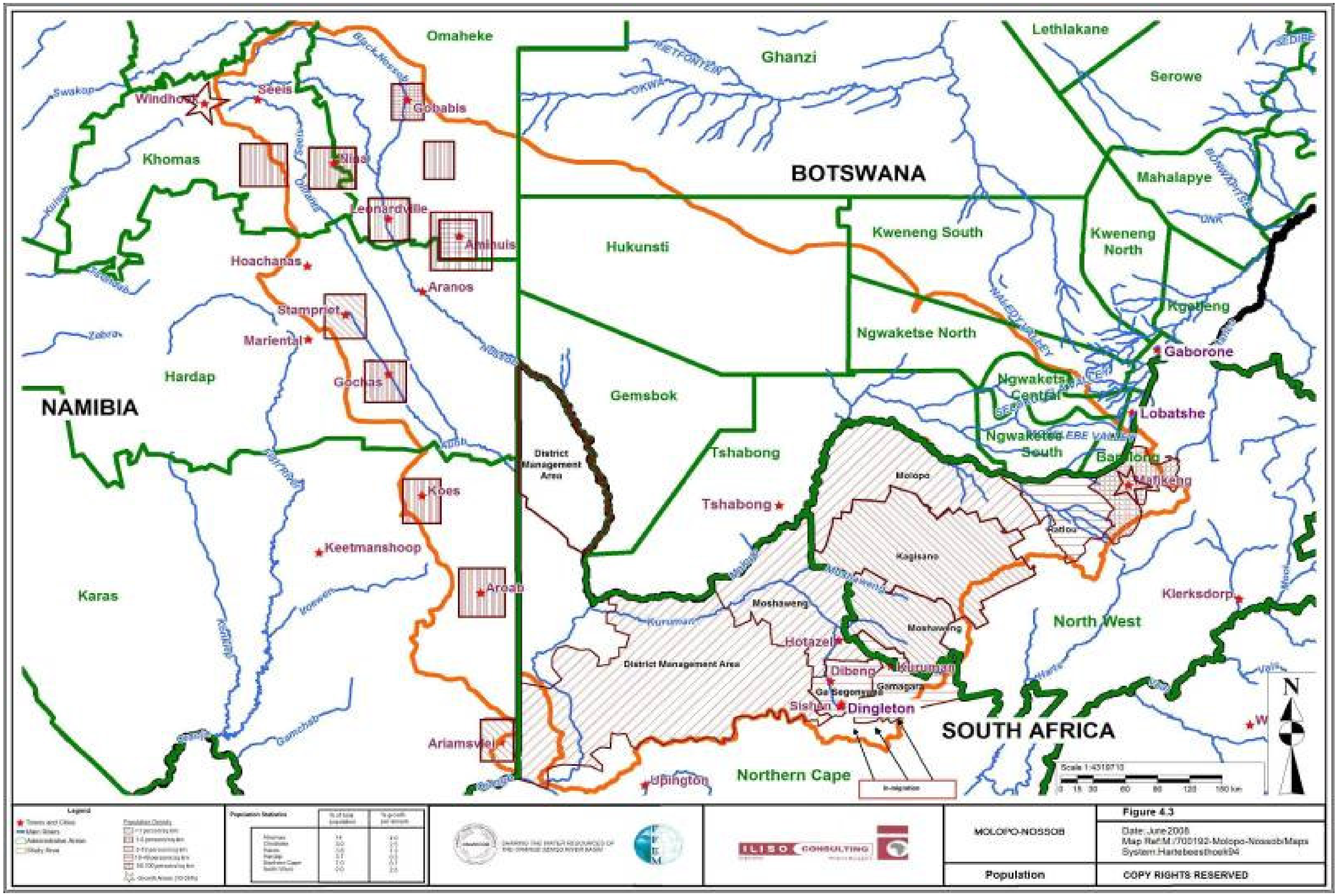

Figure 4-3: Population distribution in the catchment area

4.2.3 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 4-3**).

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 4-12 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.

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.

Table 4-12: 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%***

Region	Population (2001)	Population (2007)	Population Growth
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 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 4-11** to see the comparison between urban and rural people in this regard.

4.2.4 Implications

Drivers

Urbanisation occurs because of, amongst others, an environment of inequality, lack of opportunities, poverty, food insecurity, and poor nutrition in the rural areas. Usually not the whole family migrates, but members of a family migrate to also provide for those left behind.

Van Aardt (2007) is of the opinion that each population group has its own set of population growth drivers. As such, the drivers behind population growth for the Black African population group is believed to be factors such as fairly high levels of HIV/AIDS, high levels of migration (including in-migration) and high levels of fertility.

Commercial farmers tend to stay on in the area. This might be as a result of lack of alternative opportunities, economic welfare, and also attachment to the farm and the landscape.

Impacts and Pressures

It does not seem as if the number of people in the catchment will grow significantly in South Africa and Namibia. Namibia aims to increase their urbanisation rate, which will impact on water demand in rural areas. A strong negative population growth in the basin is evident in South Africa.

When considering the demographic profile in the basin, it becomes evident that vulnerable people will increase, also considering the HIV/AIDS pandemic. Orphaned children because of AIDS related illnesses will probably increase, which will enlarge the pool of vulnerable people. For example, in Namibia the number of aids orphans will have grown to about 35 000 in 2011, and by the year 2021 as high as 190 000. Adult mortality due to AIDS is becoming an increasingly important household shock. With unemployment and the lack of a supportive social network, poverty increases and a general decrease in the individuals' and/or households' socio-economic conditions become evident; these people usually have little bargaining power, and that their focus is on addressing their basic needs.

Natural resources are important in rural livelihoods and serve as a buffer against household shocks (e.g. meeting energy & dietary needs or providing opportunity for generating income).

Responses

Namibia (as per 2030 Vision) wants to:

- Ensure equity between women & men: access to resources.
- Boost employment creation for the rural young (71 %).
- Ensure food security at household level (also people living with HIV/AIDS).
- Integrate HIV/AIDS responses in all (water resource) development plans.

Northwest Province Provincial Growth and Development Strategy:

- Opportunities for quality employment for rural people to ensure sustainable livelihood (North West State of the Environment Report).

Northern Cape

- The Northern-Cape Provincial Growth & Development Strategy (2004 - 2014) which envisages food security (women constitute 80 % of all Food Security projects that the Department is supporting);
- Women in Agriculture and Rural Development (WARD): 30 % of the annual allocation of Comprehensive Agricultural Support (CASP) for women only driven projects (provision of infrastructure on the farms and implements).
- Agri-BEE.

Despite rural-urban migration patterns in Namibia (high), the Northern Cape and North-West Province, the plans of both countries strongly emphasise the need for ongoing rural development, with specific focus on the poor and female headed households. For example, the Northern Cape Integrated Sustainable Rural Development Strategy (ISRDS) calls for the maximisation of development of rural communities, targeting the rural poor, women, youth and the disabled in particular. The Namibian Vision 2030 emphasizes the importance not to neglect of rural economic activities; and to prevent over-concentration of population in few cities. It envisages a key role for water in this regard and aims to increase water provision (rural population) to 85 % by 2010 and 95 % by 2020.

4.2.5 Future Planning

"*Furthermore, any rural water development strategy will have to deal with multilocal diversified livelihood systems with limited capacities for agricultural investment, a predominance of risk-avoiding strategies"* (IFAD, 2005), female-headed households, high workloads, and rural people's limited ties to their land. Such characteristics and trends have both methodological and strategic implications. In methodological terms, the complexity of the new rural reality reinforces the need for a livelihoods approach to development. In terms of water, this "*means a fundamental shift beyond considering water as a resource for food production to focusing on people and the role water plays in their livelihood strategies*" (WWAP, 2006); and implies *de facto* a multiple-use perspective (Molden, 2007). Any water intervention needs should target not only according to farming systems but also according to socio-economic categories. Identifying different categories of farmers and rural workers according to the level of their integration into the local economies is necessary in order to ensure the effectiveness of interventions. In addition, other context-related criteria – according to the stage of food self-sufficiency / food security, the share of income from agriculture, and gender – are also relevant. In strategic terms, these characteristics of the rural poor require that particular attention be given to low capital investment and low external input technologies, taking the limited financial assets of poor households and the weaknesses of rural service systems into account. The provision of water for small productive activities, such as home gardens, fruit trees and small off-season vegetable plots, helps in addressing land and labour bottlenecks, in particular of female-headed households in multilocal livelihood systems. Focusing on women (and the elderly who stay in the village) and taking their specific assets, constraints and coping strategies into account is of paramount importance in ensuring the success of water interventions. In short, agricultural water interventions should no longer be based on the assumption of specialized or increasingly specializing irrigation farm units managed by full-time professional farmers, but be prepared to assist in overcoming water bottlenecks in manifold context-specific ways (Faurès & Santini, 2008 page 7-8).

4.3 ECONOMY

For a summary, please see **Figure 4-4.**

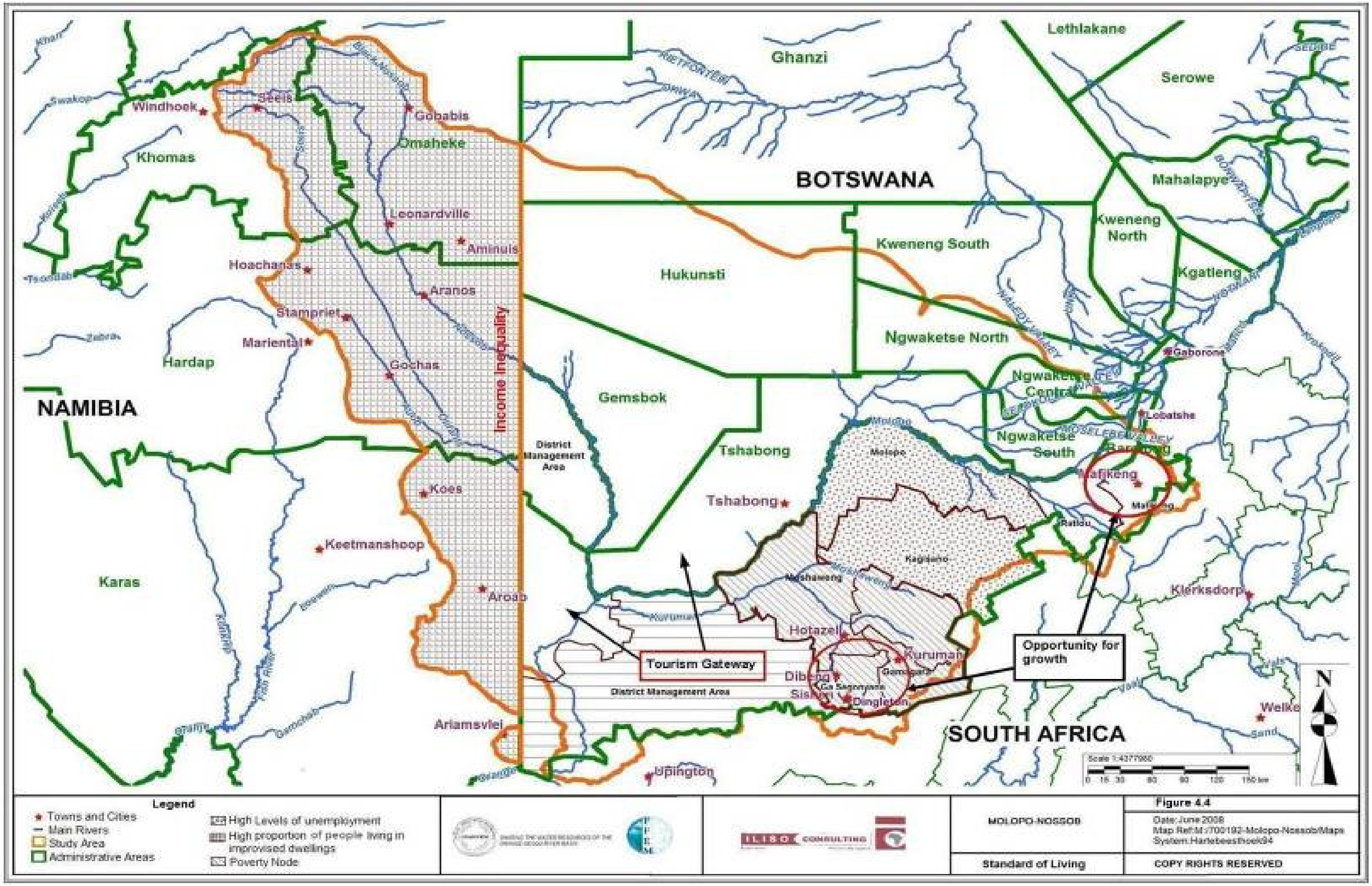

Figure 4-4: Map representing the standard of living in the catchment area

4.3.1 Botswana

4.3.1.1 Kgalagadi District

The Kgalagadi District 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.

4.3.1.2 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.

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.

4.3.2 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.

4.3.3 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 Local Municipality 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).

4.3.4 Implications

Despite the diversification of rural livelihoods and increasing urbanization, at least half of the poor people are expected to remain in rural areas by 2035, and a significant number of them will depend on smallholder farming as their main source of livelihood (IFAD, 2001 quoted by Faurès & Santini, 2008 page 7).

Drivers and Impacts

The Komas Regional Poverty Profile summarises the causes of poverty as follows (2005, page 34): "*Insufficient rainfall, drought, lack of natural resources, poor management of natural resources, lack of family planning ('too many children'), having to take care of relatives' children, stock theft, laziness and demoralisation, human and animal diseases, small size of accessible grazing land, veterinary cordon fence forcing low prices, unemployment, lack of relevant skills, extremely low wages for farm labourers, high cost of water, remoteness and isolation, lack of infrastructure and communication facilities, and lack of development. Sometimes the causes and effects of poverty are one in the same… these include: lack of education, lack of access to quality education, HIV and AIDS and other human diseases, alcohol abuse and drunkenness, lack of food, overgrazing, deforestation, death, loss of property, crime and violence, imprisonment, and orphans*".

There is a correlation between the level of educational attainment and income levels. Those with higher educational levels tend to be economically better off, and therefore contribute more to the reduction of the unemployment rate. Educational attainment is also linked to poverty in that money is needed for further studies, and the poor therefore tend to be unable to further their education, staying in a downward poverty spiral.

There is a correlation between race and educational attainment, which then has implications for income levels for different race groups. More whites have higher educational levels compared to other races.

Although many households rely heavily on remittances or wages of family members employed in urban areas, the responsibility for food production and preparation and the overall wellbeing of the household, continues to fall on women. This takes up time, and does not open up time to seek employment opportunities. These women are often not well educated. Those with low educational levels get employed in low wage jobs. A low income means that people are unable to afford basic needs and services. This increases the poverty rate.

There is a negative correlation between income and housing indicators (improvised housing, cooking and lighting without electricity, gas or solar energy, bucket, bush or no toilet and flowing or stagnant source of drinking water). For example, as household income increases, the use of bucket or bush as toilet decreases. This situation may result in a number of positive impacts, which may include less degradation of natural resources such as soils, vegetation and water resources (North West State of the Environment Report, 2002).

The results of the desktop study indicate that an economic base in most of the rural settlements does not exist, and this was confirmed in interviews with local people in rural areas. They "do nothing" during the day. The dependency ratio is high, in that many people are dependent on the income of one household member. The lack of household income also keeps households in impoverished situations. The income derived from agriculture and household work is low, and because of low education levels the likelihood of improving living standard is slim. Food security remains uncertain.

The 2030 Vision of Namibia reveals that rural females comprise the largest demographic group in Namibia. For South Africa, the male/female unemployment distribution in the Province indicates that more females were unemployed compared to males. These females remain disadvantaged by level of access to land, labour, agricultural services and assets, natural resources and employment opportunities.

Pressures

There is a need to create employment that can lead to sustainable livelihoods. The higher the level of unemployment, the more food insecure the population becomes. This has a spiralling effect in terms of other social elements such as health and crime. Increased global food demand has resulted in food price increases, further eroding household spending power.

To meet economic needs, poor households might overgraze land and over use resources such as water, rendering their agricultural activities unsustainable. The growing work burden on women also prompts them to over utilise wood, water and other resources.

It is crucial for an economy to grow at a pace faster than the rate at which the population is growing so that there will be more resources available for each person. In addition, it creates new jobs at a rate that will significantly reduce unemployment over time. Permanent employment in the formal sector is probably the most important factor for sustainable improvement in the standard of living, given the benefits associated with a permanent formal job. This is difficult in the catchment, and mining seems to be the main economic growth area.

Mining: The challenge is that Kgalagadi DM has one of the world's highest delivery costs and competitors such as Australia, Ghana and Gabon have lower costs. Potential solutions that were identified (Kgalagadi Nodal Economic Profiling Project, 2007) included: develop sufficient processing infrastructure, establish local markets through local processing and beneficiation of raw materials, provide for SMME development within mining, and provide shares to local communities. All of these solutions have implications for water demand, also in light of the fact that other beneficiation activities will be stimulated. In addition:

- The price of oil has risen to above $120 per barrel in May 2008, impacting on production, service and distribution costs.
- The rising interest rates of 2007/2008 have meant that lenders in all market segments have found it harder to finance debt.
- Inflation is on an upward trend and is near the 10% mark.

Constraints to agricultural growth are:

- The semi-arid climate;
- The infertile sandy soils;
- Scarce fresh water; and
- The sheer vastness of the district.

Responses

The Kgalagadi Nodal Economic Profiling Project (2007) reports a number of plans for expansion through new investments and existing companies increasing their production through new operational sites. These are:

- United Manganese of Kalahari (UMK), which is a South African-Russian joint venture between a Black Economic Empowerment company (BEE) and RENOVA (49 %). The plan is to open a pit with the annual capacity of 1.5 - 2.0 million tonnes. The plan includes building processing facilities.
- Khumani Mine Project. This entails the development of an 8.4 million tonnes per annum iron ore export mine. The site is in close vicinity to the Sishen mine.

The Northern Cape Provincial Government (source undated) identified the following three interrelated aspects in the context of poverty:

- Poverty of access - not having access to basic infrastructure and services;
- Poverty of power - the poor suffer from both traditional and environmental; and
- Poverty of money - results in the inability to accumulate assets that is the key ingredient to the creation of wealth and breaking the cycle of poverty, health risks and lack of access to information.

The following principles were identified as important for the reduction of poverty:

- the utilization of natural resources in a sustainable manner;
- ensure that all people lead healthy and productive lives; and
- improve the economic and social infrastructure - the emphasis should be on transport, communication, urban renewal, rural development**,** fresh water supply and sanitation.

In terms of growing its economy, Namibia aims to achieve the following:

- avoid neglect of rural economy;
- substantial investment in rural infrastructure;
- rural population diversified earnings;
- healthy living environment prevails;
- people have access to save drinking water, adequate housing and sanitation – promoting health living, longevity healthy human environment;
- men and women have equal access to opportunities for livelihood;
- natural resources are sustainably used;
- a national water transfer management system;

- optimise sustainable water use including social and ecological needs;
- curb poverty & create employment opportunities;
- promote integrated rural development;
- reduce income inequality; and
- facilitate economic empowerment and promotion of women.

Namibia aim to avoid to *"treat marginalised communities and individuals as welfare cases and finance their situation of deprivation and poverty, instead of listening to them and using their strength and ingenuity as a solution to various challenges. No further marginalisation of vernacular communities" (Vision 2030).*

4.3.5 Future Planning

Specifically the constraints facing females and female headed households and their specific needs require attention, also bearing in mind parity with Government Strategies, and the planning of sustainable water resources development schemes within the sub river basin needs to be informed by the above dynamics.

4.4 TOURISM

4.4.1 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.

4.4.2 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.

4.4.3 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.

A comprehensive list of accommodation in the North West Province area of the sub river basin are listed on http://www.tourismnorthwest.co.za/accommodation/acomnw22.html#Mafikeng, and were identified as being the Protea Hotel, Boga Legaba, Buffalo Park Lodge, Tusk Mmabatho Casino Resort, Bush Fern Lodge and Conference Centre, Ditlha Guest House, Ferns Country House, Getwaya Lodge, Ikanyeng Guest House, Ikaya Lethu, Kobo Segole, Libertas, Lion's Rest, Lodge Garona, Mafikeng Scene, Molopo, Mommy's Guest House, Motshiwa, Oakburn Lodge, Park Lodge, Reviera Park, Herbs, St Joseph's Cathecetical Center, Mini Miotel, Buffalo Ridge Safari Lodge, Manyane Game Lodge, and Meroba, and Botsalano Game Reserve.

It was not clear whether the Botsalano Game Reserve was in the sub river basin, and an overview from their website follows to give an indication of the profile of this reserve as per 2001/2002 (http://www.tourismnorthwest.co.za/botsalano/management_plans.html).

4.4.4 Implications

Drivers

The areas in the sub-basin are marketed for its desert systems – the Namib and Kalahari deserts. The term "Kalahari" was derived from the Kgalagadi word for 'the land which dried up', 'the dry land' or 'the thirstland'. The Southern Kalahari is defined as the area to the south of the Bakalahari Schwelle, which is an indiscernible ridge that runs roughly from Gobabis in the north-east of Namibia to Lobatse in the south-east of Botswana. The Schwelle separates the Okwa and Hanahai River system in the north and the Nossob and Twee Rivieren in the south (www.kgalagadihistory.co.za).

Impacts

Negative

- Overuse water resources; and
- Pressure on environment (littering, air quality, ecology).

Positive

- increase economy; and
- job creation.

Pressures

Constraints in development of the tourism market are (Kgalagadi Nodal Economic Profiling Project, 2007):

- Roads and services - opportunities in the tourism sector are constrained by inadequate or non-existent access to telecommunications, electricity and water. The prioritisation of basic services delivery is deemed critical;
- A lack of information;
- Lack of execution of tourism plans set out in the IDPs; and
- Lack of knowledge and skill to grow tourism industry.

Responses

Tourism in (remote) rural areas is perceived as a particularly lucrative and sustainable income-generating and poverty reducing proposition, both by the Namibian and South African governments, including the Northern Cape.

According to Vision 2030 (Namibia) tourism already plays an important role in economic development but it has not yet been exploited to its full potential. In the sub-basin, the number of tourism facilities decreases towards the south, and the tourism potential decreases proportionally. The southern part of the sub basin in Namibia is identified with low tourism potential and between Windhoek / Gobabis and Mariental, medium-high to high (Namibia Vision 2030).

Vision 2030 of Namibia identified the following relevant key issues in the development of tourism:

- the recovering of wildlife populations on land outside state owned land present economic opportunities;
- because tourism in Namibia operates under arid and ecologically sensitive areas, attention to potential environmental and social impacts as a result of tourism activities must be assessed prior to establishing these activities, with ongoing monitoring once it has been established;
- in establishing tourist activities, the unsuitable use of scare resources such as wood and water was identified as one of the key concerns;
- the Tourism Master plan seeks to increase high quality tourism activities with low impact on the environment; and
- develop tourism and wildlife employment and economy.

Relevant strategies that have been identified to ensure the above include:

- avoid poor land use planning and zoning that result in prime tourism areas being used for other activities;
- educate tourist about ecological sensitivity; and
- use low impact design and technologies.

As per its Agri-BEE strategy, Namibia is intent on focusing on tourism/other services sectors (N$574/$m^3$ of water used) and manufacturing (N$272/$m^3$) as a means to utilise water in the most economically viable and ecologically sound manner.

South Africa

- Strategic interventions to stimulate the development of tourism in the Northern Cape have been identified, as it is considered to have the potential to become a preferred adventure and eco-tourism destination in South Africa with its recognised cultural heritage. The preservation of the natural and cultural heritage of the Province is crucial to ensure this, and transformation in the sector needs to be accelerated to ensure equitable growth (Northern Cape Provincial Government, 2007).
- The tourism potential can be developed should plans promote activities for contractors, a meander option is developed to encourage stays longer than one night, an integrated strategy between municipalities are developed, joint marketing is done, the focus is on eco-tourism in more remote areas – including hunting and game farming, more hiking trails are developed as well as 4x4 routes, more mining tours are available apart from the tour at Kumba, training is

done, and the municipalities developed focused achievable plans (Relevant IDPs).

- IDPs all mention tourism as an economic potential.

4.4.5 Future Planning

Tourism will be developed, more so in the Northern Cape area.

- Water provision for tourism activities must take into account the arid conditions in the area; and
- Planning should be done in conjunction with the relevant authorities.

4.5 WATER AND SANITATION

See **Figure 4-5** for a summary of water sources**.**

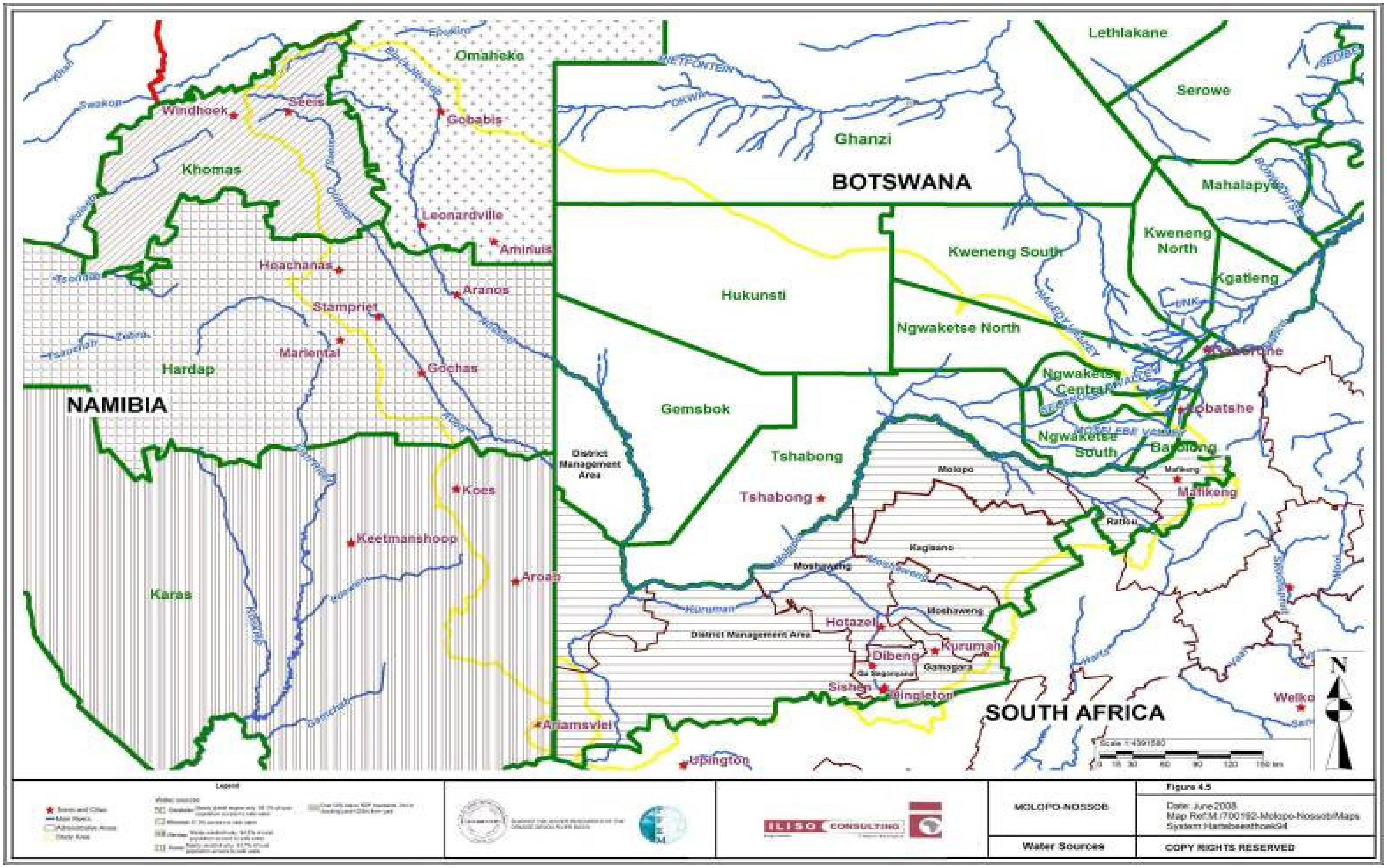

Figure 4-5: Water sources

Snapshot

A day in the life of a woman in Makgobistad

Makgobistad is one of the villages in the North West Province, just south of Mmabatho/Mafikeng towns. The village is characterized by shacks and self built houses. Here Ms Ketlane lives with her 2 daughters in a tent. Apart from dealing with the fact that she lost her shack to a fire recently, like most women in the village she has to wake at 3:00 am and walk the 200 m distance in order to queue with her plastic cans for water. Water can be accessed through the windmill tap, piped taps on the streets, ticket taps, water vendor or other households. Small rivers are available but only used for cattle.

Using the windmill tap is one way that she is able to get the water and not pay for it. However this choice has its own pitfalls, it only functions when the wind blows and she sometimes gets her cans filled in the afternoon. The piped taps are used by most households in the village. The time Ms Ketlane spends queuing just waiting to fill the cans could be reduced if the other windmill pipe nearby was working. However, it has been broken for 10 years and queries raised with municipal councillors have been fruitless.

The other way of not paying for the water is to get it from the pipes in the streets, but the water supply from these is not consistent. For over 4 months no drop came out of them. When they do work this is usually for less than 2 weeks. Though the municipality is the owner and responsible for maintaining the water infrastructure, Ms Ketlane blames the locals because some of the copper taps are stolen at night to be sold for individual use. Most of the women complain about the stealing of taps but no one has been able to prevent it.

For Ms Ketlane and lots of other households, getting water from the vendor might be a lot easier but it is not that affordable since they only live on social grants with limited jobs being available in the area. They either pay R20 for two 25ℓ plastic cans from the teenage boys. These boys use their donkey carts to get water from other villages, when it is available. Some women are allowed to get water from these carts on credit and pay later when they can. These teenage boys also sell wood, charging from a minimum of R50 to R250 maximum, depending on how full the cart is. Wood is mostly needed for cooking and heating and not necessarily for the boiling of water because the water currently used is already purified and not salty. Still, Ms Ketlane and some women prefer to get wood for themselves in the bush. This exposes them *to dangers of being raped and killed like other women have been, but they try to prevent this by walking in groups. For other households, having a man in the house comes in handy when it comes to the collecting wood.*

Ms Ketlane is also surrounded by households with big green "JOJO" water tanks. The owners of these households mostly work at the Rustenburg mines or in Mafikeng. Some are educated and have academic jobs. She believes that one of the quickest ways to get her house to look the same is to get married to a mine worker, since she didn't have an opportunity to educate herself.

Currently the only way she can get water from those "JOJO" tanks is to buy at least one 25l can for either R5 or R10. The amount payable is determined by the owners, who claim that the electricity costs required to extract water from the tanks are high. Other households are more generous in that they only charge R20 to R50 maximum for a period of a month. These are the households she prefers to buy water from but only when she can spare the amount from her kids' social grants.

The one thing that Ms Ketlane knows she has in common with all the households with or without the "JOJO" tanks in her village is the fact that they use the same clinic that has limited water, unless of course some pay to use facilities in private clinics and hospitals. The clinic in their village is generally useful but should be assisted with the greater water quantities. For instance, when one women is about to give birth she will be taken to the clinic with at least one 25ℓ plastic can. If there is no water in the house, help from neighbours is requested.

Sometimes while in Mafikeng town or on her pay date she usually meets women from other villages. While chatting to them she learns that they have cards which can be used to activate street taps. There are some complaints about the theft of these taps. However, one only needs to pay R20 for a card that will last for over 2 months, even when using five 25ℓ plastic cans per day for laundry, cleaning, cooking, bathing etc. Again for Ms Ketlane the R20 meter card might last even more than 2 months because she has a smaller family than most of the households with more than 5 people. Ms Ketlane hopes for one of these cards.

Figure 4-6: Various water sources

4.5.1 Botswana

4.5.1.1 Kgalagadi District

The district lacks surface hydrological features except for seasonal shallow pans and the Molopo and Nossob fossil valleys. 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.

Table 4-13: 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

Settlement	Water source	No. of boreholes	Yield (m/day)	Demand (m/day)	No. of standpipes	No. of private connections	Water quality
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.

4.5.1.2 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.

4.5.1.3 Water demand

The tables in **Appendix A** shows water demand in urban areas of Botswana and in Southern and Kgalagadi Districts.

4.5.2 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 4-14**. 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 4-14: 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.

4.5.3 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 4-15 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 (**Appendix A – Table 3**).

The number of households with toilets below RDP standard is listed in **Table 4-15**, 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 4-15: 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.

4.5.4 Implications

Water use drivers

In rural and peri-urban areas of developing countries, everyone uses water for various domestic purposes and many people use or could use water for productive purposes to earn an income, such as gardening, field crops, livestock, brick making (Moriarty, Butterworth & van Koppen, 2004). Water is needed to drink, prepare food, for cleanliness, and for livelihood.

The results from the Regional Poverty Profile show that water was considered as one of the most important resources to the poor (Hardap Region), whilst those who were better off did not put such a high priority on water as a necessary part of their lives.

Pressures

- Weather conditions
- Lack of job opportunities
- Depend on land for livelihood in a dry area
- Lack of infrastructure and expense of infrastructure
- Limited capacity of WSA's
- Distances to communities
- Ground water and surface water quality resources unhealthy
- Lack of sanitation
- Poverty
- Mining development
- Household members who die who were responsible to collect water/paid for water, putting more pressure on other members in terms of household chores and time needed to execute these chores.
- In most cases, water sources, uses and users are not well integrated, leaving much scope for improvements in water use efficiency, livelihood, and equitable water use (Moriarty, Butterworth et al. 2004).
- Drought relief interventions have been necessary in most parts of the South Africa to ensure continued provision of water to communities who depend on ground water. This has confirmed the necessity to develop additional sources to secure supplies of water in the long term. Despite relative drought, flooding events have occurred in the Northern Cape and North West Provinces, which has caused damage to water related infrastructure.
- The Kgalagadi District Municipality (IDP, 2002) conducted a survey to assess whether residents wanted Municipal water, and 8.8 % responded positive and 91.2 % responded negative. Reasons were not reported.

Impacts

Lack of water:

- Lack of time for income generating activities because of time it takes to collect water (1 minute up to eight hours);
- Household with reduced number of household members might not have time to collect sufficient water for the garden, and have to purchase food with the bit of money they have;
- The winter months might be more difficult- more water needed to collect water for plants, again might rather buy / or miss more school;
- Hunter, Twine & Johnson (2008) found a correlation between socio-economic status and daily winter consumption of water. It is possible that this reflects greater use of water by more disadvantaged households for watering food grown in homestead gardens, and used as substitute for purchased food, in the dry winter months. The results suggest that less time is required to collect water in households with higher SES, likely because of better access, usually from a tap in the yard. Finally, higher SES is associated with a decreased likelihood of a daughter collecting.
- Contributes to poverty cycle;
- Negative impact on nutrition and health;
- Decrease in life expectancy;
- Water pollution through the washing of clothes / dishes in streams, contamination by human and animal faeces, discharges from factories (including wastewater works), and oil spills, solvent spills, solid waste dumps;
- Water pollution: Imbalance in biological life, human and animal illness, taste, colour and odour, limited access to safe drinking water;
- Households consuming river water attribute higher value to the resource than collective tap users;
- Safety concerns;
- Over exploitation of water resources;
- High nitrate concentrations can have serious health impacts, particularly babies and young children. Nitrate concentrations of above 20 mg/l in drinking water is known to cause a blood disorder known as methaemoglobinaemia or blue baby

syndrome in infants which may result in death (North West Province State of the Environment Report, 2002).

- Diarrhoeal diseases can result from drinking borehole water that contains viruses, bacteria, protozoans and helminths. Human health can also be affected by long-term exposure to either an excess or a deficiency of certain chemicals in ground water. This includes iron, copper, zinc, cobalt, magnesium, chromium, and selenium.
- Mushrooming of new settlements which have to be provided with essential services such as health, water and primary education; and
- The scarcity of drinking water especially in the Mabutsane Sub-District as most boreholes either have poor quality water or they are dry.

Adequate, available water above RDP standard:

Positive

- Subsistence gardening;
- Plant trees;
- Income growth and human development;
- Time available for income generating activities;
- Might have extra money as a result of water available to sell crops;
- Higher work productivity;
- Better school attendance (don't have to fetch water);
- Increase in tourism;
- Income growth and human development;
- Better sanitation;
- Savings in health costs;
- Reduced water treatment costs; and
- Improve ground water and surface water quality resources.

Negative

- Irresponsible increase in water consumption/over exploitation of water recourses;
- Still not enough to lift out of the poverty cycle;
- Water only for subsistence use, and not productive use;
- Lack of money to pay for extra water;
- Water losses through leaking taps / cisterns, taps not turned off, leaking or broken pipes, overflowing water tanks, over watering of gardens, meter errors, leaking reticulation system, etc.; and
- Theft of taps.

Responses

South Africa's RDP's short-term aim is to provide every person with adequate facilities for health. The RDP will achieve this by establishing a national water and sanitation programme which aims to provide all households with a clean, safe water supply of 20 - 30 ℓ per capita per day (ℓ/c/d) within 200 m, an adequate/safe sanitation facility per site, and a refuse removal system to all urban households.

In the medium term, the RDP aims to provide an on-site supply of 50 – 60 ℓ/c/d of clean water, improved on-site sanitation, and an appropriate household refuse collection system. Water supply to nearly 100 % of rural households should be achieved over the medium term, and adequate sanitation facilities should be provided to at least 75 % of rural households. Community/household preferences and environmental sustainability will be taken into account. The RDP's long-term goal is to provide every South African with accessible water and sanitation.

With regard to the reliability of water supply, the acceptable standard is the provision of water at a minimum of ten (10) ℓ per minute with interruptions of less than seven (7) days per year at every service point (South Africa).

In the Northern Cape the Kgalagadi Household Sanitation programme was implemented by DWAF (http://www.environment.gov.za/HotIssues/2006/WEC/present/workshop2/Tshidi.pdf) The focus was SARAR: self-esteem of mothers, illiterate women; associated strengths, capacitating of women; responsibility, clarify roles in sanitation; action planning, involvement of women in planning; resourcefulness, solutions to problems are highlighted. The slogan is: “by women for women.” The indicators of success are: community gardens, trees are planted, hand washing facilities are implemented, and pit latrines are demolished.

In terms of fresh water and associated resources **Namibia** wants to be at the point where

- Water is allocated and used efficiently;
- Irrigation is only used for high value strategic crops on suitable soils;
- Access to potable water is equitable;
- Natural wetlands are productive and healthy with rich biodiversity;
- Tenure over wetland resources is appropriate; and
- Economic development options are optimal and strategic.

Namibia (Vision 2030) mentions the following challenges:

- Once ground water becomes polluted it is difficult to get rid of the pollution;
- Fresh water depletion and degradation threatens human health and livestock health, and socio-economic development;
- Increasing costs of supply are inevitable since expensive new infrastructure needs to be developed;
- As water in some areas becomes scarce and expensive, development options become increasingly limited; and
- Cost recovery of the capital spent on developing expensive new water resource is likely to become more difficult (especially as the number of teenage headed households are said to increase as a direct result of the HIV/AIDS endemic).

Namibia recognises that the enforcement of integrated Water Resource Management and Water Demand Management Strategies are essential if goals regarding social well-being, economic development and environmental health are to be realised. Efforts to reduce water threats include:

- Stricter economic approach to water pricing, encourage all sectors to use water efficiently;
- Water conservation initiatives including efforts to reduce evaporative losses from dams to the development of water re-use and reclamation strategies and the development of alternative water sources;

- Using water in the most economically viable and ecologically sound manner. Tools such as Natural Resource Accounting and Strategic Environmental Assessment are being adopted. Ultimately these tools will help guide policies regarding future water use, and will prevent impact on fresh water systems and the resources and services they provide; and
- Improving catchments, river, and aquifer management through the establishment of several agreements between Namibia and her neighbours re shared river basins. In addition, rural communities are becoming increasingly responsible for their own water points through the establishment of water points committees.

4.5.5 Future Planning

The provision of reliable and healthy water for domestic and productive use should be a priority, more so in the South African and Namibian sections of the catchment. Such improvements increase the ability of water users to pay for installation and maintenance of the systems, which in turn prepares the ground for accelerated up scaling and implementation of multiple-use systems (Moriarty, Butterworth et al. 2004). An increase in the demand for water is also caused by the need for water for productive use, but the weakening of people affected by HIV/AIDS must be taken into consideration in project design and the choice of technologies (Faurès & Santini, 2008 page 44).

The following should be taken into account: communities in isolated areas, more so the poorer communities are very dependent on each other socially and economically. They tend to live in close proximity to each other. The poor inhabitants tend to support each other, and this dependency binds them together as a social groups.

WSS with house connections may be considered should this be the case. Where households are further away from each other, scattered over an area, other alternatives, for example hand pumps, should be considered. Institutional requirements should also consider the spatial, and as a consequence social, behaviour patterns of communities. For example, communities that show a strong sense of community and cohesion, which is supported by the daily trips to the river for water, might experience the disintegration of cohesion should taps be installed in the yard; they might not understand the concept of paying for water; they might prefer one source over another because of safety issues, costs involved, and the need to share.

The way in which different groups of people use water should be considered (Faurès & Santini, 2008 pages 42-43):

"*For highly vulnerable people: water interventions should focus on highly subsidized social programmes, including labour-intensive soil and water conservation or watershed management programmes that can provide a return on labour. Domestic water supply and sanitation programmes also have good potential for impact, in part through reduction in water-related diseases and in time spent for fetching water.*

The smallholder farmers: investments in rain fed water management and supplementary irrigation where feasible. They need secure land tenure that is stable and reliable, guaranteed access to water, support to the empowerment of local communities, in particular WUAs, and improved access to inputs (through targeted subsidies) and markets. Capacity building, education and agricultural extension are also important, in addition to domestic water and sanitation programmes. Helpful public interventions will include research and development and extension support for maximizing yields with limited resources, diversifying crop production alternatives and producing more than one crop per year, where feasible.

Compared with traditional smallholders, emerging farmers typically have a higher level of technical knowledge and are more receptive to improved technology. They tend to specialize in specific crops, and are often integrated into a production/supply chain with some support from buyers through extension services and input supply. As they progress in market-oriented production, emerging farmers increasingly need to better secure production inputs. Together with fertilizers, improved control of soil moisture through irrigation is an important element of their production strategy. Therefore, access and control of water are essential, together with improved access to well-adapted financial instruments.

A subcategory of emerging farmers comprises those who produce crops on very small plots of land in home gardens or on other small landholdings, close to local markets. Small-plot irrigation technologies include treadle pump, affordable drip irrigation kits and water storage options (Keller and Roberts, 2004). These technologies are characterized by low initial investment costs, relatively short payback periods, and high farm-level returns on investments (Magistro et al., 2007). In addition, widespread use of small-plot irrigation methods can generate employment opportunities on and off farms in rural areas. Treadle pumps and drip *systems are somewhat labour-intensive, and local entrepreneurs can establish businesses that build, service and repair the irrigation equipment. Such activities stimulate greater demand for farm products and other non-tradable goods and services.*

Finally, there are the commercial farmers. Their activities usually offer local development opportunities, in particular for landless workers, and contribute to local economies. Therefore, commercial farming should be considered as a potentially important element in rural poverty reduction programmes, alongside programmes that address the needs of other categories. Commercial farmers typically benefit from favourable political, institutional and fiscal environments, good transportation, storage and marketing infrastructure, and reductions in international trade barriers. They are also well equipped to enhance the profitability of large-scale irrigation infrastructure. Where provided with the right legal framework, and where a fair and transparent balance of power is guaranteed, commercial and emerging farmers can benefit the rural poor through fair, decent and gainful employment options and, thus, contribute to local poverty reduction."

5. ECONOMICS

5.1 ECONOMIC ACTIVITIES

This section identifies and analyzes the main activities driving the economy in the area of the study, namely; the Molopo-Nossob catchment covering the three countries. This section is solely a desktop research, where reliance has been put on secondary data as opposed to survey or primary data sources and completed reports. Three activities currently taking place in the area have been identified as the main drivers of economic development in the project area. They are agriculture, mining and tourism, with agriculture further divided into irrigation and livestock farming.

5.1.1 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 of this 20 692, around 16 657 ha or 80.5 % utilises ground water and 4 040 ha or 19.5 % surface water. Although there are a diverse number of crops under irrigation, the study analyses the top six crops, namely groundnuts, lucerne, maize, potatoes, wheat and vegetables.

5.1.2 Livestock farming

Due to the semi–arid and dry climatic conditions of the area, livestock farming is a very important farming activity. This economic activity 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.

5.1.3 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.

5.1.4 Tourism

Tourism too is 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.

5.2 IRRIGATION AGRICULTURE

5.2.1 Methodology

In order to calculate the value of water used for agricultural activities, crop budgets have been compiled for each of the six major crops which have been analyzed in this study, based on the Combud Enterprise Budget frameworks developed in South Africa by the Department of Agriculture. In order to ensure that these budgets are representative of the actual situation in the Molopo – Nossob catchment, technical crop experts that are based in the catchment, have been consulted to verify the data used in these crop budgets and where necessary the data was adapted for the specific prevailing conditions in Namibia and Botswana.

The Computer Based Budgets (Combud) were used as base documents to develop the 2007/2008 production budgets. They were updated and adapted for the different production areas in terms of yield, production prices and input costs. The Combud budget provided data to the level of Gross Margin on a hectare basis, after which the fixed costs are subtracted to get the Net Farm Income per hectare and finally the Net Income or Profits per hectare.

In the next section a flow diagram explains the concept used to arrive at the Net Income which is to be used in the Macro Economic Impact Model. The flow diagram presents the process based on a hectare basis.

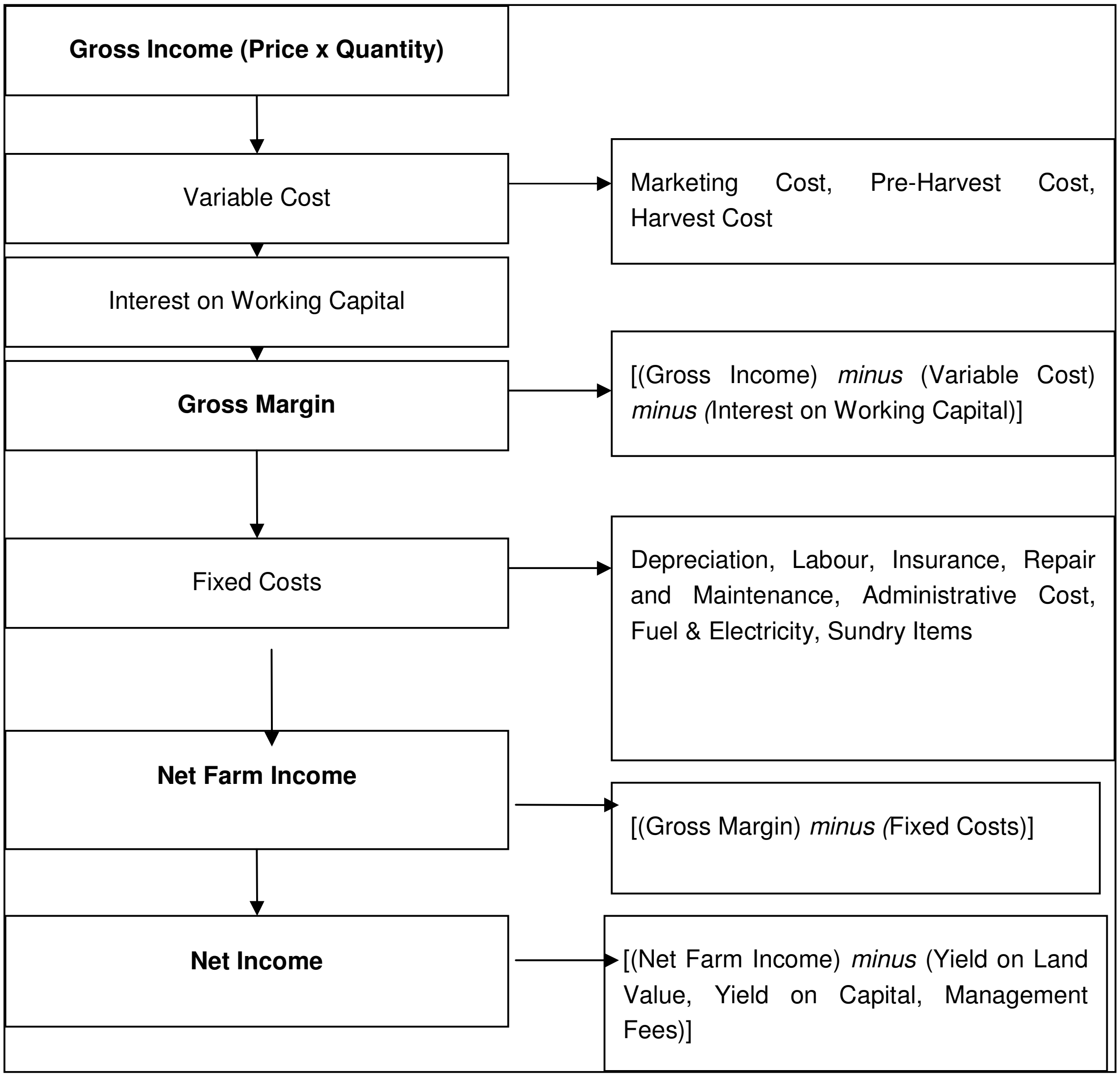

Figure 5-1: Flow diagram representing the depiction of Net Income in the Macro Economic Impact Model

For the use of the macro economic impacts determination, these costs in the budget have been allocated to structures in such a way that they are allocated to the different sectors of the economy. Those will be applied to determine the direct, and indirect and induced effects.

Table 5-1 shows the crops analyzed as well as their respective yield per hectare in tons. Given that there is currently no irrigation taking place in the catchment on the Botswana side, no provision was made for Botswana.

Table 5-1: 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 5-1 further 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 5-2 also provides a summary of the main crop types, total hectares currently under irrigation for each crop and the total water usage per crop.

Table 5-2: 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

5.2.2 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 hectares and total water use.

Republic of South Africa

Table 5-2 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 hectare is high for lucerne irrigation and low for potato irrigation. In terms of maximum yield per hectare, **Table 5-1** indicates that 34 tonnes was used as the yield per hectare of potatoes, while groundnuts being the lowest, with 4,5 tonnes per hectare.

5.3 LIVESTOCK FARMING

5.3.1 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 5-3** 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 5-3: 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	3385	2789	3303

5.3.2 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.

5.3.3 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.

5.4 MINING

5.4.1 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.

5.4.2 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 (R92mil.).

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.

5.4.3 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 5-4**.

Table 5-4: 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

5.5 TOURISM

5.5.1 Methodology

Tourism has been identified as a growth industry not only for the Molopo-Nossob region but also for all the Southern Africa states and was therefore researched in depth using literature, advertising and local tourist information centres where available. For this study it was decided not to differentiate between holiday/eco-tourists and business tourists, because no detailed data is available differentiating between the two categories. Secondly for the overall economy of the region it does not matter for what reason they visit the region.

In estimating the economic contribution of the tourism activity, the number of beds available for each country was first established together with the average tariff applicable. From national and local tourist sources the average occupation rate was established which was then used to calculate the total bed nights sold.

No provision has been made for any other spending by the visitors other than for accommodation, which obviously means that the figures quoted are an under estimation of the economic impact of the tourism activities in the catchment.

5.5.2 Country Discussion: - Tourism

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.

5.5.3 Conclusion

From data in **Table 5-5** below 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 5-5: 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

5.6 MACRO ECONOMIC IMPACTS

In the above sections the direct impacts of the economic activities have been identified. In this section the methodology is explained of how the indirect and induced macro-economic impacts of the identified activities are calculated and how this methodology can be used to calculate the impact of different water allocation scenarios.

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 (SAM) applicable to the study area, and estimating the following indicators:

Economic growth (i.e. the impact on Gross Domestic Product);

Job creation (i.e. the impact on labour requirements); and

Income distribution (i.e. the impact on low-income, poor households and the total income of households).

An example of the agriculture sector multipliers used in this study are as follows:

Direct effect: refers to effects occurring directly in the agriculture sector.

Indirect effects: refer to those effects occurring in the different economic sectors that link backward to agriculture due to the supply of intermediate inputs, i.e. fertilisers, seeds, etc.

Induced effects: refers to the chain reaction triggered by the salaries and profits (less retained earnings) that are ploughed back into the economy in the form of private consumption expenditure.

The same reasoning can be applied to the other identified economic activities.

In this case the Northern Cape Province's SAM, constructed for the Development Bank of Southern Africa (DBSA) by Conningarth, and has been used to extract the multipliers to be used in the MEIM. Because of the nature of the study the Indirect and Induced Impacts are not separated, but presented as one.

The model used the annual turnover with the total estimated employment and water use; it then calculated the direct GDP, using the SAM generated multipliers. The Indirect and Induced GDP impacts are then calculated and in the last instance this is presented as a factor of water use.

The output of the MEIM model is the Total Macro-economic Impacts like GDP, Employment and Income Directed at Low Income Households and Total Households. In **Table 5-6** a summary of the Direct and Total Macro-economic indictors of the main economic activities in the catchment are compared.

Table 5-6: - 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**	**10 994.5**

In **Table 5-6** it appears that mining is by far the largest activity followed by livestock farming. However, it is also obvious that the indirect and induced factor of mining is 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. All though 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 5-7** 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 5-7: - 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 5-7** 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.

6. SURFACE WATER

6.1 WATER USE

6.1.1 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 6.1.4**). 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.

6.1.2 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.

6.1.3 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.

6.1.4 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.

6.1.5 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).

6.2 AVAILABLE 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.

6.2.1 Quantity

Table 6-1 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 %.

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.

Table 6-1: Total Incremental MAR per main subcatchment

River	Quaternary (Fig 3.6)	Network (Fig 3.7)	Incremental MAR (no channel losses) Natural	Incremental MAR including local channel losses per quaternary	
				Natural	Present-Day
Molopo	D41A	SB1	35.99	9.85	6.22
	D41B	SB1	12.76	4.75	4.01
	D41C	SB1	9.65	2.77	2.50
	D41D	SB1	5.99	1.22	1.19
	Z10D	B4	3.57	1.11	1.11
	Z10C	B5	16.84	3.23	3.23
	D41E	SB2	0.67	0.00	0.00
	D41F	SB2	1.94	0.00	0.00
	D41H*	SB2	0.85	0.00	0.00
	Z10F	B3	0.64	0.02	0.02
	D42C*	SB3	0.10	0.00	0.00
	TOTAL MOLOPO		**89.00**	**22.95**	**18.28**
Kuruman	D41G	S1	7.13	1.42	1.40
	D41H*	S1	1.58	0.18	0.17
	D41J	S2	3.66	0.72	0.71
	D41K	S2	4.53	1.08	1.08
	D41L	S2	30.05	6.43	6.14
	D41M	S2	0.89	0.00	0.00
	D42C*	S3	1.05	0.00	0.00
	TOTAL KURUMAN		**48.89**	**9.83**	**9.50**
Nossob	Z10A	N1	2.30	2.30	1.47
	Z10A	N2	15.83	4.13	4.13
	D42A*	SNB2	0.22	0.00	0.00
	TOTAL NOSSOB		**18.35**	**6.43**	**5.60**
Auob	Z10A	N3	1.47	0.42	0.33
	Z10A	N4	6.27	4.21	4.21
	D42A*	SN2	0.01	0.00	0.00
	D42B	SNB1	0.01	0.00	0.00
	TOTAL AUOB		**7.76**	**4.63**	**4.54**
TOTAL			**164**	**43.8**	**37.9**

6.2.2 Assurance of Supply

Table 6-2 and **Table 6-3** 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 6-2: 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 6-3: 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

6.3 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.

6.4 DAM INVENTORY

6.4.1 Main Dams

There are a total of nine main dams within the study area, none of which are located in Botswana. **Table 6-4** lists their main characteristics and a brief description of each is provided hereafter. **Figure 6-1** 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 6-4.**

Table 6-4: 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

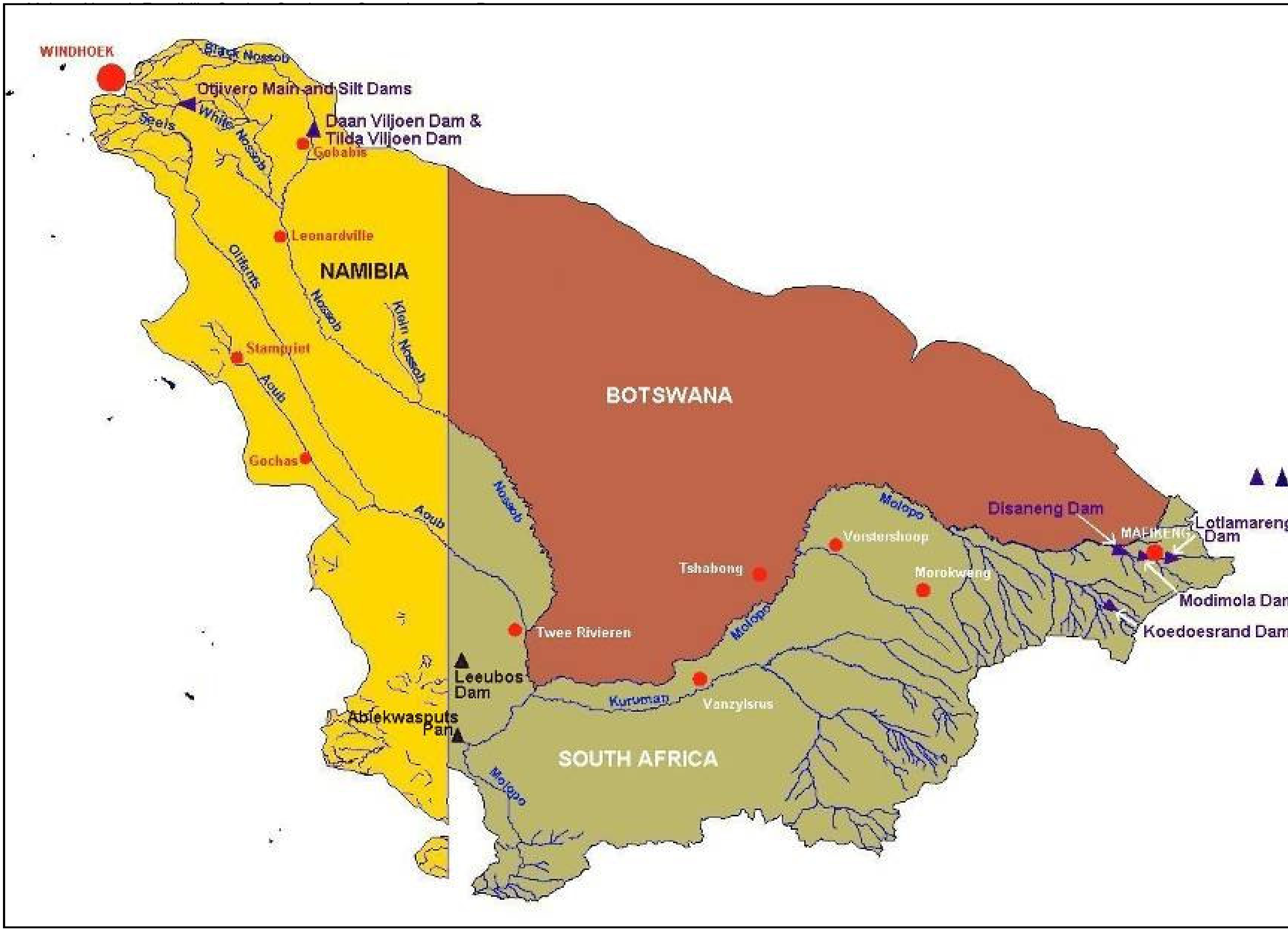

Figure 6-1: Location of Main Dams in the Molopo-Nossob Catchment Area

6.4.2 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 6-5.**

Table 6-5: 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**

6.4.3 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 6-6**.

Table 6-6: 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**

7. 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.

7.1 AQUIFERS

In the Molopo Nossob Sub river basin four main aquifer types were identified namely, fractured, fractured porous, porous, and krastic. 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 krastic 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 (see **Figure 7-1**).

Figure 7-1: Map of ground water aquifers

7.1.1 Basement Aquifers

Generally, the Basement aquifers are 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 are reduced and some boreholes are become dry.

Several boreholes were drilled in the Olifantshoek Supergroup rockas 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 over flowing 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). 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).

7.1.2 Karst Aquifers

The karstified fractured aquifers, which 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 are well developed as Chert Breccia aquifer in Kgwakgwe area and as Dolomite aquifer in 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 mbgℓ 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 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.

7.1.3 Karoo Aquifers

7.1.3.1 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).

7.1.3.2 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 study 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.

7.1.4 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).

7.2 WATER USE

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 7-1** 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 7-1: 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

Locality/Area	Source	Municipal	Agricultural Irrigation	Mining	Info source
					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 7.2** shows the estimates of water usage in the Stampriet Artesian Basin area for March 2000 (JICA, 2002).

Table 7-2: 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**

7.3 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 7-3: 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 7-3** 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.

7.4 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 Department of Water Affairs and Forestry (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.

8. RAIN WATER HARVESTING

Rainwater harvesting (RWH) describes the small-scale concentration, collection, storage, and use of rainwater runoff for productive purposes. The use of RWH in South Africa, Namibia and Botswana to help meet domestic water needs, is nothing new. It can be a significant source of domestic water, particularly where it is used to supplement more conventional sources, which typically offer higher assurances of supply.

The technique is becoming more widely adopted because of the support for integrated water resource development, in which alternative sources of water supply are being sought to supplement conventional schemes.

This is particularly relevant in remote rural areas, where access to reliable and sustainable water sources is often not to the same levels of services as might be available in the towns or larger settlements. One of the challenges in this regard is the provision of financial support to resource - constrained households, unable to afford the capital cost of rainwater storage tanks and related works.

8.1 CATEGORIES OF RAIN WATER HARVESTING

There are three broad categories of RWH, namely:

- Domestic RWH (DRWH);
- In-field RWH; and
- Ex-field RWH.

For the purposes of this study, DRWH is investigated as a possible alternative source of water.

Domestic Rainwater Harvesting

A DRWH system typically has the following components:

- a storage facility
  - either aboveground or underground tank;
- a catchment area
  - typically a rooftop surface and;
- a water use target area

  - typically garden watering, domestic use or small-scale productive activities, such as vegetable cultivation.

Figure 8-1 shows a typical application for a DRWH system used for toilet flushing. In order to use the water from a DRWH system for drinking purposes, filters would be required to prevent rooftop contaminants from entering the tank. However for non-potable use, such as garden watering and toilet flushing, a simple system as shown below is adequate.

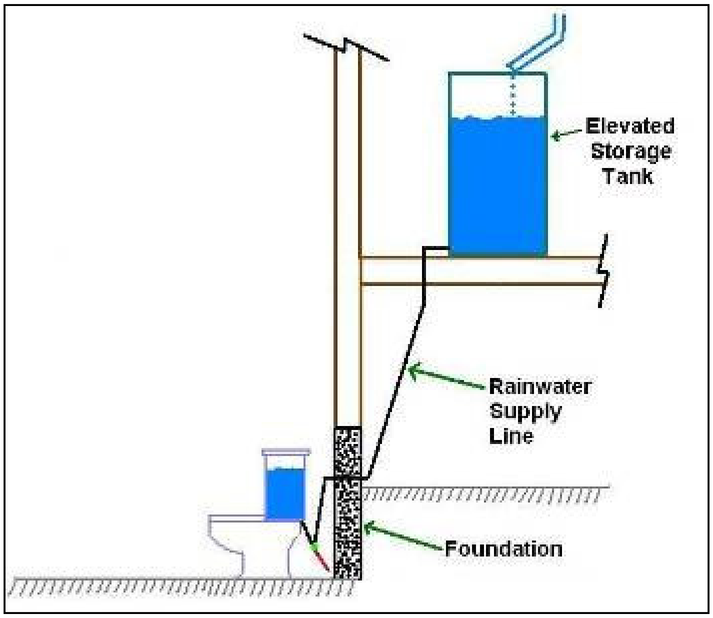

Figure 8-1: Basic DRWH Application

The advantages of DRWH include:

- access to water in the tank is in close proximity to the dwelling;
- the exposure to water related disease is reduced;
- improved sanitation opportunities; and
- small-scale home-based productive activities (vegetable cultivation, garden watering, brick making, etc).

The challenges in utilising DRWH include:

- overcoming the affordability aspect - indigent and poor households will require capital support to cover the installation costs;

- provision of training in relation to the ongoing maintenance and repair;
- the seasonal nature of the rainfall; and
- the inability of the tank sizes generally used, to provide any "carry-over" storage from the wet season into the dry season.

8.2 RAINWATER HARVEST POTENTIAL

The Rainwater Harvest Potential from a roof or similar impervious structure is determined by:

$$\frac{\text{Roof Area } (m^2) \times \text{MAP } (mm)}{1000}$$

The roof area is defined as the area seen from directly above, and not the total area of the roof surface. For a defined size of roof, the useable portion of the harvest potential will ultimately depend on:

- the rainfall distribution; and
- the size of the storage tank.

8.3 CONSIDERATIONS IN THIS STUDY AREA

It should be noted that the greatest concentration of households in which DRWH tanks are utilised in South Africa are in those areas typical of high MAP, and also where reliable year-round rainfall occurs, such as the East Coast catchments. This is illustrated in **Figure 8-2**.

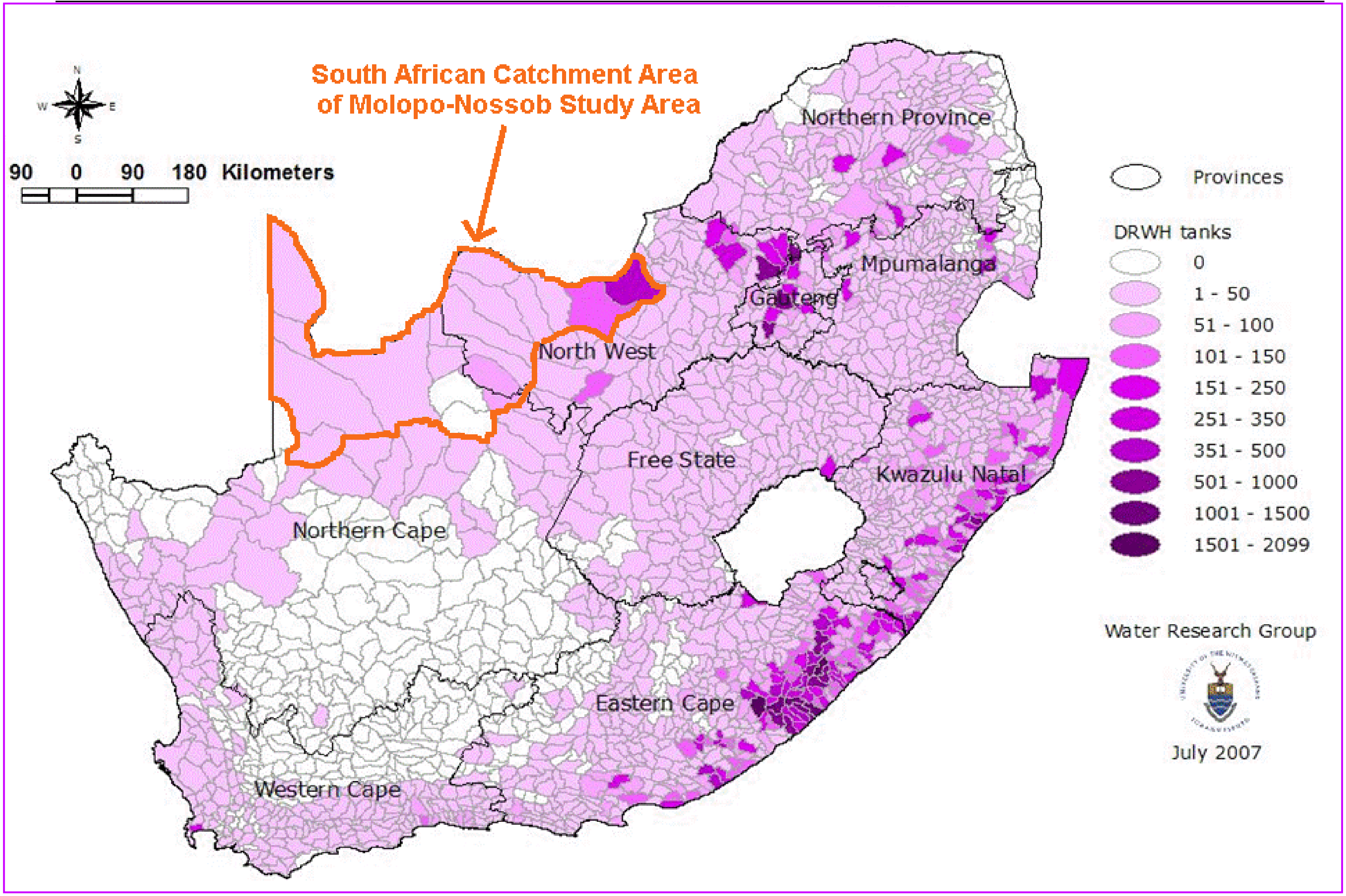

Figure 8-2: Current estimated concentration of use of DRWH tanks within RSA (Ref 1)

Figure 8-2 also indicates that in the South African portion of the Molopo River catchment, the estimated concentration in the use of DRWH tanks is greatest in the higher MAP areas (notably in the source catchments of the Molopo River). The concentration decreases towards the west, as the MAP decreases.

Equivalent information is not available for Namibia or Botswana. However, it is reasonable to assume that due to the decreasing MAP in a westerly and northerly direction, the potential for DRWH also reduces. Improved potential could be expected in the upper catchments of the Nossob River (the White and the Black Nossob), where the MAP again increases to above 350 mm per annum.

8.4 CONCLUSIONS FOR THIS STUDY AREA

In arid and semi-arid regions, such as the Molopo-Nossob catchment, the Mean Annual Precipitation (MAP) is not only low, but the occurrence of rainfall is also erratic. This would typically result in tanks filling quickly during the rainy periods, but then being relatively quickly drawn-down, with inadequate "carry-over" storage to meet the water requirements through the long dry season.

As such DRWH would not be sustainable as an independent source of water in this area. However, in such water-scarce environments, every opportunity should be taken to make optimum use of that which is available. Therefore, conjunctive / supplementary use of DRWH does offer some potential during the wet periods, where use of tanks could be an alternative to ground water abstraction or to conventional water supply from surface water sources.

8.5 GATDAMME

An innovative form of rainwater harvesting was practised in the South African part of the Kalahari in the past. This consisted of constructing a hole (gat) in the centre of a pan in order to concentrate the water and thereby reduce the evaporation losses. Some of these holes were covered by a roof in order to further reduce the evaporation loss. Gatdamme were constructed on 86 farms in an area known as the Salt Block, an area where the ground water is particularly saline and rain water provides a source of fresh water for livestock watering (Mr Pierre Nel, Kalahari Wes WGV, personal communication).

Immediately after construction the dams tended to leak, as the impermeable surface layer had been penetrated. However, this loss soon decreased as the dams silted up and again formed an impermeable layer. Some of the dams had quality problems, as the water tended to become saline after a few months. The water in the dams was also unreliable, as some dried up before the next rains could replenish them.

After the construction of the Kalahari West Pipeline most of these dams were abandoned, and at present only a very few are still used.

9. DISCUSSION

The Molopo-Nossob Catchment is predominantly an arid, flat area. In Botswana the catchment is characterised by the Kalahari sanda, a vast flat semi-arid area and comparatively featureless landscape that has no rivers or streams. The only areas that receive significant rainfall are found to the north of Gobabis (Namibia), and to the south of Mafikeng in South Africa. As a consequence the drainage pattern is poorly developed and very few tributaries join the main rivers. Dams have been constructed in the areas that drain the high rainfall areas, and most of the available yield has been taken up, the water being used for domestic water supply. The exception is the Seeis River where some yield can still be developed, but this is limited.

Activities in the study area centre around farming (predominantly stock farming), mining (mainly in South Africa), conservation and tourism.

Stock farming is limited by the availability of water. Boreholes have been extensively used to open up areas for grazing, but in many cases the quality of the ground water is such that it affects the health of the animals. As a consequence some innovative ideas have been implemented in the past to overcome this problem, such as the holes that were dug in the middle of some pans in South Africa (so-called gatdamme) to conserve rain water. This had limited success, and this method of rain water harvesting has largely been replaced by the Kalahari West Rural Water Supply Scheme that brings water from the Orange River to the area.

The commercial farmers generally apply sound farming practises, but subsistence farmers tend to allow overgrazing which has affected the condition of the veld and consequently the condition of their stock. The rangeland in the immediate vicinity of boreholes has been irreversibly damaged. Providing more water will exacerbate the situation and may in the long run destroy the rangeland to the extent where it can no longer sustain any form of pastoralisation.

The situation is further exacerbated by invasive alien species, specifically persopia, that outperform the indigenous vegetation and deplete the ground water.

Extensive irrigation has been developed in the dolomitic area in South Africa, which has led to extensive over-utilisation of the ground water. As a consequence springs that fed the rivers in this area only flow intermittently after sustained good rainfall.

This has affected the upper reaches of the Molopo specifically, and the nature of the river has been altered significantly.

Mining provides about half of the direct employment opportunities in the study area, but generates 87 % of the GDP. Up to the present dewatering of the mines provided sufficient water for their own purposes, but imports via the Vaal-Gamagara Scheme will be needed in the near future to augment their own supplies.

Conservation and tourism do not yet play a significant role in the study area, although there is some scope and many farmers are changing from cattle to game farming.

The study area is sparsely populated, and only a few relatively small towns occur. No significant growth in population is foreseen. Most of the young people migrate to urban areas outside the study areas in order to find job opportunities.

Most of the available surface water is already used (**Table 9.1**). In the Molopo River the remaining available water is equal to the required environmental flow of 29 million m^3/a and there is therefore no exploitable water left.

Although there seems to be water available in the Kuruman River, this is in fact ground water that is discharged from various fountains (eyes) that emanates from the dolomitic area. These discharges are measured and recorded as surface water flows in the South African hydrological system, and were therefore included in the catchment model as such. A storage dam on the river will therefore serve very little purpose, as it is more economically to abstract the water at source than to store it in a dam where evaporation losses will lead to a significant reduction in yield. Any scheme to exploit the water in the Kuruman River Catchment should therefore consider ground water exploitation, rather than surface run-off.

The yield that can be obtained from the upper reaches of the Auob is about 0.5 million m^3/a. This is very small and only viable for domestic purposes. The only user for such water is Windhoek and the distance and therefore associated cost of delivery does not make it a viable source of water. This means that, although there is some water available, there is no user for the water.

Table 9-1: 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

10. CONCLUSION AND RECOMMENDATION

The surface water resources of the study area have been largely 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 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 is therefore recommended that the rest of the study considers the availability of ground water in more detail, and focuses on the exploitation of this resource, rather than surface water.

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APPENDIX A

Table 4: Urban Centres and Towns by Demand Projections based on Population Projections

Centre	District	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gaborone	South East	25307798	26317369	27326660	28340520	29363172	30276621	31309055	32355878	33418703	34499959	35454992	36577020	37720677	38776099	39556727
F/town	North East	8870296	9166805	9471855	9785669	10108530	10422082	10758155	11104130	11459358	11824547	12175432	12558246	12952239	13356601	13772158
Lobatse	South East	3438761	3544440	3653165	3765018	3880114	4062561	4239001	4349019	4473315	4605325	4738567	4877180	5019818	5166581	5317587
Selibe-Phikwe	Central	6882240	7129193	7378425	7630876	7866990	8125180	8385855	8648587	8917381	9192567	9443380	9731466	10027013	10328660	10637449
Orapa	Central	793272	813738	834783	855497	857513	858773	860458	862091	863663	865184	865898	867233	868525	869769	870970
Jwaneng	Southern	1796968	1826612	1854440	1880830	1906189	1924292	1945629	1966490	1986942	2007192	2022465	2041510	2060572	2079601	2098751
Sowa Town	Central	263181	271629	280330	289290	298519	299760	300593	301411	302215	303007	303410	303900	304381	304853	305317

Table 5: Southern District by Demand Projections based on Population Projections

Centre	Area	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Kanye	Ngwaketse	2214363	2258870	2304268	2350545	2397733	2439039	2483885	2529634	2596387	2665039	2728770	2798987	2871275	2945462	3021717
Ranaka	Ngwaketse	45,207	45,286	45,366	45,446	45,525	45,566	45,606	45,646	45,686	45,726	45,746	45,766	45,786	45,807	45,827
Lotlhakane	Ngwaketse	11,173	11,275	11,379	11,483	11,588	11,641	11,694	11,747	11,801	11,855	11,882	11,909	11,936	11,964	11,991
Gasita	Ngwaketse	4,927	4,923	4,919	4,915	4,911	4,909	4,907	4,905	4,903	4,901	4,899	4,897	4,895	4,893	4,981
Lorolwana	Ngwaketse	6,373	6,422	6,472	6,523	6,573	6,599	6,625	6,651	6,676	6,702	6,715	6,728	6,742	6,755	6,768
Tsonyane	Ngwaketse	3,229	3,230	3,232	3,233	3,235	3,236	3,236	3,237	3,238	3,239	3,239	3,240	3,240	3,240	3,241
Kgomokasita	Ngwaketse	6,664	6,677	6,691	6,705	6,719	6,726	6,732	6,739	6,746	6,753	6,757	6,760	6,764	6,767	6,771
Pitseng	Ngwaketse	5,444	5,482	5,519	5,558	5,596	5,615	5,635	5,654	5,674	5,693	5,703	5,713	5,723	5,733	5,742
Mokhomba	Ngwaketse	5,449	5,470	5,540	5,511	5,532	5,542	5,552	5,563	5,573	5,583	5,589	5,594	5,599	5,604	5,610
Lekgolobotlo	Ngwaketse	9,224	9,274	9,325	9,376	9,428	9,454	9,479	9,505	9,531	9,558	9,571	9,584	9,597	9,610	9,623
Seherelela	Ngwaketse	2,932	2,940	2,949	2,958	2,966	2,971	2,975	2,979	2,984	2,988	2,990	2,993	2,995	2,997	2,999

LOTLHAKANE	**NGWAKETSE**	163987	172128	180461	188957	197655	204745	213226	221937	230708	239631	246927	257870	269214	280763	292625
SESE	**NGWAKETSE**	12,118	12,143	12,169	12,194	12,220	12,233	12,245	12,258	12,271	12,284	12,290	12,297	12,303	12,310	12,316
SESUNG	**NGWAKETSE**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MAGOTLHWANE	**NGWAKETSE**	9,296	9,310	9,324	9,338	9,352	9,359	9,366	9,373	9,379	9,386	9,390	9,393	9,397	9,400	9,404
SEGWAGWA	**NGWAKETSE**	4,171	4,183	4,195	4,207	4,219	4,225	4,232	4,238	4,244	4,250	4,253	4,256	4,259	4,262	4,265
MANYANA	**NGWAKETSE**	132249	137522	142901	148355	153909	158606	164180	169894	175638	181467	186433	193880	201589	209439	217498
MAOKANE	**NGWAKETSE**	7,808	7,825	7,841	7,858	7,874	7,893	7,912	7,932	7,951	7,970	7,996	8,021	8,047	8,073	8,099
DIPOTSANA	**NGWAKETSE**	2,176	2,188	2,201	2,214	2,227	2,233	2,239	2,246	2,252	2,259	2,262	2,265	2,69	2,272	2,275
DIABO	**NGWAKETSE**	5,165	5,140	5,115	5,091	5,066	5,054	5,042	5,030	5,018	5,006	4,999	4,993	4,987	4,981	4,975
MOLAPOWABOJANG	**NGWAKETSE**	273398	291219	310126	330179	351485	369497	389863	411317	433756	457334	477745	504601	532939	562605	593809
MOSHANENG	**NGWAKETSE**	20,361	20,433	20,505	20,578	20,650	20,687	20,724	20,760	20,797	20,834	20,852	20,871	20,889	20,908	20,926
MOSHUPA	**NGWAKETSE**	997254	1028483	1060341	1092515	1125208	1151043	1181924	1213424	1245082	1277144	1300994	1332456	1364529	1396677	1429175
NTLHANTLHE	**NGWAKETSE**	16,485	16,516	16,547	16,578	16,610	16,625	16,641	16,657	16,672	16,688	16,696	16,704	16,71	16,720	16,728

													2		
TSHWAANE	**NGWAKETSE**	1,429	1,425	1,420	1,416	1,411	1,409	1,4007	1,405	1,403	1,400	1,399	1398	1,397	1,396	1,395
SEMANE	**NGWAKETSE**	3,527	3,536	3,545	3,554	3,563	3,567	3,572	3,576	3,581	3,585	3,588	3,590	3,592	3,595	3,597
TLHANKANE	**NGWAKETSE**	3,791	3,819	3,847	3,876	3,904	3,919	3,933	3,948	3,962	3,977	3,984	3,992	3,999	4,006	4,014
SELOKOLELA	**NGWAKETSE**	6,917	6,964	7,011	7,058	7,105	7,129	7,153	7,177	7,201	7,226	7,238	7,250	7,262	7,274	7,287
MOGONYE	**NGWAKETSE**	4,926	4,931	4,937	4,943	4,948	4,951	4,954	4,957	4,960	4,962	4,964	4,965	4,967	4,968	4,970
AREA TOTAL		3980041	4087616	4198096	4311161	4427213	4524472	4634940	4748388	4884075	5023442	5143871	5290973	442904	5598483	5758537
PITSANE SIDING	**BAROLONG**	34,607	34,760	34,914	35,068	35,224	35,302	35,380	35,458	35,537	35,615	35,655	35,694	35,734	35,773	35,813
TLHARESELEELE	**BAROLONG**	6,107	6,114	6,120	6,127	6,134	6,137	6,141	6,144	6,147	6,151	6,152	6,154	6,156	6,157	6,159
PITSANE POTOKWE	**BAROLONG**	6,849	6,853	6,857	6,861	6,865	6,867	6,869	6,871	6,873	6,875	6,876	6,877	6,878	6,879	6,880
RAKHUNA	**BAROLONG**	7,380	7,393	7,406	7,419	7,432	7,439	7,446	7,452	7,459	7,465	7,469	7,472	7,475	7,478	7,482
MALOKAGANYANE	**BAROLONG**	4,305	4,297	4,289	4,280	4,272	4,268	4,263	4,259	4,255	4,251	4,249	4,247	4,245	4,243	4,241
BETHEL	**BAROLONG**	3,821	3,818	3,815	3,812	3,809	3,807	3,806	3,804	3,803	3,801	3,800	3,798	3,797	3,795	3,794

Dinatshana	**Barolong**	3,489	3,487	3,484	3,481	3,478	3,477	3,475	3,474	3,471	3,470	3,469	3,467	3,466	3,464	4,463
Ngwatsau	**Barolong**	2,284	2,284	2,284	2,284	2,284	2,284	2,284	2,284	2,284	2,284	2,284	2,284	2,284	2,284	2,284
Ramatlabama	**Barolong**	9,699	9,702	9,705	9,708	9,711	9,712	9,714	9,715	9,717	9,718	9,719	9,720	9,721	9,721	9,722
Good Hope	**Barolong**	90,149	92,784	95,503	98,285	101144	103897	106948	1101103	113328	116644	120054	123559	127163	130868	134677
Mokatako	**Barolong**	9,375	9,383	9,391	9,399	9,407	9,411	9,415	9,419	9,423	9,427	9,429	9,431	9,433	9,435	9,437
Tswanyaneng	**Barolong**	3,606	3,611	3,615	3,619	3,624	3,626	3,628	3,630	3,633	3,635	3,636	3,637	3,638	3,639	3,640
Metlojane	**Barolong**	7,233	7,286	7,340	7,394	7,448	7,476	7,503	7,531	7,559	7,587	7,601	7,614	7,629	7,643	7,657
Borobadiepe	**Barolong**	3,255	3,252	3,249	3,247	3,244	3,243	3,242	3,240	3,239	3,238	3,237	3,235	3,234	3,233	3,231
Hebron	**Barolong**	9,073	9,085	9,097	9,109	9,121	9,127	9,133	9,139	9,145	9,151	9,154	9,157	9,160	9,163	9,166
Logagane	**Barolong**	2,199	2,206	2,214	2,221	2,228	2,232	2,236	2,239	2,243	2,247	2,248	2,250	2,252	2,254	2,256
Tswagare	**Barolong**	2,171	2,180	2,189	2,198	2,207	2,211	2,216	2,220	2,225	2,229	2,231	2,234	2,236	2,238	2,240
Makokwe	**Barolong**	755	752	749	747	744	742	741	740	738	737	736	736	735	734	734
Marojane	**Barolong**	1,592	1,591	1,590	1,589	1,589	1,588	1,588	1,587	1,587	1,587	1,586	1,586	1,586	1,586	1,586

Papatlo	**Barolong**	3,312	3,307	3,303	3,298	3,293	3,291	3,288	3,286	3,284	3,281	3,280	3,279	3,278	3,275	3,276
Phihitshane	**Barolong**	4,593	4,581	4,569	4,556	4,544	4,538	4,532	4,525	4,519	4,513	4,510	4,507	4,504	4,501	4,498
Molete	**Barolong**	1,757	1,758	1,758	1,759	1,760	1,760	1,760	1,760	1,761	1,761	1,761	1,761	1,761	1,762	1,762
Ditlharapa	**Barolong**	4,717	4,716	4,714	4,712	4,710	4,708	4,706	4,704	4,702	4,702	4,701	4,699	4,698	4,695	4,694
Madingwana	**Barolong**	2,007	2,006	2,004	2,002	2,000	1,999	1,999	1,998	1,997	1,996	1,996	1,995	1,995	1,994	1,994
Kgoro	**Barolong**	7,599	7,607	7,616	7,624	7,633	7,637	7,642	7,646	7,650	7,654	7,657	7,659	7,661	7,663	7,665
Sheep Farm	**Barolong**	5,648	5,649	5,649	5,649	5,650	5,650	5,650	5,650	5,650	5,650	5,650	5,650	5,650	5,650	5,651
Motsentshe	**Barolong**	2,204	2,203	2,202	2,201	2,200	2,199	2,199	2,198	2,198	2,197	2,197	2,197	2,197	2,196	2,196
Mogwalale	**Barolong**	1,151	1,150	1,149	1,148	1,147	1,147	1,146	1,146	1,145	1,145	1,145	1,144	1,144	1,144	1,144
Gathwane	**Barolong**	9,828	9,820	9,812	9,804	9,796	9,792	9,789	9,785	9,781	9,777	9,773	9,769	9,765	9,761	9,757
Digawana	**Barolong**	46,282	46,245	46,209	46,172	46,135	46,117	46,098	46,080	46,061	46,043	46,025	46,006	45,988	45,969	45,951
Magoriapitse	**Barolong**	10,176	10,281	1,388	10,495	10,603	10,658	10,713	10,768	10,824	10,880	10,908	10,936	10,964	10,992	11,021
Lejwana	**Barolong**	6,226	6,267	6,309	6,351	6,393	6,414	6,435	6,457	6,478	6,500	6,511	6,521	6,532	6,543	6,554
Mogojog	**Barolon**	3,715	3,708	3,700	3,693	3,686	3,682	3,679	3,675	3,672	3,668	3,666	3,664	3,663	3,661	3,659

OJO	**G**															
MMATHETHE	**BAROLONG**	252993	266044	279447	293191	307318	319126	332897	347037	361414	376115	388443	406156	424501	443319	462722
MOKGOMANE	**BAROLONG**	8,454	8,490	8,526	8,562	8,577	8,616	8,634	8,652	8,670	8,688	8,697	8,706	8,716	8,725	8,734
PITSHANE MOLOPO	**BAROLONG**	27,318	27,589	27,863	28,139	28,418	28,559	28,701	28,843	28,986	29,130	29,202	29,275	29,347	29,420	29,493
SEDIBENG	**BAROLONG**	5,043	5,094	5,145	5,196	5,248	5,275	5,301	5,327	5,354	5,381	5,394	5,408	5,421	5,435	5,449
MUSI	**BAROLONG**	1,516	1,506	1,496	1,486	1,477	1,472	1,467	1,462	1,457	1,452	1,450	1,447	1,445	1,443	1,440
TSWAANENG	**BAROLONG**	2,934	2,946	2,958	2,969	2,981	2,987	2,993	2,999	3,005	3,011	3,014	3,017	3,020	3,023	3,026
GAMAJALELA	**BAROLONG**	3,178	3,175	3,173	3,170	3,168	3,166	3,165	3,164	3,163	3,161	3,160	3,159	3,158	3,156	3,155
DIKHUKHUNG	**BAROLONG**	1,620	1,616	1,612	1,608	1,604	1,602	1,600	1,598	1,596	1,594	1,593	1,592	1,591	1,590	1,589
LEPORUNG	**BAROLONG**	4,955	4,958	4,961	4,964	4,967	4,969	4,970	4,972	4,974	4,975	4,976	4,977	4,978	4,978	4,979
MMAKGORI	**BAROLONG**	4,716	4,759	4,802	4,845	4,889	4,911	4,934	4,956	4,978	5,001	5,012	5,024	5,035	5,046	5,058
MABULE	**BAROLONG**	13,237	13,264	13,290	13,317	13,343	13,357	13,370	13,384	13,397	13,410	13,417	13,424	13,430	13,437	13,444
TSHIDILAMOLOMO	**BAROLONG**	6,639	6,642	6,645	6,649	6,652	6,654	6,655	6,657	6,659	6,660	6,661	6,662	6,663	6,664	6,664
METLOBO	**BAROLON**	11,583	11,573	11,564	11,555	11,546	11,541	11,536	11,532	11,527	11,523	11,518	11,513	11,50	11,504	11,500

	G													9		
Lorwana	Barolong	10,075	10,054	10,033	10,012	9,991	9,980	9,970	9,959	9,949	9,939	9,934	9,928	9,923	9,918	9,913
Kangwe	Barolong	771	760	749	738	728	7722	717	712	707	702	699	697	694	692	689
Sekhutlane	Barolong	3,578	3,580	3,582	3,585	3,587	3,588	3,589	3,590	3,591	3,593	3,593	3,594	3,594	3,595	3,595
Area Total		675776	692184	709037	726299	744029	758963	776162	793834	811817	830215	846127	867521	889646	912344	935733
Mabutsane	Ngwaketse West	66,947	70,545	74,242	78,009	81,868	85,081	88,922	92,870	96,875	100966	104174	108337	112615	116949	121371
Morwamosu	Ngwaketse West	9,161	9,186	9,212	9,238	9,264	9,277	9,291	9,304	9,317	9,330	9,336	9,343	9,350	9,356	9,363
Sekoma	Ngwaketse West	10,970	11,062	11,155	11,249	11,343	11,391	11,439	11,487	11,535	11,584	11,608	11,632	11,657	11,681	11,706
Khonkhwa	Ngwaketse West	3,460	3,469	3,479	3,488	3,498	3,502	3,507	3,512	3,517	3,522	3,524	3,526	3,529	3,531	3,534
Keng	Ngwaketse West	7,727	7,774	7,822	7,870	7,917	7,942	7,966	7,990	8,015	8,039	8,051	8,063	8,076	8,088	8,100
Khakhea	Ngwaketse West	22,852	22,904	22,956	23,008	23,061	23,087	23,113	23,140	23,166	23,192	23,206	23,219	23,232	23,245	23,259
Kokong	Ngwaketse West	10,153	10,201	10,249	10,298	10,346	10,371	10,395	10,420	10,445	10,469	10,482	10,494	10,506	10,519	10,531
Kanaku	Ngwaketse West	835	838	840	842	844	846	847	848	849	850	851	851	852	852	853
Mahotshwane	Ngwaketse West	3,048	3,079	3,111	3,143	3,175	3,192	3,208	3,225	3,241	3,258	3,266	3,275	3,283	3,291	3,300

ITHOLOKE	**NGWAKETSE WEST**	1,671	1,671	1,672	1,673	1,674	1,674	1,674	1,675	1,675	1,675	1,676	1,676	1,676	1,676	1,676
AREA TOTAL		**136824**	**140730**	**144738**	**148818**	**152991**	**156362**	**160362**	**164469**	**168634**	**1728885**	**176173**	**180417**	**184775**	**189190**	**193693**

Table 6: Kgalagadi District by Demand Projections based on Population Projections

CENTRE	AREA	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
WERDA	**KGALAGADI SOUTH**	31,106	31,280	31,455	31,630	31,807	31,896	31,985	32,075	32,165	32,254	32,300	32,345	32,390	32,435	32,480
MAKOPONG	**KGALAGADI SOUTH**	26,315	26,416	26,517	26,618	26,720	26,771	26,822	26,874	26,925	27,976	27,002	27,028	27,054	27,080	27,106
KHISA	**KGALAGADI SOUTH**	6,994	7,033	7,072	7,111	7,151	7,171	7,191	7,211	7,231	7,251	7,261	7,271	7,281	7,291	7,301
OMAWENENO	**KGALAGADI SOUTH**	14,833 1	14,854	14,875	14,895	14,916	14,926	14,937	14,947	14,957	14,968	14,973	14,978	14,983	14,989	14994
TSABONG	**KGALAGADI SOUTH**	392972	394771	406972	419584	432625	444302	456547	469177	482198	495626	508195	521520	535249	549388	563953
KOLONKWANE	**KGALAGADI SOUTH**	5,112	5,114	5,116	5,118	5,120	5,121	5,122	5,122	5,123	5,124	5,125	5,125	5,126	5,126	5,127
BOGOGOBO	**KGALAGADI SOUTH**	3,984	4,025	4,066	4,108	4,151	4,188	4,225	4,263	4,301	4,340	4,368	4,396	4,425	4,454	4,483
MIDDLEPITS	**KGALAGADI SOUTH**	11,294	11,358	11,422	11,487	11,552	11,584	11617	11,650	11,683	11,716	11,732	11,749	11,765	11,782	11,799
KHUIS	**KGALAGADI SOUTH**	10,342	10,380	10,417	10,455	10,493	10,512	10,531	10,550	10,569	10,588	10,597	10,607	10,616	10,626	10,636
GACHIBANA	**KGALAGADI SOUTH**	3,960	3,968	3,977	3,985	3,994	3,998	4,002	4,006	4,011	4,015	4,017	4,019	4,021	4,023	4,026

RAPPELSPAN	**KGALAGADI SOUTH**	2,345	2,368	2,391	2,414	2,438	2,450	2,462	2,474	2,486	2,498	2,504	2,510	2,516	2,522	2,529
VAALHOEK	**KGALAGADI SOUTH**	2,2761	2,779	2,798	2,817	2,835	2,845	2,854	2,864	2,873	2,883	2,888	2,893	2,897	2,902	2,907
BOKSPITS	**KGALAGADI SOUTH**	7,017	7,048	7,079	7,111	7,142	7,158	7,174	7,190	7,206	7,222	7,230	7,238	7,246	7,254	7,262
STRUIZENDUM	**KGALAGADI SOUTH**	2,081	2,083	2,086	2,088	2,091	2,092	2,093	2,094	2,096	2,097	2,098	2,098	2,099	2,099	2,100
BRAY	**KGALAGADI SOUTH**	9,538	9,561	9,583	9,606	9,629	9,641	9,652	9,664	9,675	9,687	9,692	9,698	9,704	9,710	9,716
DRAAIHOEK	**KGALAGADI SOUTH**	12,018	12052	12,087	12,121	12,156	12,173	12,191	12,208	12,226	12,243	12,252	12,261	12,270	12,278	12,287
MAUBELO	**KGALAGADI SOUTH**	7,118	7,113	7,147	7,162	7,177	7,184	7,192	7,199	7,207	7,214	7,218	7,222	7,225	7,229	7,233
KHAWA	**KGALAGADI SOUTH**	3,418	3,428	3,439	3,449	3,459	3,465	3,470	3,475	3,480	3,486	3,488	3,491	3,493	3,496	3,499
KOKOTSHA	**KGALAGADI SOUTH**	8,413	8,433	8,453	8,473	8,492	8,502	8,512	8,522	8,532	8,542	8,548	8,553	8,553	8,563	8,568
MARALALENG	**KGALAGADI SOUTH**	4,356	4,374	4,391	4,408	4,426	4,435	4,444	4,452	4,461	4,470	4,474	4,479	4,483	4,488	4,492
MALESHE	**KGALAGADI SOUTH**	2,708	2,715	2,722	2,730	2,737	2,741	2,745	2,748	2,752	2,756	2,758	2,760	2,762	2,763	2,765
AREA TOTAL		558686	571173	584065	579372	611111	623154	635768	648766	662157	675956	688720	702240	716164	730499	745260

KANG	**KGALAGADI NORTH**	177873	183179	188582	194070	199661	204325	209476	214732	220031	225408	230350	237417	244703	252135	259760
TSHANE	**KGALAGADI NORTH**	14,126	14,168	14,210	14,252	14,294	14,315	14,336	14,357	14,378	14,400	14,410	14,421	14,432	14,442	14,453
HUKUNTSI	**KGALAGADI NORTH**	166611	171588	176725	182017	187474	192481	197810	203303	208949	214761	220193	226082	232150	238380	244788
LEHUTUTU	**KGALAGADI NORTH**	26,588	26,700	26,812	26,925	27,038	27,095	27,152	27,209	27,266	27,232	27,352	27,381	27,409	27,438	27,267
LOKGWABE	**KGALAGADI NORTH**	17,596	17,657	17,718	17,780	17,842	17,873	17,904	17,935	17,966	17,997	18,013	18,029	18,044	18,060	18,076
MONONG	**KGALAGADI NORTH**	905	901	897	893	889	887	885	883	881	879	878	877	876	875	874
NCAANG	**KGALAGADI NORTH**	1,086	1,092	1,098	1,103	1,109	1,112	1,115	1,118	1,120	1,123	1,125	1,126	1,128	1,129	1,130
HUNHUKWE	**KGALAGADI NORTH**	9,178	9,205	9,232	9,258	9,285	9,299	9,312	9,326	9,339	9,353	9,359	9,366	9,373	9,380	9,387
ZUTSHWA	**KGALAGADI NORTH**	3,242	3,285	3,328	3,372	3,416	3,438	3,461	3,483	3,506	3,529	3,541	3,552	3,564	3,576	3,587
NGWATLE	**KGALAGADI NORTH**	1,262	1,277	1,293	1,310	1,326	1,335	1,343	1,351	1,360	1,369	1,373	1,377	1,382	1,386	1,390
UKHWI	**KGALAGADI NORTH**	4,282	4,306	4,330	4,355	4,380	4,392	4,404	4,417	4,429	4,442	4,448	4,454	4,461	4,467	4,473

MAKE	**KGALAGA DI NORTH**	2,801	2,831	2,862	2,893	2,925	2,941	2,957	2,973	2,989	3,005	3,013	3,021	3,029	3,038	3,046
INALEGOLO	**KGALAGA DI NORTH**	4,295	4,326	4,357	4,388	4,419	4,435	4,451	4,467	4,483	4,499	4,507	4,515	4,523	4,531	4,539
PHUDUHUDU	**KGALAGA DI NORTH**	2,624	2,625	2,626	2,627	2,629	2,629	2,630	2,630	2,631	2,632	2,632	2,632	2,633	2,633	2,633
AREA TOTAL		432470	443141	454071	465243	476686	486555	497234	508184	519328	530719	541194	554251	567705	581469	595604