



Resilience in the Limpopo Basin: The potential role of the transboundary Ramotswa aquifer - Baseline report

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Yvan Altchenko, Nicole Lefore, Karen G. Villholth, Girma Ebrahim, Andrew Genco, et al.. Resilience in the Limpopo Basin: The potential role of the transboundary Ramotswa aquifer - Baseline report. [Research Report] USAID Southern Africa. 2016. hal-02329714

HAL Id: hal-02329714

<https://hal.science/hal-02329714>

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RESILIM : Resilience in the Limpopo River Basin Program

RESILIENCE IN THE LIMPOPO BASIN: THE POTENTIAL ROLE OF THE TRANSBOUNDARY RAMOTSWA AQUIFER

Baseline report – December 2016



Submitted by:



Implemented by:



In partnership with:



This report was made possible by the support of the American people through the United States Agency for International Development (USAID). Its contents are the sole responsibility of XRI operating as a subcontractor to Chemonics International, and do not necessarily reflect the views of USAID or the United States Government.

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Acknowledgements

Country reports were submitted to IWMI in contribution to this baseline report for South Africa by Thinah Moyo (University of Pretoria) and Botswana by Bothepha B. T. Mosetlhi (Botswana University).

Similarly, Summary Report on Hydrogeological Information for the Development of Subsurface Mapping for the Transboundary Ramotswa Aquifer, using Airborne Geophysics was submitted to IWMI by XRI Blue

The authors would like to acknowledge the contributions, in no specific order, from the Department of Water and Sanitation (DWS), The Department of Water Affairs (DWA), the Council of Geoscience (CGS), the Botswana Geological Survey (BGS), the Water Utilities Corporation (WUC), the Ngaka Modiri Molema District Municipality (NMMDM) and the Ramotshere Moiloa Local Municipality (RMLM).

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ACRONYMS

AFD	Agence Française de Développement
CGS	Council of Geoscience (South Africa)
DTRP	Department of Towns & Regional Planning
DWA	Department of Water Affairs (Botswana)
DWS	Department of Water and Sanitation (South Africa)
EWB	Ecological Water Requirements
FPL	Food Poverty Line
GDP	Gross Domestic Product
GEF	Global Environment Fund
GNI	Gross National Income
GSB	Geological Survey of Botswana
IDP	Integrated Development Plan
IGRAC	International Groundwater Resources Assessment
IPCC	Intergovernmental Panel on Climate Change
JPTC	Joint Permanent Technical Committee
LBPL	Lower-Bound Poverty Line
LIMCOM	Limpopo Watercourse Commission
MLH	Ministry of Lands and Housing
NGA	National Groundwater Archive
nMAR	naturalized Mean Annual Runoff
PES	Present Ecological State
RAD	Remote Area Dweller
RESILIM	Resilience in the Limpopo Basin program
RTBAA	Ramotswa Transboundary Aquifer Area
SADC	Southern African Development Community
SANBI	South African National Biodiversity Institute
SAP	Strategic Action Programme
SAWS	South Africa Weather Services
SDDC	Southern District Development Committee
SED	South-East District
SEDDC	South-East District Development Community
TDA	Transboundary Diagnostic Analyses
SO2	Wildlife Management Area n°2 of the Southern District
UBPL	Upper-Bound Poverty Line
TGLP	Tribal Grazing Land Policy
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USAID	United States Agency for International Development
VIP	Ventilated Improved Pit
WAB	Water Apportionment Board
WLE	Water, Land and Ecosystems
WMA	Wildlife Management Area

WRB	Water Resources Board
WUC	Water Utilities Corporation (Botswana)

1. Introduction

1.1. Project description

1.1.1. Project funding

The first phase of the *Resilience in the Limpopo Basin: The potential role of the transboundary Ramotswa Aquifer* project (referred to as the Ramotswa project) is co-funded by the Resilience in the Limpopo Basin (RESILIM) program¹ with matching funding from the CGIAR Research Program on Water, Land and Ecosystems (WLE),² the International Groundwater Resources Assessment Centre (IGRAC) and XRI. The first phase of the project runs from July 28, 2015 to February 27, 2017.³

RESILIM is funded by the United States Agency for International Development (USAID). It supports the riparian countries of the Limpopo River Basin (Botswana, Mozambique, South Africa and Zambia) in their efforts to improve the shared management of water resources and ecosystem services, and equitably address the economic, environmental and social needs of each of the countries, thereby enhancing the resilience of the ecosystems and the people. The overall objectives of the RESILIM program are as follows:

- Reduce climate vulnerability in the Limpopo River Basin
- Improve the conservation of biodiversity and the sustainable management of high-priority ecosystems
- Build the capacity of stakeholders in the basin to sustainably manage water resources and ecosystem services

WLE promotes a new approach to sustainable intensification in which a healthy, functioning ecosystem is seen as a prerequisite to agricultural development, resilience of food systems and human well-being. The objectives of WLE are to learn how to intensify farming activities, expand agricultural areas and restore degraded lands, while using natural resources wisely and minimizing the harmful impacts on supporting ecosystems.

IGRAC is the Global Groundwater Centre of United Nations Educational, Scientific and Cultural Organisation (UNESCO), and facilitates and promotes international sharing of information and knowledge required for sustainable groundwater resources development and management worldwide.

XRI is an advanced water exploration, evaluation, production and services company that utilizes a series of proprietary technologies and state-of-the-art procedures to map, monitor, produce, manage, sell and transfer both potable and non-potable water.

1.1.2. Project objectives

The overall objective of the RAMOTSWA project is to support a long-term joined vision and cooperation on the shared groundwater resources of the Upper Limpopo region, where the

¹ Chemonics as the contracting party for RESILIM, funded by USAID.

² led by the International Water Management Institute (IWMI)

³ A second anticipated 3-year phase of the project (RAMOTSWA-Phase 2) is presently proposed for funding to the US Global Development Lab.

states share significant and valuable underground freshwater resources as well as space for enhanced subsurface water storage. The project will facilitate and promote joint management and better groundwater governance focused on coordination, scientific knowledge, social redress and environmental sustainability, in order to reduce poverty and inequity, increase prosperity, and improve livelihoods and water and food security in the face of climate change and variability.

The specific objectives of phase 1 of the RAMOTSWA project are as follows:

- 1) Increase awareness of the importance and vulnerability of the transboundary Ramotswa Aquifer.
- 2) Improve understanding of the socioeconomic importance of the aquifer area, and the inequalities in water access and security across the population.
- 3) Improve understanding of the extent and hydrogeology of the transboundary aquifer resources under present and future climate and population projections.
- 4) Establish national and cross-border dialogue and cooperation on the Ramotswa Aquifer, and further encourage international cooperation on transboundary aquifers in the Southern African Development Community (SADC) region.
- 5) Develop tools for shared and harmonized management and monitoring of groundwater resources, aligned with the national water resources management processes.
- 6) Develop human and institutional capacity for shared and harmonized management and monitoring of groundwater resources.

Through multilevel diplomacy, the project will contribute to the building of trust and transparency in the development and use of groundwater resources in the border region, and it will encourage the states to enter into agreements on their shared aquifer(s).

1.2. Report objectives

This report presents the baseline assessment of the greater Ramotswa Transboundary Aquifer Area (RTBAA), which covers a small part of Botswana and South Africa in the Limpopo River Basin. The baseline report covers interdisciplinary aspects related to the biophysical and socioeconomic conditions of the RTBAA. It presents the climatic conditions, and the characteristics of surface water and groundwater. The water supply and sanitation are also described. It explains the socioeconomic context, including land cover/land use, and provides an initial analysis of the relationship between the current conditions in the study area and livelihoods in relation to groundwater resources. The report highlights the institutional setting, in particular, the stakeholders involved in water management. Finally, the report identifies key environmental issues linked with the groundwater resource and the existing data gap in RTBAA.

In addition, this report is directly linked with RAMOTSWA project objectives 2 and 3 and indirectly linked to objectives 4 and 5. It is also the first step for building the Joint Strategic Action Plan which will be the document delivered to the countries to go forward on the surface and underground water management in RTBAA by providing, not exclusively, guidelines for better monitoring and future assessment of the aquifer.

1.3. Study area

1.3.1. General presentation of Botswana and South Africa

Botswana is located in the north of South Africa which is at the southern tip of the continent of Africa. Botswana is an inland country while South Africa has about a total coastline of 2,800 km between the Atlantic and Indian Oceans. Botswana was the poorest country in Africa when it gained independence from Britain in 1966. Years later, supported by the discovery of diamond, Botswana moved to the upper-middle income country, being one of the fastest growing economies in the world. However, it still faces high levels of poverty and inequity. South Africa had a considered smooth political transition to the African National Congress which has been running the country since 1994 but it remains a dual economy with one of the highest inequality rates in the world, perpetuating inequality and exclusion (World Bank 2016). Table 1 presents some selected data about both countries.

Table 1. Comparison between Botswana and South Africa on selected data at national level.

		Botswana	South Africa
Area (km ²)		581,730	1, 219,090
Population		2,220,000	54,000,000
Proportion of females		51.2%	51%
Life expectancy at birth (year)		64.5	57.4
Human development index (value)		0.698	0.666
Gross Domestic Product (GDP) (2011 PPP USD billion)		15.81	350.1
Gross Domestic Product (GDP) growth (%)		4.4	1.4
Gross National Income (GNI) per capita (2011 PPP USD)		16,646	12,122
Gini Coefficient (2011)		53.1	63.4
Literacy rate (%)	Adult (ages >15)	86.7	93.7
	Male (ages 15-24)	97.9	99.3
	Female (ages 15-24)	94.2	98.5
Climate		Semiarid	Mostly semiarid; subtropical along east coast
Average annual rainfall range (mm)		250 - 650	464
Rainy season		November – March	Depend on province
Total internal renewable water resources	(km ³ /yr)	2.4	44.8
	(mm/yr)	4	37
Groundwater produced internally	(km ³ /yr)	1.7	4.8
	(mm/yr)	3	4
Per capita renewable water resources (m ³ /yr)		1,196	894

Sources: National data from World DataBank⁴, UNDP Human Development Reports⁵ and Margat and Van der Gun (2013).

⁴ <http://databank.worldbank.org/data/home.aspx>

⁵ <http://hdr.undp.org/en/data>

1.3.2. Project location and short description

The aquifer is located in the Upper Limpopo River Basin, precisely in the Marico and the Ngotwane sub-catchments. The focus area of the Ramotswa project is RTBAA. The climate of RTBAA is semiarid. Rainfall is strongly seasonal, with most of it occurring as thunderstorms during the summer period between October and April. Mean annual rainfall ranges from 450 to 600 mm and decreases from the eastern to the western side of RTBAA. Mean annual temperature ranges between 18 and 20 °C. Maximum and minimum temperatures are experienced in January and July, respectively. Climate projections foresee not only uncertain trends in rainfall volumes in the future, but a likelihood of an increase in intensity of rainfall events (Taylor et al. 2009). Floods are recurrent with the latest major flood occurring in South Africa in early 2009.

Botswana

RTBAA is located in the South-East District (SED) (Figure 1). Besides being the smallest district in Botswana in terms of area, it is also the most densely populated. The capital Gaborone and Lobatse lie in this district. Ramotswa acts as the administrative headquarters of SED. RTBAA includes the settlements of Ramotswa Town, Ramotswa Station (Taung), Boatile and the surrounding area. RTBAA is dominated by urban development with high economic growth and an increase in population.

The Ngotwane River (Figure 2) to the east forms the international boundary with South Africa. The topography is fairly hilly, which is typical for southeast Botswana. The altitude of the plains ranges from 1,000 to 1,050 meters (m) above mean sea level (amsl), whereas the altitude of the surrounding hills varies from 1,068 to 1,189 amsl (Figure 3). The hills and escarpments are remnants of erosion cycles which began in the Tertiary period. River infiltration into the aquifers occurs beneath the Ngotwane riverbed. The overall hydraulic gradient is 1:300 along the course of the river. The Taung and Boatile streams are tributaries of the Ngotwane River. All rivers are ephemeral and belong to the Limpopo River Basin.

While water infrastructure has kept up with urban growth in Botswana thus far, through the Gaborone Dam and a couple of long-distance water transfer schemes from northern parts of the country as well as from South Africa, the situation is presently dire with a recurrent, escalating drought, further exposing the growing water demands, and underperforming water management and disaster management systems. The ongoing drought (2015-2016) has also affected agricultural livelihoods, with almost total crop failure throughout the country. The southern part of the country is one of the most affected areas. Most of the water from the Ramotswa Aquifer is presently being abstracted in the Ramotswa Wellfield in Botswana. The value of groundwater from the productive Ramotswa Dolomite Aquifer has hitherto been discounted due to pollution from pit latrines (Beger 2001), but is currently being reused for water supplies since 2014. All urban wastewater is presently reused for peri-urban crop production and watering of golf courses.

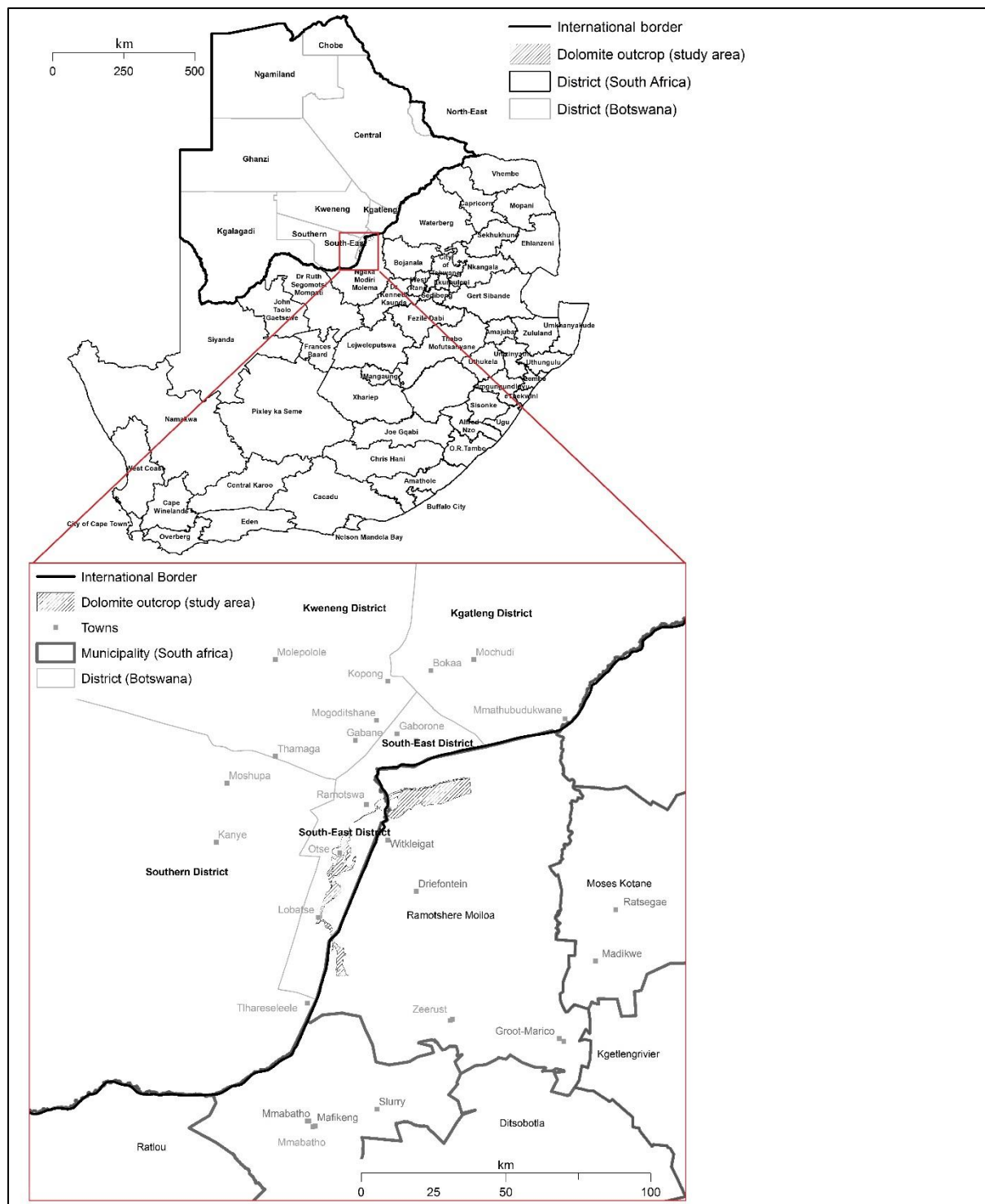


Figure 1. RTBAA location in the administrative context

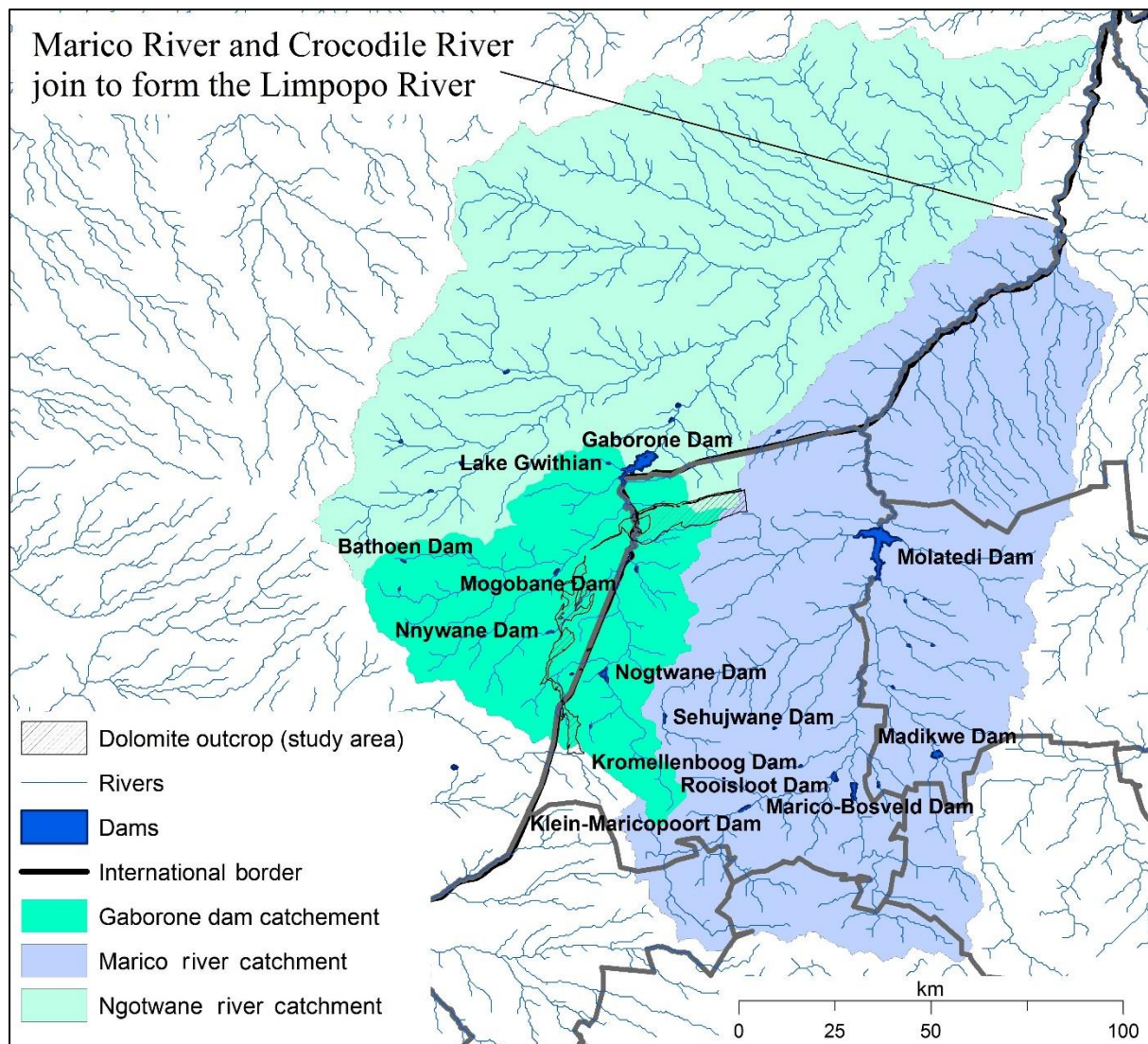


Figure 2. RTBAA locations in the hydrological/hydrogeological context

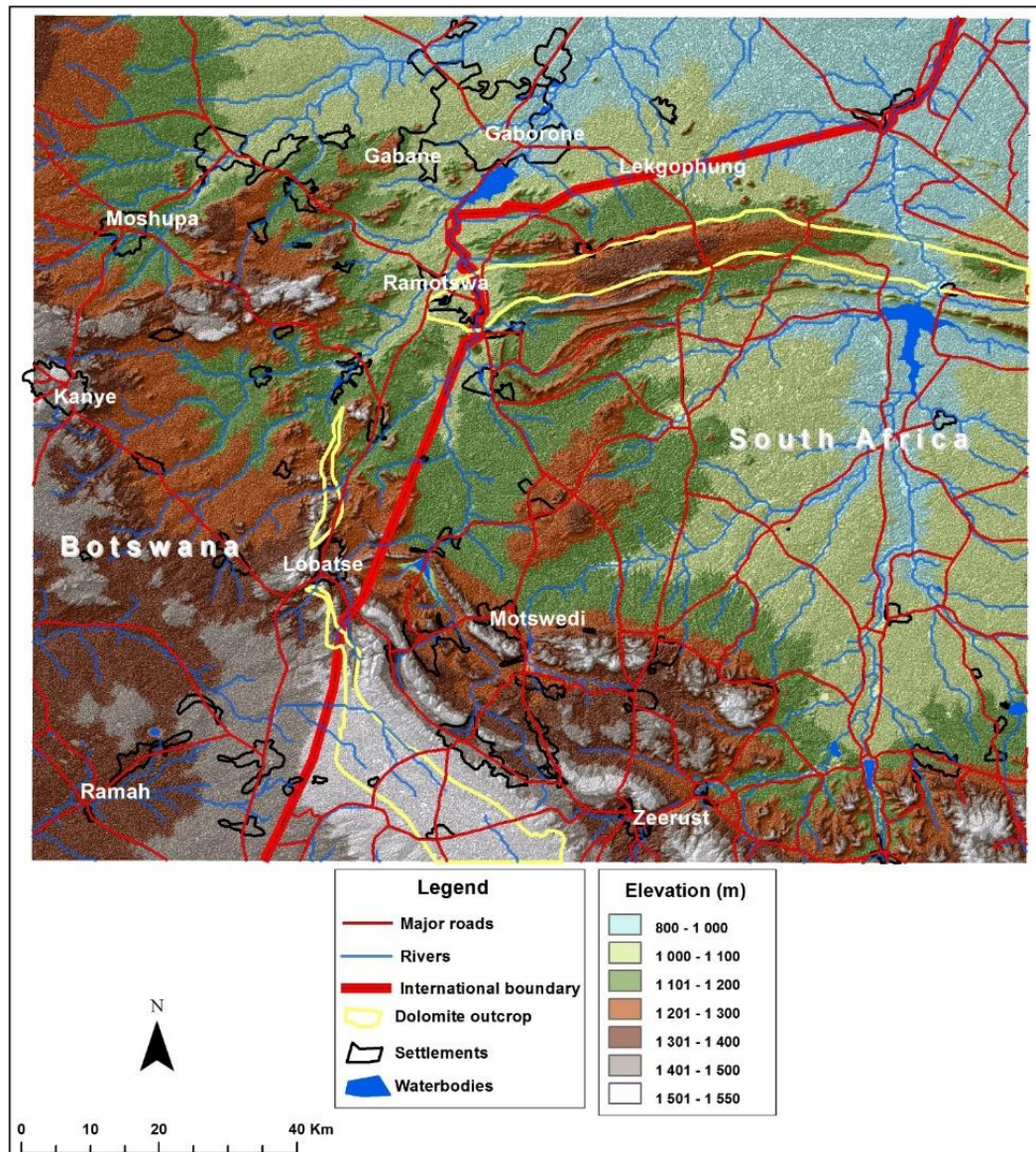


Figure 3. Elevation of RTBAA.

South Africa

RTBAA is located in the Ramotshere Moiloa Local Municipality⁶ which is situated within the Ngaka Modiri Molema District Municipality in the Northwest Province as shown in Figure 1. The Ramotshere Moiloa Local Municipality occupies an area of 7,193 km², which is 18% of the total area of the Ngaka Modiri District Municipality (Ramotshere Moiloa Local Municipality 2014). The local municipality has a stalling economic growth and a low population density, and the main urban areas are Groot Marico and Zeerust. Settlements of particular interest located close to the border with Botswana inside the RTBAA are from North to South: Swartfontein, Moshada, Wikleigat, Rietpan, Driefontein and Gopane.

The Ngotwane River, mentioned previously and Marico Rivers are the main river of the RTBAA. The Ngotwane River sources in South Africa and runs in the north direction to Botswana. It rises in Botswana about 11 kilometres south of Ramotswa. The Marico River to

⁶ Previously known as the Zeerust Local Municipality.

the east forms the boundary with the Moses Kotane Municipality (Figure 1). Main tributaries of the Marico River include the Klein and Groot Marico rivers, which are fed by a number of springs (locally referred to as 'eye' or 'oog') within the Groot Marico dolomitic aquifer compartment (Figure 2). These springs include the Molemane Eye and the Marico Eye. Elevation in the Marico catchment varies from 1,676masl to 858 masl, following a relatively important slope until the 1,000 masl (very upper catchment - first 50 km), and then an approximately constant slope to the Limpopo River (Figure 3).

RTBAA relies heavily on groundwater for most uses, with some irrigation schemes presently using larger shares of the water. Current plans for growth in the agriculture sector for emerging farmers are limited, as social inequalities are addressed (Pietersen et al. 2011). Also, the North-West dolomite aquifers receive considerable interest from national water planners because of rising water demands on the South African side, including the cities of Mafikeng, Zeerust and Lichtenburg.

1.3.3. Vegetation and wildlife

Botswana

RTBAA is part of the Hardveld Savannah (Bekker and De Wit 1991). The vegetation ranges from shrub savannah over savannah to tree savannah dominated by acacia (Department of Town and Regional Planning [DTRP] 1996; Ministry of Lands and Housing 2005a). The Hardveld is characterized by denser, taller and more diverse vegetation due to higher precipitation, heavier soil texture and higher nutrient content (Ministry of Lands and Housing 2005b). Much of the thicker vegetation is found along drainage lines, river valleys, floodplains, hills and rock outcrops. According to the Ministry of Lands and Housing (2005b), there are some areas of Sandveld vegetation, in particular, in the eastern side of the Southern District, interspersed by fossil valleys where vegetation changes relative to the adjacent Sandveld cover as a result of microclimatic factors, soil effects and shallowness of groundwater. Typically occurring in these fossil valleys are stands of species such as camel thorn trees (*Acacia erioloba* or *Acacia giraffe*), which have roots that extend to groundwater, hence enabling them to withstand droughts and grow up to 8 m. Such vegetation often provides shelter for livestock near water points.

The natural vegetation landscapes of RTBAA have previously supported different wild animals. Large wild animals, in particular, have been reintroduced in some of the freehold farms and small game reserves. In addition, the vegetation in SED supports over 300 bird species, including the Cape vultures that have a protected roost site at Manyelanong Hill near Otse, and many species of water birds found or protected around dams, including Mogobane, Mokolodi and Gaborone (South East District Development Committee [SEDDC] 2008/2009). The dams and other ephemeral surface water sources are also an important habitat for fish fauna, which are quite diverse in SED (Swedeplan 1994).

South Africa

The natural environment of RTBAA is primarily characterized by grassland and savannah biomes covering 5.6 and 94.3% of the district municipality, respectively. As documented by the South African National Biodiversity Institute (SANBI) there are 10 vegetation types: Carletonville Dolomite Grassland, Dwaalboom Thornveld, Dwarsberg-Swartruggens Mountain Bushveld, Highveld Salt Pans, Klerksdorp Thornveld, Madikwe Dolomite Bushveld, Mafikeng Bushveld, Moot Plains Bushveld, Subtropical Salt Pans and Zeerust Thornveld (SANBI 2007). The local municipality is characterized by prominent hills that run in an east-

west direction. Wildlife has been reintroduced and is protected within the game reserves, and includes white rhino, gemsbok, eland, springbok, steenbok, giraffe, jackal, hartebeest, zebra, kudu, duiker, warthog and impala. Birds found around the reserves include Southern Pied Babbler, Crimson-breasted Shrike, Pale Chanting Goshawk, Secretary bird and Kalahari Scrub-Robin, Cape Vulture and White-backed Heron.

2. Methodology

2.1. Delineation of hydrogeological and socioeconomic study areas

The study area has been defined taking into consideration the need to understand both the biophysical conditions of the aquifer, including the interaction between surface water and groundwater, and the socioeconomic importance of groundwater in a wider area. Figures 4 and 5 present the boundaries of the two complementary study areas.

Hydrogeological and hydrological study area

In terms of the hydrogeological assessment, the focus is on a buffer zone of approximately 5 km around the aquifer as delineated on the map of transboundary aquifers of the world (IGRAC 2015). This delineation is based on the outcrops of the aquifer formation. The buffer zone is chosen as the exact extent of the aquifer is unknown, and to include possible lateral extension of the aquifer underground (Figure 4). The dolomite formations with aquifer characteristics continue into South Africa, in both the northeastern and southeastern parts of the study area. The dolomite aquifers in the area tend to be compartmentalised by dikes (vertical impermeable volcanic structures) that crisscross the dolomite formations. To limit the study area, a natural cutoff of the transboundary part of the system will be determined by these dolerite dikes (not shown in Figure 5).

The hydrogeological study includes a hydrological analysis. The boundary for the hydrological study corresponds to the hydrological catchment of the Gaborone Dam, which encompasses a significant part of the aquifer, and the southern and western parts of the hydrological catchment of the Molatedi Dam (Figure 4). The reason for also using this area in our assessment is that it indicates the major flow routes and sources of surface water in the area. Since much of the water supply on the Botswana side is linked to the Gaborone Dam and other smaller dams in the catchment, including the Moladeti Dam in South Africa which transfers $7.3 \times 10^6 \text{ m}^3$ per year to Botswana, it is important to understand these systems and the linkages to the underground aquifer systems.

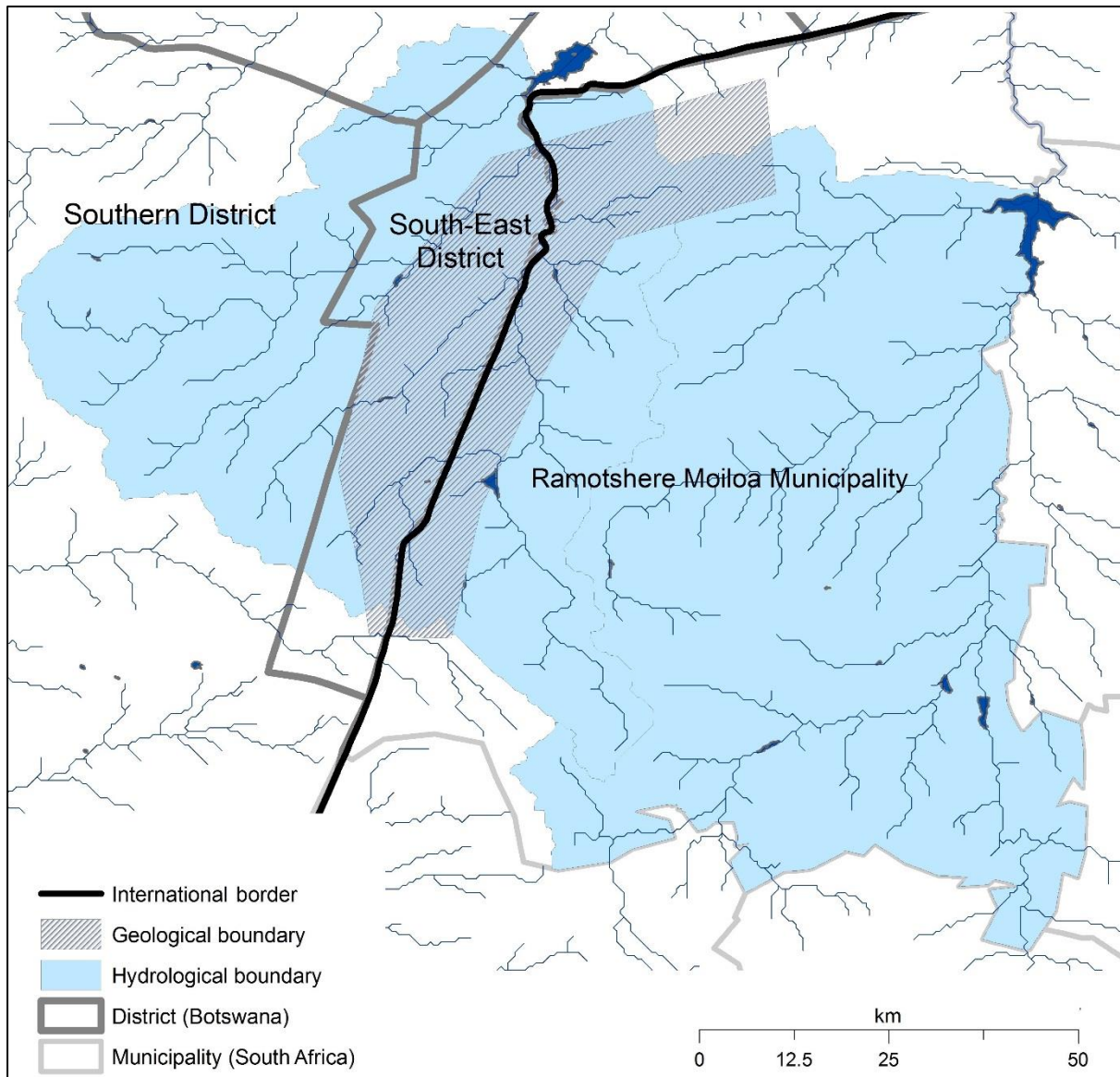


Figure 4. Geological/hydrogeological and hydrological boundary within the study area

Socioeconomic study area

In terms of the socioeconomic assessment of RTBAA, units of analysis will be determined by most appropriate political boundaries, such as municipalities (South Africa) and districts (Botswana) (Figure 1). In addition, specific communities around RTBAA will be targeted for socioeconomic assessments.

In Botswana, the immediate or core study area is SED, which is the district proximate to the aquifer boundary and immediate area. The broader catchment is made up of the entire Gaborone Dam Catchment, which includes SED, and part of Southern District (SD) and Kweneng District. Only settlements that fall within the broader study area (Gaborone Dam Catchment and SED) are considered in this assessment. However, Kweneng District is not included because only three settlements in this district are affected, while the district itself is very large and has many settlements. Figure 6 shows the study area boundary with the districts. In terms of the data presented in the report, Gaborone and Lobatse are physically in SED, but constitute districts on their own as main cities or towns; they are not included in the district. They are normally referred to as urban districts while others are rural districts.

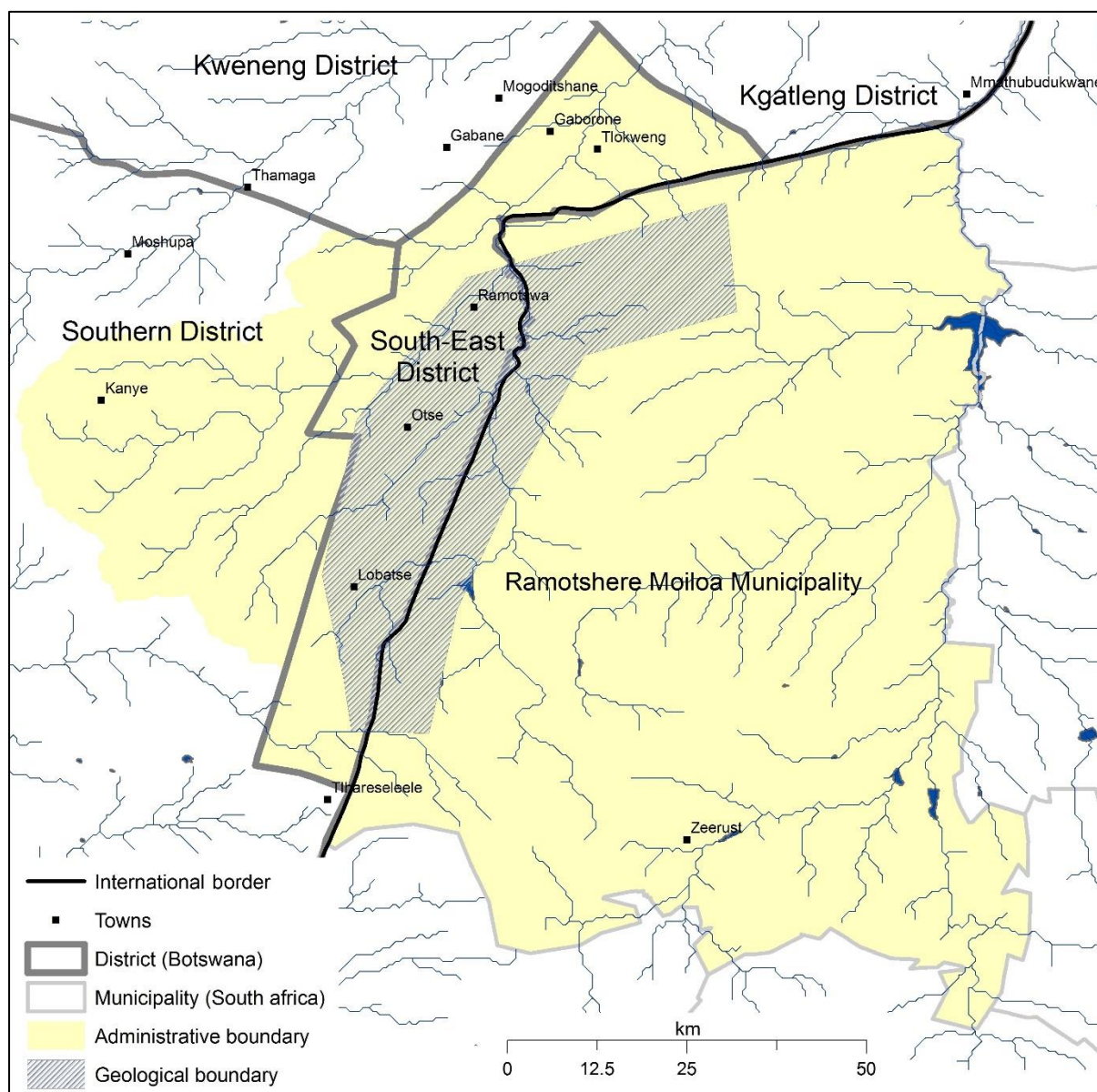


Figure 5. Administrative boundary of RTBAA.

In South Africa, the hydrogeological boundary covers only parts of the Ramotshere Moiloa Local Municipality in South Africa, but statistical data are reported based on administrative boundaries, municipalities being the smaller administrative units for all the data necessary for this report while some data are available at the settlement level. Thus, the Ramotshere Moiloa Local Municipality is the socioeconomic study area for the South African side (Figure 5).

2.2. Transboundary Diagnostic Analysis (TDA)

From a hydrogeological or technical viewpoint, a transboundary aquifer like the Ramotswa aquifer is no different from any other aquifer. As Agence Française de Développement (2011) states: “The only difference is that it underlies the territory of several countries, whose political borders add additional constraints that render a full understanding and rational management of such shared resources even more delicate and complicated. States commonly consider water in the subsurface within their borders as a national resource over which they wish to retain

absolute sovereignty. But “A country cannot manage ‘its’ transboundary groundwater without affecting – or being affected by – the management of its neighbours.”

For Botswana and South Africa to effectively deal with the (ground)water-related environmental and socioeconomic issues in the RTBAA, cooperation between the two countries is indispensable. Even though groundwater does not care about international borders there are complicating factors related to transboundary studies and management of transboundary resources: In general, there are no databases containing data from both countries, and collecting the relevant data for the study area is more complicated as the data need to be sources from different departments, institutes and databases in both countries. Synthesising these data is not straightforward as countries tend to have different protocols for data collection and categorising of data. A simple example is the naming of geological formations which is different in the two countries. Therefore harmonization of data is an important element of work in transboundary aquifer assessments. This baseline report brings together a lot of data and information from both countries, but it has not yet been feasible to fully harmonize all data into uniform categories. Throughout the project as much of the relevant information as possible will be uploaded to the Ramotswa Information Management System⁷ so that the data are easily accessible to all stakeholders in both countries.

Transboundary projects are often initiated to prevent or solve transboundary issues. But, by no means, should transboundary projects be limited to (potential) transboundary issues, as working on a transboundary basin can also prove to be a vehicle to initiate cooperation in solving shared or common issues. This baseline report describes the wider study area in terms of its biophysical and socioeconomic characteristics, and is a first step for the transboundary diagnostic by identifying groundwater-related issues (observed and emerging) in the area

The method of Transboundary Diagnostic Analyses (TDA) and Strategic Action Programme development (SAP) provides a good framework for the baseline assessment of the Ramotswa aquifer. The TDA/SAP methodology has been developed over time in projects on transboundary waters financed by the Global Environment Fund (GEF), and the approach provides a framework for a thorough analysis of a transboundary water basins. In addition to the TDA approach, the Ramotswa project also draws from the guidelines for multidisciplinary assessment of transboundary aquifers (IGRAC and UNESCO-IHP 2015). These guidelines have many elements in common with the TDA approach, but have a special focus on transboundary aquifers (while the GEF TDA approach is more generic for international basins). This section provides a short overview of the TDA approach. Information has been taken mostly from the GEF Transboundary Diagnostic Analysis/Strategic Action Programme (SAP) Manual (GEF 2013).

TDA aims to achieve the following:

- Identify and prioritize the transboundary problems.
- Gather and interpret information on the environmental impacts and socioeconomic consequences of each problem.

⁷ The Ramotswa Information Management System (RIMS) is a web-based system to view and analyze thematic maps and associated data of the Ramotswa study area. The RIMS aims to be a tool to inform stakeholders who are either depending on groundwater resources and/or are involved in the management of the resource.

- Analyze the immediate, underlying and root causes for each problem and, in particular, identify specific practices, sources, locations and human activities from which environmental degradation arises or threatens to arise.

The TDA provides the factual basis for the development of follow-up actions (SAP). The TDA is not merely a framework for reporting. The TDA approach should be part of a process of engagement and consultation with all the key stakeholders through the initial TDA development (as is applied in the RAMOTSWA project through the different stakeholder workshops/meetings and by involving parties from both countries throughout the project). The TDA approach is a mechanism to help the participating countries to 'agree on the facts'. Furthermore, the TDA approach should be seen as more than just an analysis of data and information. It is a powerful process that can help create confidence and trust among the (international) partners involved.

The TDA identifies and analyzes the transboundary problems, and their impacts and causes. Figure 6 provides an outline of the different steps in the TDA approach, which are all described in detail in the TDA/SAP manual (GEF 2013).

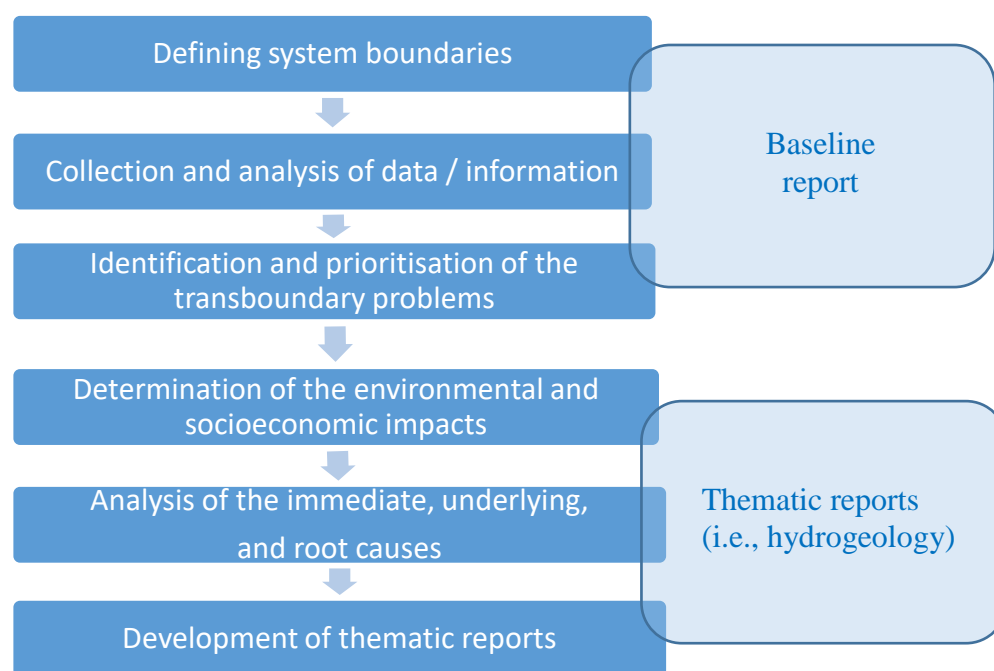


Figure 6. Schematic outline of the different steps in the TDA process (adapted from GEF 2013).

From previous TDAs of transboundary aquifers it was concluded that many of the problems facing aquifers are rather shared problems than transboundary problems. This was also the case in the recent assessment of the Stampriet Transboundary Aquifer System UNESCO-IHP et al. 2016. Identifying shared (or common) problems is still relevant as these problems may become transboundary in the future, and also because the recognition of shared/common problems which are not transboundary may be a reason for (intensified) cooperation between countries to jointly work on these problems.

The TDA is normally followed up with the development of a Strategic Action Plan, and this will also be the case in the Ramotswa project. The SAP is a negotiated document that should

ideally be endorsed at the highest level of all relevant sectors of government. The SAP establishes clear priorities for action (for example, policy, legal, institutional reforms, or investments) to resolve the priority transboundary problems identified in the TDA. A key element of the SAP is a well-defined baseline (this report). This enables a clear distinction between actions with purely national benefits and those addressing transboundary concerns with common or global benefits. Another key element involves the development of institutional mechanisms at the regional and national levels for implementing the SAP and monitoring and evaluation procedures to measure effectiveness of the outcomes of the process. A schematic representation of the TDA/SAP process is shown in Figure 7.

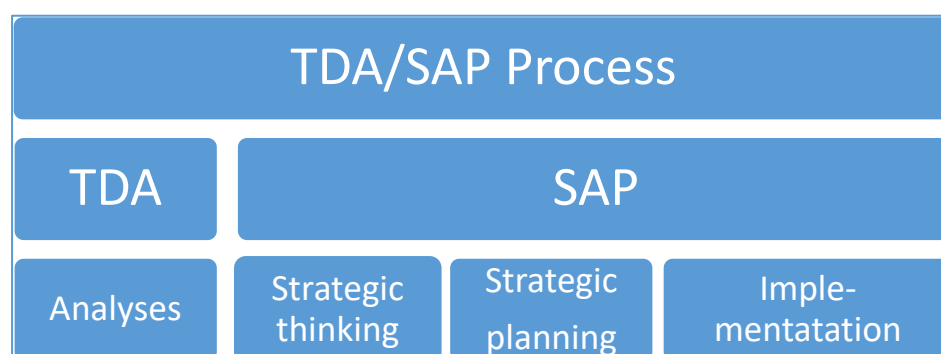


Figure 7. Schematic outline of the TDA/SAP process (GEF 2013).

2.3. Multidisciplinary team and approach for assessing the RTBAA

Sustainable management of the transboundary Ramotswa Aquifer is only possible when the states sharing the aquifer are willing to cooperate to assess the shared groundwater resources (IGRAC and UNESCO-IHP 2015). It requires insight into the hydrogeology of the aquifer, the environmental issues, relevant socioeconomic aspects of the aquifer area as well as legal and institutional settings in the two countries. The multidisciplinary character of the assessment and the complexity of the groundwater resources necessitate the involvement of several governmental bodies and civil organizations. Figure 8 presents the organigram of the multidisciplinary assessment team for the Ramotswa project, and shows the institutional origin of the different stakeholders and experts. The Assessment Coordinator (from IWMI) has a very important role in promoting and facilitating cooperation amongst the countries at both technical and governmental levels.

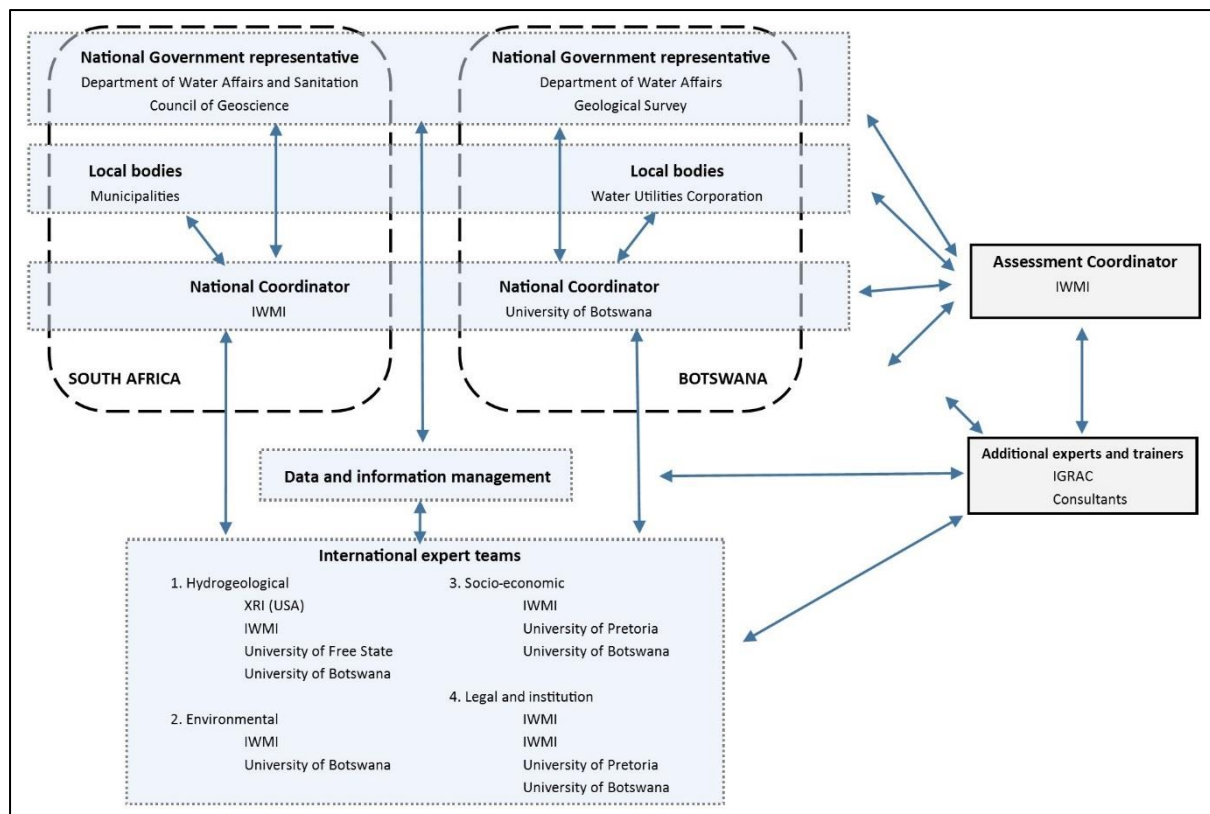


Figure 8. Organigram for the baseline assessment of RTBAA.

2.4. Data sources

The report is based on existing data and literature with a focus on Botswana and South Africa, on the study areas.

Hydrological and hydrogeological data were provided inter alia by the Department of Water Affairs (DWA) (Botswana), Department of Water and Sanitation (DWS) (South Africa), Council of Geosciences (CGS) (South Africa), Geological Survey of Botswana (GSB) and the South African Weather Service (SAWS). Data have been extracted from reports and databases, including online self-requests to freely available datasets such as HYDSTRA⁸ or the National Groundwater Archive (NGA).

Statistics Botswana was one of the key sources of data for the baseline study in Botswana. Data obtained from the organization included census reports for both 2001 and 2011, and various social, economic and environmental survey reports. Data were also sourced from several central and local government departments, including the Ministry of Local Government and Rural Development, Department of Town and Regional Planning, and Department of Lands. Among the documents obtained from these departments were district development plans, district settlement strategies, regional master plans, and district or regional integrated land-use plans.

Socioeconomic data presented for South Africa were collected from Statistics South Africa (Stats SA), local government annual reports and development plans. Stats SA is the national statistical agency for South Africa, and the data it provides covers the national censuses of 1996, 2001 and 2011. Additional data were obtained from a local municipality survey of 2007. Data were collected at local municipality level; hence, reporting on these data covers the area demarcated by an administrative boundary of the municipality. In some cases, data were only available for the district municipality, such as for health.

Data collection years, data definitions and types of data collected differ across countries, and prevent direct comparison across many of the data.

⁸ HYDSTRA is an application containing data on surface water, groundwater and rainfall.

3. Climate

Climate in the study area is generally considered as semiarid. Rainfall is seasonal, with a wet season occurring mainly between the months of October and March. It is within the same period that high temperatures are experienced, ranging between 30 to 32 °C in average during the day (maximum high temperature up to 41 °C) and between 16 to 20 °C on average at night. Low temperatures are usually experienced during the months of June and July, where minimum night temperatures near zero have been recorded over time.

3.1.Precipitation

Rainfall records in Botswana date as far back as 1922 (Lobatse Station). Other stations with significant data sets are Gaborone and Ramotswa in Botswana and Marico-Bosveld Dam in South Africa. In South Africa, six rainfall stations have been identified inside the Ramotshere Moiloa Local Municipality, although most are outside the strict hydrogeological boundaries of the study area. Figure 9 shows the location of the different rainfall stations.

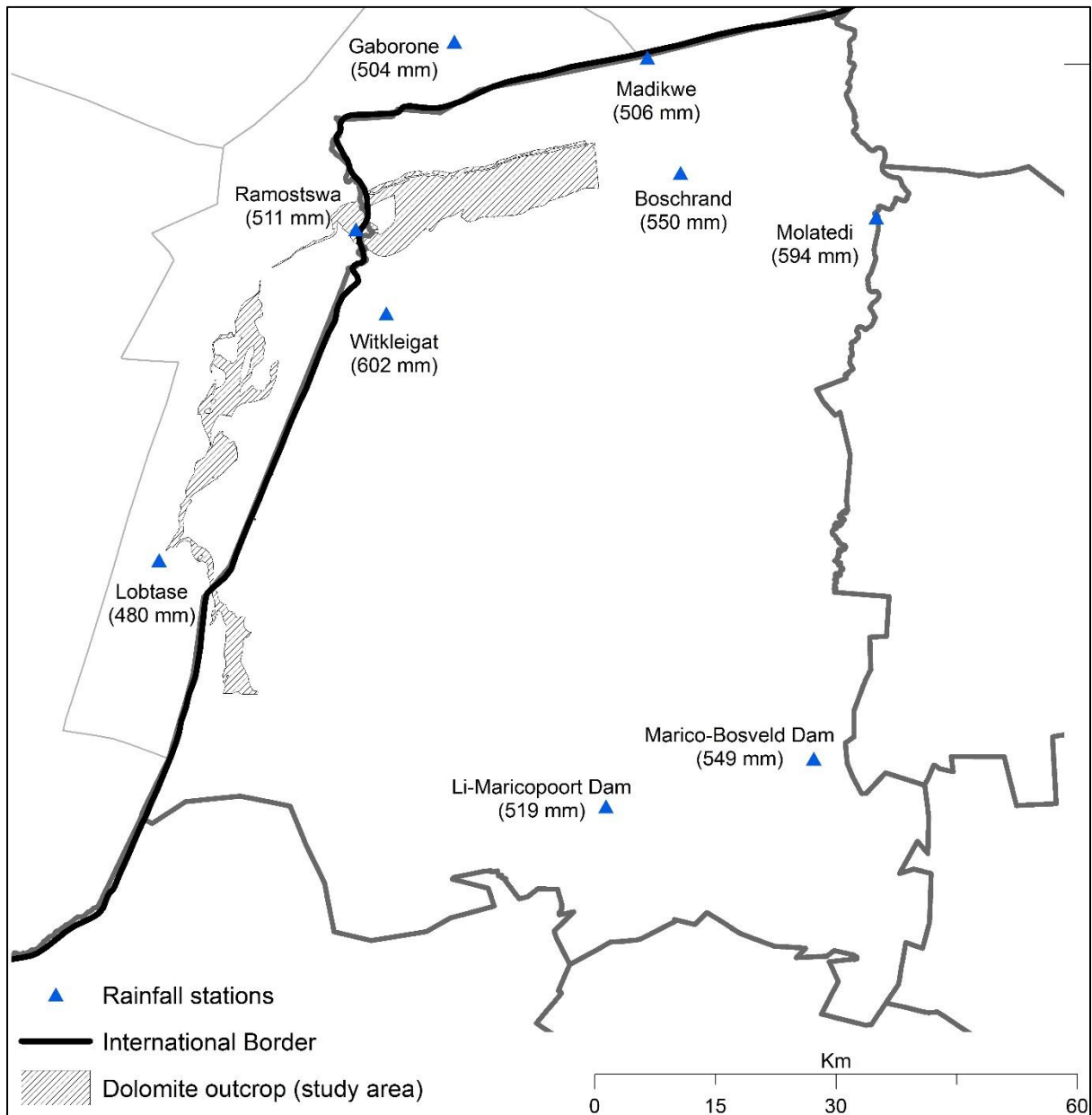


Figure 9. Location of the rainfall stations and their average annual rainfall over the period 1995-2015.

Long-term rainfall records show high rainfall interannual variability, with years of significant high rainfalls such as 1967, 1976 and 2001; and periods of low rainfalls, such as 1962, 1983 and 2002, and 2015 (Figure 10, Figure 11 and Figure 12). Regarding daily rainfall, the catchment has experienced high rainfall events, for example, in South Africa a rainfall burst of 240 mm of rainfall on the 7th of February, 2000 at Witkleigat (Figure 13). On the same date, Ramotswa Station (Botswana) recorded 209 mm (Figure 14).

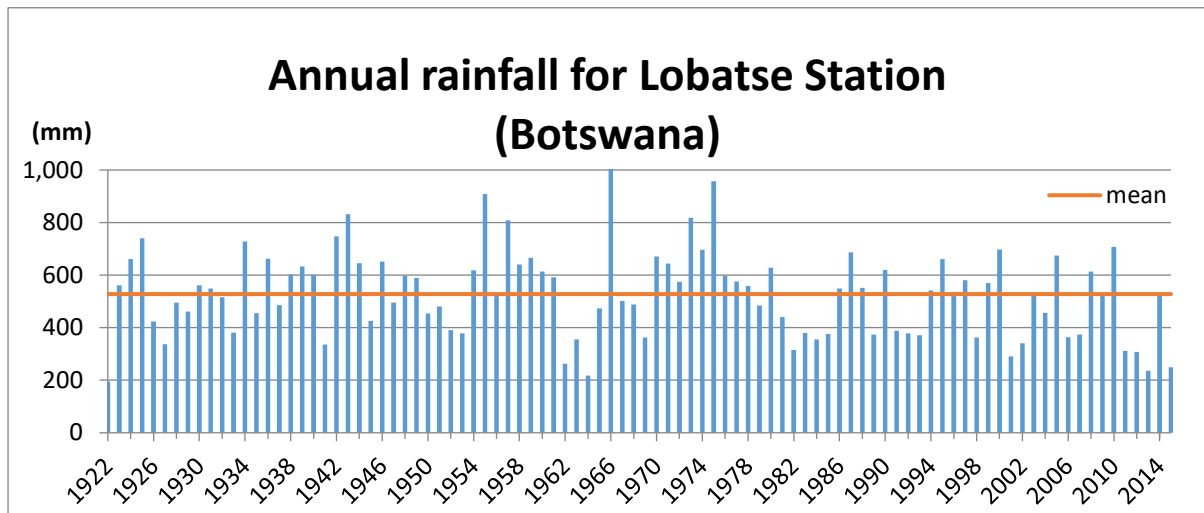


Figure 10. Rainfall for Lobatse Station (Botswana) from 1922 to 2015.

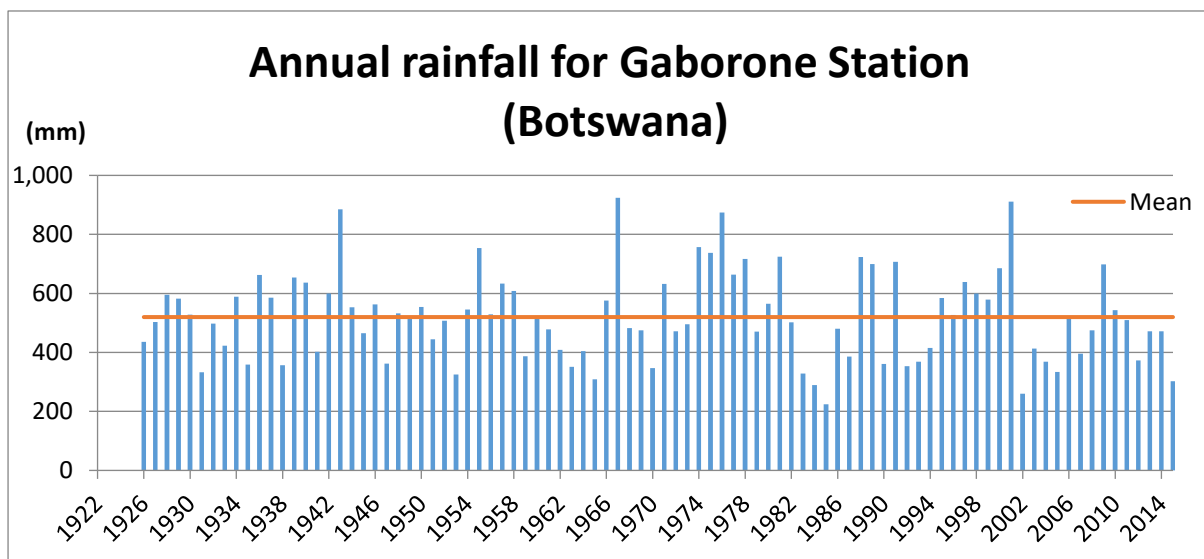


Figure 11. Annual rainfall for Gaborone Station (Botswana) from 1926 to 2015.

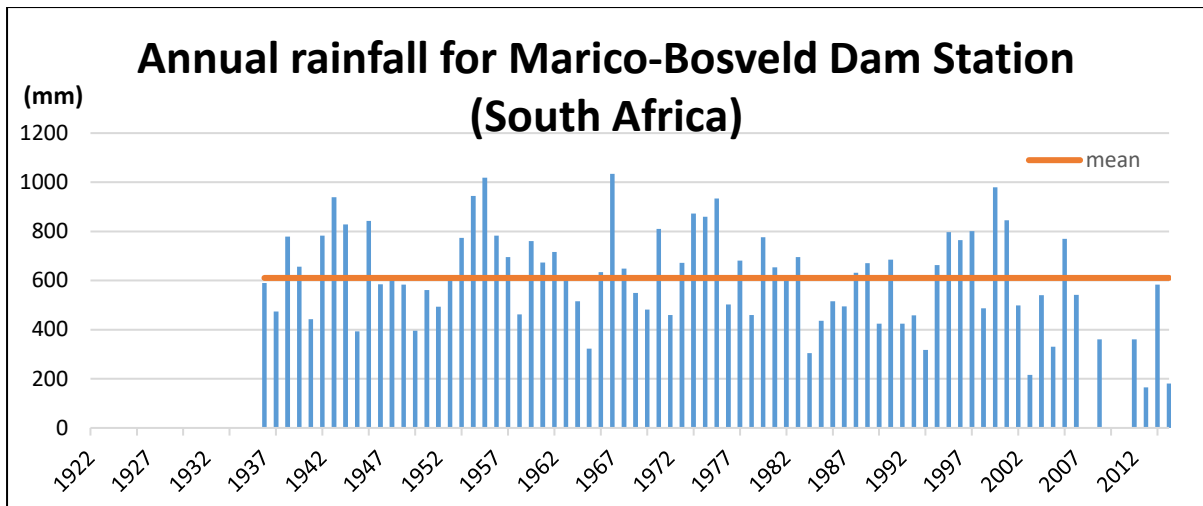


Figure 12. Annual rainfall for Marico-Bosveld Dam Station (South Africa) from 1937 to 2015.

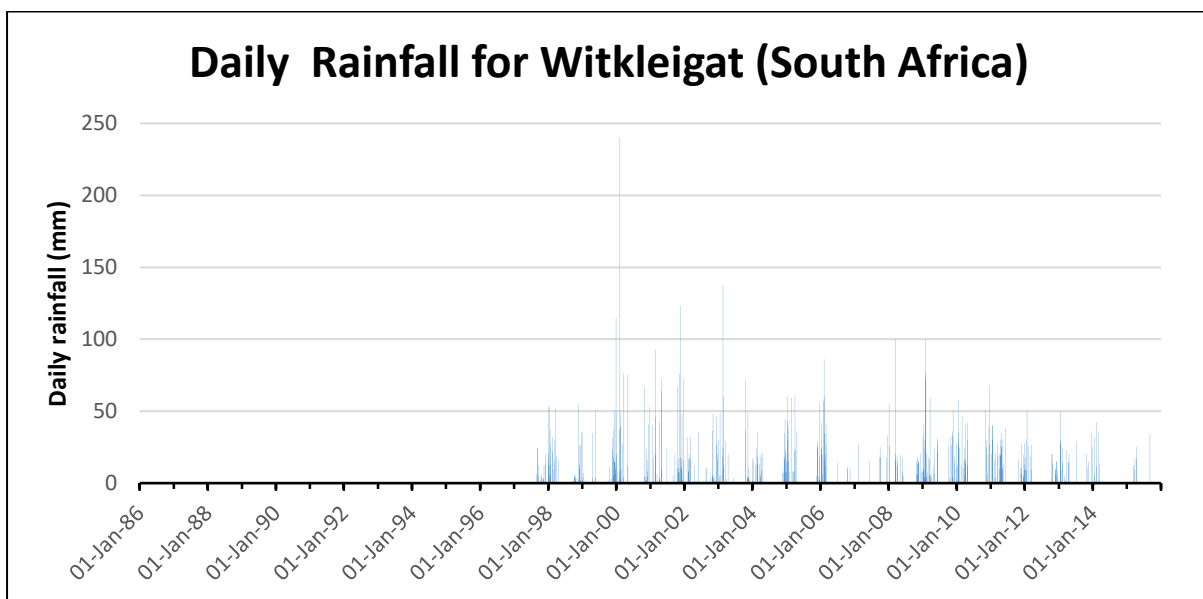


Figure 13: Daily rainfall for Witkleigat Station in South Africa showing one of the highest rainfall events in February 2000.

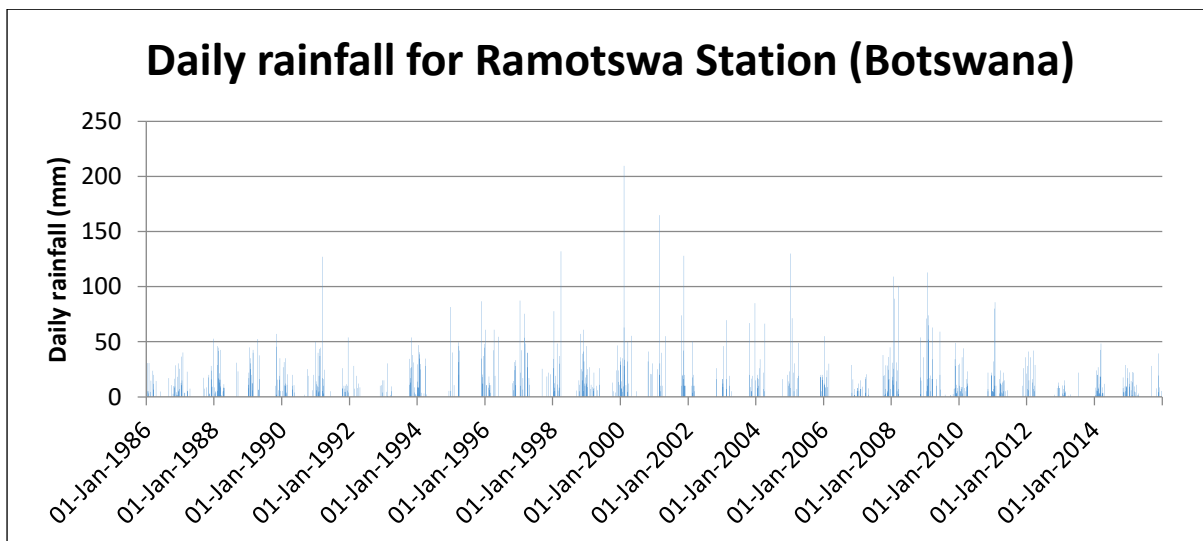


Figure 14. Daily rainfall values for Ramotswa Station in Botswana.

Monthly rainfall values for the closest stations from the hydrogeological boundaries are shown in Figure 15. The period used for comparison is 1995 to 2015 due to availability of data, except for Madikwe Station, where the period used is 2005 to 2015. It is clear from the graph that the months of December, January and February receive high rainfall events, with the peak occurring in January, where most stations recorded more than 100 mm of rainfall. In general, there are no significant differences between monthly rainfall values from Botswana and South Africa while it seems that annual rainfall is higher in the South Africa side.

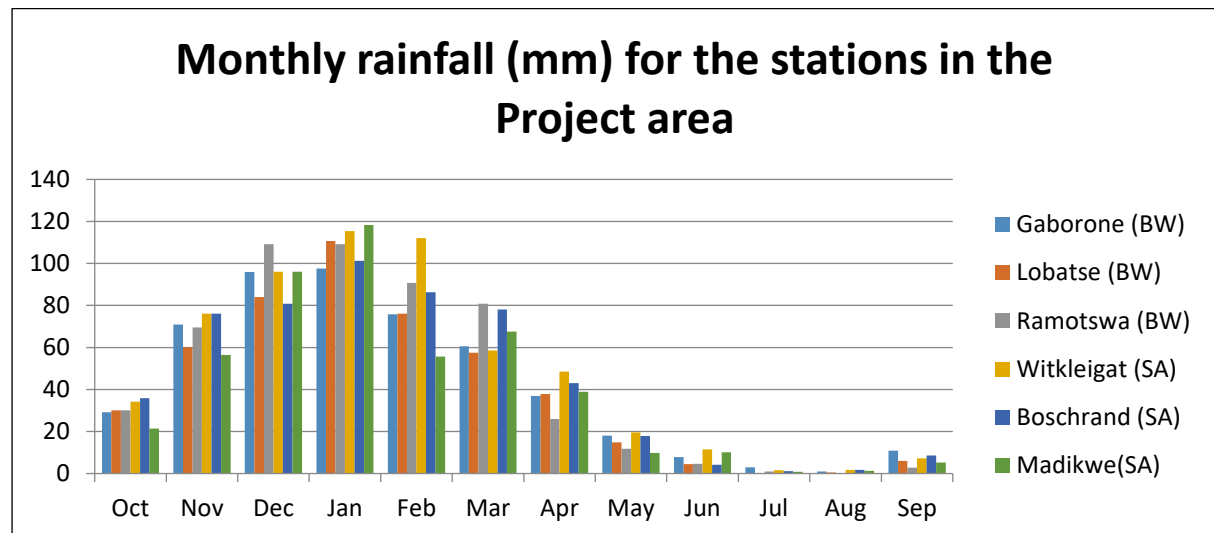


Figure 15. Monthly rainfall values for the stations in the catchment starting from the beginning of the rainy season in October.

Annual rainfall values of the same selected station (Figure 16) indicate some missing values from some stations in South Africa. However, there is evidence of declining rainfall levels during the period observed (1995-2015).

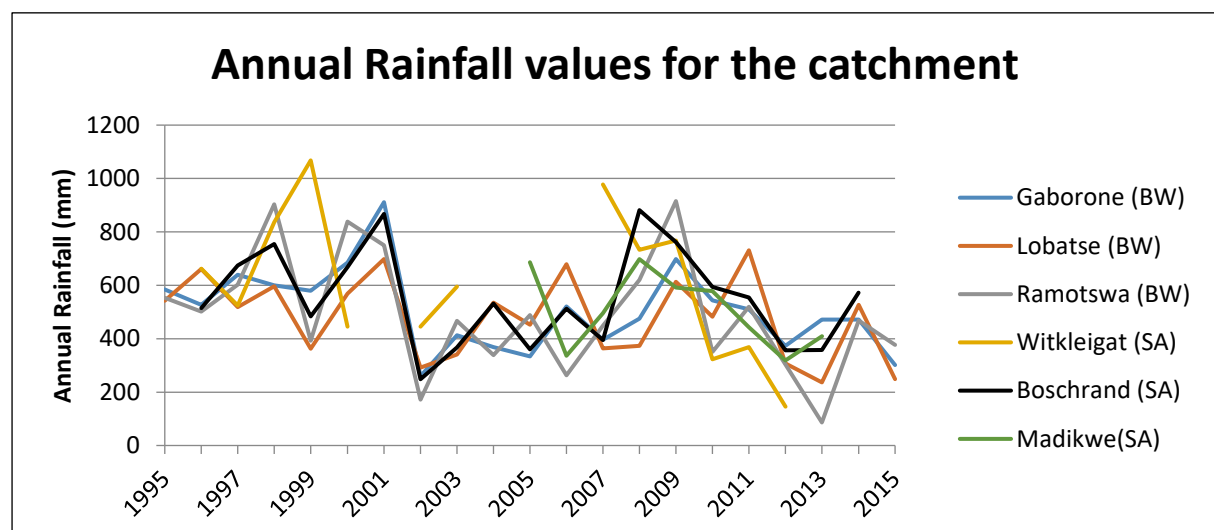


Figure 16. Annual rainfall for the catchment from 1995 to 2015.

Analysis of mean annual rainfall data indicates (Figure 9) that, in general, stations in South Africa recorded more rainfall than those in Botswana. However, this should be read with

caution owing to the presence of missing values for stations in South Africa. The mean annual rainfall varies between 480 mm (Lobatse, Botswana) and 602 mm (Witkleigat, South Africa).

3.2. Trends in rainfall data

There is a decline in annual rainfall levels during the period observed 1995-2015 (Figure 16). This is also supported by an analysis of the cumulative summation (CUSUM) values which is a sequential analysis technique used for monitoring change detection (Figure 17). The CUSUM values (Parida and Moalafhi 2008) reveal a period of intervention in the data series. This is a period at which change may have occurred due to climate change or variability. For example, when using a station with longer time series, the time of intervention happened in 1981 (shown by a dot in Figure 17), after which rainfall started declining. These findings are consistent with those reported in the literature, where the year 1981/1982 happens to be the period of intervention for most stations in Botswana (Parida and Moalafhi 2008; Kenabatho et al. 2012).

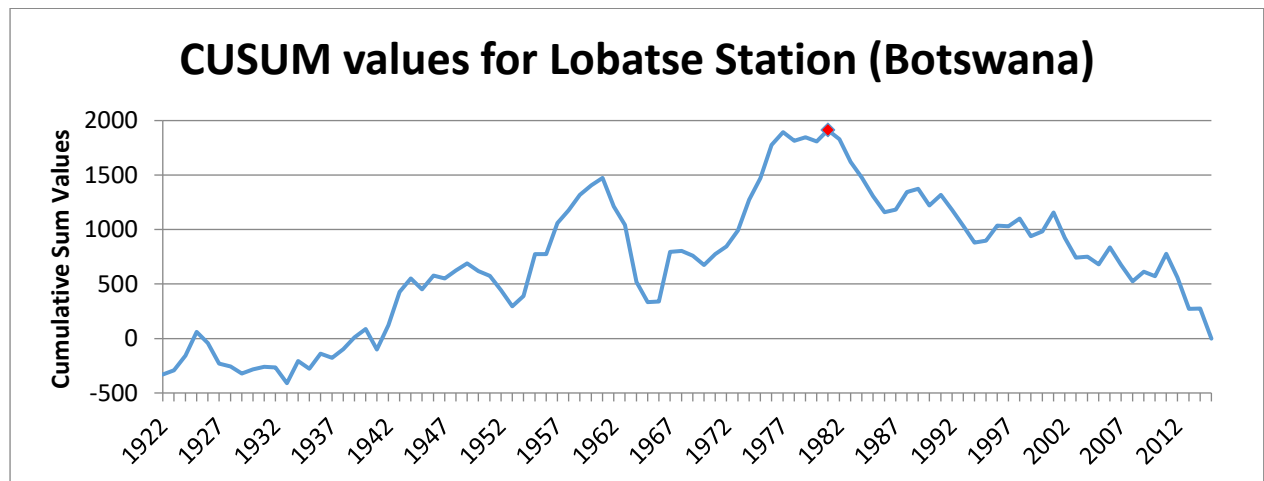


Figure 17: A plot of CUSUM values showing a point of intervention in the time series (Lobatse Station, Botswana).

Figures 18 and 19 show the temporal trends of annual rainfall for Gaborone and Lobatse stations, respectively. These stations show mild negative trends.

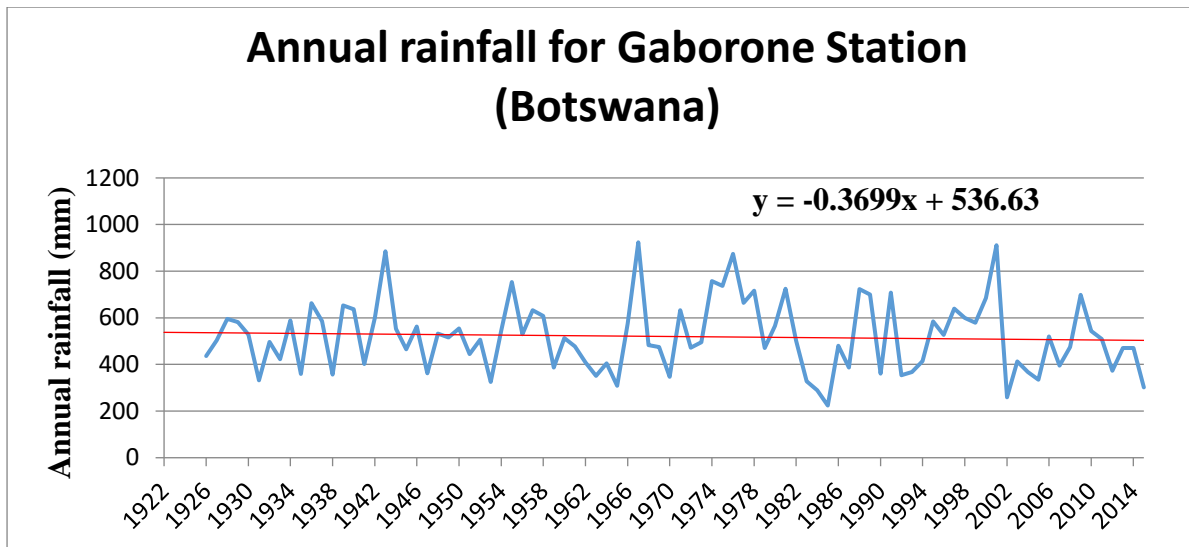


Figure 18. Rainfall trends for the Gaborone Station.

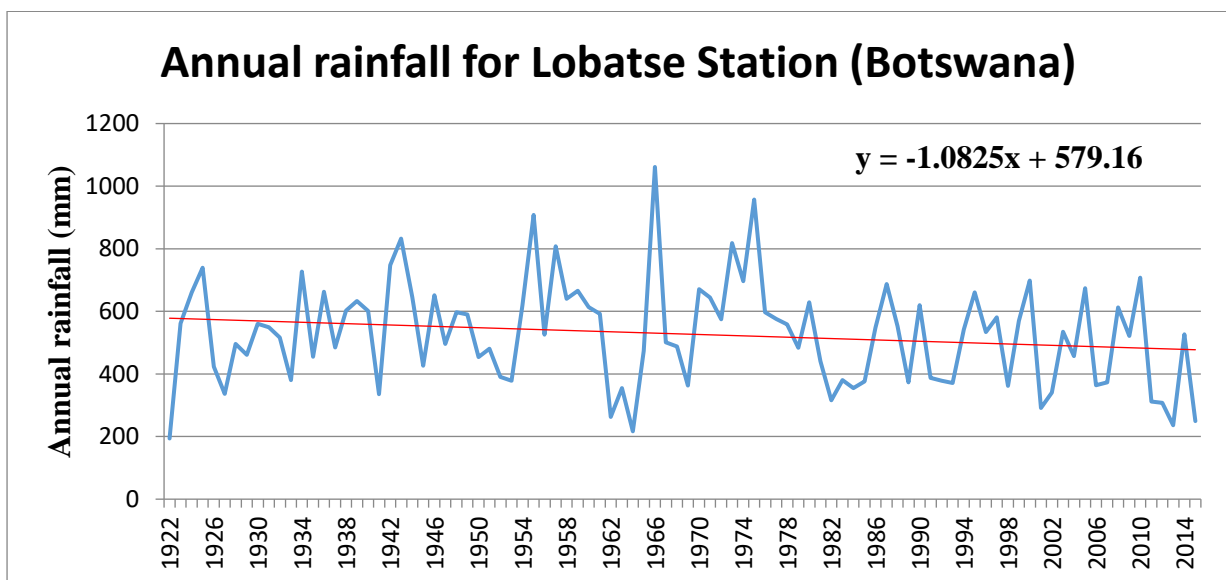


Figure 19. Rainfall trends for the Lobatse Stations.

3.3. Temperature and evapotranspiration

Climatic data are only available close to the study area at the Gaborone Station (Botswana), and Madikwe Game Reserve in South Africa (Figures 20 and 21). Data obtained for the Gaborone Station date back to 1984, and go to 2014, while those from Madikwe were from 2005 to 2015.

The highest maximum temperature recorded at the Gaborone Station was 41.5 °C, on 15th January 1989, while the lowest minimum temperature was -5.4 °C, recorded on 9th July 2014. For Madikwe, the highest temperature recorded between 2005 and 2015 was 40.9 °C, on 3th November 2010, while the lowest was -1.5 °C recorded on 2nd August 2006. Figure 22 shows monthly temperature (mean maximum) for the period between 2006 and 2015 for both stations. From this Figure it can be seen that November and December are the hottest months for both stations, while June and July are the coolest.

For the period under assessment, data show a very mild decline in maximum and minimum temperatures for the Gaborone Station while there has been a more significant increase in maximum temperature for the Madikwe Station over the last 10 years. Thus, these data are quite inconclusive about temperature trend in RTBAA. However, a study by Kenabatho et al. (2012) shows that temperature for most stations in Botswana started increasing after 1981/1982.

BOX 1 - Key findings:

- Decrease of the average annual rainfall.
- Not observed during the recorded period 1984-2014 but possible increase in temperature for a longer time serie.
- Decline in evaporation which needs to be better understood.

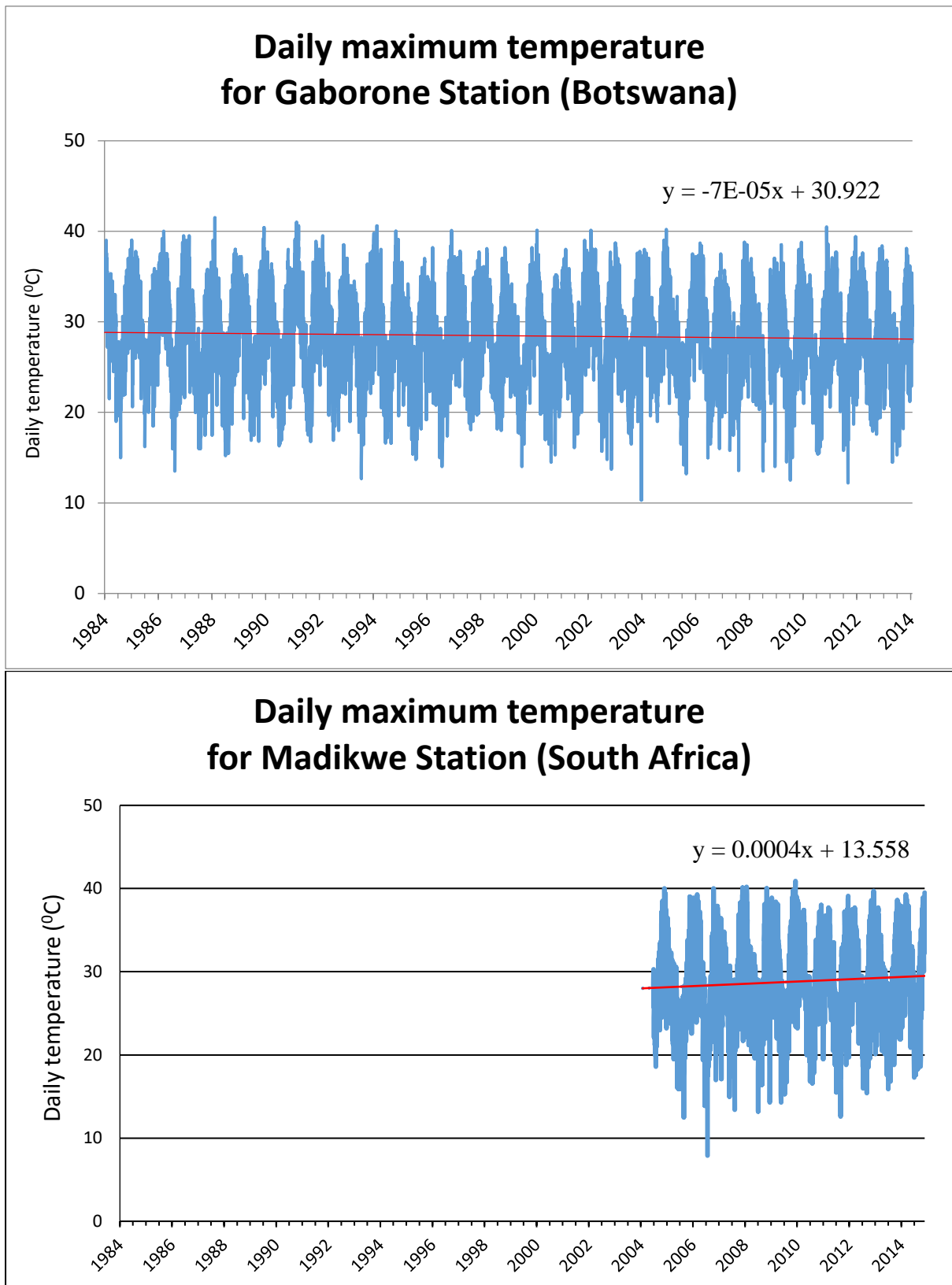


Figure 20. Daily maximum temperature and trend for the Gaborone Station (Botswana) and the Madikwe Station (South Africa).

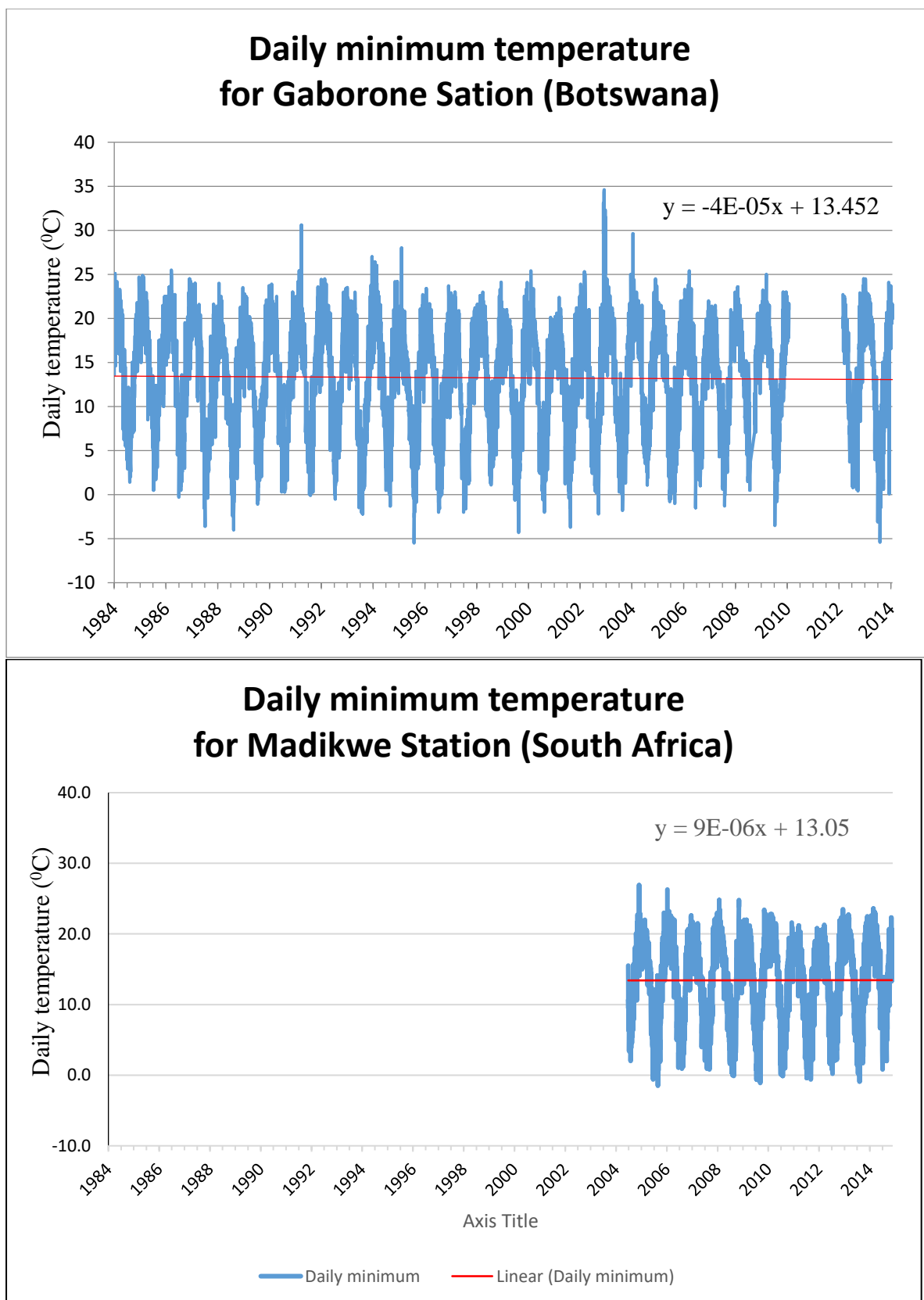


Figure 21. Daily minimum temperature and trend for the Gaborone Station (Botswana) and the Madikwe Station (South Africa).

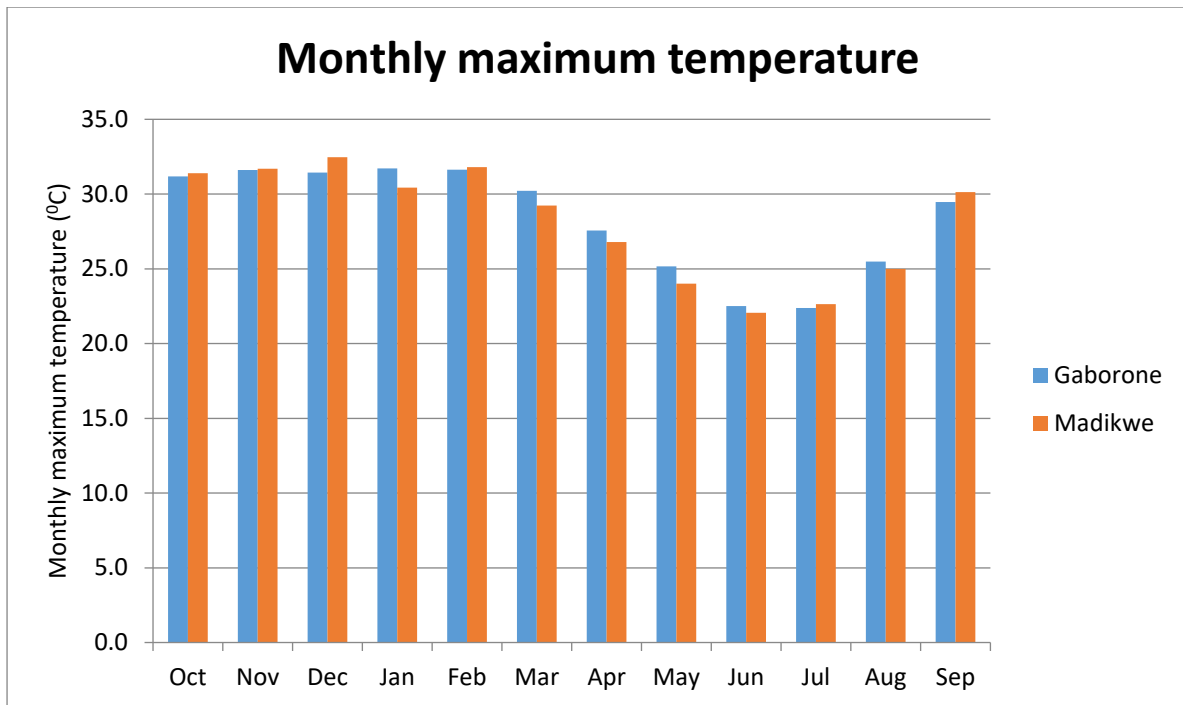


Figure 22. Monthly mean maximum temperature in the study area.

Regarding open water evaporation, two data sources have been used, both from South Africa. Figure 23 shows that October has the highest evaporation, followed by November and December. Average annual evaporation from the two stations is about 2,120 mm compared to an average rainfall of about 550 mm from the two stations. A time series for evaporation data shows declining evaporation levels (Figure 24), possibly indicating declining reservoir capacity levels between 1990 and 2015. This is because open water evaporation is dependent on available water in the reservoir.

BOX 2 - Data gap.

- Need for more evaporation data inside or close to the hydrogeological boundary. to understand the trend.

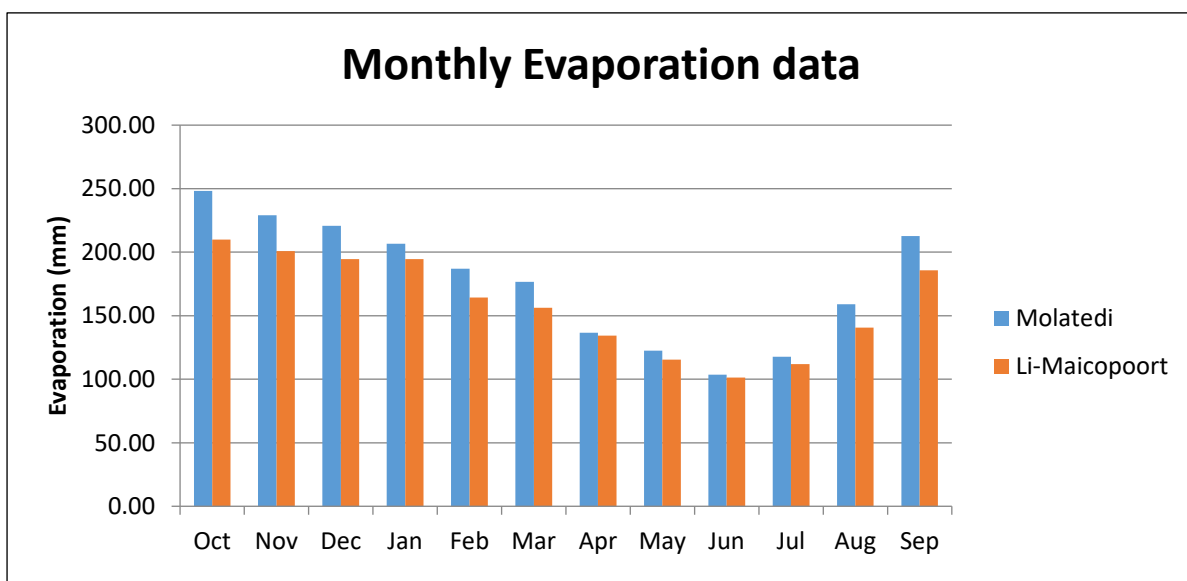


Figure 23. Evaporation data from Molatedi Dam and Li Maricopoort Dam

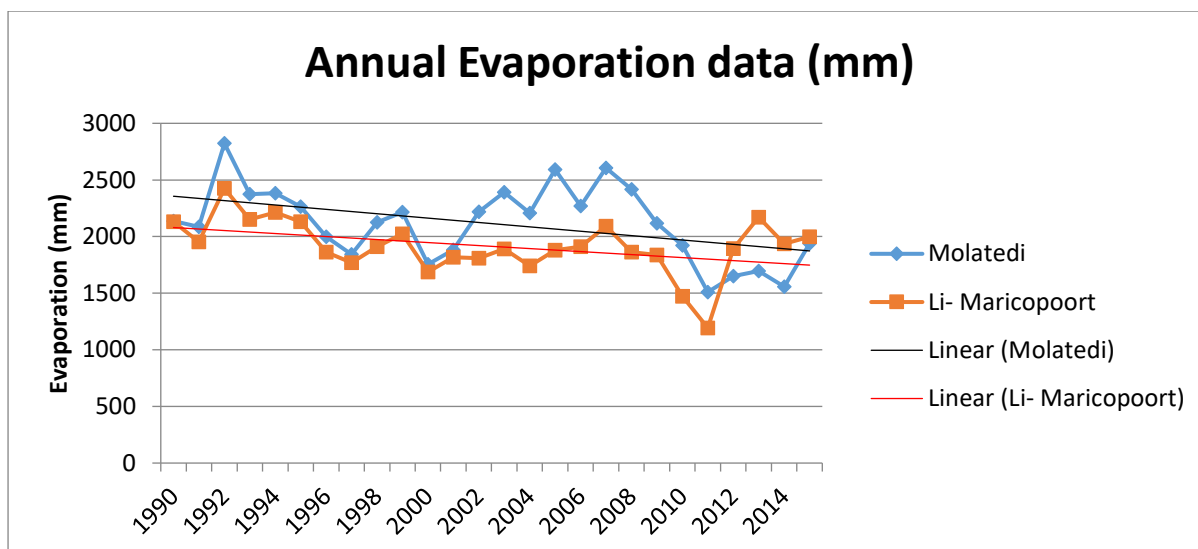


Figure 24. Annual evaporation data from Molatedi and Li Maricopoort dams.

3.4.Climate change

Botswana and South Africa, like many other countries in the SADC region are affected by the effects of climate change. Although such effects are area-specific, it is important that adaptive strategies are established in order to lessen the anticipated effects of climate change.

3.4.1. Climate projections

It is generally predicted that globally, greenhouse gas emissions could rise by between 25 and 90% by 2030 under the business-as-usual scenario leading to a temperature rise of up to 3 °C (IPCC 2007). According to the Intergovernmental Panel on Climate Change (IPCC), even with a smaller temperature rise of 1-2.5 °C, the effects of climate change could still lead to far-reaching implications on people's livelihoods, especially the vulnerable communities with low adaptive strategies. For Botswana, projections from climate models indicate a possible rise in temperature of 0.5-2 °C, and rainfall changes of between -9% and 3% by 2030, with rainfall in the southern part of the country likely to receive a marginal increase (Ministry of Environment, Wildlife and Tourism 2012). In addition, the spatial and temporal rainfall variations are expected to increase, while the rainfall season is expected to shorten as a result of climate change (ibid.). As for river flows, a decline of up to 13% is projected. These have implications on water availability, particularly inflows into the dams in the northern and southern parts of the country, and on food security, where a decline of 19% in cereal production is estimated (ibid.).

For South Africa, projections from Global Climate Models and Regional Climate Models as captured in the South Africa's Second Communication under United Nations Framework on Climate Change indicate warmer temperature conditions and extreme hot days increasing in frequency and intensity towards the end of this century (Department of Environmental Affairs 2011). Rainfall is generally projected to increase over the eastern portion of the country during summer months, while a decrease in summer rainfall is anticipated for the Limpopo Province as well as a decrease in winter rainfall for the Western Cape region (ibid.). The report further hints to the role of topography in enhancing the east coast increase in precipitation and slowing the rainfall loss on the Cape Mountains in the west.

3.4.2. Extreme events

According to the United Nations, between 1991 and 2000, over 665,000 people died in 2557 natural disasters, of which 90% were water-related (i.e., floods and droughts) indicating that adaptation to climate change is mainly about better water management (United Nations World Water Development Report 2012). In recent times, these extreme events have been notable in the study area. For example, in 2006, the village of Taung experienced floods leaving the villages stranded on either side of the Taung Bridge (Figure 22). On the other hand, there have been persistent incidents of drought in the study area, leading to the drying of the Gaborone Dam, where the dam levels reached its record lowest of 1.1% in 2015 (Water Utilities Corporation 2015).

For South Africa, four major categories of weather-related events have been identified as floods, droughts, wildfires and storms, with an estimated combined direct cost of R 8 billion (DEA 2011). With the advent of climate change, and an increase in extreme events, the cost associated with these events is likely to increase, particularly under high emission scenarios.

BOX 3 - Key findings:

- Spatial and temporal rainfall variation might increase.
- Extreme climatic event (drought/flood) might increase in frequency and intensity.



Figure 25. The floods of 2006 in Taung Village, near Ramotswa Village (*Source: Photo by B.P. Parida*).

4. Water Resources

4.1. Groundwater

This section describes the geology and aquifer characteristics in the geological study area (Figure 5). It is mainly adapted from the report on Hydrogeological Information for the Development of Subsurface Mapping for the Transboundary Ramotswa Aquifer, using Airborne Geophysics (XRI 2016), which is based on a literature review and available data from boreholes at the time of this report.

4.1.1. General geology of the Limpopo Basin

The Limpopo River Basin is a large and complex geologic area that extends into Botswana, Mozambique, South Africa, and Zimbabwe. Within the Limpopo River Basin, three Archean cratons are present: the Zimbabwe Craton, the Kaapvaal Craton (Figure 26) and the Limpopo Belt in between the two other cratons (not shown on Figure 26).

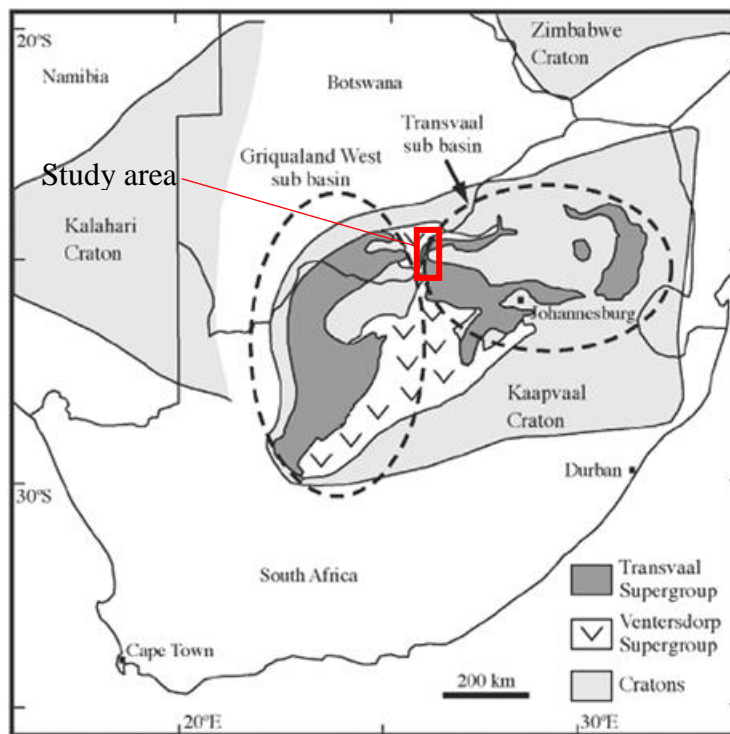


Figure 26. The Transvaal Supergroup inside the Kaapvaal Craton (Schröder et al. 2006).

The study area is within the Kaapvaal Craton. The shallower geology is made up of three lithological supergroups deposited onto the Kaapvaal Craton in different sedimentation cycles. These supergroups (Key 1980, 1983; Carney et al. 1994; Thomas et al. 1994) in order of deposition, are:

- The *Ventersdorp Supergroup* (also called Lobatse Group in Botswana) is composed of well-preserved and hardly deformed volcano-sedimentary rocks (Van der Westhuizen et al. 1991). This supergroup is expected to underlie the majority of the study area, with possible outcrops in the north and east.
- The *Transvaal Supergroup* contains three sequences (Cheyney 1996). The three sequences are preserved and exposed in two areas, the Transvaal Basin and the Griqualand Basin, which are separated by the Vryburg arc (Moore et al. 2001). The Transvaal Supergroup is one of the world's earliest carbonate platforms (Beukes 1986),

and is made up of carbonates, iron-formations, and minor silica-clastics (Meyer 2014). The Ramotswa aquifer is part of the Transvaal Supergroup.

- The *Waterberg Supergroup* consists of twelve (12) formations of reddish-brown ferruginous sandstones, shales, siltstones, and conglomerates (Chaoka 1988). While evidence pertaining to the Waterberg Supergroup is outside of the study area, its deposits are known to exist in the study.

4.1.2. Ramotswa aquifer geology

The Ramotswa Aquifer is within the western part of the Transvaal Supergroup. The three sequences of the Transvaal Supergroup include, in stratigraphic succession from the oldest to the youngest (Moore et al. 2001).

- The *Chuniespoort Group* is typified by basal quartz arenites, thick dolomite, and iron formations.
- The *Pretoria Group* is typified by alternating mudrocks and sandstones, with volcanic horizons, diamictites, and conglomerates.
- The *Rooiberg Group* is composed of volcanics, mudrocks, sandstones, and felsites.

Within the study area, the Ramotswa Aquifer is within the Pretoria Group and the Chuniespoort Group, the latter being the major water-bearing unit for the area (Meyer 2014). Table 1 includes a simplified stratigraphic column for the Pretoria and Chuniespoort Groups. The naming convention of the geologic formations of the Pretoria and Chuniespoort Groups used in this report is primarily consistent with names used in existing South African publications. Tables 2 and 3 correlate corresponding geologic formation names used in Botswana when applicable.

Table 2. Simplified stratigraphic column of the Pretoria and Chuniespoort Groups which compose the Ramotswa Aquifer. The naming conventions are consistent with South African geologic mapping and reports with alternate Botswana naming conventions listed in bold, when applicable. The Ramotswa Aquifer appears in grey.

Age (Ga)	Thickness (m)	Supergroup	Group	Formation		Lithology	
	~450-1500	Transvaal	Pretoria (Segwagwa)	Timeball Hill (Lephala Formation)		Mudrock (including shale), quartzite	
~2.72-2.05	10-150			Rooihooigte		Quartzite, mudrock, Bevets conglomerate/breccia member	
			Chuniespoort (Taupone)	Duitschland		Carbonaceous mudrocks, limestone and dolomite	
2.5				Penge (Ramotswa Formation)		Banded ironstone	
2.64 - 2.5	~400			Malmani Subgroup (Ramotswa Dolomite)	Frisco		Chert-free dolomite
	~600				Eccles		Dolomite and chert
	100-200				Littleton		Chert-poor dolomite
	300-500				Monte Christo		Chert-rich dolomite
	10-200				Oaktree		Chert-free dolomite
	25-30				Black Reef		Quartzite, conglomerate and shale

Table 3. Simplified explanation of the geologic formations composing the Ramotswa Aquifer.

Group	Geologic formations of the Ramotswa Aquifer				
	Lithologic description of formation	South Africa naming convention	Botswana naming convention	Ramotswa aquifer classification	Name of aquifer
Pretoria	Carbonaceous shale and quartzite	Timeball Hill Formation	Lephala Formation	Shale portion	Lephala Aquifer
Chuniespoort	Dolomite with varying chert content	Malmani Subgroup	Ramotswa Dolomite	Dolomitic portion	Ramotswa Dolomite

The main water-bearing unit of the Ramotswa Aquifer corresponds to the Malmani Subgroup (Chuniespoort Group) which is the dolomitic part of the Ramotswa Aquifer, called the “Ramotswa Dolomite” (Tables 1 and 2). Dolomite is used to describe the sedimentary carbonate rock which is composed, predominantly, of the mineral dolomite, a calcium-magnesium carbonate. The Malmani subgroup is a succession of five carbonate formations, which all contain dolomite and are divided based on chert-content, the variety, absence, or presence of stromatolite structures, intercalated shales, and erosional surfaces as described in Table 1 (Button 1973; Eriksson et al. 2006; Obbes 2000). Chert refers here to a very hard and

resistant microcrystalline variety of quartz while stromatolite structures are carbonate fossil constructions of biological origin (cyanobacteria or blue algae). Both chert and stromatolite structures are extremely resistant to weathering and remain in the soil that forms from the weathering of dolomite. A simplification of the geologic description of the five formations results in being referred to as either “chert-free” or “chert-rich” dolomite. While a current discrepancy in the existing geologic data exists because of the lack of harmonization of the 1/25000 geological map of South Africa, Figure 27 presents the surface geology within the study area, based on the 1/25000 digitalized map of Botswana and South Africa. The dolomite outcrops are highlighted on this map.

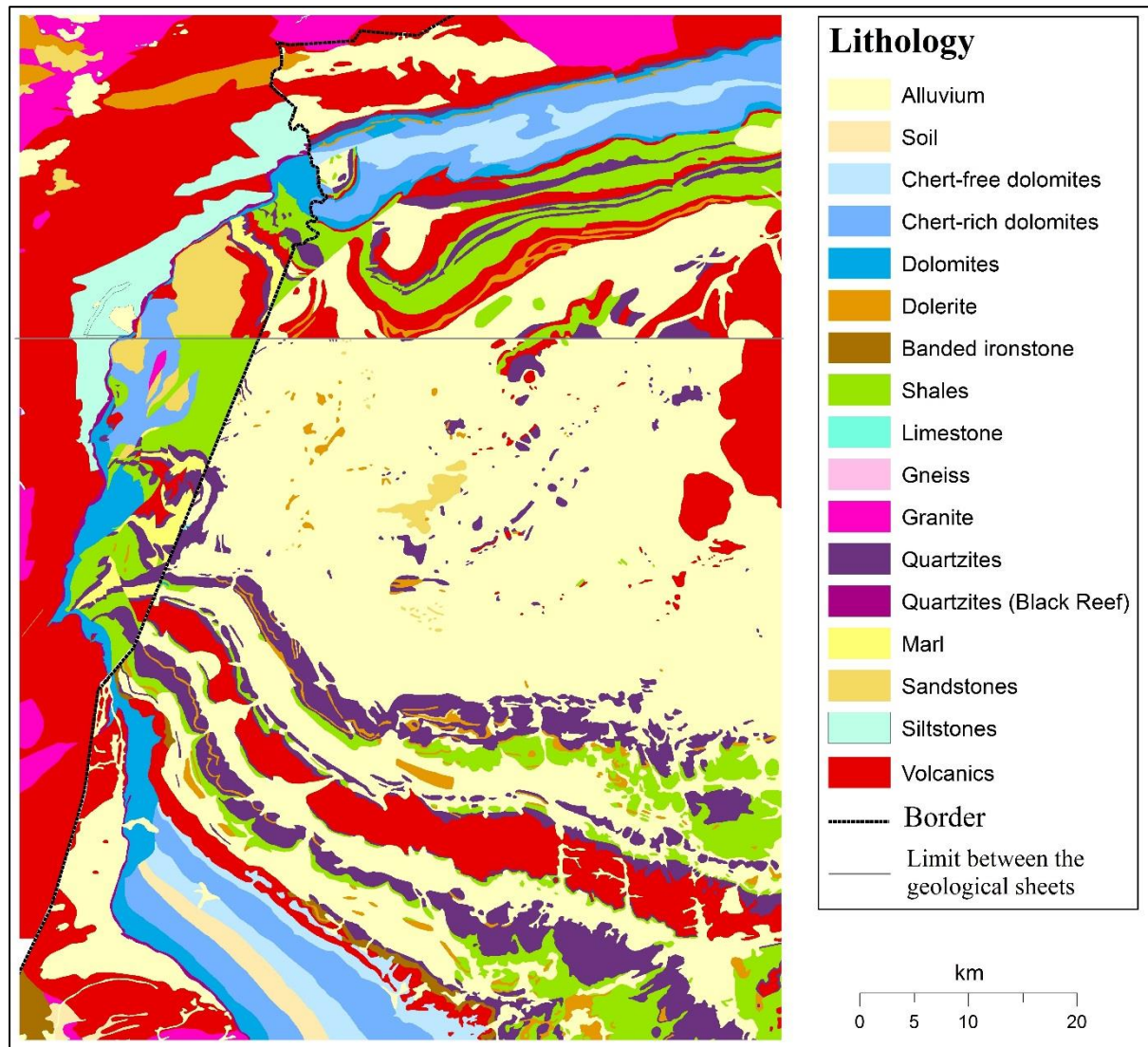


Figure 27. Lithology of the study area.

The Ramotswa Dolomite has been intruded by three vertical to near vertical dolerite dike swarms, which are large geological structures consisting of a major group of parallel, linear, or radially oriented dikes. The dike swarms correspond to mafic subvolcanic intrusions, with low permeability that act as barriers to groundwater flow (Meyer 2014). Dolerite are also called diabase or micro-gabbro. These dike groups

BOX 4 - Data gap.

- Need to harmonize the geological maps inside the two countries and in between the countries.
- Need to identify the dolomite compartments.

were recognized by Day (1980a, b) and strike North-South, North-North-West and East-West, depending on the age of the dike. The dikes are not shown in Figure 26. The dikes create compartments into the Ramotswa Dolomite and the compartments are thought to be independent.

As a complement, another water-bearing unit of the Transvaal supergroup is the Timeball Hill Formation of the Pretoria Group, called Lephala Formation in Botswana (Eriksson et al. 1995). This formation is generally referred to as the shale part of the Ramotswa Aquifer, and it will be called the “Lephala Aquifer” (Tables 1 and 2). In the southern portion of the study site, the Timeball Hill formation (Pretoria Group) overlays the Chuniespoort (Meyer 2014). The discordantly overlying (and older) Timeball Hill Formation is composed of a coarsening upward carbonaceous shale – hematite oolite-bearing quartzite unit overlain by a second carbonaceous shale, capped by a second glacial diamictite (the well-known Rietfontein diamictite) (Coetzee 2001). The Lephala Aquifer is not the main focus of the study because it is not the main water-bearing unit of the Ramotswa Aquifer.

4.1.3. Hydrogeology: Aquifer description

The Ramotswa Dolomite forms part of the Malmani subgroup in the Chuniespoort Group of the Transvaal Supergroup. The name Malmani was derived from the Malmani Spring having its origin on the dolomites and giving rise to the Malmani River. The Ramotswa Dolomite,) is the main water-bearing unit of the Ramotswa Aquifer, which is the primary focus of this study. Within the Ramotswa Dolomite formations, it is interpreted that chert content is a primary factor in aquifer productivity. Previous work from Jans van Rensburg (2002) has interpreted that the Frisco, Oaktree and Lyttleton Formations are poor aquifers (chert poor); and the Monte Christo and Eccles Formations are important water-bearing formations (chert-rich). The hydraulic conductivity is enhanced by fracturing and karstification (Ranganai et al. 2002). Karstification is a natural process of dissolution of soluble rock such as limestone and dolomite by infiltration of rainwater which is generally acidic, allowing such dissolution. It is characterized by underground drainage systems with sinkholes and caves. The Ramotswa Dolomite aquifer (about 120 meters thick) has low primary porosity (Staudt 2003) but it is very heterogeneous due to this fracturing. However, it contains two karst zones: the upper (20 to 50 meters thick) and lower (25 to 50 meters thick) karst zones that have high transmissivity and storativity. These two karst zones correspond to potentially good areas for groundwater abstraction. The source of recharge to the upper karst zone is thought to be direct rainfall infiltration and the Ngotwane River, in spite of the ephemeral flow (Beger 2001). Outside the aquifer study area and downstream of the Molatedi Dam, the perennial Marico River is believed to be a source of recharge of the upper karst zone as the river is crossing the dolomite outcrop. The locations of the Ngotwane and Marico rivers in relation to the study area are shown in Figure 3. Groundwater discharge occurs mainly in South Africa under springs and eyes, eyes being a spring from a circular or

BOX 5 – Key findings.

- There are two aquifers in the study area: the Lephala Aquifer and the Ramotswa Dolomite, the latest being the major water-bearing unit and the focus of the project.
- Groundwater is found in the dolomite when there is karstification.
- The Ramotswa Dolomite corresponds to five dolomites referred to as either “chert-free” or “chert-rich” dolomite, the most important water-bearing formation.
- Dikes create compartments inside the Ramotswa Dolomite.

oval bowl-shaped surface depression sinkhole. The main discharge area is mainly located in the southern part of the study area, on the north of the dolomite outcrop where the more noticeable springs are found.

Of lesser importance is the Lephala aquifer located within the shales, quartzites and conglomerates of the Lephala Formation (Pretoria Group), which plays a role in local hydrogeology of the urban area of Ramotswa. The Lephala Aquifer is not affected by karstification and has two fissured zones, the upper with a thickness of 30 to 40 meters and the lower, which is approximately 30 meters thick. The fissured zones correspond to the area with potential groundwater abstraction possibility, and yields within the Lephala depend on the location relative to the fissured zones as well as to the river. The Ramotswa dolomites and the Lephala Aquifer are thought to have a local hydraulic connection through the north-south trending fracture zones. This aquifer is also anisotropic due to this fracturing, and has low primary porosity (Staudt 2003). Surface runoff and the river account for the recharge within the Lephala (ibid.) while the discharge area is uncertain.

BOX 6 - Data gap.

- Need to confirm the identification of the discharge locations (springs).

Finally, Figure 28 shows the potential springs/depressions using satellite images but improved fieldwork is necessary to check the veracity of the identified springs/depressions and to determine the source of the groundwater (dolomites or shales).

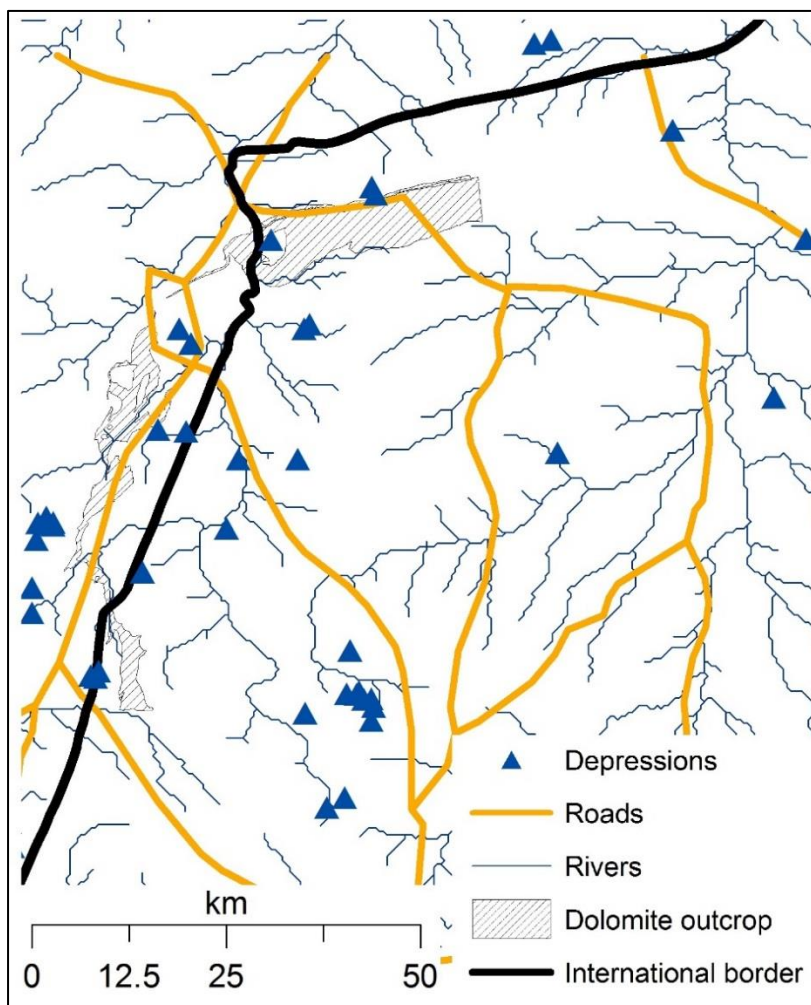


Figure 28. Potential spring and depressions from satellite imagery analysis

4.1.4. Hydrogeology: Groundwater level and aquifer properties

Data source and water table

Data for the groundwater level and the aquifers characteristics are mainly from the Ramotswa Wellfield in Botswana located within the town of Ramotswa some 20 kilometers (km) south of Gaborone, Botswana. Other data are from the Lobatse Area, Botswana, about 50 km south of Ramotswa where an environmental hydrogeology study has been conducted (Beger 2001), which used data from approximately 180 borehole/well locations in an area of approximately 250 km². In addition, the Botswana Department of Water Affairs and the Water Utilities Corporate provided long term time series of water level from 1999 to 2012 in the Ramotswa and Pitseynane wellfields. The Pitseynane Wellfield is located on the north of Lobatse. While the boreholes of the Ramotswa Wellfield are all located in the dolomites, boreholes from the Pitseynane Wellfield are only partly in the dolomite, some being probably in the Lephala formation. For this reason, the groundwater table of the Pitseynane Wellfield is not presented in this report. The recorded period correspond to a period when the Ramotswa Wellfield was not used for abstraction. Figure 29 shows the groundwater level variation of some of the monitoring borehole in the Ramotswa Wellfield.

BOX 7 – Key findings.

- Groundwater data are mainly from the Ramotswa, the Pitseynane and the Lobatse wellfield in Botswana.
- There is little information on the South African side of the hydrogeology boundary.

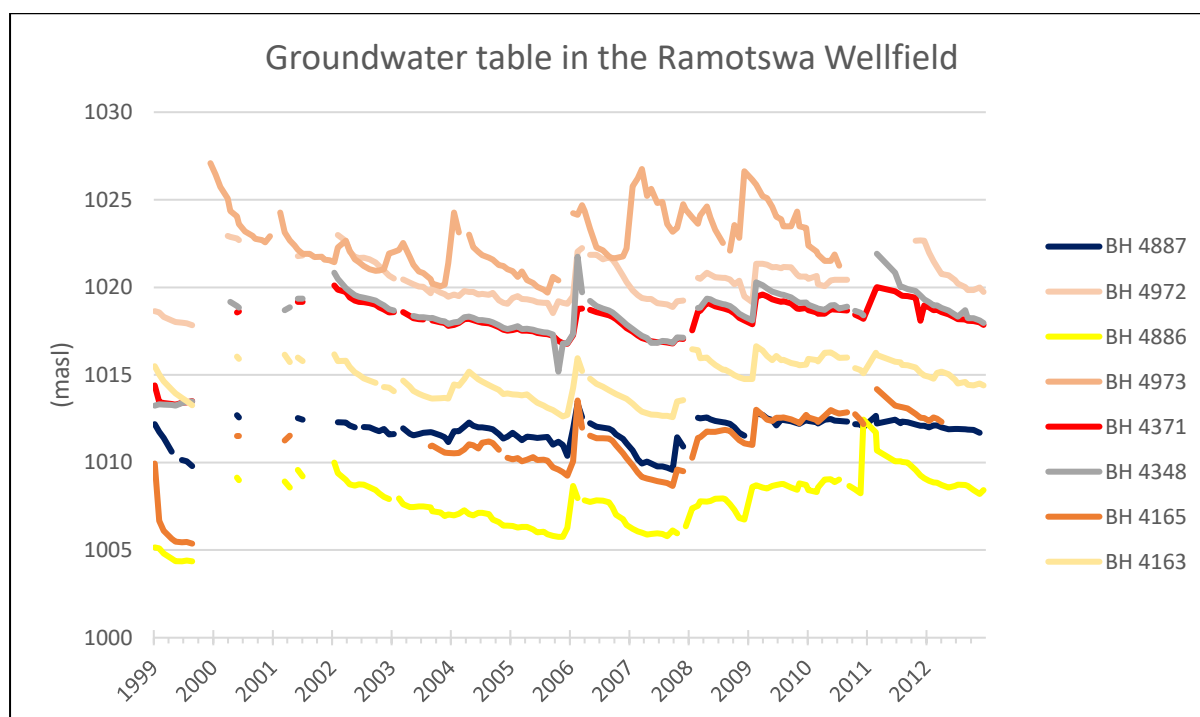


Figure 29: Groundwater level of selected monitoring boreholes in the Ramotswa Wellfield, expressed in masl.

Figure 29 indicates possible seasonal variation of the groundwater table with rise of the groundwater table during the rainy season from November to March and decline of the groundwater table during the dry season from April to October. This is particularly noticeable during the year 2008 and 2009 for borehole BH 4371 and BH 4972. Moreover, globally,

groundwater table decrease from 2002 to the end of 2005. That corresponds to years with annual rainfall under the average.

In complement, data covering approximatively the entire study area were provided by the Botswana Department of Water Affairs and The South African Department of Water Affairs and Sanitation but they only show one static water level for each borehole in different years. However, analysis of the static water level data in the study area shows that, generally, the depth to water is shallower in the northern portion of the study area, where the average water level is approximately 24 meters below the ground surface. In the southern portion, the average water level is approximately 41 meters below ground surface. In complement, according to an analysis done on the Ramotswa Wellfield by Ranganai et al. in 2002, the median depth to the groundwater table was 9 meters (below ground surface) and there were 0 to 12 meters of surface unconsolidated sediment. Unfortunately, there are few boreholes identified in the South Africa side of the study area (hydrogeological boundaries).

Flow direction

As a consequence of the lack of information on the water level on the same date for the whole study area, it has not been feasible to construct a piezometric map of the study area at this stage. Piezometric maps are used to determine the direction of groundwater flow of the study area. However, piezometric maps inside the Ramotswa and Lobatse wellfields have been done (Beger 2001; Staudt 2003) (Annex 1). Groundwater flows north-eastward in the southern part of the Ramotswa village and north-westward in the northern part of the village (Staudt 2003). Flow direction is assumed to be north-eastward in the Lobatse Region (Berger 2001).

Borehole yield and aquifer properties

Data on water yield show that the majority of the boreholes in and around the study area (hydrogeological boundary) have yields of 5 liters per second (l/s) or less (Annex 2). The aquifer type data indicates that the Lephala Aquifer is primarily located in the center of the study area, and the Ramotswa Aquifer is present throughout (Annex 3).

As a complement, Table 4 provides some information on the boreholes inside the Ramotswa Wellfield (Staudt 2003) and Table 5 lists the range of yields and transmissivities of wells located in the Lobatse Area (Beger 2001).

Table 4. Aquifer statistics from the Ramotswa Well Field (Staudt 2003).

Aquifer properties	Ramotswa Dolomite	Lephala Formation
Specific Capacity (l/s/m)	2.7	3.5
Average transmissivity (m ² /d)	1,170	492
Storage Coefficient	5, 7 x 10 ⁻²	8, 7 x 10 ⁻⁴

Table 5. Aquifer statistics from boreholes/wells in the Lobatse, Botswana area (Beger, 2001)

Aquifer properties	Low range	High range
Yield (l/s)	0.28	0.63
Transmissivity (m ² /d)	1-10	400

The variations are primarily due to the degree of karstification. Wells that are not within the karst areas are typically low yielding, with a calculated mean transmissivity of 10 m²/d. Away from the Notwane River Valley dry boreholes are common (Staudt 2003). Yields within the Lephala Aquifer depend on the location relative to the fissured zones as well as to the river.

Spring flow

Figure 30 presents the flow from the Dinokana eye (South Africa). This perennial spring is from the one compartment of dolomite and inside the Ngotwane River catchment.

BOX 8 - Data gap.

- Need to identify the recharge and discharge mechanisms and areas.
- Need to understand the rainfall-groundwater-river interactions.
- Need to increase monitoring of the water table in order to understand groundwater flow direction.
- Need to understand the aquifer characteristics (storativity, yield) and extent.

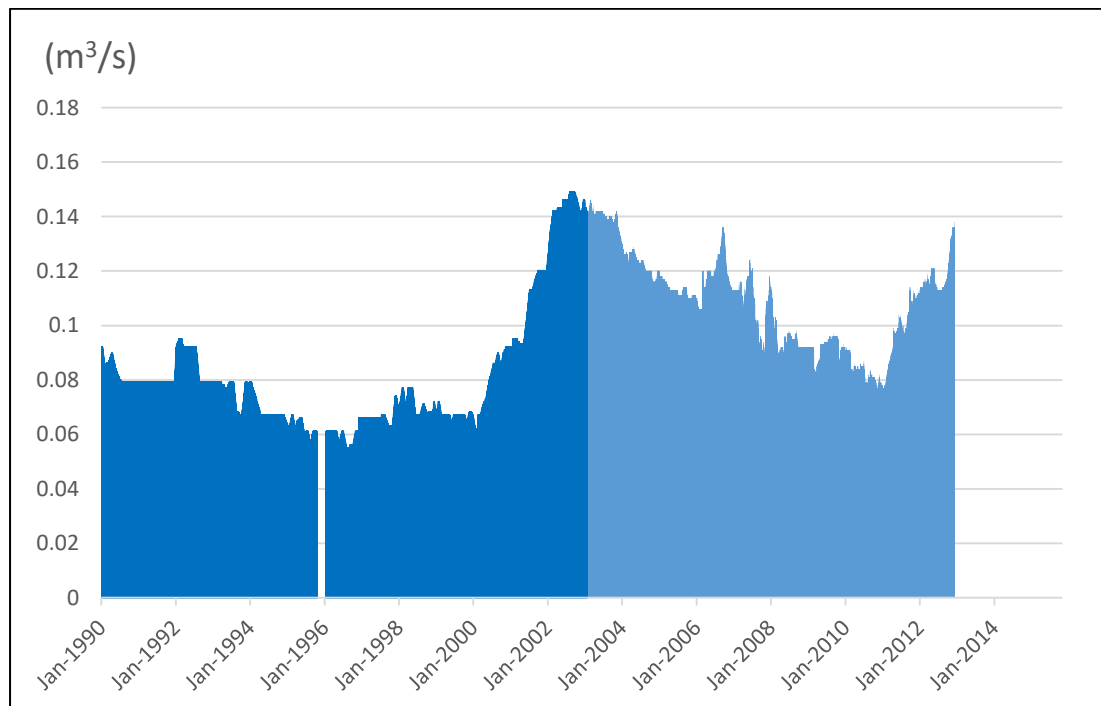


Figure 30. Dinokana eye flow record 1990-2015.

Minimum recorded spring flow is about 0.06 during the period 1995-1997 while the maximum value occurs in 2012 with more than 0.15 m³/s. Rapid assessment between rainfall data (Figure 12) and the spring show a delay in response to the precipitation: while the period 1999-2001 shows an increase in precipitation (Boschrand Rainfall Station), increase in the spring flow is spread over the period was the 2000-2002. Because of the distance between the spring and the rainfall station, more investigation is necessary to understand the response of the aquifer to precipitation.

4.1.5. Groundwater use

In this section, groundwater use is considered at the scale of the administrative boundary of the study area

Botswana

In Botswana, there are four wellfields used for domestic and industrial purpose: Ramotswa Wellfield, Lobatse Wellfield, Pitsenyane Wellfield and Wooldland Wellfield. At the time of writing this report, there was no additional information about the total number of borehole recorded in the study area and their use.

South Africa

In South Africa, there are 3,238 boreholes recorded in Ramotshere Moiloa Local Municipality but only 499 borehole (15.5%) have a specified purpose. Water from the boreholes is used for both agricultural (both crops and livestock) and domestic purposes. For those boreholes where a purpose was indicated, more than 70% of the boreholes in use supply agricultural activities, as shown in Table 6. Most records do not indicate any purpose.

Table 6. Use of water from boreholes with specified use in the Ramotshere Moiloa Local Municipality.

Water use	Number of boreholes
Agriculture	178
Domestic	143
Stock watering	130
Irrigation	41
Public	3
Gardening	3
Mining	1
Total	499

Note: Data should be interpreted in view of the enormous data gaps

Source: NGA 2016.

4.1.6. Groundwater quality and contamination

Beger (2001) and Staudt (2003) worked on the environmental hydrogeology of Lobatse and Ramotswa; Table 7 presents some results of the chemical analysis.

Table 7. Chemical analysis of groundwater in Lobatse and Ramotswa.

Parameter	Unit	Value range		Botswana Drinking Water Standard-BOS32 (2009)		Additional information
		Ramotswa (31 samples)	Lobatse (55 samples)	Acceptable	Maximum allowable	
pH		6.4 – 7.7	N/A	5.5 – 9.5	5 - 10	If > 7, then dolomites If < 7, then shales
Temperature	°C	22.6 – 26.7	N/A			
Electrical conductivity	µS/cm	258 - 6070	N/A	< 1500	3100	A value >1,500 indicates pollution
Dissolved oxygen	mg/l	0 – 4.4	N/A			Low oxygen content is typical of groundwater
Total dissolved solids	mg/l	122 – 2872 (6 above 1,000)	N/A	1000	2000	
Bicarbonate (HCO ₃)	mg/l	234 - 734	N/A			High concentration indicates the presence of dolomite
Sulfate (SO ₄ ²⁻)	mg/l	Mainly < 250 (3 above 400)	< 250	250	400	
Nitrate (NO ₃)		0.02 - 442	0.05 – 59.7	50	50	
Chloride (Cl)	mg/l	2.26 - 989	1.4 – 433	200	600	
Sodium (Na ⁺)	mg/l	High in the industrial complex	1.2 – 231	200	400	

Globally, pollution is from human activities. Results show that the most obnoxious groundwater pollution problem is due to high nitrate concentrations in several boreholes. This pollution is probably from the continued use of pit latrines, especially at sites where waste may directly enter the aquifer. This is particularly true in the case of Ramotswa. Contamination from pit latrines is less significant in Lobatse. In fact, In parallel to the development of pit latrines, the increase in nitrate concentration in the Ramotswa Wellfield seems to be observed during the period 1983 – 2005 (Figure 31). Due to the nitrate contamination, the Ramotswa Wellfield was decommissioned in 1996 (Ranganai et al. 2002). Nitrate contamination was expected to decrease since the building of the Ramotswa wastewater plant but recent water quality data from the Ramotswa Wellfield do not show a significant decrease in nitrate concentration. Groundwater from the Ramotswa Wellfield is abstracted again for

BOX 9 – Key findings.

- Groundwater use is mainly for domestic and agricultural purposes.
- Groundwater quality is only known for the Ramotswa and Lobatse wellfields in Botswana.
- Groundwater is contaminated with nitrate from human activities (pit latrine).
- Groundwater from Ramotswa Wellfield has been used since 2014 and blended with other water sources in order to reach potable standards.

domestic purposes since 2014, as an emergency water source because of the current drought event. The water is blended between the borehole and with other water sources to reach potable standards. Another area of concern is the industrial complex in the Ramotswa where several parameters have high concentrations.

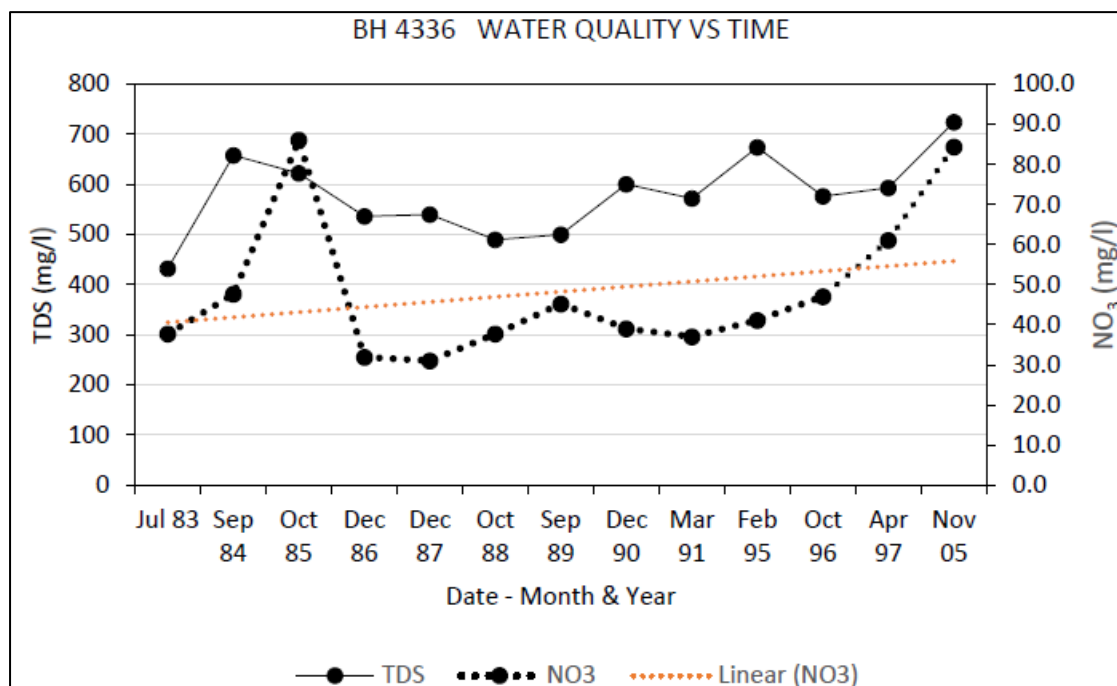


Figure 31. Trend of nitrate concentration for one borehole in the Ramotswa Wellfield (WUC 2015).

In addition, the households are not all connected and the current water shortage does not allow the use of a flush toilet. The householders start to reuse the abandoned pit latrine.

There is no specific data on the groundwater quality in the South Africa side. However, groundwater in the upper Ngotwane catchment is classified as B for the Present Ecological State.⁹

BOX 10 - Data gap.

- Need to improve the knowledge of the groundwater uses in the RTBAA.
- Need to have long-term groundwater quality monitoring, inside the RTBAA particularly on nitrate concentration.

⁹ Present Ecological State ranges from A to F, where A is Natural and F is critically modified biophysical components of the river.

4.2. Surface water

The Limpopo River Basin drains an area of approximately 408,000 km² encapsulating four riparian countries (Botswana, Mozambique, South Africa and Zimbabwe). Passing through diverse landscapes, the Limpopo River travels a distance of over 1,750 km from the confluence of the Marico and Crocodile rivers in South Africa to the Indian Ocean at Xai-Xai in Mozambique. The study area is located in the upper part of the Limpopo River Basin and corresponds to part of two sub-catchments: Ngotwane (or Notwane) and the Marico rivers.

4.2.1. The Ngotwane River

Ngotwane River catchment

The Ngotwane River catchment is about 18,200 km² and starts in South Africa, while most of the catchment area is in Botswana (90% of the total catchment area). It is an ephemeral river flowing roughly north-eastward with river flow directly dependent on rainfall. River flow does not occur during a large dry season (extended winter season). The dominant Ngotwane River Valley follows mainly North-South trending structures through the study area. The valley is approximately 125-150 m wide and features riverbank terraces of different ages. The clayey and sandy river alluvium was deposited in the last thousand years and is up to 20 m thick. River infiltration into the aquifers might occur beneath the Ngotwane riverbed. Elevation in the catchment varies from 1,534 to 834 masl, and the overall hydraulic gradient is 1:300 along the course of the river. Its Naturalized Mean Annual Runoff (nMAR) is about 54.7 10⁶m³/a, but is reduced by 55% due to the impact of development in the river catchment (Gorgens and Boroto 1997).

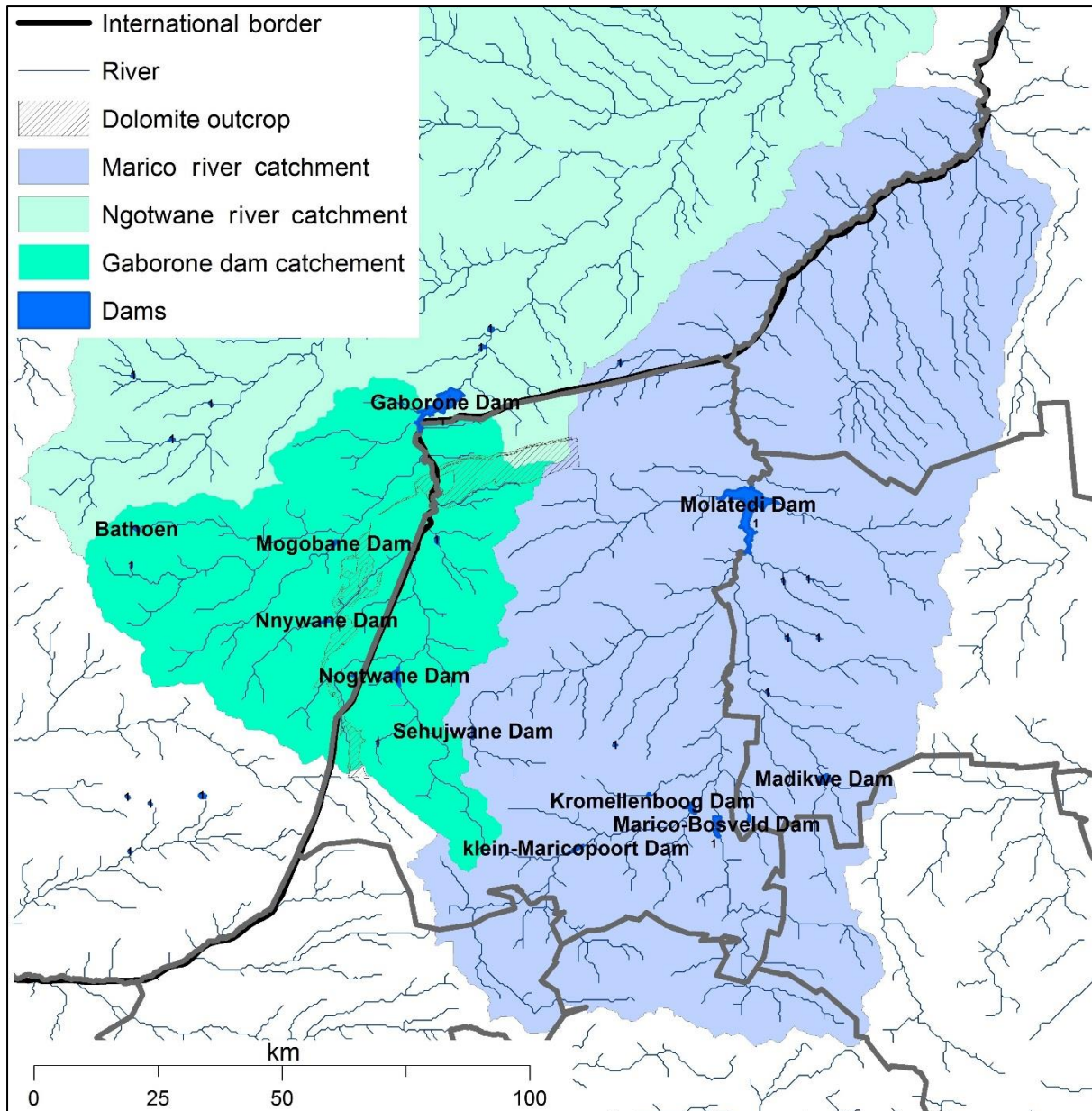


Figure 32. Localization of the dams and the river catchment in the study area.

Study area and storage capacity

The study area focuses on the Gaborone Dam catchment which is located towards the upper part of the Ngotwane River catchment, as shown on Figure 32. That corresponds to an area of about 4,300 km². Table 8 presents the main dam existing on the Gaborone Dam catchment.

Table 8 Characteristics of the main dams inside of Gaborone Dam catchment.

Dam name	Country	Catchment area (km ²)	Active storage (10 ⁶ m ³)	Year of construction	Water use
Gaborone	Botswana	4,300	144.2	1964 (raised in 1984)	Domestic/ industrial
Nnywane	Botswana	238	2.3	1970	Domestic
Mogobane	Botswana	418	Unknown	Unknown	Irrigation/ conservation
Ngotwane	South Africa	518	19.1	1982	Irrigation

Unfortunately, no data on natural river flow has been provided inside the Gaborone Dam catchment. However, data on the dams exist. Figures 33 and 34 show the percentage of the full capacity of the two main dams in Botswana and the water level of the Ngotwane Dam in South Africa, respectively.

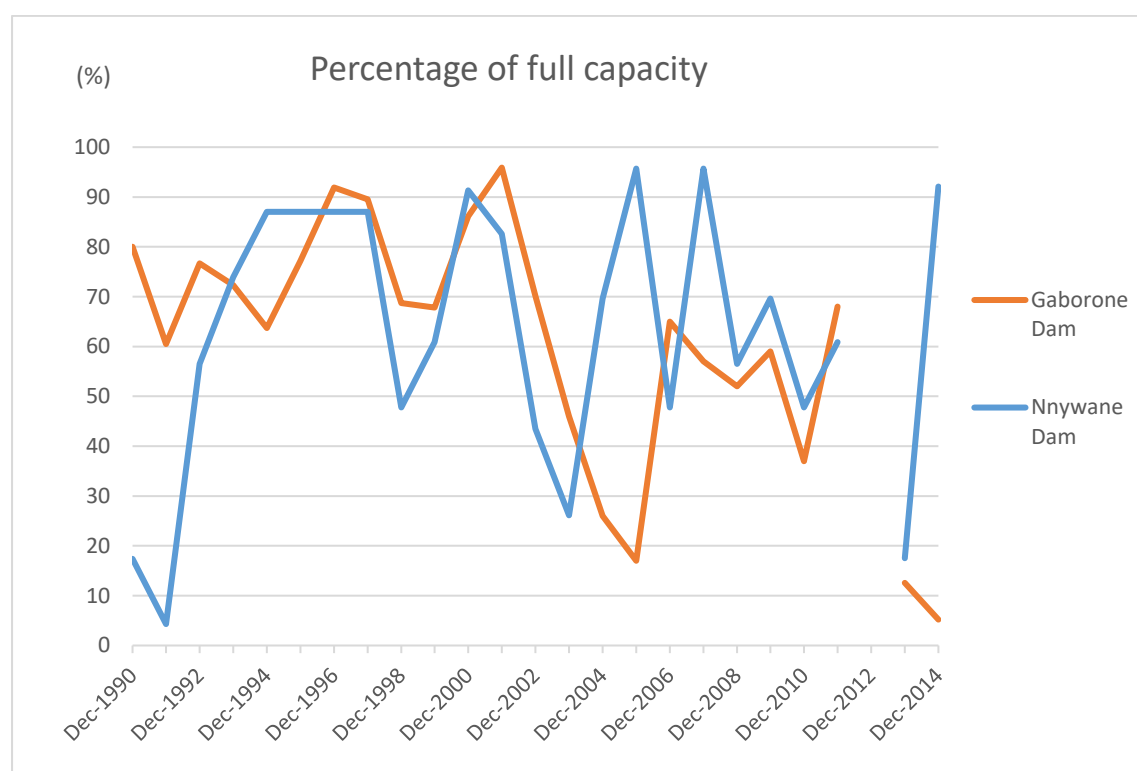


Figure 33. Annual percentage of full capacity of the main dams on the Ngotwane River in Botswana, expressed as the full capacity percentage in December for the period 1990 – 2014

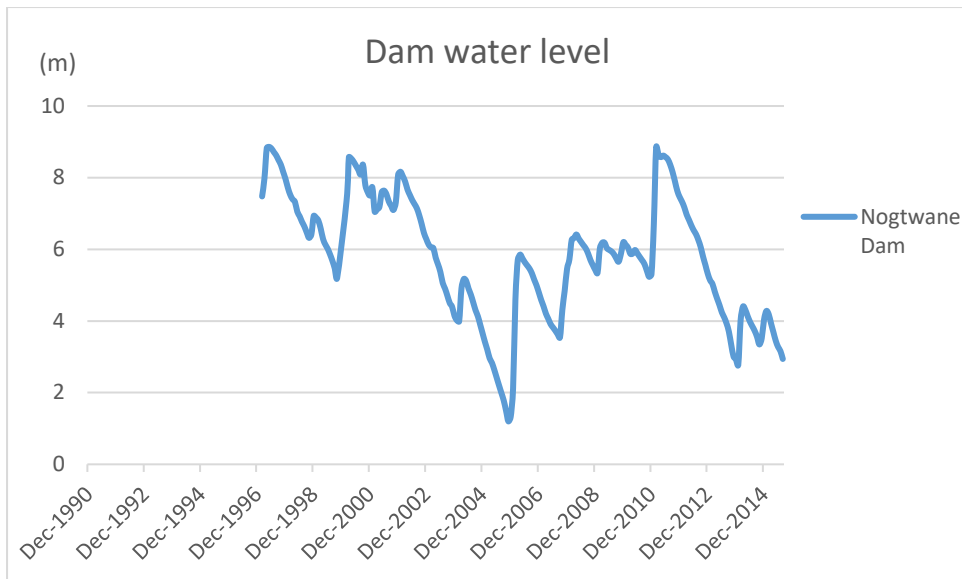


Figure 34. Variation of water level of the Ngotwane Dam in South Africa for the period 1997-2014.

There are four notable periods of decreases in water level (1997-1999, 2002-2005, 2007-2011 and 2011-2016) which correspond to periods where the rainfall was below the annual average. While water level can also be affected by an increase or decrease in uses, dry periods have a significant impact on the water level in the dams. The year 2005 corresponds to the lowest water level in the Ngotwane River since 1990 with a minimum of 1.2 m and to the lowest capacity of the Gaborone Dam during the period 1990-2012. Since 2013, capacity of the Gaborone Dam has dropped and the dam has failed to provide water to Gaborone during the autumn of 2015. Water level in the dam is at the lowest level since the dam was built. This is due to the lack of rainfall since 2013 while the evaporation in the area is about 2000 mm per year, more than the Gaborone city water requirement.

A study analyzing the impact of other existing dams on the Gaborone Dam catchment (Meigh 1995) shows that there are more than 200 dams in the Gaborone Dam catchment, which corresponds to a cumulative capacity of $26 \times 10^6 \text{ m}^3$ and 18% of the capacity of the Gaborone Dam. The Ngotwane Dam in South Africa represents 73% of the cumulative capacity of the Dam on its own. These dams impact the Gaborone Dam up to a 25% decline in nMAR.

Water quality

No data on surface water quality were provided in time for this report. However, the upper catchment of the Ngotwane River in South Africa is classified with a D for the Present Ecological State,¹⁰ and 'moderate' for the Ecological Importance and Sensibility¹¹(DWA2012). It has been reported that water in the Gaborone and Mogobane dams is infected with the parasitic bilharzias, which can transmit the serious disease schistosomiasis.

¹⁰ It ranges from A to F, where A is Natural and F is critically modified biophysical components of the river.

¹¹ It ranges from 'low' to 'very high' sensitivity to flow modification and uniqueness of the biodiversity.

4.2.2. The Marico River

While study area is not comprised inside the Marico River catchment (hydrogeological boundary), the river is the water source of different users in the Ramotshere Moiloa Municipality. As a consequence, the description of the Marico River catchment focuses on the part of the catchment inside the administrative boundary of the RTBAA.

Marico River catchment

The Marico River catchment is about 13,200 km² long and starts in South Africa where most of the catchment area is situated (92%). It is a perennial river flowing roughly northward. The two main tributaries (Klein Marico and Groot Marico rivers) are located in the upper catchment and are fed by a number of springs within the Groot Marico dolomitic aquifer compartment. These dolomitic eyes include the Molemane Eye and the Marico Eye. River flow is also affected by rainfall. Elevation in the catchment varies from 1,676 masl to 858 masl, following a relatively important slope until 1,000 masl (upper part of the catchment - first 50 km) and then an approximate constant slope to the Limpopo River. Its nMAR is about $172 \times 10^6 \text{ m}^3/\text{a}$ with an ecological reserve¹² of $29 \times 10^6 \text{ m}^3/\text{a}$ (Department of Water Affairs and Forestry 2004). The impact of the development of the catchment is estimated to reduce nMAR by 63% (Gorgens and Boroto 1997).

Study area and storage capacity

The study area focuses on the southern and western parts of the Molatedi Dam catchment, which corresponds to an area of about 6,900 km² as shown in Figure 35. Table 9 indicates the nMAR and the percentage of Ecological Water Requirements (EWR) for some of the quaternary catchments considered, while Table 10 presents the characteristics of the main dam existing on the Gaborone Dam Catchment.

¹² Quantity and quality of water required to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource.

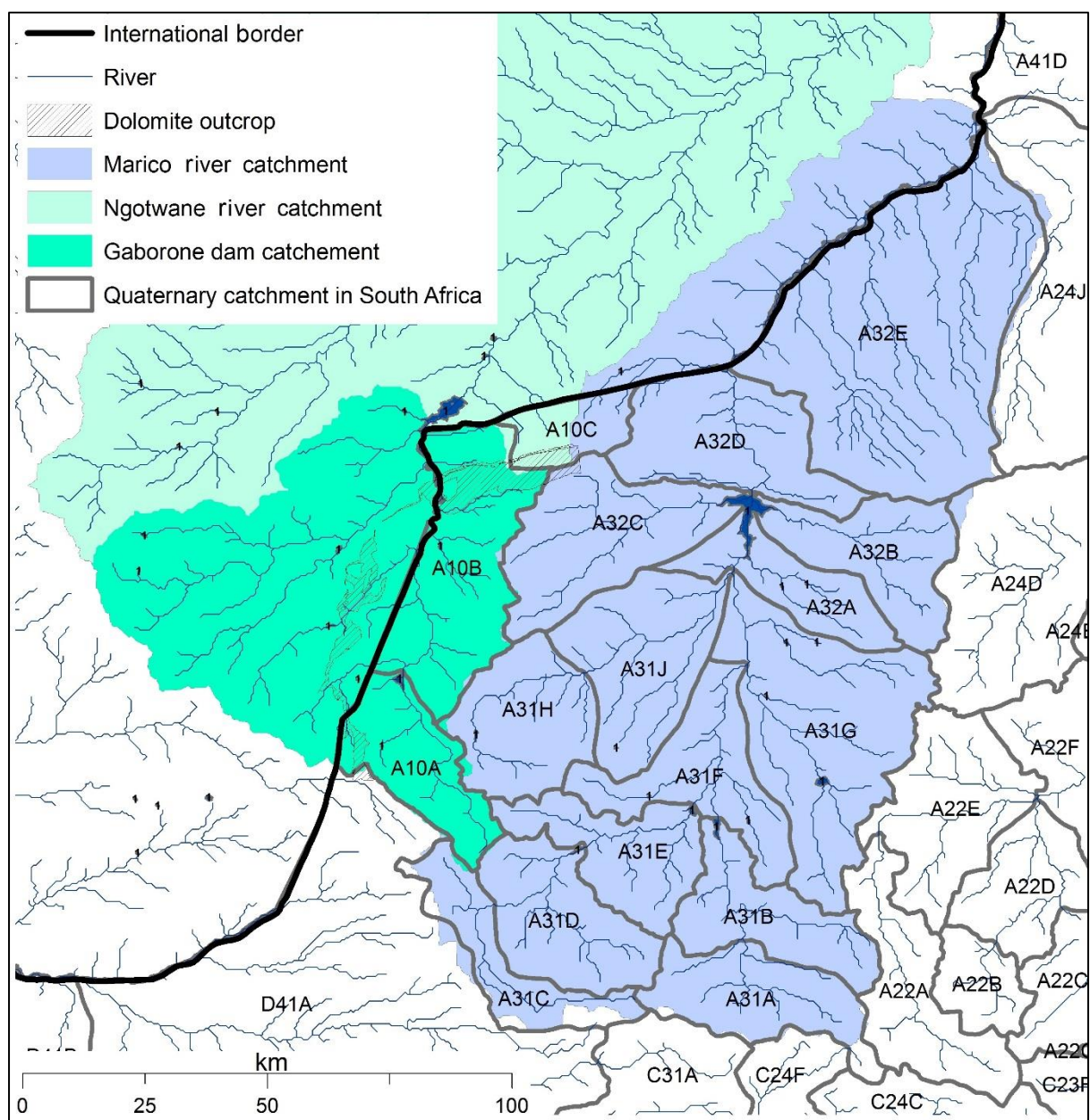


Figure 35. Quaternary catchment in South Africa.

Table 9. Naturalized Mean Annual Runoff (nMAR) and percentage of Ecological Water Requirements (EWR) for some quaternary catchment in the Moladeti Dam Catchment (DWA 2012).

Quaternary Catchment	Rivers	nMAR (10^6m^3)	EWR (%)
A31A	Kaaloog-se-Loop	10.539	76.32
A31B	Groot Marico	42.08	50.26
A31F	Groot Marico	65.083	23.62
A32D	Groot Marico	153.251	7.96
A31E	Klein Marico	29.42	4.67
A31 H/J	Sandsloot	Unknown	Unknown

Table 10. Characteristics of the main dams in the southern and western parts of the Molatedi Dam Catchment (South Africa).

Dam	Country location	Catchment (km ²)	Active storage (10 ⁶ m ³)	Year of construction	Water use
Marico-Bosveld	South Africa	1228	27.0	1934	Irrigation
Klein Maricopoort	South Africa	1189	7.1	1936	Irrigation
Kromellenboog	South Africa	1762	9.0	1955	Irrigation
Molatedi	South Africa	8619	200.8	1987	Irrigation/domestic (7.3x10 ⁶ m ³ /a transferred to Botswana)
Sehujwane/Buispoort	South Africa	201	3.7	1996	Irrigation/domestic

Source: DWS

Data on river flow are available for the study area, but the gauging stations are usually located after some of the existing dams. In order to be consistent with the previous section on the Ngotwane River, only the water level of the dam is presented here. Figure 36 presents the water level of the main dam of the study area for the Marico River for the period 1990-2015, and Figure 37 shows the long-term data recorded since 1934 for the water level of three of the dams.

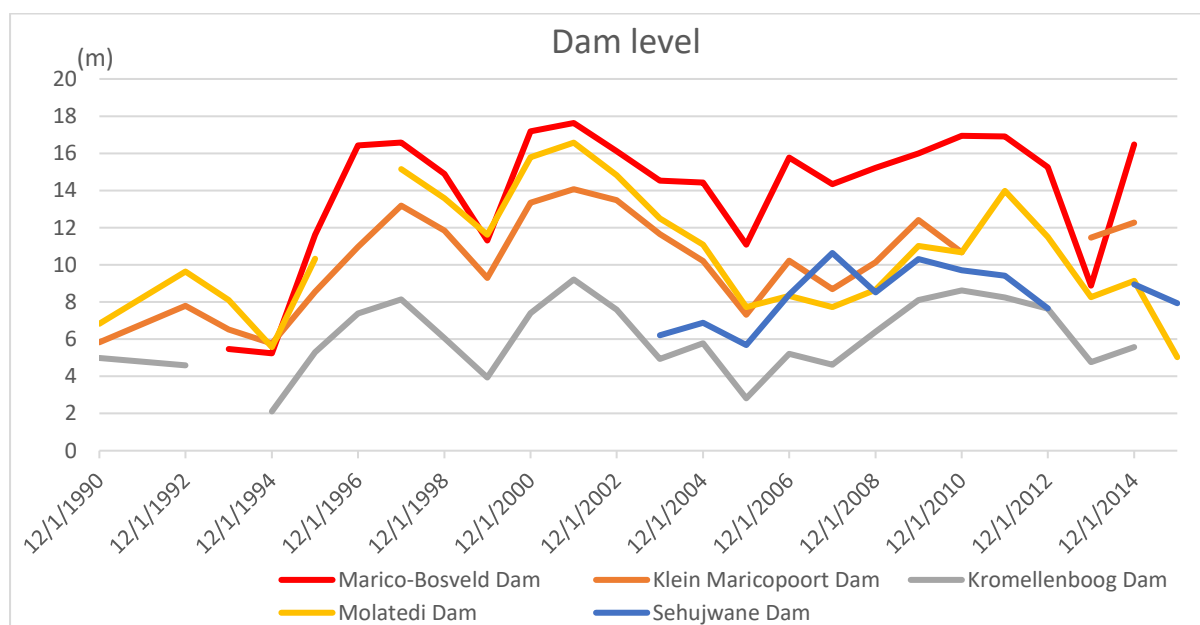


Figure 36. Water level of the dams in the study area (Marico River catchment) for December over the period 1990-2015, expressed in meters and based on daily data.

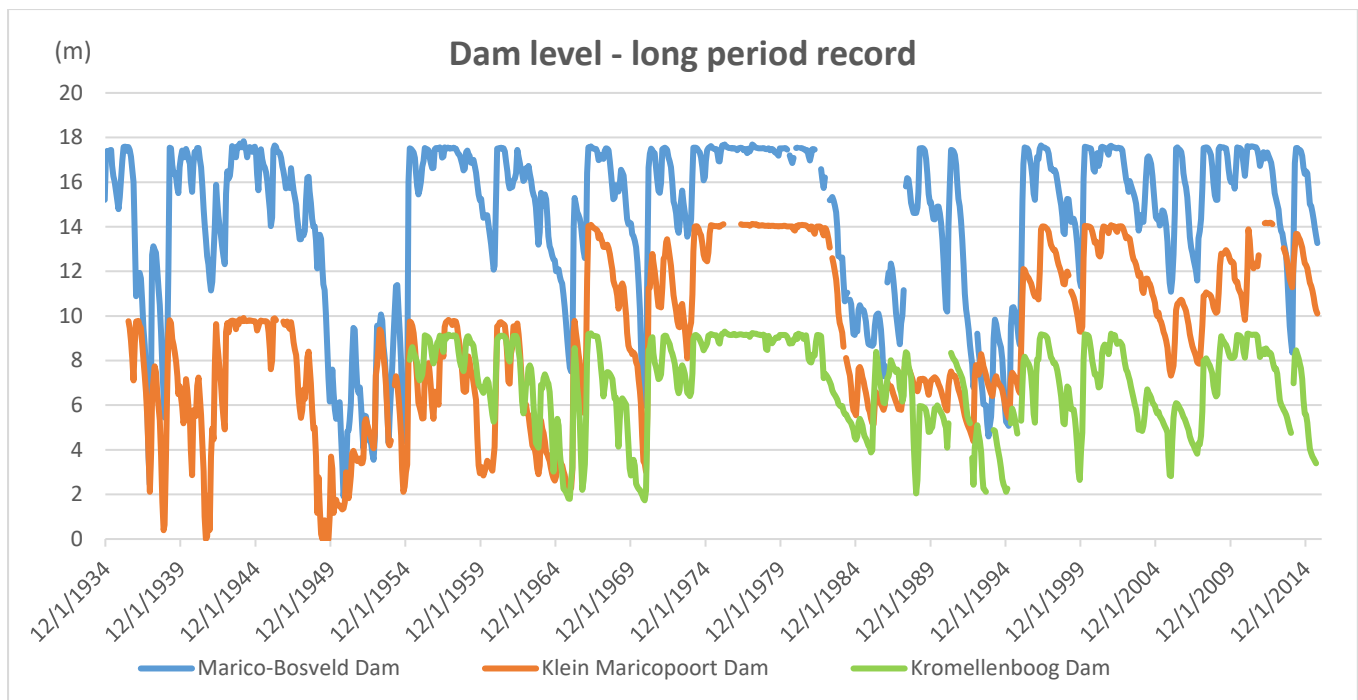


Figure 37. Daily water level of the dams in the study area (Marico River Catchment) for the period 1934-2015.

There are three notable periods of decreases in water level (1997-1999, 2002-2005 and 2011-2016), which correspond to the period where the rainfall was below the annual average. In comparison to the dam on the Ngotwane River, the dams in this catchment seem to be less sensitive to the 2007-2011 period with lower than average rainfall. This indicates that the dam (and the river flow) is not dependent on the river alone. As the main source of water from the dolomite spring in the upper catchment, groundwater seems to play a buffering effect during non-drastic dry periods.

Decreases and increases in the water level in the upper part of the Molatedi Catchment (Figure 37) are regular. Before 1990, notable years with low water levels were 1938, 1941, 1950, 1968, 1970 and 1988.

BOX 11 – Key findings.

- There is an international water transfer from South Africa to Botswana (Moladeti Dam).
- Evaporation from the dams is an important water loss.
- The dams inside the Gaborone Dam Catchment reduce the inflow to the Gaborone Dam by 20%.
- Surface water quality is globally fairly good.

Water quality

The Ecological Water Requirements Report (DWA 2012) provides information on water quality of most of the quaternary catchments in the Molatedi Dam Catchment. Table 11 presents the results of this report.

Table 11. Water quality and descriptive information on the water-quality issues (DWA 2012).

	Water quality consideration	Factors influencing water quality
A31A	Fairly good	Localized impacts from mining and agriculture
A31B	Fairly good	Constant releases made for agricultural water use
A31D	Acceptable	No information
A31E	No information	Urban runoff Localized catchment activities Nutrients Sedimentation in the dam Upstream activities
A31F	Acceptable	Agricultural runoff (nutrients and sediments)
A31H/J	Acceptable	No information

Globally, the upper part of the catchment has fairly good water quality, which is impacted by local mining and agriculture. The rest of the catchments have acceptable water quality. Water-quality issues occur as a result of agricultural runoff, both nutrient and sediment, and from urban runoff.

BOX 12 - Data gap.

- Need to identify natural river flow as all the river flow data are linked to the dams in the Ngotwane or Marico River.

5. Water Supply, Sanitation and Health Status

5.1. Water supply

5.1.1. Botswana

In Botswana, the 2011 Census results show household access to potable water. 86.4% of the households have yard connections (made up of 47% piped indoor water and 39.4 % outdoor piped water) while 10.5% use a neighbor's or communal tap. Nearly all of Gaborone and Lobatse access water from pipe or tap water sources, as with most of the Southeast District. However, 8.7% access water through other sources, including small agricultural dams, wells and rivers, which are often used in cattle posts and farm plots with no access to potable water or public water supplies. The Ngotwane Catchment alone is shown to have over 200 such small dams (DWA 2014; Meigh 1995). The percentages from the 2011 Census are given in Figure 38 below.

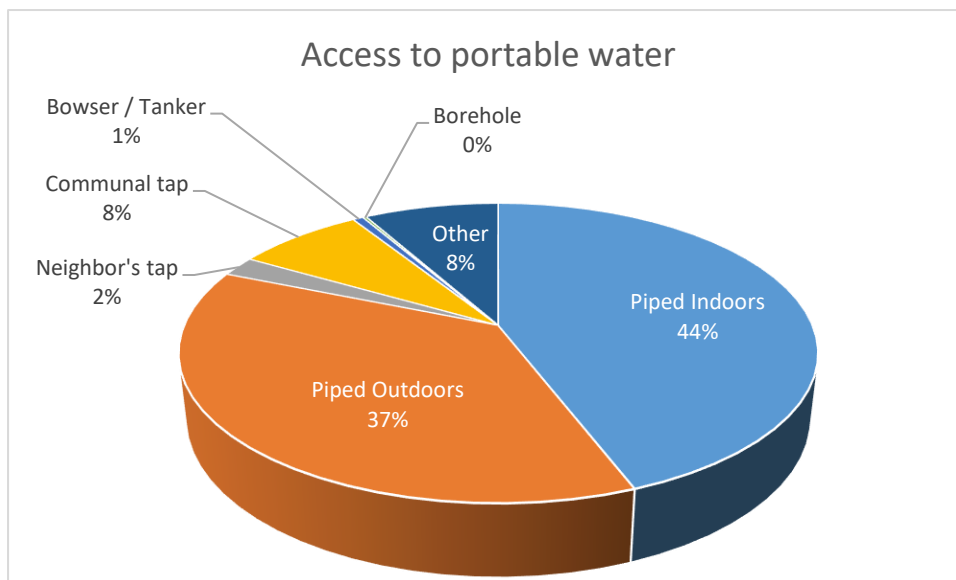


Figure 38. Access to potable water by source for the study area in Botswana.¹³

Source: Statistics Botswana 2015a-e.

The water supply scheme in the study area is complex as shown in Figure 39. The water supply scheme comprises several water sources (surface water and groundwater) mixed together at different level of the scheme. The North-South carrier is the main water source. There is one international water transfer from the Molatedi Dam in South Africa ($7.3 \times 10^6 \text{ m}^3 / \text{a}$). Table 12 summarizes the daily water volume from the different sources in February 2016.

¹³ Note: Households may have more than one source, so percentages may total over 100% of households.

Table 12: Water volume and water origin for the water supply scheme in February 2016
(Source: WUC)

Origin of water resources	Daily volume (10 ³ m ³)
North South Carrier (NSC)	60
Masana Wellfield	20
Bokaa Dam	16
Molatedi Dam	4.8
Gaborone Dam	0
Ramotswa Wellfield	5
Nnywane Dam	2
Pitsenyane Wellfield	No data
Woodland Wellfield	No data
Lobatse Wellfield	No data
Total	107.8

Current water requirements for the scheme are estimated at 125x10³ m³/d, showing a real daily deficit of 17.2x10³ m³ in February 2016. The scheme is under high water stress under the current drought context.

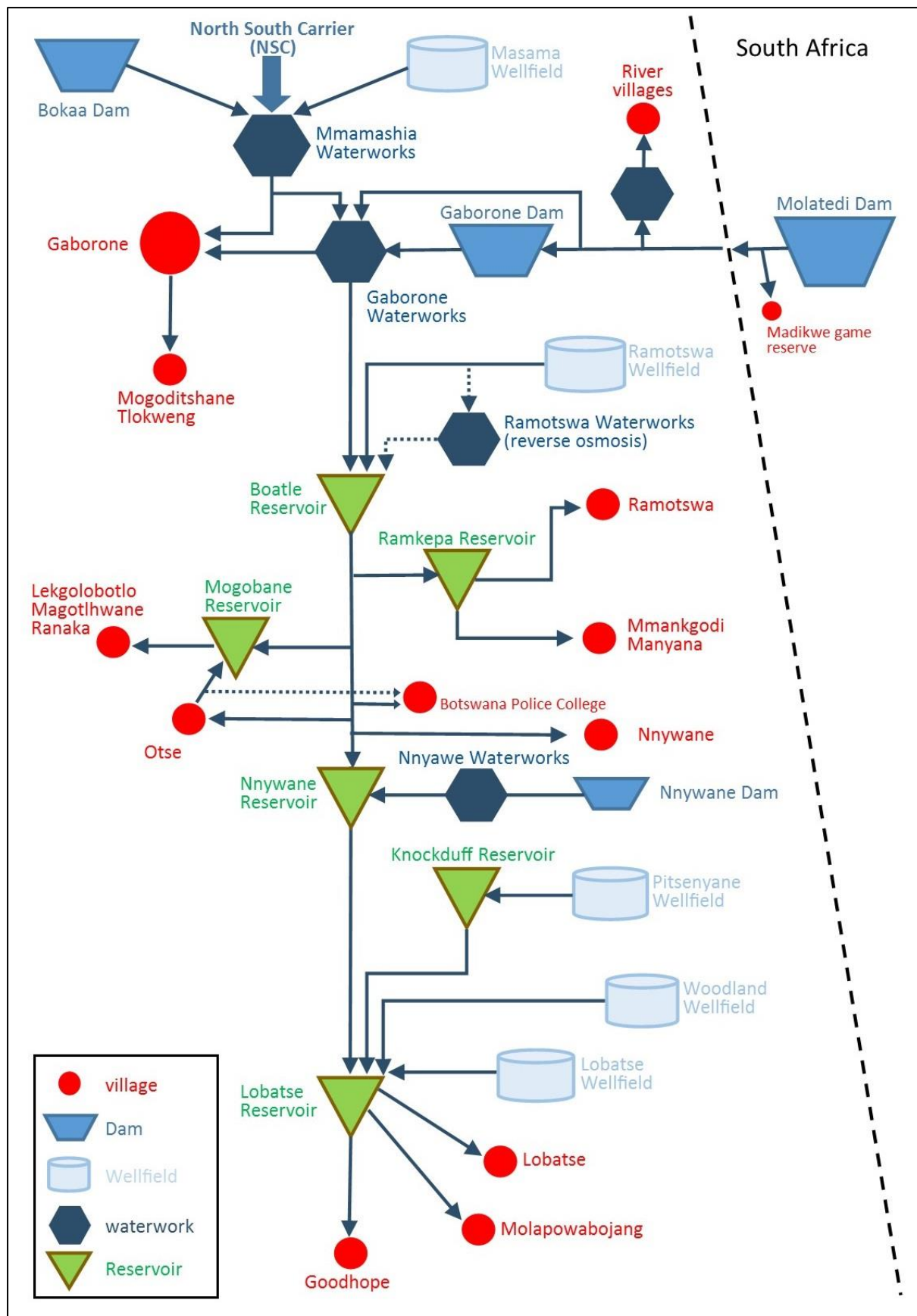


Figure 39. Schematic of the water supply of the study area in Botswana.

5.1.2. South Africa

The larger Ngaka Modiri Molema District has the lowest access to infrastructure in North West Province and well below the national average at 19% in 1996 and 23% in 2009. In terms of water infrastructure, there has been a slight decrease in the number of households having access to piped water above RDP level in the District Municipality over the years (62% in 1996 to 61% in 2009). The Blue Drop score¹⁴ for the District Municipality, which scores drinking water quality management, increased from 31.4% in 2010 to 40.72% in 2012. An increase in the Blue Drop score indicated an improvement of water quality management in Ngaka Modiri Local Municipality together with the Water Services Providers.

In 2011, 8.3% of households in Ramotshere Moiloa Local Municipality still did not have any access to piped water. Of those that had some form of access to water, 65.4% of the households in the South Africa study area received water from a regional or local water scheme operated by municipality or other water services provider; only 19% had access to piped water in their dwelling and 38.2% had access to piped water in the yard. The next important source of water was boreholes. The source of that water supply is not reported, but the Ngaka Modiri Molema District Profile noted that many people receive water from natural sources such as rivers, dams, and springs, which can pose health risks. Figure 40 provides an overview for 2011 water sources in the study area.

BOX 13 – Key findings.

- Botswana RTBAA side is extremely dependent of water transfer from outside the RTBAA.
- There is mismatch between the water requirement in the RTBAA and the current locally water availability from the RTBAA.
- Groundwater use in Botswana represents less than 20% of the domestic water use (and current abstracted from the Ramotswa Wellfield is less than 5% of the total water requirement in volume).
- Rural population remains on groundwater.

¹⁴ The Blue Drop for water quality is a regulation program that certifies that water service providers are managed, conveyed and treated to the highest possible standards in order to minimise risk to public health and the environment. Gaining Blue Drop certification is an indication that the water supply authority has complied with a stringent set of procedural, chemical, biological and other requirements. The Blue Drop score serves as a Performance Indicator that reflects upon the Water Services Institution's water business practice and compliance.

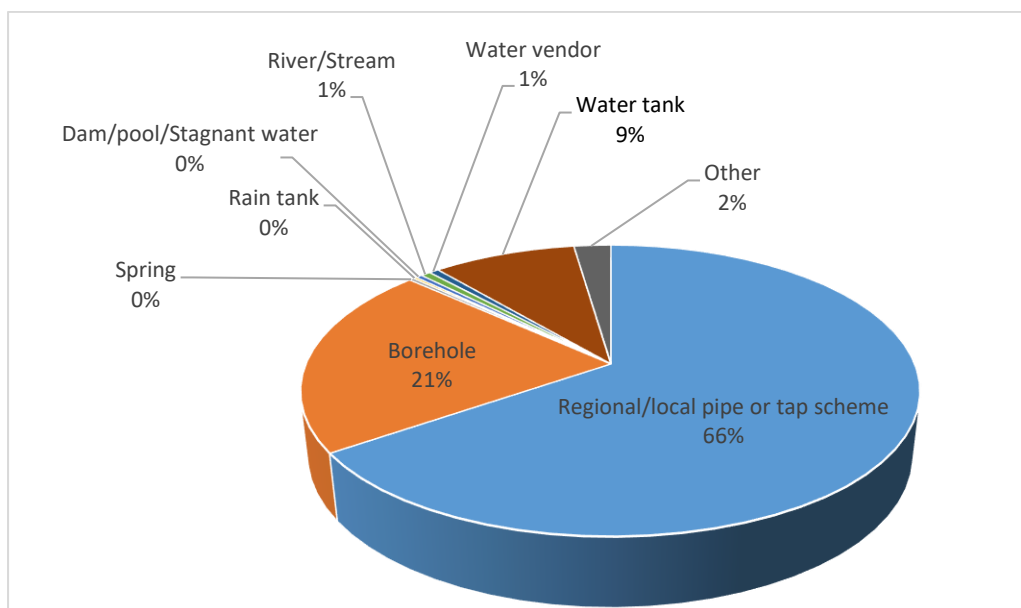


Figure 40. Sources of water for Ramotshere Moiloa Local Municipality for 2011.
Sources: Stat SA 2012b; Ramotshere Moiloa Local Municipality 2013/14.

In South Africa, public water supply is the mandate of the district municipality. As such, the Ramotshere Moiloa Local Municipality is not the Water Services Authority but only a Water Services Provider in Zeerust, Sandvlagte and Ikageleng.

The DWS estimates the annual water need and the annual available water for the year 2000 in the Upper Ngtowane and Marico catchments, which roughly correspond to the Ramotshere Moiloa Municipality delineation (Department of Water Affairs and Forestry 2004). Tables 13 and 14 show these estimates.

BOX 14 - Data gap.

- Need to better understand the current and future water requirement for both countries.
- Need to better identify the different water sources and their respective roles in the water supply scheme.

Table 13. Water requirements¹⁵ for 2000 development ($10^6\text{m}^3/\text{a}$).

Subarea	Irrigation	Urban	Rural	Mining and bulk industrial	Total	Transfers out	Total
Marico	32	9	12	5	58	7	65
Upper Ngotwane	5	2	3	0	10	0	10

¹⁵ Water requirements at catchment level are estimated from (1) domestic requirements (combination of Stats SA figures and housing development plans using per capita water use for each housing category, including data for hospitals and public utilities, some of the data being confirmed through measuring, (2) irrigation requirements (crop water requirements models), (3) industrial requirements (depending on industrial process), (4) strategic water use (i.e., Eskom), (5) international obligations (calculated and negotiated), and (6) environmental water requirement (calculated reserve).

Table 14. Available water in year 2000 ($10^6\text{m}^3/\text{a}$).

Subarea	Natural resource		Usable return flow			TOTAL
	Surface water	Groundwater	Irrigation	Urban	Mining and bulk	
Marico	30	23	2	3	1	59
Upper Ngotwane	1	5	0	0	0	6

The total water requirements are estimated at $75 \times 10^6\text{m}^3/\text{a}$ while the total available amount is estimated at $65 \times 10^6\text{m}^3/\text{a}$, highlighting that the local municipality is under water stress with a deficit of $10 \times 10^6\text{m}^3/\text{a}$.

5.2. Access to sanitation

5.2.1. Access to sanitation and toilet facilities

Household access to sanitation and flush toilets are important factors in health and nutrition status. The Millennium Development Goals and the newly constituted Sustainable Development Goals have both monitored changes to access to sanitation and emphasized the critical investment needed to ensure that larger percentages of the population have toilet facilities. At the same time, the type of toilets used by a population can also have an impact on the groundwater contamination, so expanding access to improved toilet facilities should also consider water sources and pollution. In the study area, the high use of pit latrines may represent an increase in access to toilets, but at the same time, presents a threat to the water sources in the area. In fact, groundwater pollution has been particularly observed in Ramotswa since the 1980s. Ventilated Improved Pit (VIP) proposes an alternative to the traditional pit latrine as the improved system protects better against health issues and environmental protection contamination. In addition, flush toilets linked to a municipal wastewater treatment plant seems to be the more efficient for health and environment protection. However, wastewater treatment plant needs to be correctly designed and adequately maintained to prevent contamination of surface water and groundwater.

Botswana

In 2011, in Botswana, access to sanitation was measured at the household level by access to flush toilets or to a sanitary pit latrine (Statistics Botswana 2015a). A comparative overview between the national village average and the average of the two primary urban centers (Gaborone and Lobatse) is indicated in Table 30 and shows a significant difference between rural and urban areas in access to the type of sanitation. Over 63% of urban households and only 34.8% of rural households had flush toilets while 44.5% used pit latrines (Figure 41). The high use of pit latrines by village households may pose a pollution threat to the environment, notably groundwater resources.

BOX 15 – key findings.

- Pit latrine (traditional and VIP) is the major sanitation system in South Africa.
- Pit latrine (traditional and VIP) is an important sanitation system in Botswana.
- In RTBAA, sanitation with flush toilets increases but that of pit latrines also increases.

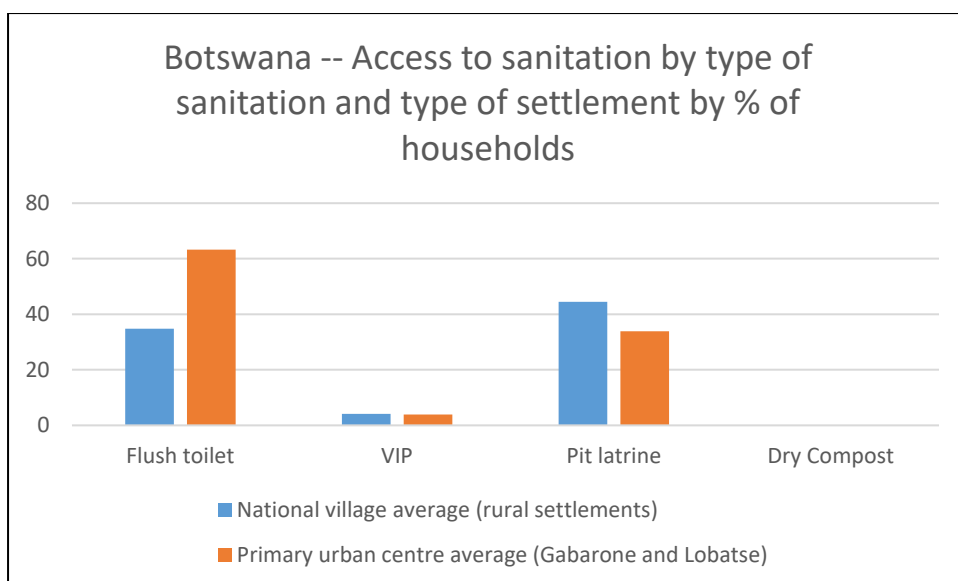


Figure 41. Botswana: Access to sanitation facilities comparing village households and primary urban centers (Gaborone and Lobatse) 2011.

Sources: Adapted from Statistics Botswana 2015a; Statistics Botswana 2015b-e; Statistics Botswana 2014b:

Access to sanitation in respect of main urban areas of Gaborone and Lobatse shows relatively high access to flush toilets, which increased for both urban centers (Figure 42). Over the same time, the use of pit latrines also increased. Sanitation type access differs across urban areas compared to rural areas in the study area. Use of the ventilated improved pit dropped.

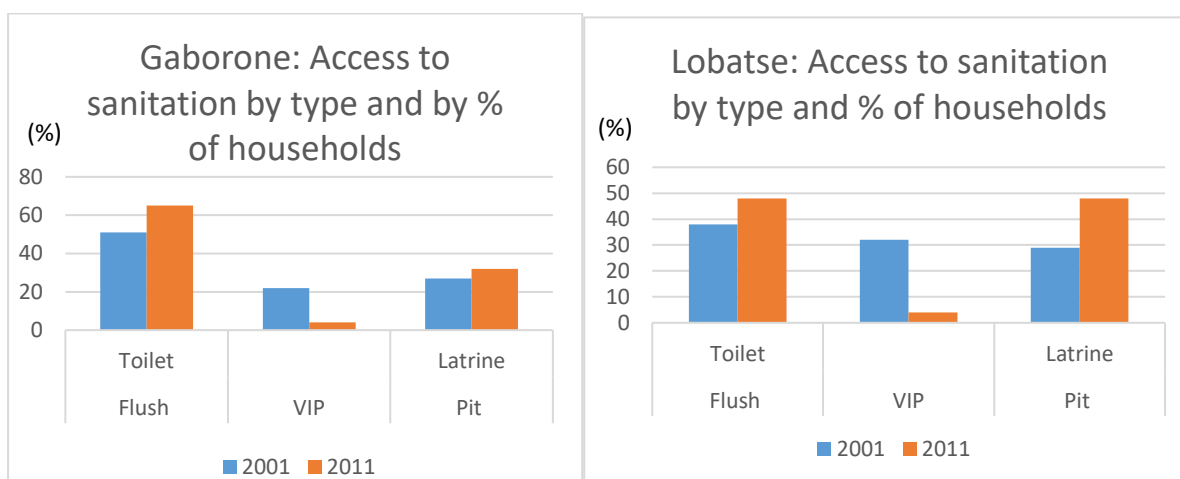


Figure 42. Trends in household access to improved sanitation in the study area -- urban districts. Gaborone and Lobatse 2001;2011.

Source: Adapted from Statistics Botswana 2014b.

South Africa

In South Africa, the Ngaka Modiri Molema District municipality's household access to hygienic toilets has improved from 27% in 1996 to 42% in 2009 with the increase in the use of flush toilets and Ventilated Improved Pit (VIP). About 50% of the households used pit toilets in 2009. In the local Ramotshere Moiloa Local Municipality area, however, the situation is worse with 59% of the households using pit latrines (Figure 43). Only 26% of the households had access to water system toilets in 2011.

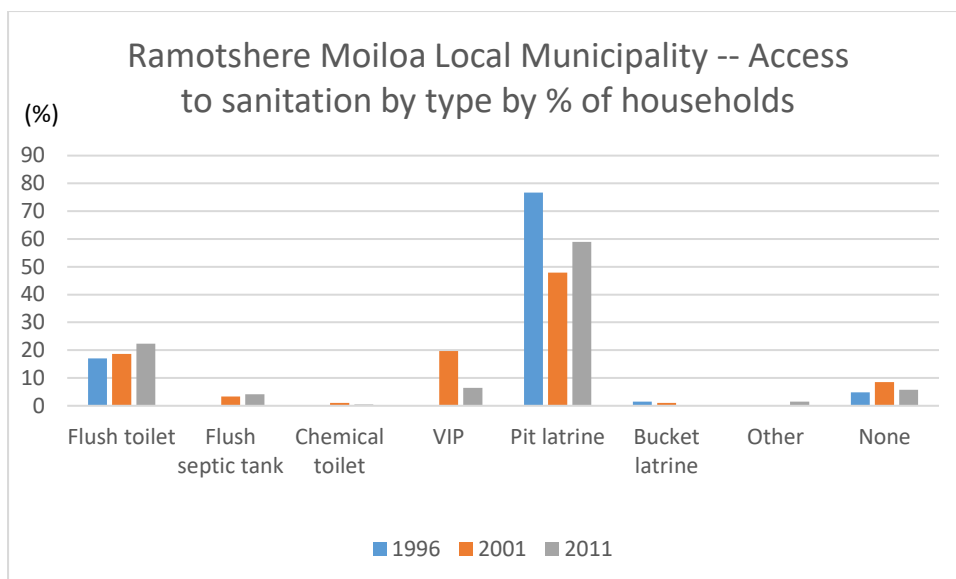


Figure 43. Access to sanitation in the Ramotshere Moiloa Municipality expressed by type and by percentage of households

Source: Ramotshere Moiloa Local Municipality 2013/14.

5.2.2. Solid Waste Management

South Africa

In the Ngaka Modiri Molema District Municipality, 64% of residents dispose of refuse in their own dump. Only about a quarter of homes have their refuse removed by a local authority at least once a week. As these are figures for the district municipality and include the major urban areas that have higher access to refuse collection, it is likely that the rural areas mainly use their own refuse dumps and very few have access to refuse collection by a local authority. No studies were available to suggest the potential risk to water quality from this practice.

5.3. Health status

Access to clean, potable water and sanitation facilities reduces risks of certain waterborne diseases and illnesses. Where access is low, risk increases, including for childhood mortality associated with low drinking water quality and poor sanitation.

Botswana

In Botswana, diarrhea-related illnesses are reported across the study area. According to Statistics Botswana (2014b:65), for the years 2009 and 2010, diarrhea and gastroenteritis of presumed infectious origin were the second highest causes of death in infants and children under the age of 5. The prevalence of diarrhea-related illnesses across the study area in Botswana fluctuates by year, but still remains a health concern (see Annex 4 for numbers of new and repeat diarrhoea-related illnesses in 2012). Gaborone and Kweneng East districts had significant numbers of diarrhoea. National trends show that recorded cases of the condition were substantial in 2002 and 2003 with 109, 466 and

BOX 16 - Data gap.

- Need to understand the volume of wastewater that can be reused.
- Need to better assess the risk of surface water and groundwater contamination from wastewater (both flush toilet and pit latrine) and other land use risks.

103,724 cases, respectively (Statistics Botswana 2014b). However in 2004, there was a 68% drop (29,322) from a 103,724 recorded in 2003. In 2006 there were 55,015 cases which decreased by 9% between 2007 and 2008.

South Africa

In South Africa, the disaggregated figures were not available for the Ramotshere Moiloa Local Municipality, but for the overall Ngaka Modiri Molema District Municipality, the diarrheal incidence under 5 years decreased over three years from 134.0 per 1,000 children in 2008/09 to 88.6 per 1,000 in 2011/12 (Massyn et al. 2013). Although there has been a marked decrease in the incidence, the district still ranks highest in the province. Of particular concern is the fact that the mortality rate among children under 5 years due to diarrhea with dehydration was 4.9%. The situation may worsen with the increase of informal settlements in the study area that have no water or sanitation services (as cited by Eales 2015).

6. Land Tenure and Use

6.1.Land tenure types

Botswana

All three land tenure types for Botswana are found in the study area: state, freehold and tribal (MLH 2005a). Land tenure type in the mostly rural southeast and southern districts is primarily tribal. In contrast, there is no tribal landholding in Gaborone and Lobatse. Gaborone is 84% state land and 16% freehold and Lobatse is 39.4% state land and 60.6% freehold. Table 15 shows the amount of land held under each tenure type in the study area for Botswana.

Table 15. Land tenure by land area in the study area.

District	Tribal land		State land		Freehold land		District total (km ²)
	Area (km ²)	Percent share	Area (km ²)	Percent share	Area (km ²)	Percent share	
Southeast	982.8	76.4	56.6	4.4	247.6	19.2	1 287.0
Southern	26,420.0	98.7	322.0	1.2	34.0	0.1	26,776.0
Gaborone	0.0	0.0	171.4	84.0	32.3	16.0	203.7
Lobatse	0.0	0.0	43.2	39.4	66.4	60.6	109.6
Total	27,402.8	96.6	593.2	2.1	380.3	1.3	28,376.3

Source: Adapted from MLH 2005a.

South Africa

According to the Integrated Development Plan (IDP) for the Ramotshere Moiloa Local Municipality 2014-2015, around 35% the total area is land under traditional authorities. The remaining 65% is freehold and state or public land. Generally, large areas of land in the North West Province remain under the administration of traditional authorities and communal property associations (CPAs), which means that freehold tenure is not granted to individuals.¹⁶

6.2.Land use

6.2.1. Settlement type

While settlement types in Botswana and South Africa do not have the same definition, it is possible to observe important differences between the two countries in the study area: 18% of the population in South Africa live in urban settlements compared to 91% for Botswana. Details are given below.

Botswana

Settlement types of Botswana are different from those in South Africa, as seen in Figure 44 below and as defined in Annex 5. Most of Botswana's population in the study area live in primary settlements that are urban without rural or agrarian characteristics. Statistics show 54% of the population in the study area live in the Primary settlements, all of which is accounted for

¹⁶ In traditional tenure, land is usually obtained through the tribal chief or the village headman who acts on his behalf (Lahiff 1999). CPAs are landholding institutions established under the Communal Property Associations Act No. 28 of 1996 to enable communities to form juristic persons, to be known as communal property associations in order to acquire, hold and manage property on a basis agreed to by members of a community in terms of a written constitution; and to provide for matters connected therewith (SAFLII 1996).

in Gaborone. Another 33% live in Primary III settlements, which have a population range of 20,000 to 49,999. Rural or agrarian settlements are more likely to be tertiary centers with a population range of 250 to 9,999 including Remote Area Dweller (RAD) settlements. All tertiary settlements combined in the study area of Botswana constitute less than 10% of the population.

Settlement classification	Limit (inhabitants)
Primary I	..> 100,000
Primary III	20,000 – 49,999
Secondary	10,000 – 19, 999
Tertiary II	5,000 – 9,999
Tertiary II	1,000 – 4,999
Tertiary III	500 – 999
Tertiary IV	250 – 499

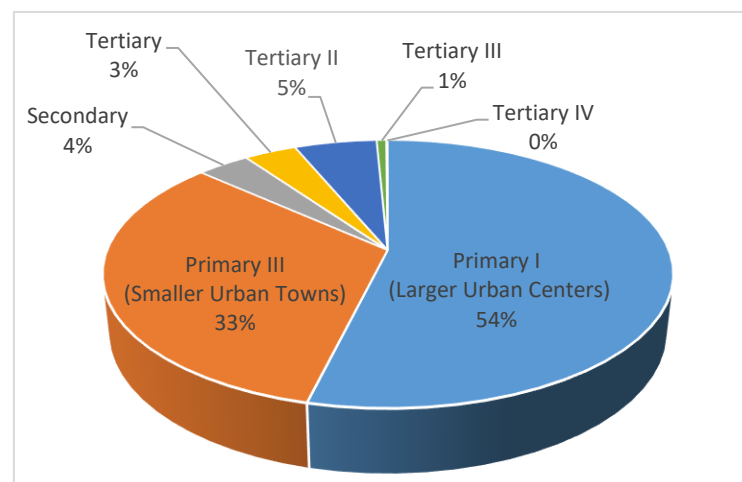


Figure 44. Settlement types in Botswana, study area, 2012.

South Africa

Using the settlement types for South Africa, Figure 45 shows settlement types in the Ramotshere Moiloa Local Municipality by urban, farm or tribal area. Most of households were in tribal or traditional areas in 2011 (71%), which are characterized as rural. Another 11% are farms, which are also rural, but commercial agrarian areas. Only 18% of the population in the study area on the South Africa side live in urban areas, and those comprise the relatively small settlements of Zeerust (17,708) and Groot Marico (3,384).¹⁷

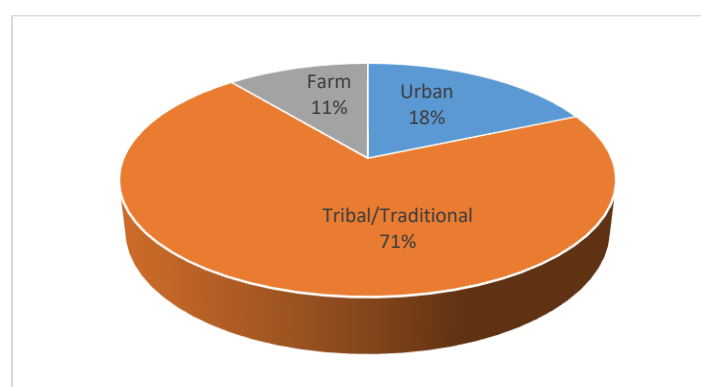


Figure 45. Settlement types in South Africa, Ramotshere Moiloa Local Municipality 2011.
Source: Stats SA 2012b.

6.2.2. Agriculture: Crops and livestock

¹⁷ Classification by Botswana's definition would make Zeerust a Secondary Center and Groot Marico a Tertiary 3 settlement.

Botswana

Most of the Botswana study area that is agrarian is primarily under livestock farming and arable agriculture, depending on rainfall, terrain and soil conditions (SDDC 2008/9). Livestock and wildlife grazing on communal rangeland and veld product gathering¹⁸ can be found but arable farming is more common, though still restricted by the terrain and soil conditions in the river valleys and the hilly terrain.

Commercial and private TGLP¹⁹ freehold game and livestock ranching is a significant land use in the broader area, but commercial farms and ranches only constitute 4% of land use. The significant amount of freehold land in Gaborone, Lobatse and South East District is mainly under freehold ranches; Lobatse is completely surrounded by freehold ranch lands. In the Southern District, the land use is accounted for by farming in the TGLP ranches.

South Africa

The number of farms in the North-West Province declined by 8.3% between 2002 and 2007, which is attributed to the consolidation of farms through the land restitution process (Department of Agriculture, Forestry and Fisheries 2013; Eales 2015). In the study area for South Africa, the rural area is characterized mostly by small-scale or subsistence agriculture and game farming. Agricultural activities in the predominantly rural Ngaka Modiri Molema District Municipality are primarily in cattle ranching, game farming around Zeerust, and some maize, wheat, fruit, and vegetable cultivation (Department of Cooperative Governance and Traditional Affairs 2011; Stats SA 2011) showing poultry is the most common agricultural activity for households (9,796 households); 6,307 households keep poultry as the only agricultural activity. Livestock is the second most common form of agricultural activity (6,647 households), whereas fodder production or provision of pasture is the least common (609 households) (Stats SA 2011). Figure 46 below shows agricultural households by type of activity.²⁰ The majority of agricultural households were involved in animal husbandry only, suggesting the significance of livestock farming in land use; only 10% of the households practiced mixed farming.

BOX 17: Data gap.

- Understand the agricultural practices.
- Estimating the water uses per hectare and the water economic value.

¹⁸ Product gathering refers to natural product (i.e. grasses, reeds, natural dyes, medicinal plants, ...) which are used in handicrafts or traditional artisanal industries. It often stated as ecosystem services related to tourism, handicrafts and natural medicine.

¹⁹ Tribal Grazing Land Policy.

²⁰ Note: An agricultural household may not fall under more than one agricultural activity.

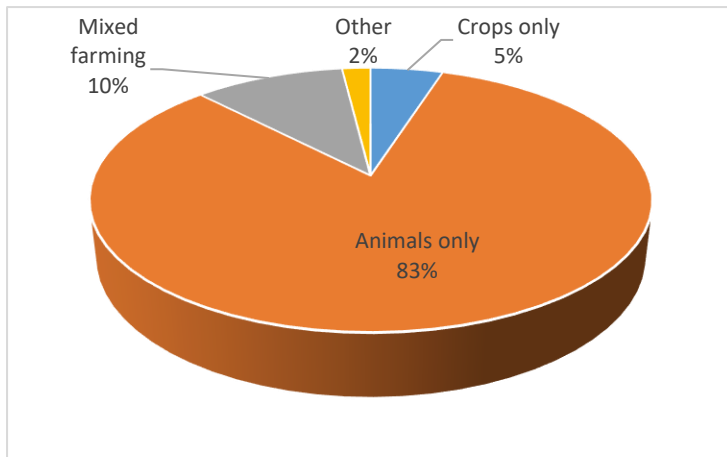


Figure 46. Agricultural households by type of activity 2011.
Source: Stats SA 2012b.

6.2.3. Game reserves and parks

Botswana

National parks and game reserve areas have increased in SED in Botswana, often from conversion of agricultural land. Examples in the district include the state-owned Gaborone Game Reserve, the privately owned nature reserve Mokolodi Nature Reserve and the privately owned recreational park St Claire's Lion Park. In the Southern District, tourism is underdeveloped and wildlife utilization and/or conservation is in the form of the establishment of the Wildlife Management Area (WMA) n°2 of the Southern District, called SO2 and private game ranches in the western part of the district.

South Africa

On the South African side, Ramotshere Moiloa Local Municipality has four formal land-based protected areas which cover 9,737.6 ha (1.4%) of the municipality. The four nature reserves are Madikwe Nature Reserve (5.5ha), Marico-Bosveld Nature Reserve (6,742.2ha), Pienaar Nature Reserve (2,975 ha) and Rust De Winter Nature Reserve (14.9 ha) (SANBI 2007).

6.2.1. Tourism

Botswana

In Botswana, as noted above, conservation-related tourism activities are practiced in the study area. This includes, but is not limited to, the Nature Reserves, Mokolodi Nature Reserve and the Gaborone Game Reserve, St Claire's Lion Park, which is a recreational park, and the Bathoen II Bird Sanctuary in a wider study area. National parks and game reserve areas have increased in SED, but tourism is underdeveloped in the Southern District, despite wildlife and conservation found in the SO2 Wildlife Management Area (WMA) and private game ranches in the western part of the district. Interested actors have pushed for an increase of resources to be dedicated to tourism in the Southern District.

South Africa

In spite of its rural nature, the dominant economic activities in Ramotshere Moiloa Local Municipality are tertiary sector activities such as retail trade and services. Primary and secondary activities are not very prominent in the local economy. Tourism in the study area is mainly game reserves, crocodile farms (e.g., Mmadikwena Crocpark) and heritage sites (e.g.,

Kaditshwene Ruins, Ka-Ditshwene Ancient City Resort). Tourism has led to a considerable number of guest houses around Zeerust and Groot Marico. On 7th November 2014 the Ngaka Modiri Molema District Municipality through its LED unit held a successful Tourism Products Awareness Campaign in Ramotshere Moiloa Local Municipality, as part of the District-wide Tourism Development Programme pointing towards resuscitating tourism and heritage sites in the Zeerust area (Tsa Modiri 2015). Although available data did not indicate the contribution of the tourism sector to the local economy, at national level, tourism contributed 3.0% to the South African economy in 2014, which was higher than the contribution of agriculture (2.5%) and smaller than that of all other industries.

6.2.2. Mining and Industry

Botswana

In term of areal coverage, mining is the lowest land user in Botswana using only about 0.3% of the surface but mining is significant to the overall economic base. Mining in the wider study area is only at the diamond mining town of Jwaneng in the Southern District (approximatively 100 km west of Ramotswa), so this is not considered to be of relevance to the study area.

South Africa

Mining is important to the economy of the larger Ngaka Modiri Molema District Municipality, extracting gold, diamonds, lime, and salt. Mining forms a significant part of the economic backbone of the district. Within the study area, some exploration is underway, but workshop participants were uncertain of the specific mineral (probably kimberlite and nickel). The manufacturing and services sectors are mostly located in towns (e.g., Zeerust and Groot Marico), with most of the manufacturing in Zeerust. Services constitute an important part of the local economy, particularly as an employer. While mining is not a significant activity in the area, there are a few active mines near Nietverdiend.

6.3.Risks and potential conflicts over water and land

Botswana

A number of critical issues that pose risks to land have been identified in Botswana, as summarized in Table 16 for the study area.

Table 16. Environmental and land use issues in the Botswana study districts.

South-East District	Southern District (including Ngwaketse Subdistrict)	Ramotshere Moiloa Local Municipality
Shortage of grazing land, land degradation and bush encroachment	Depletion of rangeland resources due to overstocking, overgrazing and deforestation	Mafikeng bushveld is a vulnerable ecosystem in the local municipality covering 8,047.9 ha (1.1% of municipality)
Pollution of underground and surface water resources	Land use conflicts (livestock, arable agriculture, wildlife and settlements)	
Loss of agricultural land due to settlement encroachment and pressure from Gaborone and Lobatse (urbanization)	Loss of agricultural land	
Illegal abstraction of sand and gravel from the river	Overharvesting of veld products	There are no endangered ecosystems in the local municipality
Illegal dumping of solid waste	Land and water pollution	
Littering	Illegal dumping of building rubble	There are no critically endangered terrestrial ecosystems in the local municipality
Veld fires	Veld fires	
Lack of stormwater drainage	Borrow pits and sand mining	

Sources: MLH (2005b); DTRP (1996); SEDDC (2008/2009); Swedeplan (1994).

South Africa

South Africa does not have critically endangered ecosystems within the Ramotshere Moiloa Local Municipality (Table 16), according to a 2007 report from SANBI. However, the Municipal District Profile for 2011 did note the risks associated with the high use of pit latrines and the high incidence of households disposing of their waste in their own refuse dumps.

In February 2016, a training workshop was organized in Mahikeng, South Africa. One of the exercises was a participatory mapping activity for all participants to contribute to identifying potential or existing contests or conflicts related to water and sanitation. The results of the exercise are based on expert opinion from both countries in the study, as opposed to data, but suggest risk issues in access to and management of water and sanitation in the study area. This is represented in Figure 47 below.

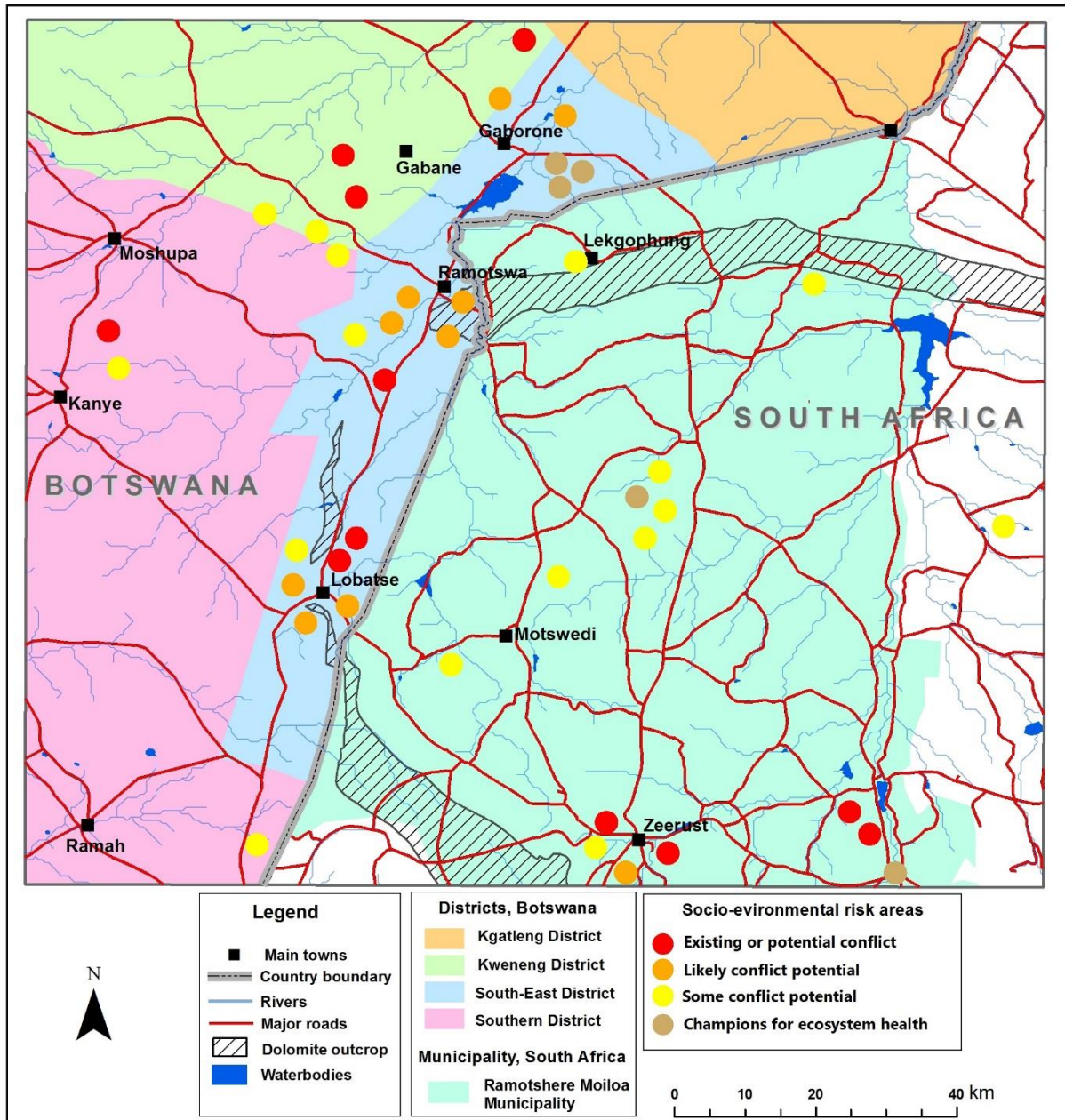


Figure 47. Perceived existing or potential conflicts related to water in the study area.
Source: Ramotswa Training Workshop Report 2016.

7. Demography and Economic Activities

7.1. Population

The population of the study area in Botswana (including Gaborone) is 444,282 and is higher than the population in the study area in South Africa at 150,713 (Figure 48). In addition, the annual population growth rate in the Botswana study area is 4.55%, which represents a far higher growth rate than in the study area of South Africa at 0.92%. The contrast in the growth rate between the study area and across the border is a reflection of the urban migration trend, which brings more people into the urban Botswana study area and out of more rural South Africa study area.

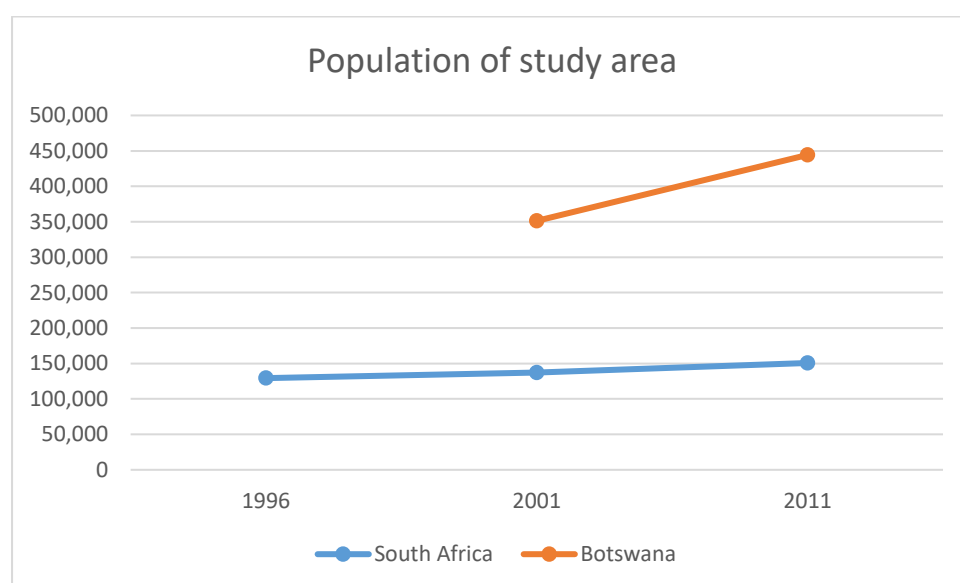


Figure 48. Population in Ramotshere Moiloa Local Municipality and in Botswana's South East District, and the affected settlements in Ngwaketse Subdistrict, and Kweneng East Subdistrict. *Sources:* Stats SA (2011); Statistics Botswana (2014a, 2015a and 2015e).

Botswana

Much of the population of the study area in Botswana is concentrated in the Ramotswa aquifer core area; almost 25% of Botswana's national population lives in the study area.²¹ According to Statistics Botswana (2012, 2015a-e), more than half of the population in the study area live in Gaborone at 231,592, with other key centers being Lobatse, Ramotswa and Tlokweng in the South East District, and Kanye in Ngwaketse Subdistrict in the Southern District.

BOX 18 – Key findings.

- In RTBAA, population growth is four time more in Botswana than in South Africa.
- There are more females than men.
- The age group has 14-64 increased significantly.

South Africa

According to the South Africa Census of 2011, Ramotshere Moiloa Local Municipality had a total population of 150,713, of which 99.6% were black African, with the other population

²¹ The total population of Botswana in 2011 was 2,038,228, according to the 2011 Population & Housing Census.

groups making up the remaining 0.4% (Stats SA 2012b). This represents 0.29% of the national population of South Africa for 2011.²² The population density was 21 persons per km².

7.2. Gender composition of the study area

In the study area across countries, the gender distribution pattern shows a higher percentage of females (Figure 49). This higher percentage of females may be ascribed to a combination of factors, such as migration labor practices, HIV/AIDS and other social influences related to outward migration. The gender distribution is relevant in regard to livelihoods; female employment rates and occupations differ from males, and female-headed households tend to have higher poverty rates than male-headed ones.

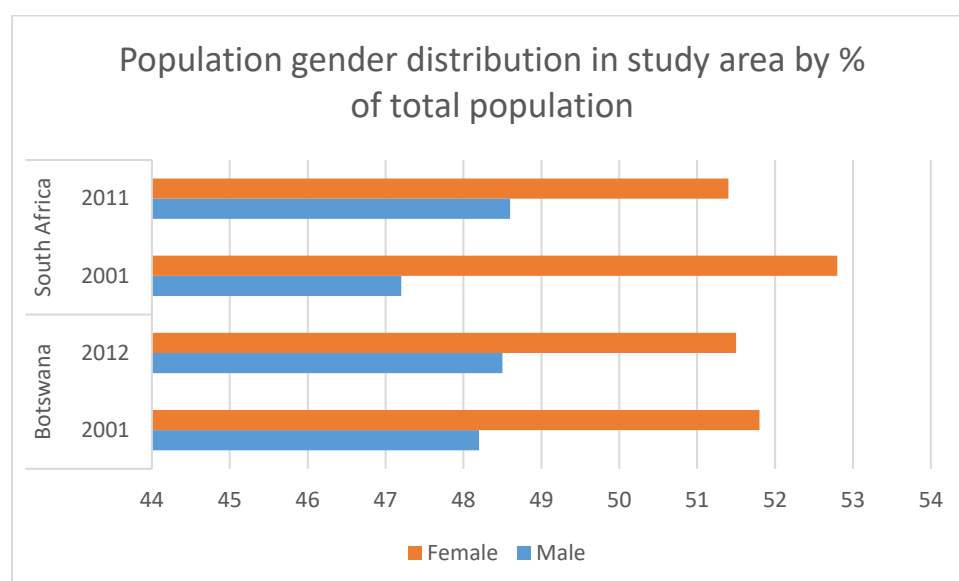


Figure 49. Gender distribution in Ramotshere Moiloa Local Municipality and in Botswana's Southeast District, and the affected settlements in Ngwaketse Subdistrict, and Kweneng East Subdistrict.

Sources: South Africa Census 2001²³; Ramotshere Moiloa Local Municipality 2012/13; Statistics Botswana 2012.

7.3. Age structure of study area

Age structure and trends are important in understanding livelihoods and potential needs of a population in the study area.

Botswana

The age structure and gender distribution of the population in Botswana for the broader district study area is represented in Figure 50. There has been a decrease in the percentage of the population under 14, but a significant increase in the percentage of the population age group between 15 and 64. This suggests a likely migration of youth into the study area in Botswana, though a further breakdown of age groups was not available.

²² The total population of South Africa in 2011 was 51,770,560, according to the 2011 Census.

²³ http://www.statssa.gov.za/?page_id=993&id=ramotshere-moiloa-municipality [Accessed 7 march 2016]

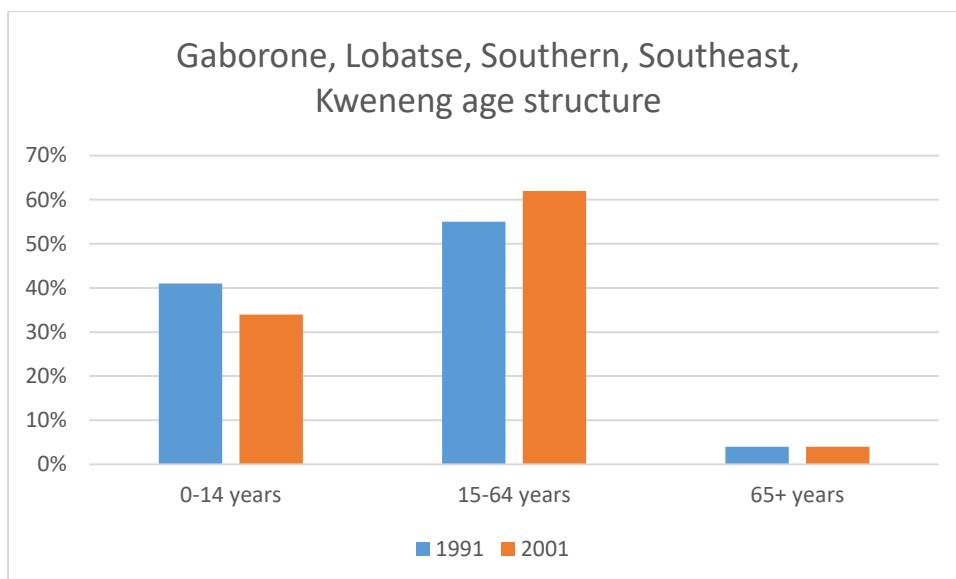


Figure 50. Population age structures of the study area broader districts, 1991 and 2001.
Source: Adapted from MLH 2005a.

South Africa

Figure 51 below shows the age structure of the population in Ramotshere Moiloa Local Municipality for 1996, 2001 and 2011, with the vast majority of the population under the age of 64. More specifically, there was a decline in the male and female population between ages 10 and 19, which is consistent with outward migration of youth from the study area; all other age groups increased as a percentage of the population over the period (the breakdown for specific age bands and gender distribution of the population in Ramotshere Moiloa Local Municipality for 2011/12 and 2013/14 is given in Annex 6).

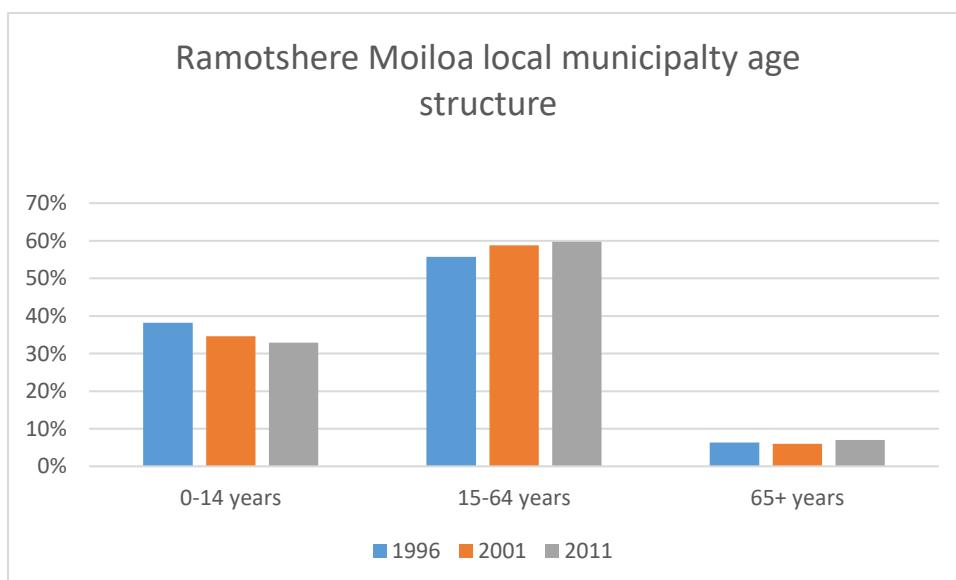


Figure 51. Age structure in Ramotshere Moiloa Local Municipality, 1996, 2001 and 2011.
Sources: South Africa Census 2001²⁴; Ramotshere Moiloa Local Municipality 2012/13.

²⁴ http://www.statssa.gov.za/?page_id=993&id=ramotshere-moiloa-municipality

7.4. Education and literacy

Education and literacy levels point to the key livelihood factors, including employment potential and health issues, and also suggest the opportunities and mechanisms to engage with a population about ecosystem services, water and environment (Figure 52). In both South Africa and Botswana, completion of different levels of education is used as the basis for literacy rates.

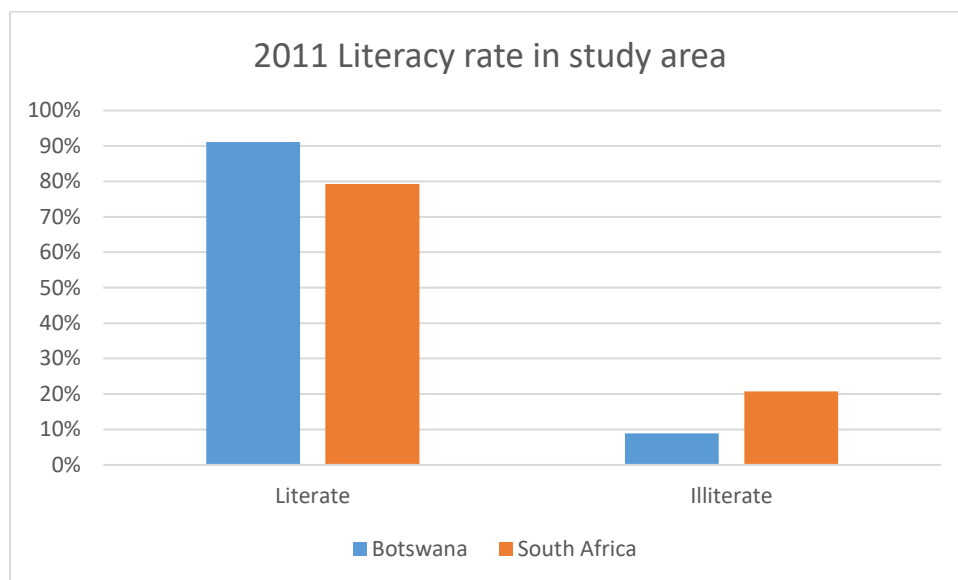


Figure 52. Literacy rate in the study area.

Botswana

In Botswana, the results of the 2011 Census show that the study area has a literacy level of 91.08%, with females having a higher average (89.84 male literacy rate and 92.25 female literacy rate). These estimates were based on the population aged 10 years and above who had completed Standard Four or above, and therefore considered literate. This is higher than the national average, according to the UNDP Human Development Report which is based on population ages 15 and older.

South Africa

In Ramotshere Moiloa Local Municipality in 2011, 20.7% of the population aged 20 years and above had no formal education, compared to 34.7% in 2001 and 36.6% in 1996. The proportion of the population that completed primary education stayed constant at only the 5% range between 1996 and 2011. While the literacy rate is very similar across the study area for both countries, the local municipality illiteracy rate is significantly higher than the national average illiteracy average of 7.1% in 2011 (Stats SA 2012c). According to the UNDP Human Development Report, South Africa's

BOX 19: Data gap.

- Working across two countries presents some challenges as definition or data structure can be different.
- The frequency of, and changes in, categorizations of data collection by Stats SA result in some data gaps.
- Working across three rural districts (Ngwaketse, Kweneng East and South-East) and the two urban districts of Lobatse and Gaborone presents some data challenges which included the question of scale and data discrepancies.

adult literacy rate is 93.7%²⁵, whereas about 80% of the adult population of Ramotshere Moiloa Local Municipality has had some formal schooling and therefore might be assumed to have a literacy capability to read and write short simple statements.

7.5. Poverty status

The income disparity for both countries is among the highest in the world. In 2011, SA's Gini coefficient was 63.4, while Botswana's was 53.1, according to the World Bank GINI Index.²⁶ The disparity is also gendered, as Botswana has one of the highest percentages of female-headed households globally and also female-headed households were found to be significantly poorer than male-headed households (Magombeyi et al. 2015). Poverty indicator data were not available for the study area and must be viewed from other levels or proxies.

Botswana

The poverty rate represented in the figure below is based on the percentage of the population living on less than \$2.00 USD a day. However, data were available on poverty trends at the city/town, urban village, rural and national levels (Figure 53). This disaggregation is important given that poverty profiles indicating rural households are more likely to be poorer than urban and urban village households, according to the UNDP (2005). As much of the present study area is in cities and urban villages, it is likely that the population in the study area may have a lower household poverty incidence than the national average. The poverty head count and household poverty incidence have declined for all settlement types over the timespan shown. However, women are still more likely to fall under the poverty line than men, regardless of settlement type (see Annex 7).

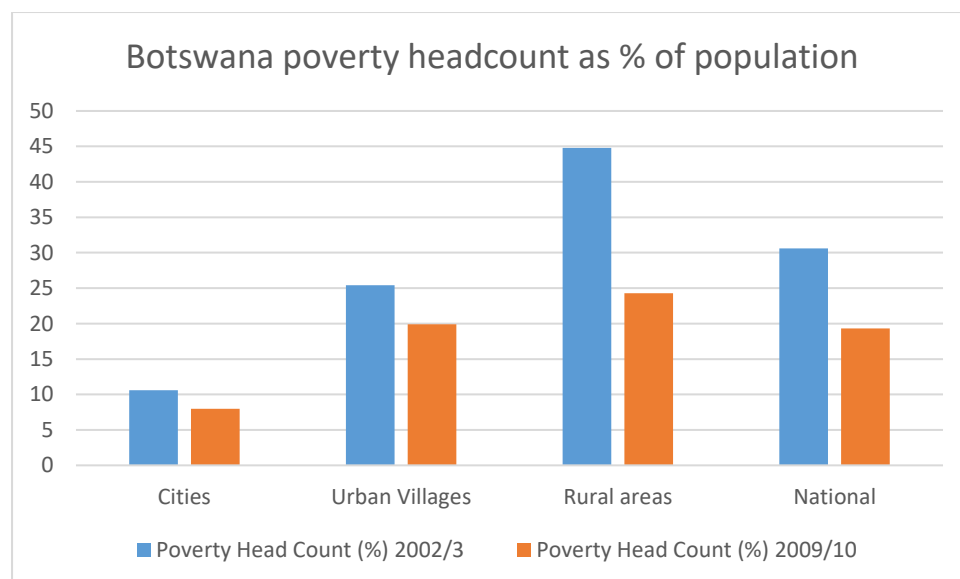


Figure 53. Poverty headcount by settlement type in Botswana, 2002/03 and 2009/10.
Sources: Central Statistics Office (2004), Statistics Botswana (2014c).

²⁵ UNDP Human Development Report 2015, Country Profile. <http://hdr.undp.org/en/countries/profiles/ZAF>

²⁶ The GINI index measures the extent to which the distribution of income (or, in some cases, consumption expenditure) among individuals or households within an economy deviates from a perfectly equal distribution. A Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality.

South Africa

The population of Ngaka Modiri Molema District Municipality living under the minimum living income is 554,668. In 2012, South Africa published a set of three national poverty lines, namely, the food poverty line (FPL), the lower-bound poverty line (LBPL) and upper-bound poverty line (UBPL) which are used for poverty measurement. The national poverty lines include food and non-food items. The FPL is the level of consumption below which individuals are unable to purchase sufficient food to provide them with an adequate diet. Those below this line are either consuming insufficient calories for their nourishment, or must change their consumption patterns from those preferred by low-income households. The poverty rate, represented in Figure 54, is the percentage of people living in households with an income less than the poverty income. The poverty income is defined as the minimum monthly income needed to sustain a household and varies according to household size; the larger the household the larger the income required to keep its members out of poverty. The 2011 poverty rate in Ramotshere Moilwa Local Municipality was 64.69%, which is one of the highest in the North-West Province and higher than the national average. Figure 54 shows poverty incidence within the study area in South Africa. The poverty headcount at local municipality, provincial and national levels all declined significantly between 2001 and 2011, but this may be associated with social programs, as suggested by Altman et al. (2009) in Magombeyi et al. (2013).²⁷ In addition, gender-disaggregated poverty data were not available for the study area, which makes it difficult to identify if improvements affected women and men differently.

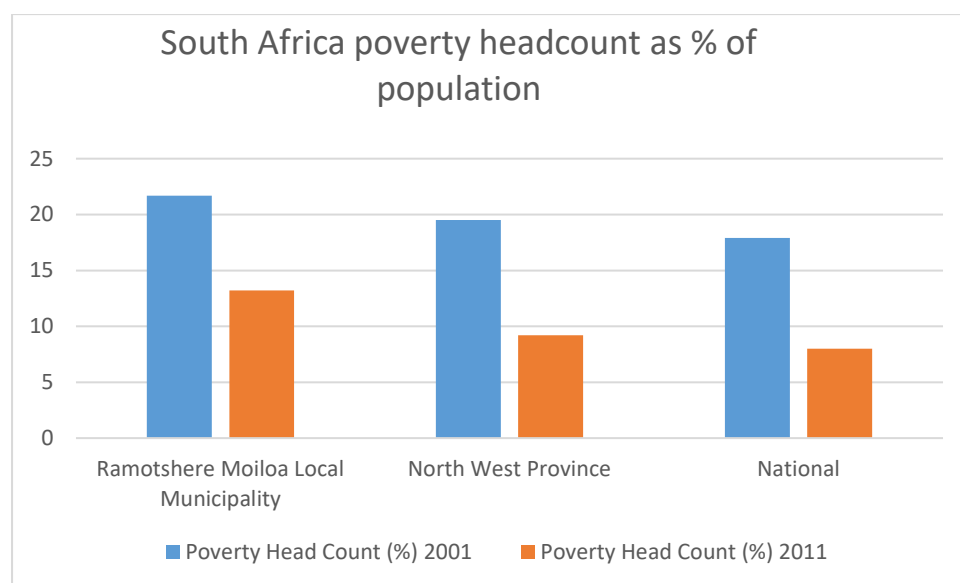


Figure 54. Poverty Headcount at Local Municipality, Provincial and National Level in South Africa, 2001 and 2011.

Source: Stats SA 2014b.

²⁷ Stats SA 2014a shows that 45.4% of households in North West province relied on grants in lieu of salaries or other household income.

7.6. Employment

Bostwana

In Botswana, the 2011 Population & Housing Census showed a total unemployment rate in the study area of 19.5%, with females having a higher percentage of unemployment at 22% (Malepa and Komane 2014). Between 2005/06 and 2011, there were large increases in absolute numbers for paid employment and self-employment with employees, but an equally large decline in the number of people that own farms or land (Statistics Botswana 2009; Malepa and Komane 2014). Figure 55 below shows the figures for employment by occupation. Along with the rise in population numbers, there is an expected increase in absolute numbers in all occupations with the exception of those employed in agriculture and those in professional positions.

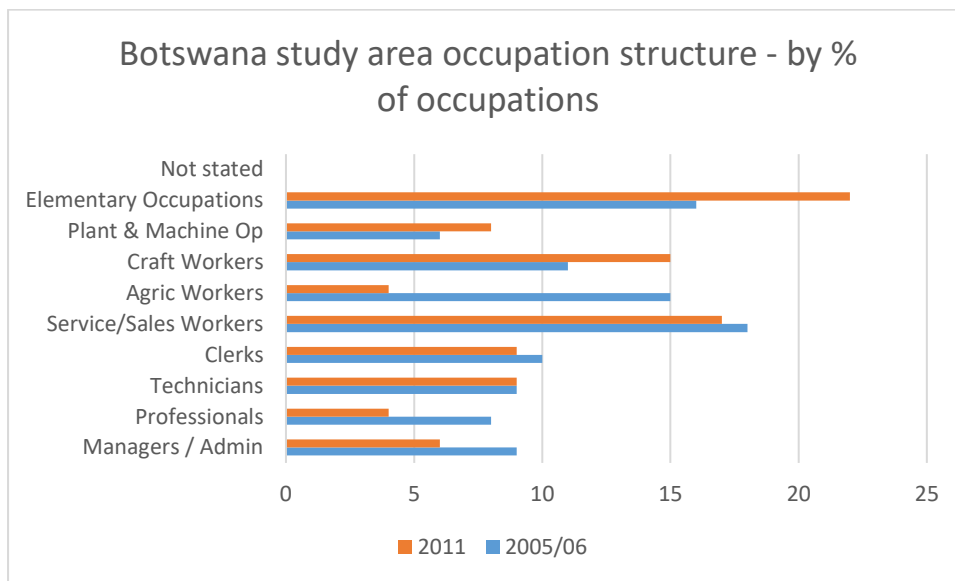


Figure 55. Occupation structure in the study area expressed as percentage of occupation
Sources: Central Statistics Office – (Statistics Botswana 2009); Malepa and Komane 2014.

South Africa

At a national level, among the economically active population (15-64 years) of South Africa, the unemployment rate was 36.2% in 2011 down from 53.6% in 2001. Of the economically active youth (15-34 years), youth unemployment rate declined from 64.6% in 2001 to 45.8% in 2011. In the study area, the tertiary sector (social, financial, wholesale, etc.) represented the largest employer, at 40.0% of the economically active population in 1996 and then 43.8% in 2001. The community/social/personal industry group dominated the economy of the study area in both 1996 (26.4%) and 2001 (27.6%) as an employer. This tendency is directly related to the employment of workers in the professional and government services, such as teachers and civil servants. Agriculture represented an important industrial group employer within the local economy both in 1996 (22.1%) and 2001 (26.3%). The

secondary sector (construction, electricity, manufacturing and transport) employed in 1996 some 13.4% of the economically active population. This figure declined to 10.3% in 2001 indicating a contracting share in the local economy. The role of mining as an economic industrial group remained unchanged on 3.3% in 1996 and 2001, a relatively minor employer in the area. However, in terms of new job creation for 2012/13, community and social employment provided 73.8% of new jobs, and construction 12.4% of new jobs, followed by agriculture with 8.3% and construction with 5.5% of the new jobs created. In many sectors, no new jobs were created in the local municipality at all.

In terms of type of occupation, which can be relevant to income strata, the figure below shows the occupational structure for the study area in 1996 and 2001 in South Africa. The occupational structure in the study area has been dominated by elementary occupations, i.e., low-skilled (39.2% in 1996 and 38.4% in 2001). Employment in professional positions (15.7% in 1996 and 4.6% in 2001) and services (11.3% in 1996 and 10.6% in 2001) represents other important occupations, but still below those employed in elementary positions (Figure 56).

BOX 20 – Key findings.

- The literacy rate is about 80% in South Africa and 90% in Botswana.
- In Botswana, poverty rate is less than 25% in urban and rural area while it reaches 64% in South Africa.
- Unemployment rate is 19.5% in Botswana and probably much higher in South Africa.
- Employment in the agriculture sector decreases globally in RTBAA but the decrease in Botswana is very

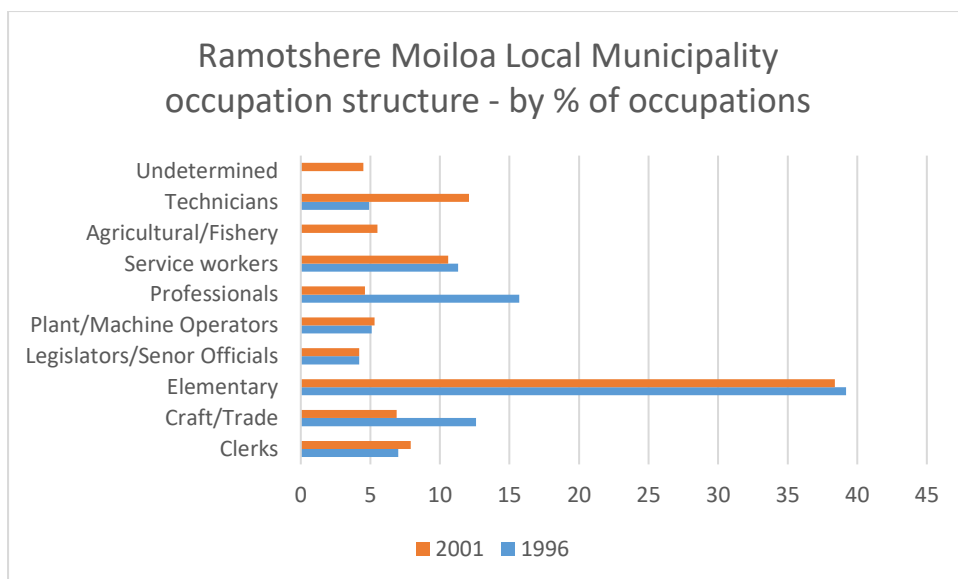


Figure 56. Occupational structure in the Ramotshere Moiloa Municipality expressed as percentage of occupation.

Sources: Census 2001; Ramotshere Moiloa Local Municipality 2012/13.

7.7.Livelihoods and ecosystem services in the study area

During the February 2016 Ramotswa training workshop in Mahikeng, South Africa, participants mapped out their perceptions on ecosystem- and groundwater-dependent livelihoods in the study area in both Botswana and South Africa. The results of the exercise are based on expert opinion from both countries in the study, as opposed to data, but suggest important economic activities that relate to the ecosystem context. This is represented in Figure 57 below.

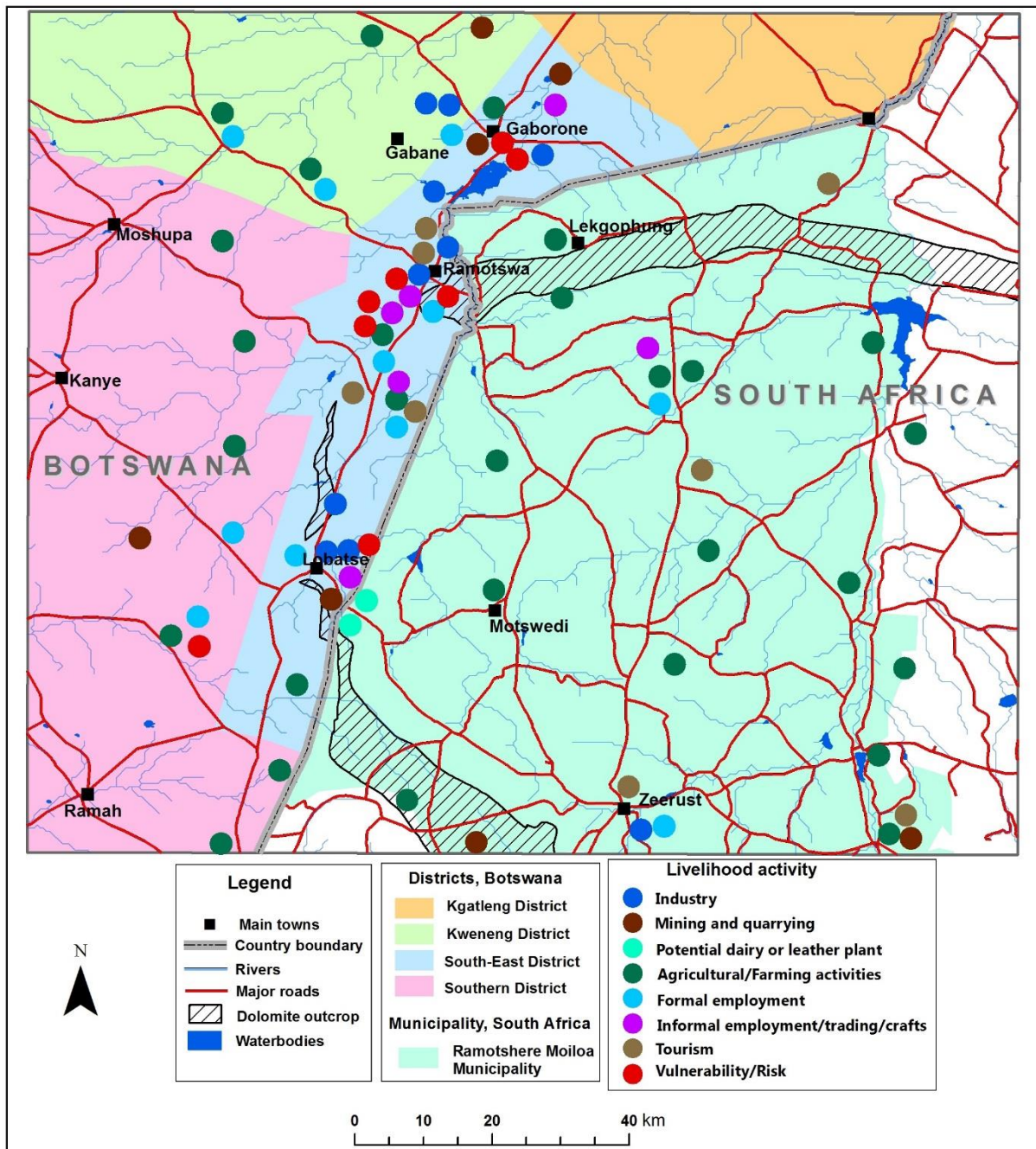


Figure 57. Map of perceived livelihood activities and vulnerability related to ecosystems and groundwater.

Source: Ramotswa Training Workshop Report 2016.

8. Institutions and Governance

8.1. Key water and water-related institutions and functions

8.1.1. Transboundary agreements and regional (SADC)-level policies

At the regional level, no legal instruments exist specific to transboundary aquifers. The Revised SADC Protocol on Shared Watercourses provides the overarching regional, legal framework for shared water resources. Botswana and South Africa are both members of SADC and became signatories in 2000 to the SADC Protocol that seeks to “foster closer cooperation for judicious, sustainable and coordinated management, protection and utilization of shared watercourses and advance the Southern African Development Community (SADC) agenda of regional integration and poverty alleviation”. The Protocol is implemented by the Water Resources Management and Sanitation unit of SADC, which is responsible for transboundary water management principles and national water policy harmonization. However, groundwater management is regulated by the Protocol only in so far as surface water bodies are linked to groundwater aquifers, though not explicitly included in the transboundary river basin and watercourse agreements.

Following SADC Protocol, the Limpopo River Basin riparian states, including Botswana, South Africa, Mozambique and Zimbabwe, signed the *Agreement for the Establishment of the Limpopo Watercourse Commission* (LIMCOM) in 2003 toward improved cooperation on the Limpopo, its tributaries and its waters for protection, preservation and management of the river. LIMCOM countries further agreed in November 2011 to establish a Secretariat to assist in the implementation of the LIMCOM Council decisions. The LIMCOM agreement includes both surface and groundwater in the definition of the Limpopo watercourse (Article 1). In addition, the Limpopo River Awareness Kit includes groundwater and aquifers, specifically identifying Ramotswa as one of the three transboundary aquifers in the Limpopo basin²⁸. The website mentions surface and groundwater interaction, groundwater dependent ecosystems, groundwater quality concerns, and groundwater exploitation, and also includes groundwater within the water balance. Groundwater is also identified as important to ensuring water availability for populations living within the basin to reduce vulnerability and enhance poverty alleviation. LIMCOM is a potential key institution for collaborative management of groundwater.

More specific to Ramotswa, Botswana and South Africa are members of a Joint Permanent Technical Committee (JPTC) tasked with oversight and planning for shared water bodies in the North West Province of South Africa and the peri-urban area of Gaborone, both of which fall within the study area.²⁹

In addition, Botswana, South Africa and the Homeland of Bophuthatswana entered into agreement in 1988 on water allocation from the Molatedi dam (TSWASA agreement). The

²⁸ The Limpopo River Awareness Kit is described as an **information and knowledge management tool** for the Limpopo River basin, to support capacity development and the sustainable management of the environment and resources within the basin. It is one of a number of such River Awareness Kits globally. The Limpopo resource can be found at: (http://www.limpopo.riverawarenesskit.org/LIMPOPORAK_COM/EN/RIVER.HTM).

²⁹ The JPTC appears to have been established under the 1983 treaty, Agreement between the Government of the Republic of Botswana and the Government of the Republic of South Africa Relative to the Establishment of a Joint Permanent Technical Committee.

Agreement allowed South Africa to transfer water from the Molatedi Dam in South Africa to Botswana. The agreement was revised following institutional changes in South Africa, including the integration of one of the agreement signatories, the Homeland of Bophuthatswana, into the Republic of South Africa in 1994. In 2014, a revised TSWASA Water Supply Agreement was undertaken by the Bi-National Commission between Botswana and South Africa, which would allow the allocation of water to the greater Gaborone area between the rainy seasons, though the amount transferred to Botswana would be subject to Molatedi dam water levels.

8.1.2. National policies and regulatory bodies

Botswana

Botswana's water sector is currently in a process of institutional reform. The 1968 Water Act did not account for changes in economic structure, population and human settlement (e.g. urban growth), and climate, among others, as well as new knowledge on water resources. In addition, Botswana committed to the principles of the Integrated Water Resource Management (IWRM), and the Water Act did not reflect those principles and related governance mechanisms needed to implement IWRM effectively. In addition, the 2005-2006 National Water Master Plan Review (NWMPR) noted that the construction of the Dikgatlong dam and expansion of the North South Water Carrier would not be adequate to meet all future water demand. In response to the gaps, a new water policy has been proposed, Botswana National Water Policy, which integrates the IWRM principles, and notably, gives consideration to the management of groundwater resources. The Botswana National Water Policy is still in draft and has been resubmitted to the Parliament of Botswana for consideration.

The 2005-2006 NWMPR also outlined the need for sectoral reforms to enable Botswana to meet water demands, including institutional change to separate the function of water resources management and of water service delivery. To that end, The Office of the President instructed that institutions be reformed so that only two organizations would be responsible for the sector. Botswana's Department of Water Affairs (DWA) is now the custodian and manager of all water resources in the country and the parastatal Water Utilities Corporation has the responsibility of water supply. The Water Resources Board (WRB) has not yet been established, but was proposed to operate as an autonomous body supported by The Ministry of Minerals, Energy and Water Resources to oversee and monitor water resources and support water-related policy development. The shift of responsibilities is still underway and some organizations will be phased out when the reform process is complete.

South Africa

The South African water sector has a number of distinct characteristics with two that are notable. First, South Africa recognizes at national constitution level that water is a human right, which has translated into a policy for free access to the basic human requirement for water. Institutions and regulatory frameworks must be considered in terms of how they either support or constrain the ability of the state to deliver on that commitment. Second, South Africa has policies and programs that seek to balance the historical inequities that continue to have a legacy.³⁰ Financial and human resources are required to review historical and current water

³⁰ The 1983 establishment of the JPTC and the 1988 development of the agreement between South Africa and Botswana to supply water to Gaborone from the Molatedi Dam were both influenced by the political and

access, allocations and use, and to develop measures of redress. Water management institutions and mechanisms, licences and permits are being assessed, and may lead to substantial institutional and regulatory changes.

Not surprisingly, South Africa's water and water-related institutions are in transition. The Department of Water and Sanitation has responsibility for regional monitoring and assessment of geohydrology, including abstraction of groundwater. Catchment management agencies, which are in different stages of development, and water users' associations are currently responsible for the management and coordination of water activities at local level. The study area is within the scope of the Limpopo North-West Catchment Management Agency. The agency has been gazetted, the Business Case approved by the Minister, and the Regional Steering Committee is active, but the Minister is to appoint the Board and Chairperson (Eales 2015). DWS is transferring the functions for the local management to the Catchment Management Agency. Water boards are bulk water-supply agencies that operate pipelines and sell water from reservoirs to municipalities; Sedibeng Water Board is responsible for bulk water services in the Ngaka Modiri Molema District Municipality. Figure 58 shows one possible interpretation of the main water sector organisations, and the relation between them in South Africa (Cobbing et al. 2014) and Table 17 summarizes the institutions relevant to water and sanitation governance and management for Botswana and South Africa.

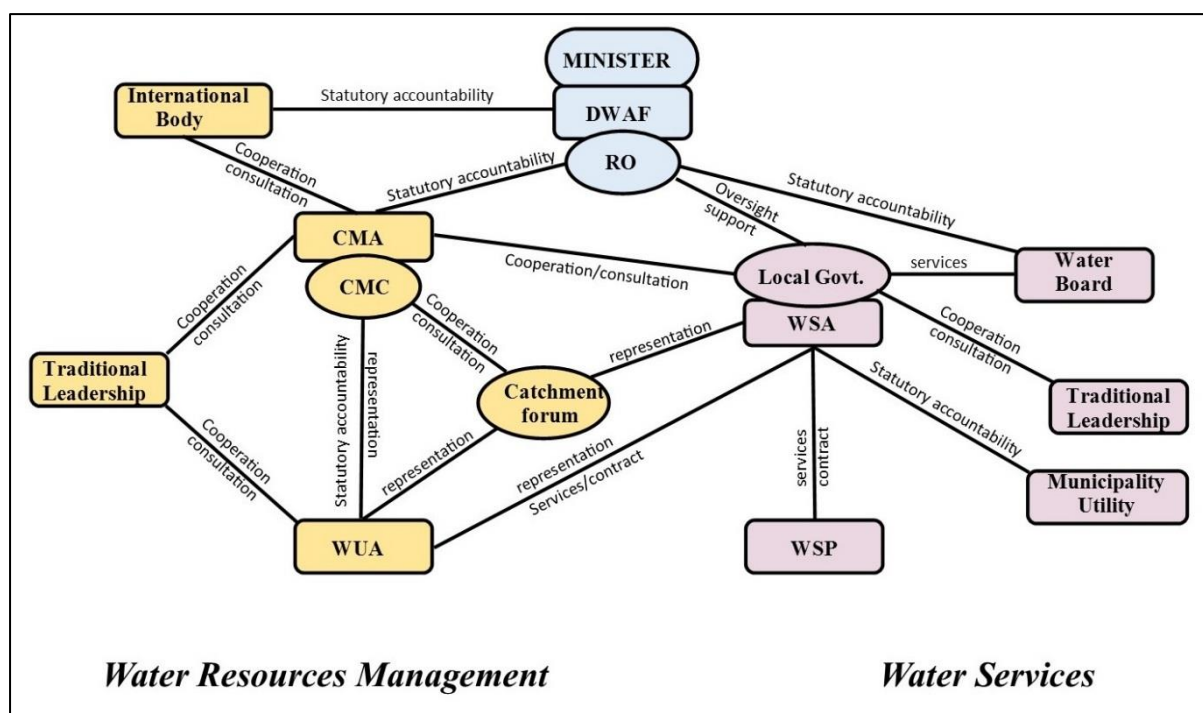


Figure 58: Primary institutional relationships between water sector organisations in South Africa

Source: adapted from Cobbing et al. (2014)

institutional context of the apartheid era. See: Turton AR *et al.*, *A Hydropolitical History of South Africa's International River Basins*, report to the WRC. Pretoria: WRC, 2004.

Table 17. Institutions relevant to water and sanitation for Botswana and South Africa.

Policy/Institution (and role or function applicable)	Botswana	South Africa
National water policy, plans and/or acts governing the sector.	<ul style="list-style-type: none"> • Water Act (1968) • National Water Policy (2012) • Botswana Integrated Water Resources Management & Water Efficiency Plan (2013) • National Master Plan for Sanitation and Wastewater (2003) • Waterworks Act (1962) provides for set up of water authorities and to confer duties and responsibilities. • Boreholes Act (1956) stipulates records and samples must be submitted to the Geological Survey. 	<ul style="list-style-type: none"> • Constitution of South Africa (1996) and the Bill of Rights (Chapter 2), Sections 24 and 27. • National Water Act (1997) • The National Water Resource Strategy adopted in 2004 and 2013 • National Environmental Management Act (1998) • National Environmental Management: Waste Act, (2008) • Mineral and Petroleum Resources Development Act (2002) • Free Basic Water Policy Act (2001)
Water policy, plans and/or acts governing water supply/services.	Water Utilities Corporation Act of 1970	Water Services Act (1997)
Wastewater and sanitation policy, plans and/or acts.	<ul style="list-style-type: none"> • National Master Plan for Sanitation and Wastewater (2003) • Wastewater and Sanitation Management Policy (2001) 	<ul style="list-style-type: none"> • Draft National Sanitation Policy (January 2016) • Strategic Framework for Water Services (2003) (The Department of Human Settlements drives the sanitation policy review process).
National level policy making and coordination body at national for water, wastewater and/or sanitation	The Ministry of Minerals, Energy and Water Resources	The Ministry of Water and Sanitation National Water and Sanitation Advisory Committee (to be established) Department of Human Settlements
Custodian of water resources at national level.	Department of Water Affairs (DWA): Overall responsibility to assess, plan, develop and maintain water resources for domestic,	Ministry of Water and Sanitation , through the Department of Water and Sanitation (DWS).

	<p>agricultural, commercial, industrial and other uses in the whole country. In order to effectively implement these leadership roles, DWA also has the responsibility of assisting and advising in the formulation of water resources development and management policies and legislation.</p> <p>Water Resources Board (WRB): Autonomous body supported by (MMEWR) that oversees and allocates water resources; monitors resources and develops water-related policies. Intended to ensure independence and equity in the sustainable allocation of water resources.</p>	<p>Branch: Water Planning and Information Management Responsible for water resource sustainability and availability, planning and development.</p> <p>Branch: Water Infrastructure Development Responsible for infrastructure development and rehabilitation, operations of water resources and water service infrastructure</p>
Water Regulator	<p>The Water and Energy Regulator: This entity has the responsibility of ensuring financial sustainability across the water sector, reducing wastage by facilitating the streamlining of operations and determining revenue requirements to inform regular tariff adjustments. The other responsibility is to oversee compliance of service standards, ensure efficiency and protect consumer rights.</p>	<p>The Ministry of Water and Sanitation, through the Department of Water and Sanitation (DWS).</p> <p>Branch: Water Sector Regulation Responsible for ensuring the development, implementation, monitoring and review of regulations across the water supply chain.</p>
Water rights allocation and monitoring	<p>Water Apportionment Board (WAB) with secretariat at DWA: Granting and administration of water rights; to be abolished after the water sector reforms have been concluded.</p>	<p>The Ministry of Water and Sanitation, through the Department of Water and Sanitation (DWS).</p> <p>Branch: Water Sector Regulation Responsible for ensuring the development, implementation, monitoring and review of regulations across the water supply chain.</p>

		Water Tribunal (independent body that reviews disputes over water allocations and licenses).
Manager of water resources at subnational level		Catchment Management Agencies.
Manager of water supply services	Water Utilities Corporation (parastatal). District Councils	District and Local Municipalities Sedibeng Water Board provides bulk potable water services to the municipality and other water service institutions.
Manager and/or regulator of environment	Department of Waste Management and Pollution Control: Administration of policy, legislation and programs regarding waste management and pollution control.	Department of Environmental Affairs
Regulator of waste management and related environment	Department of Waste Management and Pollution Control: Coordination and monitoring of sanitation and waste management; Planning and development of wastewater treatment works.	Department of Environmental Affairs
Manager of wastewater treatment and sanitation services	Water Utilities Corporation.	Department of Water and Sanitation (DWS). District and Local Municipalities. Department of Human Settlements
Manager and/or regulator of groundwater	Ministry of Agriculture (Water Development Division): Development of small agricultural dams. Development of groundwater resources for irrigation.	Department of Water and Sanitation: At national and provincial level through the directorates. Catchment Management Agencies.
Small water storage and dams	Small Dams Committees: Manage Small Community Dams.	Catchment Management Agencies. Agencies District and Local Municipalities Water Boards Water Users' Associations.

Sources: RAMOTSWA Training workshop 2016; UNESCO-IHP (2016), DWS, DWA.

8.2. Water management

In South Africa, surface water is managed and distributed under various schemes. The Molatedi Gaborone Water Supply Scheme supplies the northern parts of the municipality with water. Ngotwane Water Supply Scheme supplies water to Ga-Seane, Lobatleng, Rietgat, Tsholofelo, Driefontein. Motswedi Water Supply abstracts water from the Sehujwane Dam and supplies Reagile, Borakalalo, Motswedi, Gopane East, Gopane West and Sebalagane. The local municipality still needs to identify a water supply source for Luhurutshe and neighboring villages.

Regarding groundwater, the Department of Water and Sanitation has a record of 3,238 boreholes currently in use within Ramotshere Moiloa Local Municipality (NGA 2016). It is evident from Table 24 that boreholes play a major role in water supply in the local municipality, an increase in the proportion of households supplied by boreholes from 9.6% in 1996 to 21.3% in 2011.

8.3. Capacity in the water sector

The capacity of the organizations and institutions responsible for the various functions at different spatial scales is important to understanding the current and future management of water resources. The 2011 municipal district profile for Ngaka Modiri Molema District states that the State of Local Government Assessment in South Africa found that the Ngaka Modiri Molema District Council undermines laws and policies that govern local government. More specific to the water sector, it also states that there is poor prioritization of services and functions by the council, with the technical unit responsible for service delivery unable to deliver infrastructure. Furthermore, the district does not provide sufficient support to its local municipalities on water and sanitation. The report concluded that infrastructural prioritization in the Ngaka Modiri Molema District should focus on improved delivery of infrastructure, with water and sanitation in the rural areas as critical priorities, but there must be increased technical capacity to enable the district to carry out its mandated functions on water and sanitation. This appears to be the case at other institutional levels; a 2015 Water Research Commission (WRC) report noted that DWS does not have adequate capacity to implement the National Water Act and is unable to ensure its compliance (Eales 2015; Rossouw 2016).

9. Key issues

The key issues has been identified after the data collection period from September 2015 to April 2016 and through the findings of the baseline report produced on the 15th of June 2016. Group discussions have been organised in November 2016 with governmental institution partners in both Botswana and South Africa in order to discuss and agree on the wording and ranking of the key issues. The key issues were then harmonised during discussions at the 2nd Regional Meeting on Tools for the Sustainable Management of Transboundary Aquifers, 28 November – 02 December 2016, South Africa. The key issues presented below are a consolidation across countries of these discussions.

9.1. Understand the resource and filling the data gap

The baseline report identifies some data gaps which will need to be filled in order to improve the understanding of the resource and to provide realistic and relevant guidelines to the Joint Strategic Action Plan. Table 19 lists all data gaps identified in this baseline report.

Table 19. Data gaps in the RTBAA identified in the baseline report.

Climate and hydrology	<ul style="list-style-type: none"> • Better evaporation data, including inside or close to the hydrogeological boundary, including long-term time series, which are necessary to understand the trend in evaporation. • It is necessary to know the interlink rainfall – river – groundwater. One identification issue is the lack of information on the spring from the dolomite and the natural river flow. All the river flow is done at the level of the dam and usually downstream of the dam.
Hydrogeology	<ul style="list-style-type: none"> • Long-term monitoring of the groundwater quality is necessary to follow the water-quality trend, especially the nitrate concentration. The monitoring being concentrated in the Ramotswa Wellfield, is also necessary to monitor a larger area in order to identify the contamination spread. It is necessary to have long-term groundwater quality data, specially about nitrate concentration inside RTBAA • The 1/25, 000 digitalized geological maps are not harmonized inside the country, particularly in South Africa. RTBAA is split into four different shapefiles/sheets. As a consequence, the harmonization in between the country is very difficult. More work is needed to provide a satisfactory geological map of the RTBAA. • There is a lack of information on the underground inside RTBAA. The location of the dike needs to be improved in order to determine the compartments of the Ramotswa dolomite and to identify its transboundary compartment(s). In addition, the mapping of the underground (work in process) should give information, but not exclusively, on the thickness and extent of the aquifer. • Complementary aquifer characteristics are also required inside RTBAA. For example, storativity and yield are important factors to determine the abstraction capacity of the aquifer.

	<ul style="list-style-type: none"> • The recharge and discharge mechanisms are essential to identify adequate groundwater management. The different springs should be located and monitored while recharge areas should be protected against contamination. Globally, identifying groundwater flow using piezometric maps is one of the essential requirement for groundwater management
Water supply and sanitation	<ul style="list-style-type: none"> • The quality of the data on water uses (including groundwater) does not give a sufficient understanding of the role that groundwater plays for domestic and agricultural use in the RTBAA. More localized data are required. As a complement, better knowledge on groundwater use in RTBAA is needed while improved knowledge of the current and future water requirements in RTBAA is key for developing strategic action for better (ground)water management. • Better understanding of the capacity of the wastewater treatment plant in terms of treatment volume and wastewater quality is needed to understand the potential of wastewater reuse in the RTBAA. • A detailed risk assessment of contamination of surface water and groundwater from wastewater (wastewater plant and pit latrine) and land use should be performed.
Socioeconomics	<ul style="list-style-type: none"> • Working across two countries is challenging; challenges as a definition or data structure can be different between Botswana and South Africa. Choosing common definitions would be a welcome step. • In Botswana, the data collection from the three rural districts (Ngwaketse, Kweneng East and Southeast) and the two urban districts of Lobatse and Gaborone presents some data challenges which included the question of scale and data discrepancies. • In South Africa, the frequency of, and changes in, categorizations of data collection by Stats SA resulted in some data gaps. • The agricultural practices, including the water consumption per hectare, need to be identified as agriculture remains mainly on groundwater in RTBAA. Livelihood in RTBAA is thought to be improved with agricultural development, particularly in the poor South Africa. Thus, agricultural development using groundwater (i.e., irrigation and livestock watering) should be done in parallel with adapted and better agricultural practices.

9.2. Current groundwater contamination and resource vulnerability to pollution

One of the major environmental issues is the high prevalence of pit latrines in the study area and proximity of pit latrines to boreholes. Given that boreholes are a main source of water, especially in rural areas and in small urban areas such as Ramotswa and Lobatse where the nitrate contamination from human excreta is recognized, the potential risk is high. However, data on the extent of human-related pollution were not available for South Africa. Figure 59 shows how pit latrines can be close to drinking water supply boreholes in the Ramotswa Village.



Figure 59. Ramotswa Wellfield at its closest from the Ramotswa Village, February 2016. Photo by Yvan Altchenko.

Elsewhere in the RTBAA, the type or extent of pollution (actual or potential) is associated with the land use activities practiced, population densities and levels of development. The literature emphasizes that the sustainability of groundwater resources in Botswana is threatened by pollution, particularly in urban centers and larger villages. There are a couple of settlements of this latter type in the study area.

Although data were not accessible on pollution levels, Table 18 suggests actual sources of groundwater pollution identified in Botswana in the study area, including an indication of the intensities of the sources of pollution and reasons. Table 18 also includes additional potential source of pollution related to land use in Botswana from the although dated study entitled “Protection Zones and Guidelines for Major Wellfields, Aquifer and Dams in Botswana” which was commissioned by DWA and undertaken by the Water Surveys Botswana (Water Surveys Botswana, 1993). All identified groundwater pollution sources are considered as potential groundwater pollution sources in South Africa, even if it has not been specifically identified. This is a subjective analysis based on the study area’s land use background outlined above, and discussions held in the RAMOTSWA workshop in February 2016 on environmental issues and risks.

Table 20. Sources and intensities of groundwater pollution and rationale in the Ramotswa Aquifer Project area.

Pollution source	Pollution intensity	Pollution status		Rationale for pollution source intensity/impact
		Botswana	South Africa	
Pit latrines	High	Identified	Potential	High use of pit latrines in the remoter part of the study area.
Septic tanks and effluent soakaways	High	Identified	Potential	The water table is shallow in the study area.
Storage of agricultural waste, and intensive livestock feedlots	High	Identified	Potential	Existence of some feedlots in the study area in the freehold land ranches, especially around Lobatse. Existence of a big poultry farm and abattoir near Ramotswa
Burial sites	Low	Potential		Possible if not properly located.
Oil/fuel storage and disposal including waste oils	Low	Potential		The study area is quite urbanized on the eastern side; hence, such occurrences are likely.
Solid and liquid sanitation waste disposal	ND	Potential		Water Surveys Botswana (1993).
Sewage works, oxidation ponds,	ND	potential		Water Surveys Botswana (1993).
Production, storage, and use of hazardous chemicals (agricultural, commercial and industrial) uncluding use of fertilizers and pesticides	ND	Potential		Water Surveys Botswana (1993).
Mining and associated activities, mine waste and quarrying	ND	Potential		Water Surveys Botswana (1993).
Major infrastructural developments including new roads, and industrial and residential areas	ND	Potential		Water Surveys Botswana (1993).

ND = No Data

Source: RAMOTSWA training workshop 2016 and Water Surveys Botswana (1993).

9.3. Congruity between water requirements and available water

Considering constraints on knowledge related to groundwater availability in the RTBAA, another issue is the discrepancy between the local water availability and the aggregate water requirements in RTBAA, especially in the current context of drought where surface water storage is at this lowest level. RTBAA is currently under high water stress. There is indeed a massive water transfer in the Botswana side within the Limpopo Basin (North South Carrier). In fact, about 40% of the current RTBAA water requirements comes from outside RTBAA. In addition, the trend in precipitation shows a decline in annual rainfall over the last 25 years indicating that available water inside RTBAA could decrease if not managed properly. A key conclusion from the data and literature, as well as the participatory livelihoods mapping exercise, is that the challenging management of groundwater and surface water is a potential source of conflict in the study area. This relates to over-abstraction and aquifer vulnerability to depletion in some cases

9.4. Limited policy implementation

In South Africa, the literature points to difficulties to fully implement national-level policies and programs, and low compliance with regulatory frameworks that govern both surface water and groundwater (Eales 2015; Rossouw 2016). For example, in South Africa, only two out of the nine Catchment Management agencies³¹ decided in 2012 are currently established (Meissner et al., 2016). For both Botswana and South Africa, the poor implementation of policies and compliance with institutions is related to lack of capacity by institutions to carry out their functions across multiple levels. This lack of capacity is rooted in limited staff and financial resources as well as constrained technical skill/expertise. Both Botswana and South Africa are in process to implement policy with regard to water planning, management and regulation, which makes it difficult to identify clear functions and roles. This includes a relatively recent focus on groundwater management in South Africa. At the same time, the transition provides an opportunity to influence policy, including transboundary policy, and practices of new and developing institutions to take decisions based on research evidence and to develop mechanisms for more cooperation. Strengthening existing research would be needed in both countries to assess the extent of capacity gaps and opportunities to intervene positively in evolving institutional arrangements.

9.5. Water and sanitation access for vulnerable people

Potential tensions in the study area are perceived from water access and poor water and sanitation service delivery for vulnerable people. Water access for vulnerable people refers to the lack of private/individual financial resources to prevent discontinuous service because of drought conditions or infrastructure failure. Data from census reports in both countries support the position that there is inequality in economic status and opportunities, and these are reflected in access to water and sanitation. Given that female-headed households are poorer, and considering the higher percentage of female-headed households than in male-headed households in the study area, the inequitable access to water and sanitation is likely to disproportionately disadvantage female-headed households. The potential tensions are reported

³¹ Limpopo, Olifants, Inkomati-Usuthu (established), Pongola-Umzimkulu, Vaal, Orange, Mzimvubu-Tsitsikamma, Breede-Gouritz (established), and Berg-Olifants

by participatory mapping participants to have worsened with the recent drought and decrease in water resources. In addition, urban areas have higher level of water and sanitation services than those in poorer, rural areas. In fact the study area in South Africa is primarily rural and agricultural, with high levels of poverty and low levels of literacy while it is more urban and in some areas more affluent with higher literacy rates in Botswana. The contrasting conditions across the border create also differences in water demands and needs in the study area, despite relying on shared water resources.

10. Conclusion

Contribution of the baseline report. The baseline report of the Ramotswa project has vastly expanded the state of knowledge on water resources, quantity and quality in the RTBAA and laid a critical foundation for future water management in the aquifer area. The report represents the biophysical and socioeconomics assessment of the greater RTBAA located in the Upper Limpopo Basin and shared by Botswana and South Africa. The assessment highlights the key environmental issues linked with groundwater and the data gaps which need to be assessed in order to provide adequate and relevant guidelines for groundwater management in the forthcoming Joint Strategic Action Plan.

Aquifer parameters: quality and quantity. There are two main aquifers in RTBAA: the Lephala Aquifer and the Ramotswa Dolomite, the latter being the major water-bearing unit and the focus of the project. Groundwater in the Ramotswa Dolomite is located in the part of the dolomite where karstification has occurred. That means that acidic rainfall naturally dissolved the dolomite, creating fracks, cavities and sinkholes. The Ramotswa Dolomite corresponds to five carbonate formations referred to as either “chert-free” or “chert-rich” dolomite, the latter being the most important water-bearing formation. The aquifer is compartmentalized by dikes which stop groundwater flow. Currently, there is uncertainty in the location of the compartments, the interactions between the compartments and the extent of the aquifer. While the quality of surface water is generally fairly good, in RTBAA, groundwater has been contaminated by human activities. Nitrate concentration can be very high at close proximity to the Ramotswa habitation. This is due to contamination from pit latrines. In fact, pit latrine (traditional and VIP) is the major sanitation system in South Africa and pit latrine as a percentage of the sanitation system still increases in RTBAA.

Improving knowledge. While groundwater from the Ramotswa Wellfield is used for domestic purposes, groundwater does not reach potable standards for the nitrate parameter. Thus, groundwater is blended with other water sources. Whereas there are data on water table, borehole and groundwater quality, there is scope for improving the hydrogeological knowledge of the Ramotswa Aquifer, particularly outside the limit of the two main wellfields in Botswana (Ramotswa and Lobatse wellfields). In particular, knowledge of the extent and the storage capacity of the aquifer can be a key for further water use development in RTBAA.

Challenges will not abate. Climatic data in RTBAA show that average annual rainfall is decreasing while the temperature and evaporation trends do not indicate significant change. Evaporation in RTBAA is about 2,000 mm per year and annual evaporation from the Gaborone Dam is higher than the water needs of Gaborone. More spatial and temporal rainfall variations are expected, increasing frequency and intensity of extreme climatic events like drought or flood. 2015/2016 is already identified as a significant drought year. Moreover, there is congruity between the water requirements in RTBAA and the current local water availability

from the RTBAA. The Botswanan RTBAA side is extremely dependent on water transfer from inside and outside the RTBAA, corresponding to the TSWASA agreement and the North South carrier respectively. Globally, future climate changes and increasing water requirements in RTBAA should exacerbate the existing water stress of the area.

GW use in Ramotswa Aquifer Area. Groundwater represents less than 20% of the domestic water use in RTBAA but current abstraction from the Ramotswa Wellfield is less than 5% in volume of water requirements in the Botswanan RTBAA side. Groundwater use is mainly for domestic and agricultural purposes, the rural population generally depending on groundwater. In fact, inside RTBAA, 82% of the population in South Africa lives in rural areas while the corresponding proportion is only 9% in Botswana. Population growth is four times more in Botswana than in South Africa. The poverty rate which is much higher in South Africa than in Botswana reflects this situation. Employment in the agriculture sector decreases in RTBAA but the decrease in Botswana is very important, agriculture employing less than 5% of the working population. The contrasting conditions across the border create differences in water demands and needs in the study area, despite relying on shared water resources

Improved water management as vehicle for vulnerability reduction. Water management, including surface water and underground water, is key for reducing inequality in access to water and sanitation, which is a consequence of the economic inequity between Botswana and South Africa and inside each country. Unfortunately, there is a lack of implementation of policies and compliance with institutions. This is related to lack of capacity by institutions to carry out their functions across multiple levels.

Looking ahead: harnessing the opportunity. Using on-going phases as opportunity to influence policy and practices of new and developing institutions to take decisions based on research evidence, the baseline report identified data gaps which need to be assessed for improving water management and enhancing international mechanism cooperation. For example, knowledge in recharge and discharge mechanisms, and in aquifer storage capacity is crucial to understand the role of the Ramotswa Dolomite could play in the water stressed RTBAA. As a complement to determining the sustainable groundwater abstraction capacity of the aquifer, better understanding of the aquifer is key for developing alternative solutions like using the aquifer as a water storage through an artificially managed recharge.

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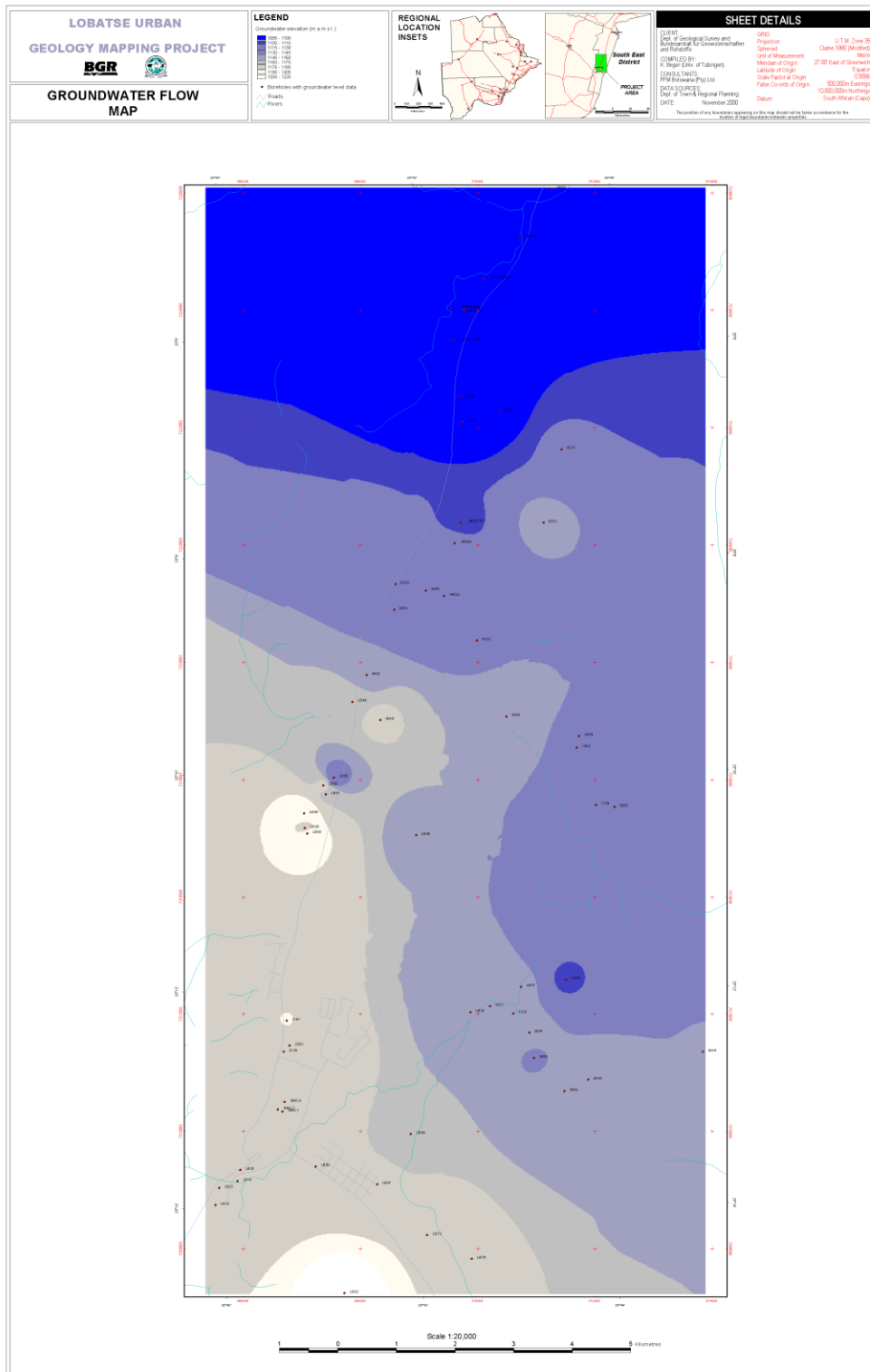
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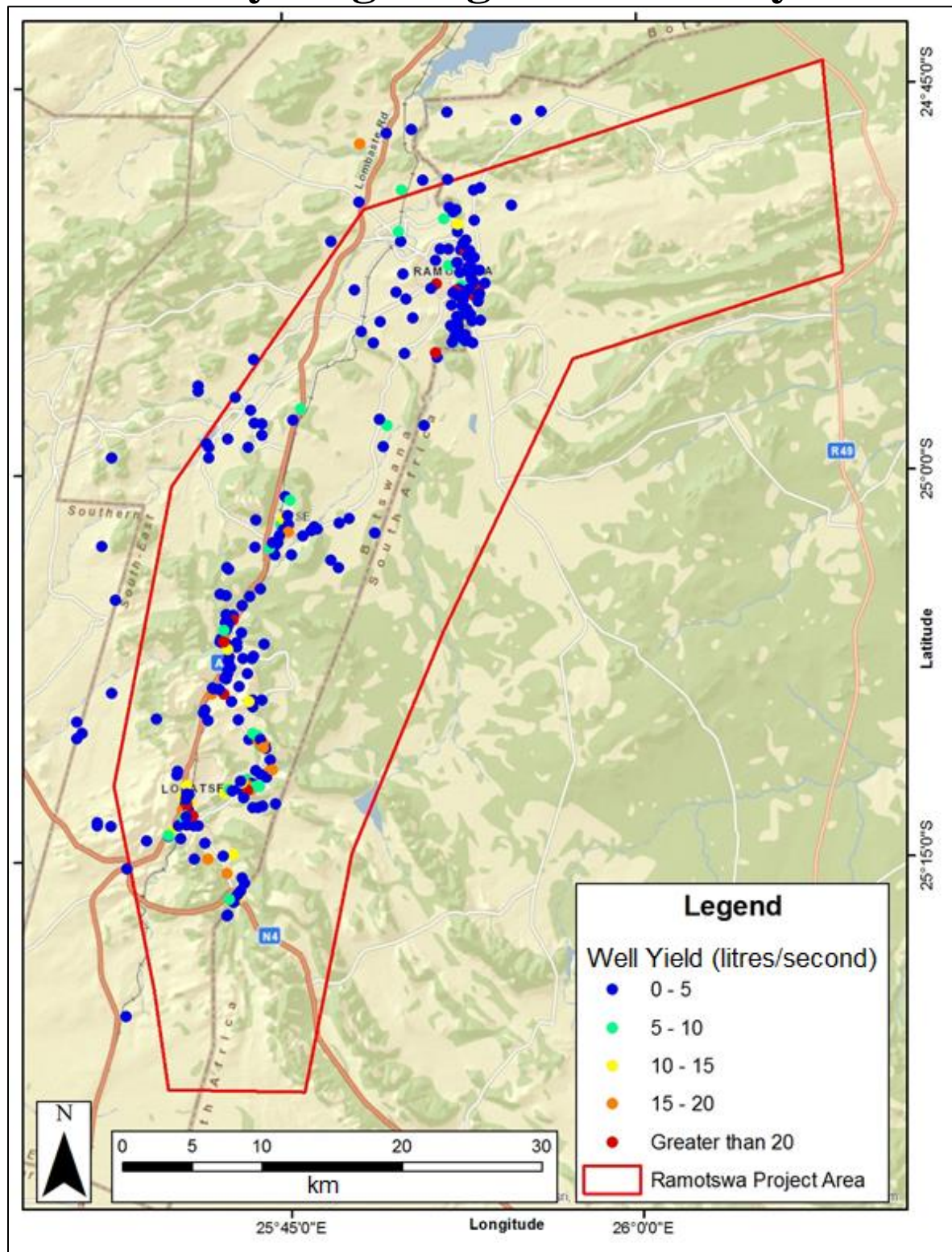
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Annexes

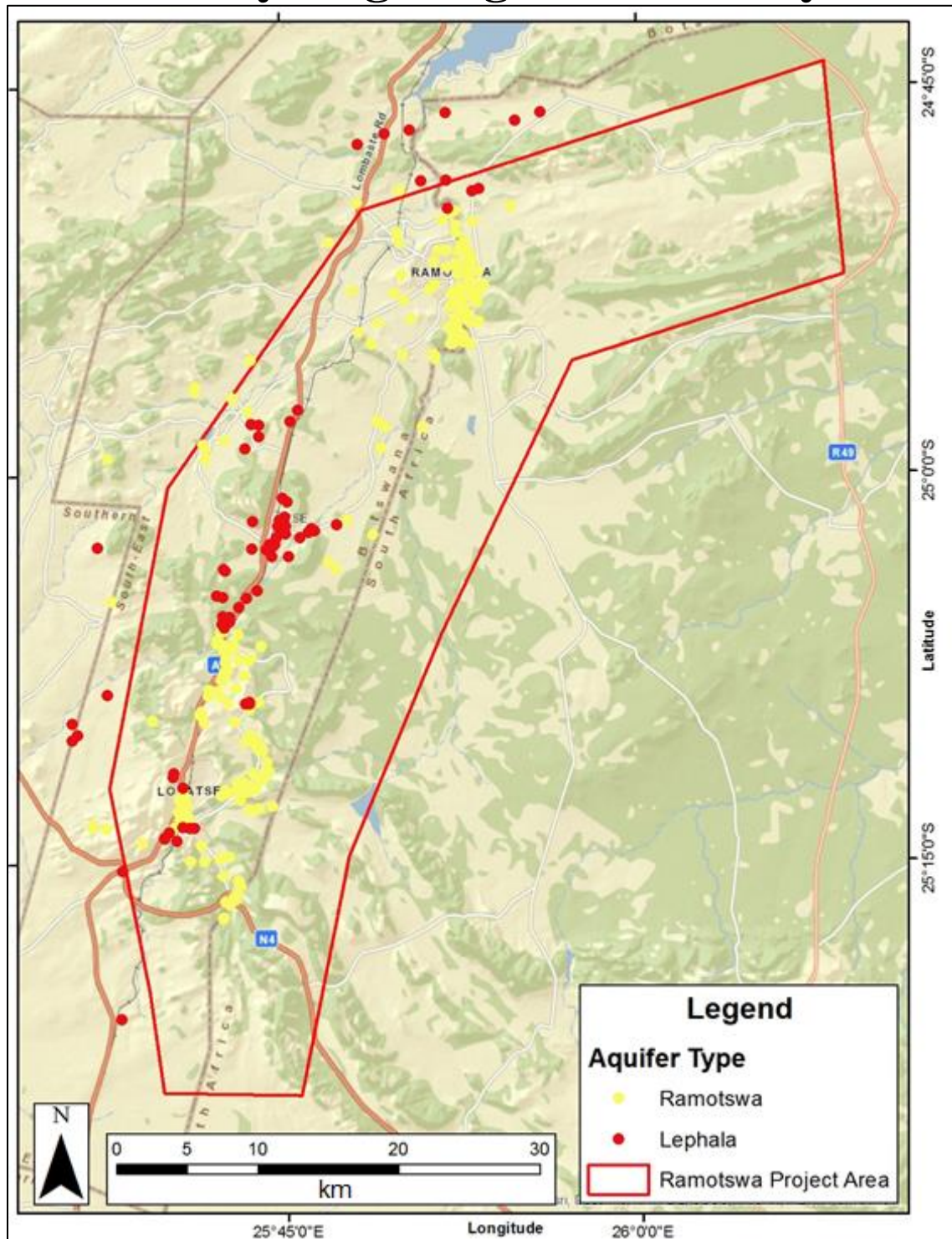
Lobatse urban area



Annex 2: Yields of the boreholes inside the hydrogeological boundary



Annex 3: Localization of the Ramotswa Dolomite and the Lephala Aquifer inside the hydrogeological boundary



Annex 4: Numbers of new and repeat diarrhea-related illnesses in 2012

Diagnosis	New/ Repeat	South East District		Southern District		Kweneng East		Gaborone		Lobatse	
		M	F	M	F	M	F	M	F	M	F
Diarrhea with blood	N	26	27	91	86	288	244	206	185	63	44
	R	2	-	2	1	13	15	22	11	1	8
Diarrhea (acute) with some dehydration	N	295	260	516	573	1,084	1,031	1,347	1,272	281	265
	R	12	11	39	28	127	76	164	155	20	14
Diarrhea (acute) with severe dehydration	N	23	22	63	68	284	204	152	144	21	25
	R	-	-	2	3	21	19	16	9	4	3

Source: Statistics Botswana 2012

Annex 5: Botswana National Settlement Policy – Settlement Hierarchy (Government of Botswana, 1998)

Primary Centres	<p>Primary centres are settlements with a population of at least 20,000 people. They are divided into:</p> <ul style="list-style-type: none"> - Primary I: Settlements with population of at least 100,000. - Primary II: Settlements with a population range of 50,000 to 99,999. - Primary III: Settlements with a population range of 20,000 to 49,999.
Secondary Centres	<p>Secondary centers include intermediate urban centers or district/subdistrict centers with the capacity to act as administrative, market distribution and service centers. Their populations range from 10,000 to 19,999.</p>
Tertiary Centres	<p>Tertiary centers are settlements with a population range of 250 to 9,999 including Remote Area Dweller (RAD) settlements. They are subdivided as follows:</p> <p>Tertiary I: Settlements with a population range of 5,000 to 9,999.</p> <p>Tertiary II: Settlements with a population range of 1,000 to 4,999.</p> <p>Tertiary III: Settlements with a population of 500 to 999.</p> <p>Tertiary IV: This level includes settlements with a population of 250 to 499.</p>

Annex 6: Age structure and gender distribution of Ramotshere Moiloa Local Municipality, 2011/12, 2012/13 and 2013/14

Age (years)	2011/2012			2013/14		
	Male	Female	Total	Male	Female	Total
0-4	7,334	7,107	14,441	9,482	8,972	18,454
5-9	7,801	7,983	15,784	8,100	7,824	15,924
10-19	16,638	16,812	33,450	15,192	14,324	29,516
20-29	10,647	12,029	22,676	12,207	12,235	24,442
30-39	7,653	9,083	16,736	9,051	9,633	18,684
40-49	5,885	6,990	12,875	6,780	8,276	15,056
50-59	4,006	4,855	8,861	5,782	6,762	12,544
60-69	2,746	3,701	6,447	3,870	4,879	8,749
70+	2,197	3,977	6,174	2,755	4,588	7,343

Source: Ramotshere Moiloa Local Municipality 2013/14.

Annex 7: Poverty Incidence Percentage Shares by Sex and Strata in Botswana

% Share Distribution of Overall Poverty Incidence by Sex and Strata			
Stratum	Male	Female	All
Cities/Towns	0.8	0.9	1.7
Urban villages	3.1	4.1	7.2
Rural areas	4.8	5.7	10.5
National	8.6	10.7	19.3
Percentage of the Poor by Sex within the Strata			
Stratum	Male	Female	All
Cities/Towns	45.8	54.2	100
Urban villages	43.5	56.5	100
Rural areas	45.4	54.6	100
National	44.8	55.2	100

Source: Botswana Core Wealth Indicators Survey 2009/10.