URBAN WATER SUPPLY AND DEMAND MANAGEMENT, A CASE STUDY OF WINDHOEK, NAMIBIA

By MARELIZE MOSTERT

Mini-thesis presented in partial fulfilment of the requirements for the degree Masters in Urban and Regional Planning in the Faculty of Arts and Social Sciences at Stellenbosch University

Supervisor: Professor HS Geyer

March 2017

AUTHOR'S DECLARATION

By submitting this mini-thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: March 2017

ABSTRACT

Water is essential to life. Historically, water is often seen as an infinite resource resulting in little attention being given to the sustainable use of water. The importance of sustainable water resource management has only become one of the top priorities in the recent century. Arid or semi-arid regions, characterised by low annual rainfall, large amounts of evaporation, overall low moisture levels and extreme variations of temperature, often experiences water scarcity. However, there are a number of factors that affect the availability and quality of water and thus water scarcity is not limited to semi-arid regions. The usage of water has already increased by twice the amount of the rate of population increase and half of the global population could be facing water shortage by 2030. The majority of the earth's population resides in urban areas. Urbanisation and population growth is inevitable and therefore cities and municipal planners have to supply water to a constant growing society. Integrated Water Resource Management (IWRM), thus forms an important part of spatial planning and every city needs to have some type of action plan for water supply and demand management. One of the cities in a developing world that has been facing water scarcity as a possible issue is Windhoek, the capital city of Namibia. Namibia, is the most arid country in Sub-Sahara Africa and experience drought on a regular basis. The population is expected to double within the next 20 years which means that the demand for water will increase as well. Despite the limited amount of water available Windhoek has, throughout its history, managed to expand and grow thus setting a good example for other cities, facing similar problems.

Keywords and phrases: Arid-regions, Water Scarcity, Integrated Water Resource Management (IWRM), Climate change, urban growth, Windhoek

OPSOMMING

Water is n' noodsaaklik hulpbron wat dikwels beskou word as 'n oneindige bron. Histories het die handhaafbare gebriuk van water in die agtergrond geval. Die noodslaaklikheid van volhoubaare water water bron bestuur het eers n prioritiete geword in die hudige eeu. Waterarm lande ervaar lae jaarlikse reenval vlakke, hoe water verdampings, min vogtigheid en gewoonluk ook 'n groot variasie in temparatuur. Alhoewel daar is aanleidende omstandighede wat kan lei tot water tekorting, en dus is water tekortings nie beperk tot halfdor lande nie. Die gebruik van water het reeds twee maal hoer gestyg as die bevolkings groei en omtrent die helfte van die wêreld se populasie woon is stedeluke areas. Die helfte van die wêreld kan teen 2030 waterarm sal wees. Dit omhels dat stede en munisipaale beplanners water moet toesien aan n konstante groeiende populaasie. Integreurinde Water Bron Bestuuring is dus n belangruke elament van stads en streeks beplanning, elke stad het een of ander aksie plan nodig wat fokus op water voorsiening en aanvraag bestuur. Windhoek, hoofstad van Namibia, is een so stad, in n derdewerld land, wat lei onder water skaarsheid en water tekorting. Namibia is die droogste land in sub-sahara Afrika wat greeld lei onder droogte. Dit word verwag dat die populasie binne die volgende 20 jaar sal verdubble, wat beteken dat die aanvrag vir water ook sal verduble. Teen spyte van die beperkheid van water bronne, Windhoek kon deur die loop van geskidenis steeds onwikkel en uit sit, en kan dus as n goeie voorbeeld gesien word vir ander lande met soortgeleike proebleeme.

Trefwoorde en frases: Dorheid, halfdor, water skaarste, intergreurende water bron bestuur, klimaat verandering, stedelike groei, Windhoek, Namibia

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation and thanks to the following people for their assistance with my mini-thesis:

- my supervisor
- my parents, Elize and Martin Mostert, who supported me emotionally and financially in my academics over the past five years.
- Heloise, my sister, who is always willing to help me. No matter how busy you were or how much work you still needed to do or if it's the middle of the night, you were always there to listen to my problems, calm me down, and give me advice. You are my rock, my diamond.

CONTENTS

TABLES

page

FIGURES

Page

APPENDICES

ABBREVIATIONS AND ACRONYMS

Page

SECTION 1: INTRODUCTION

1.1 INTRODUCTION

Water is essential to life. It has social, environmental and economic value (Pereira, Cordery & Iacovides 2009). Historically, water is often seen as an infinite resource with little attention being given to the sustainable use of water. Globally the importance of sustainable water resource management has only gained one of the top spots on the list of priorities in the recent century (Malkina-Pykh & Pykh 2003). Water scarcity is often experienced in arid or semi-arid regions which are characterised by low annual rainfall, large amounts of evaporation, overall low moisture levels and extreme variations of temperature (Malkina-Pykh & Pykh 2003; Pereira, Cordery & Iacovides 2009). However, there are a number of factors that affect the availability and quality of water and thus water scarcity is not limited to semi-arid regions. Water scarcity may be attributed to natural conditions, including low rainfall and precipitation levels with high levels of evaporation, climate change, a long-term change in temperature and thus an increase in the demand and availability of water, and man-made causes, which includes poor water management and the misuse of land leading to desertification (Gleick 2000; Pereira, Cordery & Iacovides 2009). As a result, water scarcity is one of the primary challenges of the twenty first century (Pereira, Cordery & Iacovides 2009; Van Rensburg 2016). Even if a country is not currently characterised as being semi-arid, there is still a possibility that it can suffer from water shortages or water scarcity in the future, even if it is just temporary.

The usage of water has already increased by twice the amount of the rate of population increase and half of the global population could be facing water shortage by 2030. The majority of the earth's population resides in urban areas and this number is expanding (Pennington & Cech 2010; Feldman 2012; UN Water 2015). It is predicted that 60% of the world's population will be found in urban areas by 2025 (Magnusson & van der Merwe 2015; Lafforgue & Lenouvel 2015). This means that cities and municipal planners have the grave task of supplying an increasing number of citizens with basic services including water. IWRM thus forms an important part of spatial planning and every city needs to have some type of action plan that considers future population growth, demand management and supply management. Windhoek, the capital city of Namibia, is a city that has battled with water scarcity, and therefore water supply management, for about 50 years (van Rensburg 2016). Thus far, Windhoek has been successful in water demand and supply management. The city also experiences a high influx of urbanisation, resulting in the physical expansion and development of the city. Windhoek can thus be looked at as an example of how to management water resources in a city that suffers from water shortages while constantly growing in terms of population growth as well as city growth.

1.1.1 Problem statement

The demand for water, specifically the demand for freshwater, is increasing all over the world (World Bank 2015; UN water 2015). The usage of water has already increased by twice the amount of the rate of population increase and half of the global population could be facing water shortage by 2030 (Pennington & Cech 2010; van Rensburg 2016). The demand for water is expected to increase by 55% by the year 2050 (UN Water 2015). The sector which currently has the highest demand for water is irrigation. The demand for water for irrigation is increasing as a result of population growth, more food is needed to sustain the increasing population, and climate change resulting in certain crop types requiring more water in order to grow (Pereira, Cordery & Iacovides 2009; Pennington & Cech 2010). However, the demand for water in the industry and domestic (urban water use) is increasing at a faster rate than the demand for water for irrigation (World Bank 2015). What makes this increase in demand (and therefore use) of water more alarming is that these two sectors, industry and urban water usage, are the main sources of pollution, having a serious impact on water quality if the effluent is not properly treated before returning to the main water source (Pereira, Cordery & Iacovides 2009; World Bank 2015). Thus, the poor water management or lack of water treatment by urban municipalities can cause water scarcity even in areas with higher rainfall and precipitation rates.

The majority of the earth's population resides in urban areas today and the numbers of the urban population are increasing every day by both natural population increase (birth) and urbanisation (World Bank 2015). Local authorities and city planners need to meet the water demands of their citizens in a sustainable manner in order to avoid disaster, thus good planning and water management policies are needed within urban areas to ensure the sustainable use of water. Semi-arid regions specifically are pressured with water resource management as they are already faced with water scarcity (Pereira, Cordery & Iacovides 2009). Developing countries tend to battle more with the integration of water resource management in urban areas as they experience rapid urbanisation of the poor who mostly reside in informal housing (Magnusson & van der Merwe 2005).

Namibia, is the most arid country in Sub-Sahara Africa, consisting of about 80% desert or semi-desert terrains that experiences drought on a regular basis (Seely 2001; Karuaihe *et al* 2012; van

Rensburg 2016). The average rainfall of Windhoek amounts to about 260 mm a year of which 83% is lost through evaporation (Bravenboer 2004; Lahnsteiner & Lempert 2007, Mapani & Schreiber 2008). The population, currently about 370 000, is expected to double within the next 20 years which means that the demand for water will increase as well (Bravenboer 2004; van Rensburg 2016). Despite the limited amount of the available water in the area and the harsh climate conditions, the City of Windhoek (CoW) manages to expand and provide water for the increasing demand of the growing population.

The way in which the CoW has managed its water resources has attracted the attention of a number of researchers, including J.H van Leeuwen (1996) P.L. du Pisani (2006) and P. van Rensburg (2016), who focuses on water engineering and wastewater management. However, the focus point of these researchers normally falls on water management alone. Over the years little attention has been given in terms of the link between urban planning and Integrated Water Resource Management in Windhoek. Development planning and water management needs to be considered together in order for the city to grow in a sustainable manner. The success of water related policies should also be considered as water scarcity is not simply a short term problem in Namibia.

1.1.2 Aim

The overarching aim of this study is to discuss the different ways in which Windhoek, a water scarce country, manages water resource demand and what are the implications on city development. The study focuses on the way in which the city decrease the water demand while stabilising the water supply to the city. Hopefully this study will deliver information that will not only be informative of different methods used to deal with water scarcity and urban development, but can also be used in future studies on water scarcity and urban development.

1.1.3 Research questions

- What is water scarcity (characteristics, causes and effects)?
- What are the threats to future water supply
- Who is in charge of the water supply in Windhoek? How is water “governed”?
- What are the different ways in which water can be supplied to water scarce cities such as Windhoek?
- How did the City of Windhoek historically deal with water scarcity (supply and demand)?
- What are the effects of water scarcity on urban development?
- What can be learned from the way the City of Windhoek handles development in a water scarce country?
- What are the important points to consider in water management?

1.1.4 Methodology

The study will firstly consist of a literature study of similar work done as well as information on the subject of water management and urban growth. Reports from international organisations, such as the World Bank and UN water, will be looked at to gain an understanding of the current water facts, issues, management techniques and water use guidelines. The literature will consist of a combination of books, journal articles, newspaper articles and laws and policies. Namibia, and more specifically Windhoek, shown in

below, will be used as a reference for more specific discussions on water management and its role in urban growth is arid regions.

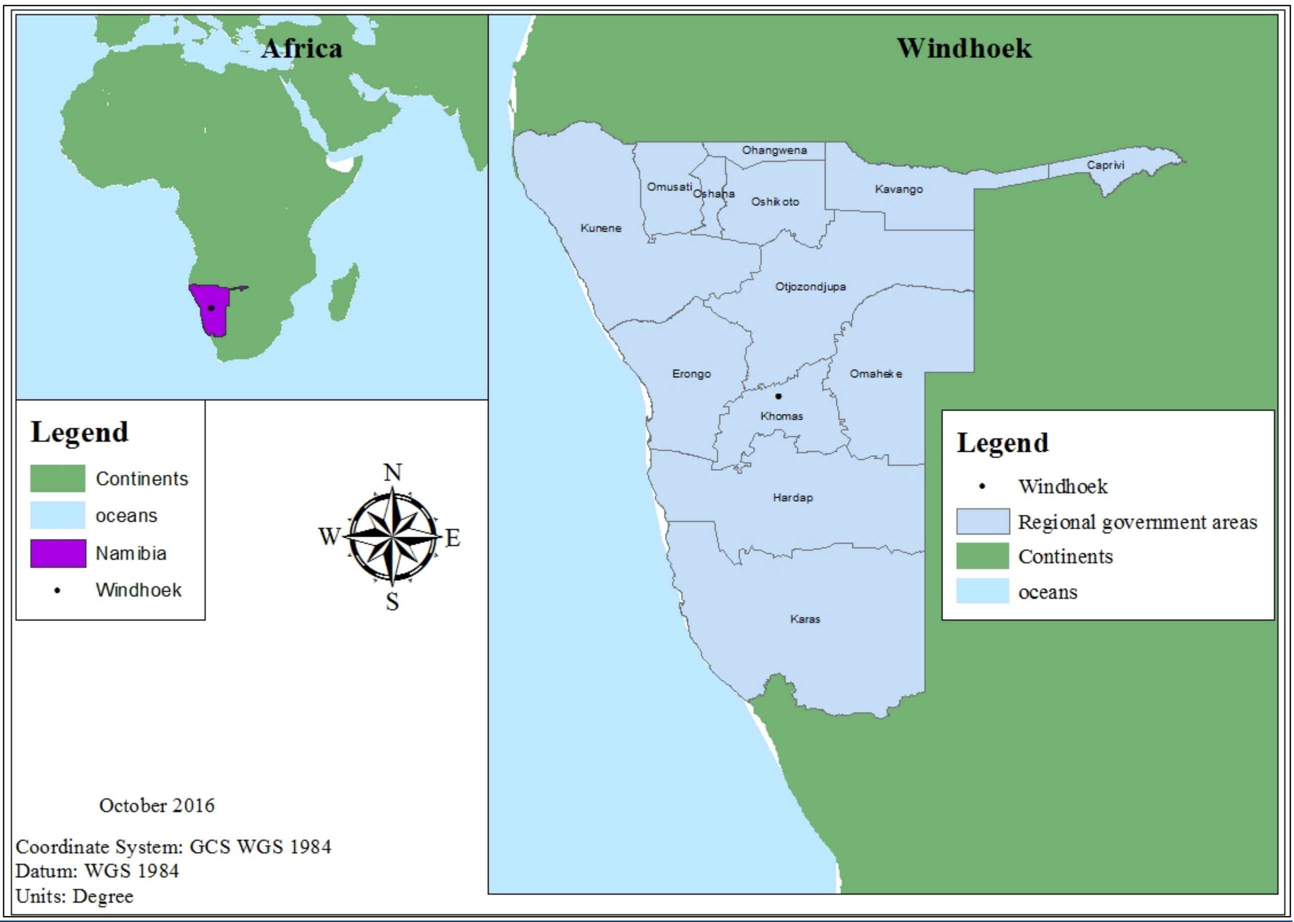


Figure 1.1 Windhoek, Namibia

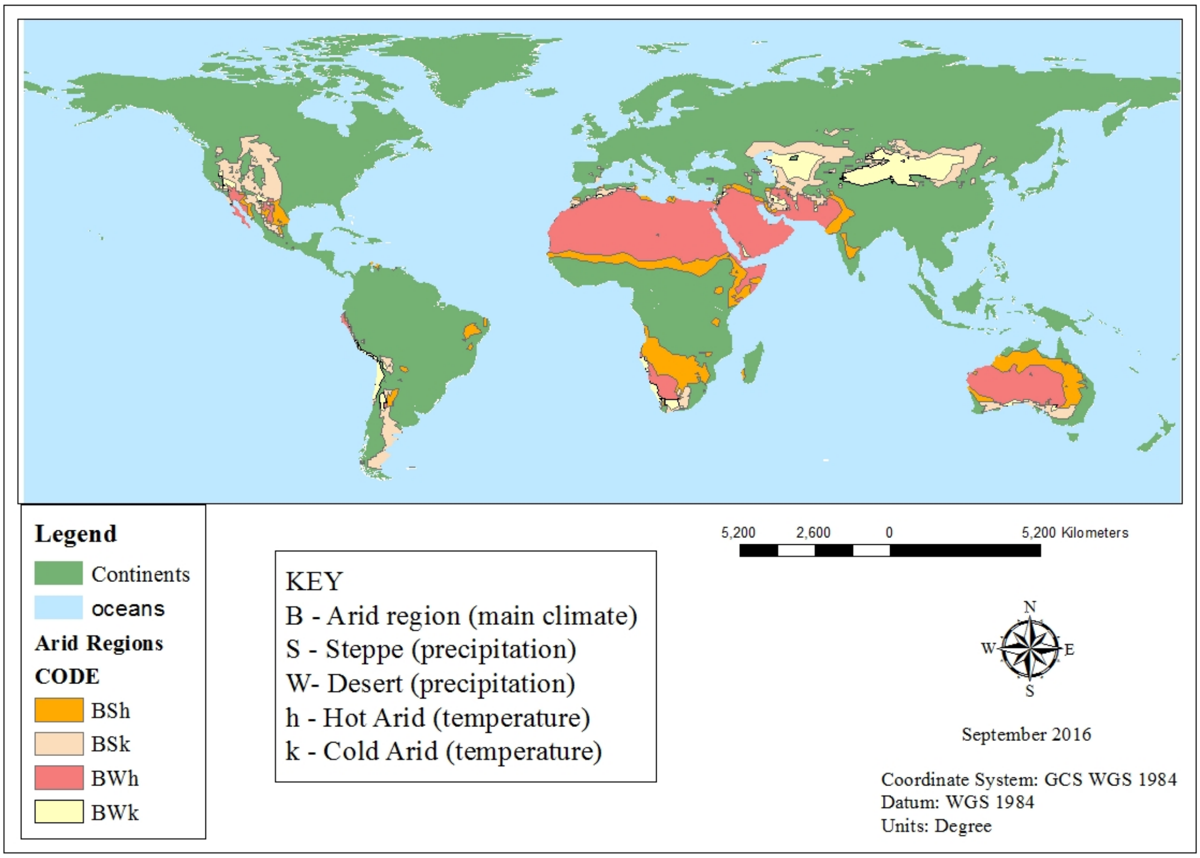
Quantitative data includes information on the average temperatures and average rainfall, collected from weather station located throughout the city. The census data of 1991, 2001 and 2011 will be used to gain an understanding of the demographics of the country and its capital city, and how population growth influences water supply and demand and city development plans. This data was obtained from Namibia Statistic Agency. Interviews were conducted with three current town planners, one of which worked for the municipality for a long time before going private. There were no pre-selected questions allowing the discussion to flow. The information obtained from these interviews was purely qualitative, and in some cases, opinion based. A combination of the interviews and the latest newspaper articles (2015 and 2016) assisted in finding the main focus points of this research.

SECTION 2: WATER SCARCITY

There are a number of phenomena that leads to water scarcity. These phenomena can be natural or man-made or in some cases both can be the cause of water scarcity (Pereira, Cordery & Iacovides 2009). Historically, human civilisations settled in areas with favourable climate conditions, suitable soil terrain and a natural water source, avoiding areas in which natural phenomena cause's water shortages. However the increase in innovative technologies has allowed civilisations to settle in water scarce regions, classified as semi-arid or arid regions were they have to deal with the natural causes of water scarcity (Seely 2001). This increase in innovative technologies also contributes to population growth as a result of the increase in the quality of life. This increase in population results in a number of activities that damages and degrades the environment, therefore resulting in water scarcity that is man induced. This section discussed the natural characteristics of arid regions which results in water scarcity as well as the human activities that leads to water scarcity.

2.1 ARID REGIONS

Aridity, in its simplest definition, is defined as a lack of moisture which affects the soil, vegetation and typology of on area (Agnew & Anderson 1992; Pereira, Cordery & Iacovides 2009). Arid or semi-arid areas typically experiences low average precipitation per annum and extreme variations in temperature, all contributing to large variation in the discharge that can lead to flash floods. In these areas agriculture is difficult and as a result food shortages are often a reality (Malkina-Pykh & Pykh 2003; Pereira, Cordery & Iacovides 2009). There are a number of regions around the world that can be classified as arid regions (see Figure 2.1 below), which includes subtropical areas (Australia), continental interior areas (Asia), shadow-rain areas (Sierra, Nevada) and cool coastal areas such as the Namib (Agnew & Anderson 1992). The map shown in Figure 2.1 below identifies the areas where the main climate is described as arid regions. They are then further divided according to the precipitation of the area (desert or steppe) and then according to the typical temperature of the area (hot or cold arid). These areas experience the natural characteristics that causes water scarcity and is constantly battling with supplying water (Pereira, Cordery & Iacovides 2009).



Source: Adapted from Rubel and Kottek (2010)

Figure 2.1 Arid regions

Africa and Australia consists mostly of arid regions that have a high temperature and low levels of precipitation. Naturally these are also the areas that have been identified as experiencing water stress. Both Africa and Australia experiences high pressure and most of the continent of Africa and the whole of Australia is situated in the parts of the ocean that has cold ocean currents (Agnew & Anderson 1992).

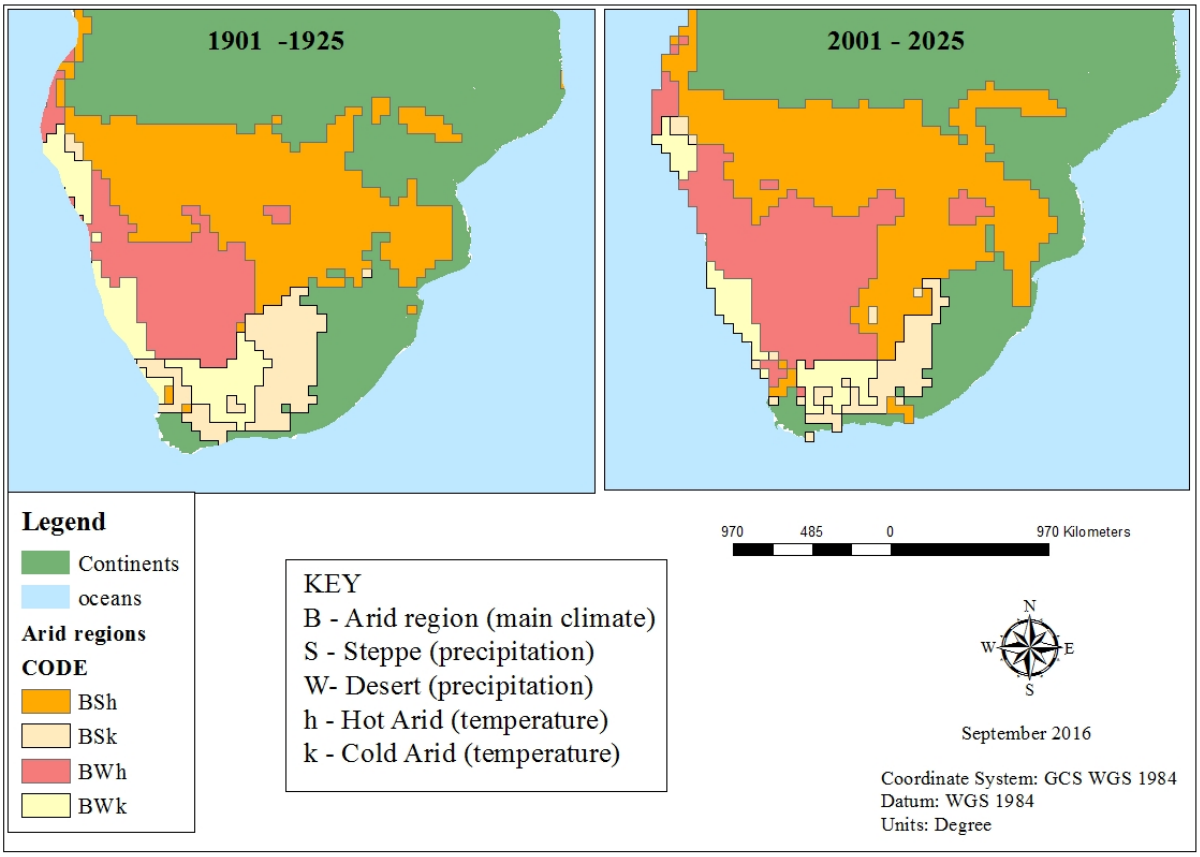
2.1.1 Climate change

Climate change is one of the major threats against water supply as the water cycle is sensitive to climate change (UN Water 2014). According to Agnew and Andreson (1992) the change in climate is significantly greater in the 20th Century than it has ever been historically. Many believe[1] the factors that contribute to climate change is man-induced which means that with the increase in population and technology, climate change and its effects are also expected to increase. Some of the effects of climate change on freshwater includes the change in the seasonal distribution, amount and intensity of precipitation, increase in evaporation, decrease in soil moisture, change in vegetation cover (refer to Figure 2.2) resulting from the changes in temperature and precipitation, accelerated

[1]see sources under climate change for more information

melting glaciers, increase in fire risk and changes in the management of land resources (Xu & Braune 2010; Feldman 2012). Climate change not only influences the supply of water but also the quality of water. The melting glaciers causes a raise in sea level which in turn chases the water found in rivers or other water sources close to the ocean to increase in its salt content lowering the water quality and limiting its uses (Xu & Braune 2010). The decrease of available freshwater resources also increases the need and use of wastewater which is of poor quality. The need for groundwater also increases, however the recharge decreases resulting in either the depletion of groundwater or the artificial discharge of groundwater which also effects the water quality.

Southern Africa in particular has been identified as an area that is vulnerable to climate change as it causes an increase in aridity. Figure W below shows the vegetation type of Southern Africa as it was recorded between 1901 – 1925 and 2001 - 2025. The first map (left) shows the general vegetation type that has been observed between the years 1901 and 1925 while the map on the right shows the recorded and predicted vegetation of Southern Africa. In general, the main climate of the region is "Arid" with two types of precipitation (steppe or desert) and two types of temperatures. Figure W above shows how the precipitation and temperature of Southern Africa has and is still expected to change.



Source: Adapted from Rubel and Kottek (2010)

Figure 2.2 Change in aridity, southern Africa

By 2025 most of Southern Africa will be classified as Arid with steppe precipitation. Another notable change is the spread of desert precipitation inland. Namibia in particular will experience a decrease in precipitation and increase in temperature. This change in vegetation is not only as a result of climate change, however climate change does play a role in this long term change in vegetation. This section has shown how the vegetation of a country can change over time to become more arid. Arid –regions are thus negatively affected by climate change and surrounding regions have the potential to become arid as well. All countries need to plan for future water supply and demand management, and climate change statistics can help give an indication of what can be expected of the future climate.

2.1.2 Groundwater

Groundwater is an important water source in semi-arid regions. It is estimated that at least 1.5 billion people around the world is dependent on groundwater as their only source of drinking water (Pennington & Cech 2010). Groundwater is all the water that has penetrated the earth's surface and infiltrated into the ground, residing in water bearing rocks known as aquifers (Malkina-Pykh & Pykh 2003). Groundwater basins are recharged mostly by rainfall, consisting of all the water that has not been absorbed by the vegetation (Xu & Braune 2010; Pennington & Cech 2010). The recharge process is important for the quality of the groundwater as it allows a variety of chemical constitutes and the artificial recharge of groundwater may influence the quality of the water. Groundwater supply is limited and therefore the management of groundwater in semi-arid regions are particularly important in water management (Pereira, Cordery & Iacovides 2009). A total of 20% of the world's aquifers are currently overexploited and already a number of areas in countries such as India, Mexico, New Zeeland, China and North America have experienced serious groundwater depletion (Pennington & Cech 2010; UN water 2015). It is also difficult to estimate the amount of groundwater that is available worldwide, however is has been estimated that the majority of the earth's groundwater is located in the Asian continent, followed by Africa and North America.

2.2 HUMAN ACTIVITIES LEADING TO WATER SCARCITY

Densification is a permanent imbalance in the availability of water which is caused by human activities. This phenomenon goes hand in hand with the misuse of soil and water resources including damaging the soil, inappropriate land use and extraction of groundwater without putting the necessary steps in place in order for the aquifers to become recharged. Water stress is also classified as a man-induced phenomenon. Water stress is a temporary phenomenon in which the water demand and extraction is more than the natural supply. Thus, it refers to the unsustainable usage of water for human activities. Municipalities specifically can be held responsible for the man-induced water scarcity in urban areas, a combination of poor planning and poor water management as well the overuse of water by the citizens all contribute to water scarcity (Malkina-Pykh & Pykh 2003).

Pollution also leads to water shortages as it affects the quality of the water and thus the availability of fresh water resources. Certain levels of water quality can be used for different functions; for example, water of poor quality can be used for irrigation but not for domestic use (Pereira, Cordery & Iacovides 2009). Thus, an increase in poor water quality through pollution, typically attributed to activities such as mining and industrial uses, can lead to water scarcity or water shortage. The effects of climate change are experienced worldwide and in semi-arid regions this means that rainfall seasons may become shorter or rainfall may decrease per annum. Temperatures may also increase which in turn affects precipitation (Pereira, Cordery & Iacovides 2009).

In terms of population growth, the rapid growth of people worldwide increased water demand. Developing countries specifically experiences population increase though urbanisation (Agnew & Anderson 1992; Malkina-Pykh & Pykh 2003). The great number of urbanisation results in houses being built on land not suitable for this type of development and the area lacks basic services, further decreasing the social conditions of that said society. Most municipalities are struggling to supply all its current citizens with basic services and infrastructure. Developing countries also struggles with the urbanisation of the poor, which means that the citizens cannot afford all of the basic services. Citizens living in poor households often have to make sacrifices by choosing between services they can afford and need versus services they can find elsewhere for cheaper, but at lower quality. Water is one of the resources that becomes a trade-off, instead of paying for indoors piping, poor communities often find water from nearby (untreated) rivers, dams and boreholes. This in turn leads to poor sanitation and health (Malkina-Pykh & Pykh 2003). Windhoek also suffers from this problem of the urbanisation of the poor, specifically on the periphery of the city, making the planning and management of water resources even more important (Tvedten 2011).

Water is an important resource that is used in all aspects of life including recreation, transport, energy, food production and sanitation, but the water supply available for human use is limited by nature and water resources is unevenly distributed as a result of different climates, geography and geology (Feldman 2012). A combination of a limited water supply, increasing population growth, water pollution and other factors such as climate change has emphasised the importance of sustainable or integrated water resource management (IWRM).

SECTION 3: CHARACTERISTICS OF NAMIBIA AND WINDHOEK

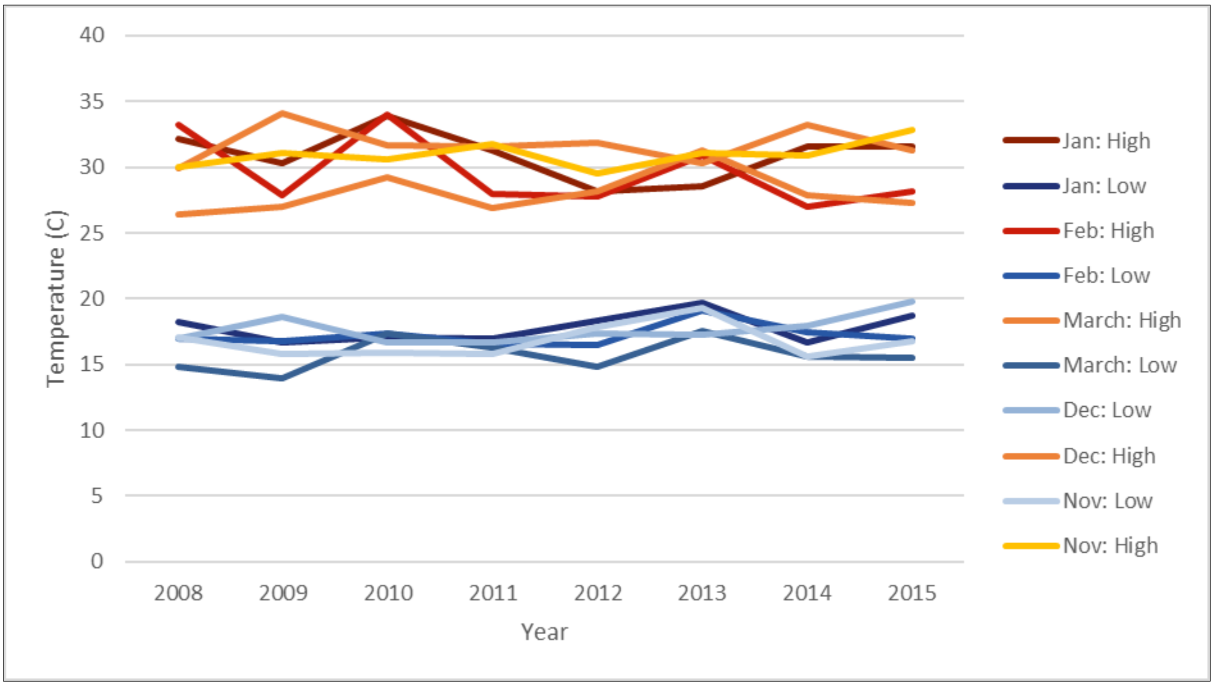
3.1 INTRODUCTION TO NAMIBIA

Namibia (known as South-West Africa until 1990) was a German colony from 1884 up to 1914 when became part of South Africa, following South African laws until it gained its independence in March 1990 (Bravenboer 2004; Pietilä 2005). The country is divided into 13 administrative boundaries with the capital city, Windhoek, located in the Khomas region found more or less in the centre of the country. Namibia is classified as a middle-income, developing country, however inequality, in terms of income, is high with Namibia being one of the most unequal society in the world (Bravenboer 2004). Namibia's economy is primarily based on the extraction of raw minerals, such as diamonds, zinc, copper, lead and uranium, agriculture, consisting predominantly of livestock, millet, maize and dairy products, the fish industry and tourism (Tvedten 2014; Tötemeyer 2014).

3.1.1 Temperature

Namibia is classified as a semi-arid region consisting of about 22% dessert terrain. The temperature is relatively high during daytime, but can drop to below freezing point at night. During summer months, which falls between December and February, temperatures during the day can go above 30º Celsius (depending on the area). The temperature in the North can exceed 35º C while the temperature along the coast generally stays lower than 30˚ C. In Windhoek temperatures ranges between 20º C and 35º C during the summer, that ranges from December to February. Figure 3.1 below shows the average high temperature and average low temperature of the summer month of Windhoek[2]. The temperature has been relatively consistent each month for the last eight years, increasing or decreasing no more than 5º C.

[2] The graphs were made by using the data presented in Appendix B



Source: Adapted from Namibia Weather Network (2016)

Figure 3.1 Average summer temperatures, Windhoek

The average high and low temperature during the winter seasons drops about 10º C from the general temperature of the summer, however during night-time the temperature can drop below 0º C, resulting in frost. Because there is no rain during the winter (Figure 3.2) the days can become relatively warm during the evening as a result of solar radiation. The figure below shows the average temperature of each month during the last eight years. Again it is clear that there is not much difference in temperature per month from year to year.

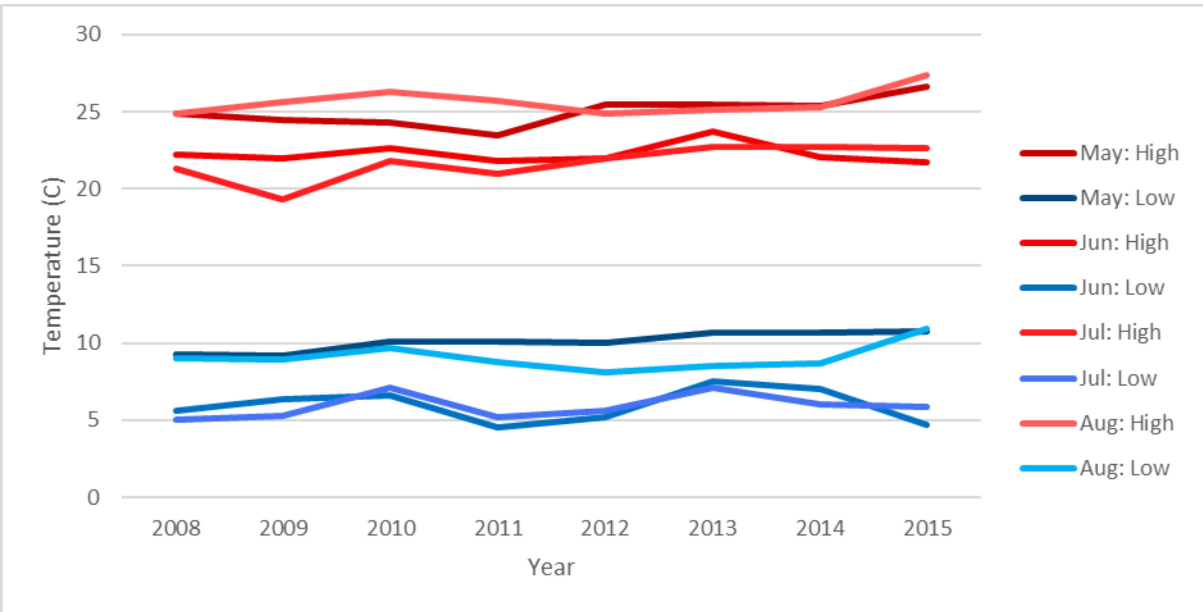
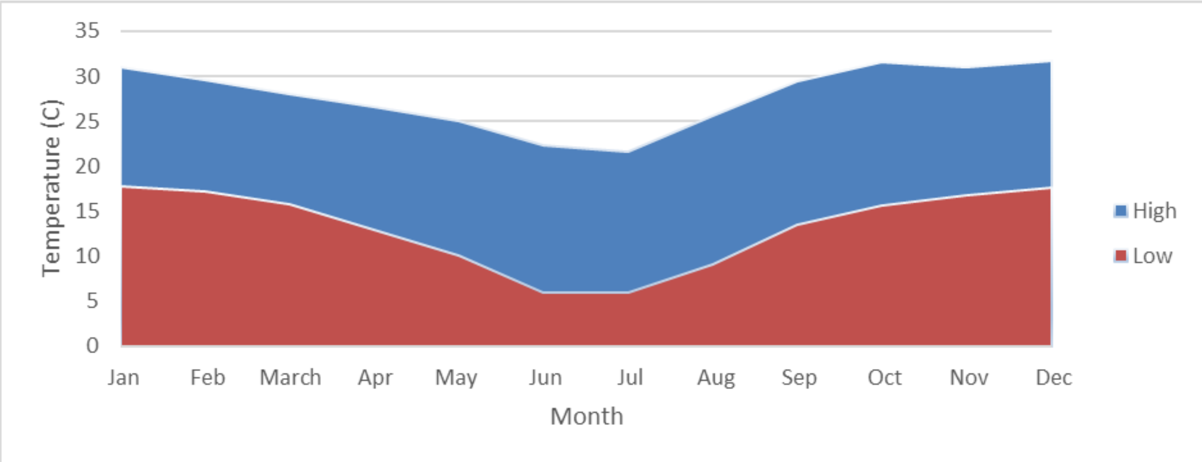


Figure 3.2 Average winter temperatures, Windhoek

Figure 3.3 compares the average high and average low temperatures of the last eight years according to the month. The lowest average temperature falls between June and July while the highest temperature is during October and January. Only the average monthly temperature of the last eight month was used as additional older average temperature can potentially skew the data.



Source: Adapted from Namibia Weather Network (2016)

Source: Adapted from (2016)

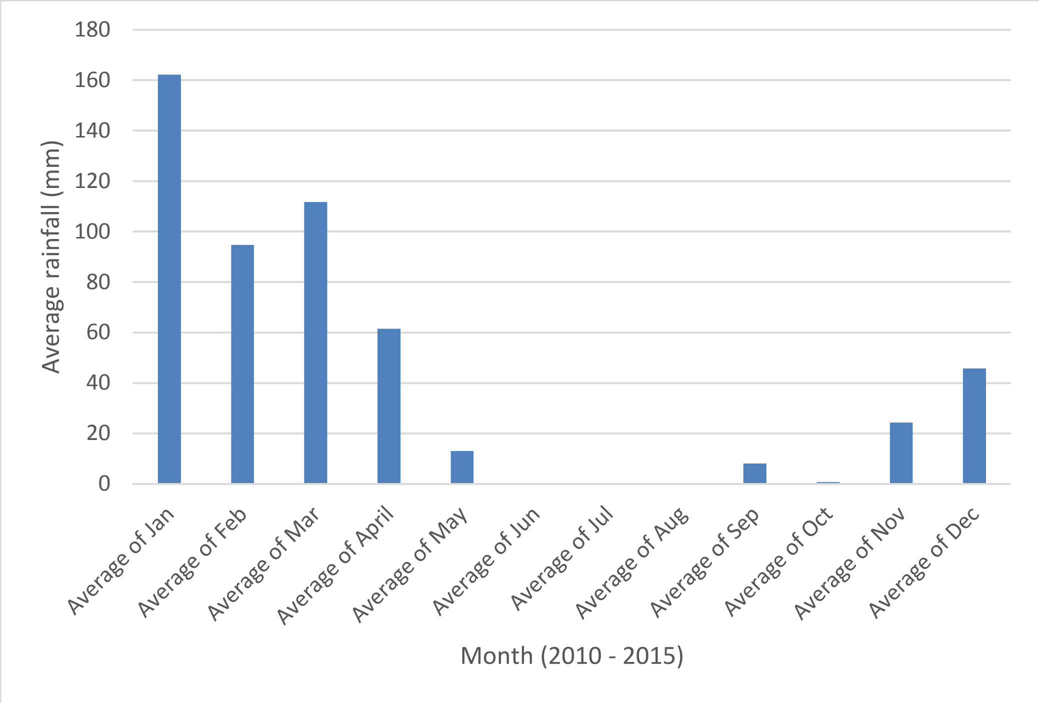
Figure 3.3 Average monthly temperature, Windhoek

Because of its climate conditions, Namibia experiences high solar radiation, leading to an evaporation rate of about 70% of all service water. Namibia is a summer rainfall area, experiencing rain between the months of November and April. Rainfall varies across the country as well as across time. The Tsumeb, Grootfontein and Otavi triangle located in the North receives the highest average rainfall (Seely 2001). The area also receives rain more often than the rest of the country, has a good groundwater supply and has access to the perennial rivers on the border.

3.1.2 Water

The main sources of water include perennial rivers, ephemeral rivers, dams and groundwater obtained though boreholes (Ministry of Agriculture, water and Forestry 2014/2015). The only source of fresh water supply comes from the rain, therefore Namibia is dependent on its rainy season and water storage system to supply the country with water (Bravenboer 2004; Desert Research Foundation 2009). Temperature and evaporation rates are lower along the coast and higher inland. The south has the highest evaporation, falling between 3400 – 3800 per year, and relatively high average summer temperatures. The north of Namibia experiences the highest temperatures, however it also receives higher rainfall (540 mm mean annual rainfall) and experiences less evaporation than the South (Christelis & Struckmeier 2001).

Windhoek receives rain from November until April, when summer ends and winter begins. Windhoek receives no or very little rain (> 1 mm) during the winter. Even though temperatures are low in the winter time (*Figure 3.3*), the solar radiation during the sunny days, still causes a substantial amount of water loss through evaporation. Figure 3.4 indicates the average rainfall of Windhoek per month for the last eight years. The graph is a good indication of which month receives the highest rainfall and during which months it is necessary to save water.

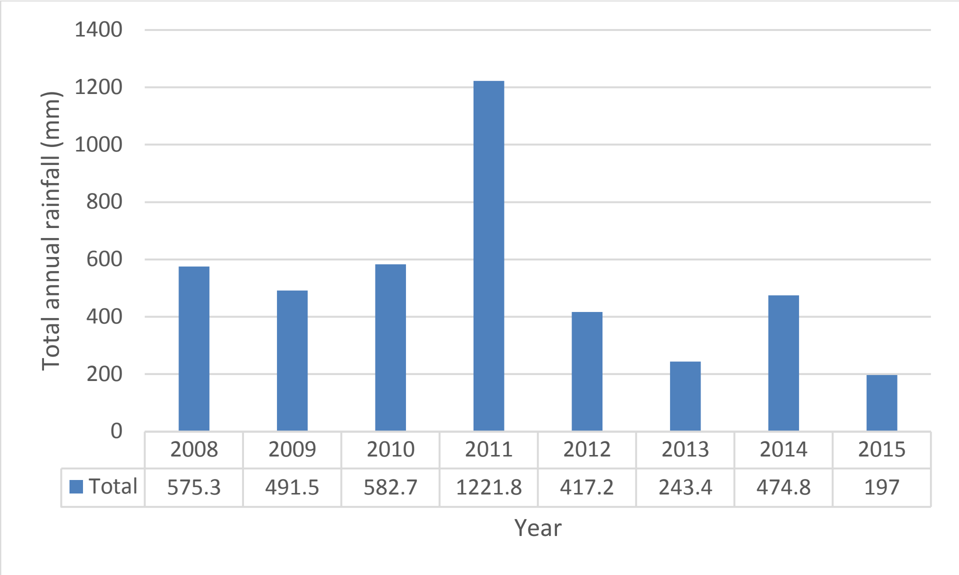


Source: Adapted from Namibia Weather Network (2016)

Figure 3.4 Average rainfall per month

Windhoek's average rainfall per year has shown unpredictable and inconsistent results. The average rainfall between 2008 and 2015 amounts to 525. 4 mm annually[3], however the graph below shows the annual average rainfall of each year and how rainfall has differed across time. Unlike the temperature, rainfall is not constant from one year to the next. The municipality and other water cooperation such as NamWater, cannot accurately predict the rainfall of the next year, thus water resources has to use as efficiently as possible in order to increase water savings for future usage during low rainfall years.

[3] This amount was calculated from the rainfall data provided in Appendix B



Source: Adapted from Namibia Weather Network (2016)

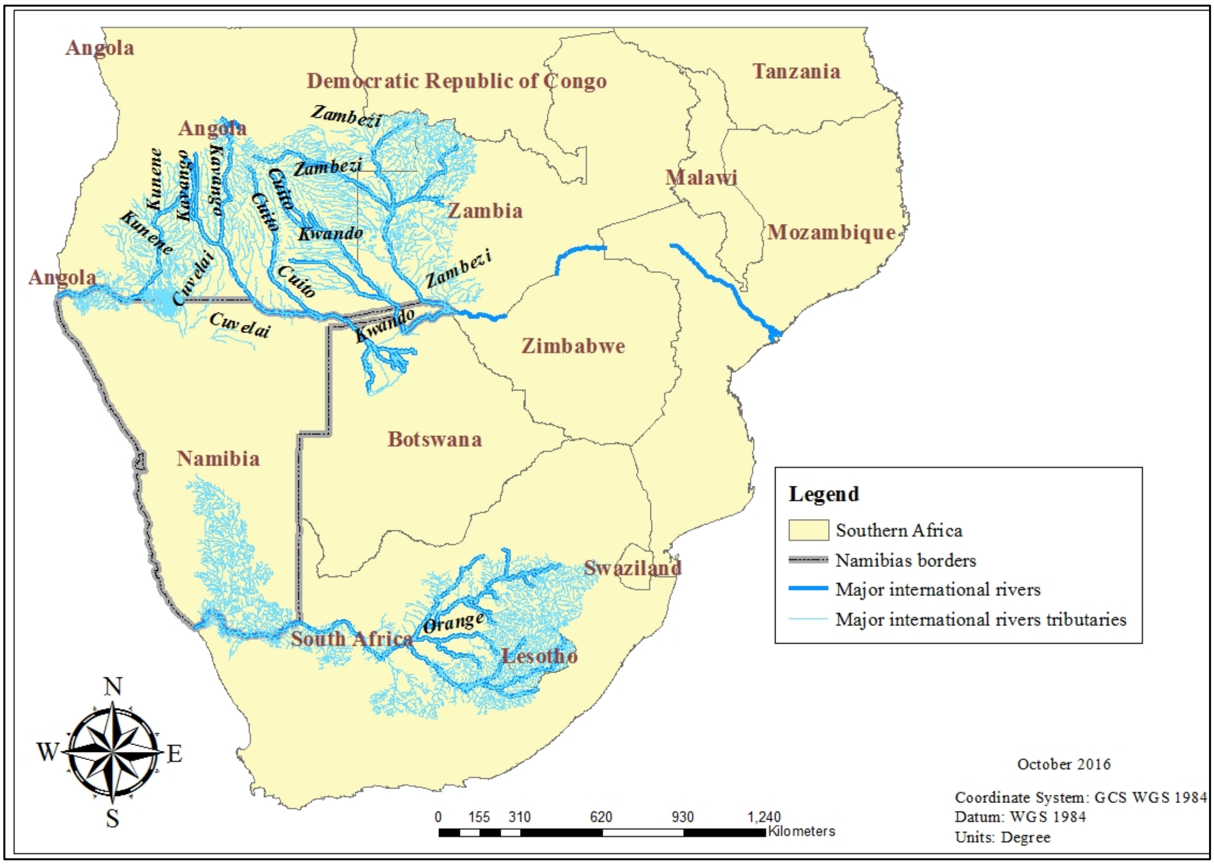
Figure 3.5 average rainfall (2008 - 2015)

The year 2011 shows the highest average rainfall, amounting up to 1221.8 mm annually, with 2015 showing the lowest rainfall year. However, the annual rainfall is not enough to calculate the water available for supply as the amount of water available is also influenced by temperature and solar radiation, which leads to evaporation and therefore the loss of available freshwater.

3.1.3 Rivers

Rivers transports water (as well as other mineral and soil deposits) from inland to the ocean. Rivers are an important water source for those living within the catchment area. Because rivers are a natural occurrence and many of the rivers worldwide are shared amongst two or more countries as they flow across borders (Gunawansa, Bhullar & Hoque 2013). The construction of dams can help collect water in an area in need, however dams affect the flow or discharge of the river, affecting the water sources downstream. Rivers can also carry pollution caused upstream, to other areas. The maintenance, extractions and use of rivers or catchment areas are therefore very sensitive and an important factor in water management. The ecosystem of any given area can also be negatively impacted if there is a change in the river flow (Pennington & Cech 2010).

Namibia consists of both ephemeral and perennial rivers, however all the major water basins, in which the perennial rivers are found, are located on the boarders of the country, refer to Figure 3.6, and therefore these rivers are shared with Namibia’s neighbouring countries. The Orange River is shared with South Africa, the Cuvelai and Kunene is shared with Angola, the Kavango is shared with Angola and Botswana and the Zambezi is shared with Zambia. Water is an important source for all of the countries, especially for those villagers that live and farm along the river. Namibia cannot simply extract water from these rivers and pump it to the south and centre of the country where it is needed. The responsibility of water basin management is the responsibility of all the countries that shares the resource. International standards and guidelines, as supplied by the UN Water etc. is useful in cases like this as it can be used as a baseline from which the different governing parties can work.



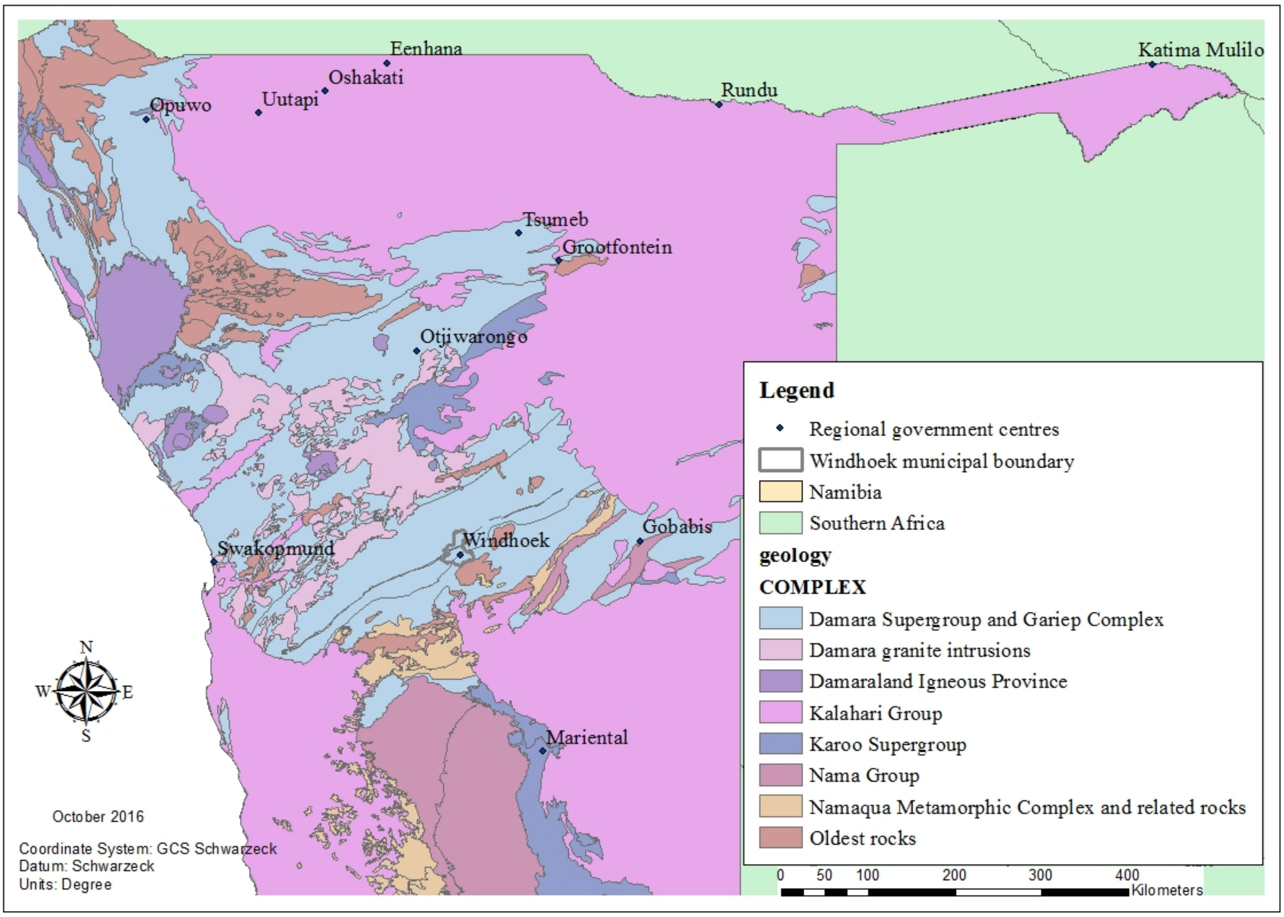
Source: adapted from Digital Atlas of Namibia (2002)

Figure 3.6 major international river tributaries, southern Africa

3.1.4 Groundwater

Namibia has a rich geology allowing a number of mining activities to extract the rich mineral resources of the earth. The complex groups includes the Damara granite, Karoo Super group, Kalahari group and more all of which has their own characteristics. The amount of groundwater water that can be obtained depends on these characteristics, which determines how much water can be stored or extracted from the aquifers as well as the quality of this water. One of the best water bearing geology type in Namibia is located in the north at the Tsumeb-Otavi-Grootfontein Mountain Land (Source: *adapted from Digital Atlas of Namibia (2002)*

Figure 3.7). The characteristics of the geology complex group found in this area, the Damara group, include highly permeable aquifers which can store large amounts of water (groundwater report).



Source: adapted from Digital Atlas of Namibia (2002)

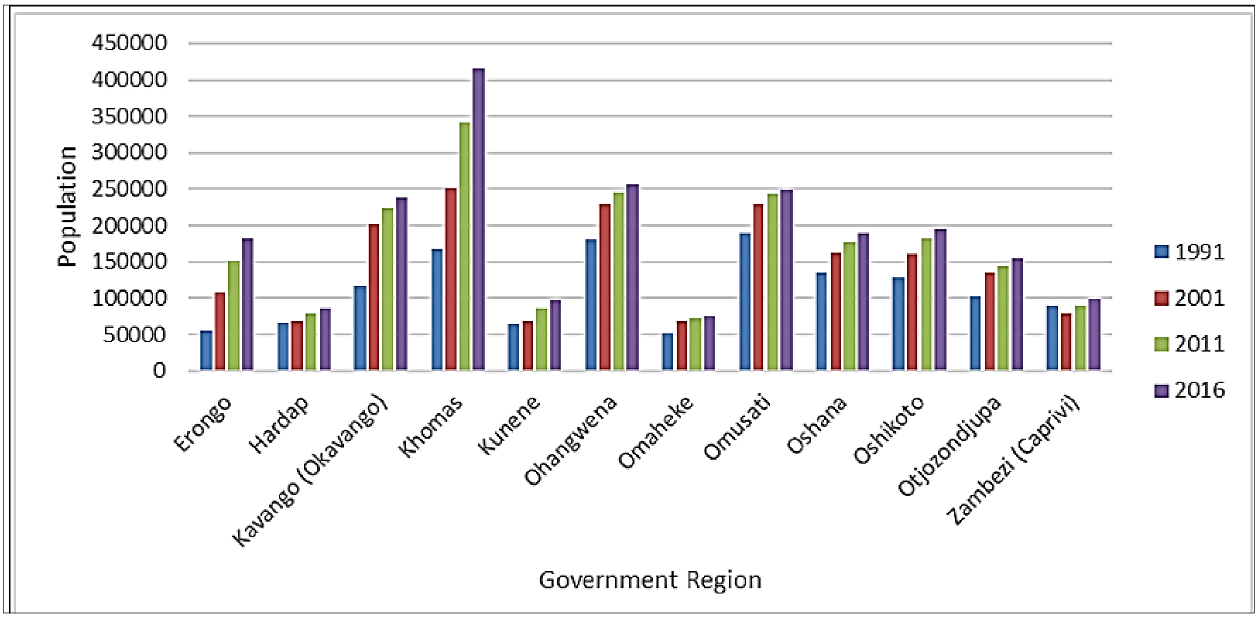
Figure 3.7 geology complex of northern Namibia

The majority of Namibia's water comes from its groundwater basins with approximately 670 boreholes located throughout the country (MAWF 2014/2015). Rural areas and villages are dependent on these boreholes for their water supply. Groundwater is a cheap source of water and can be pumped directly from the ground (Mapani 2005). However, the continuous abstraction of groundwater causes the depletion of these water resources as there is a limited amount. It also takes long to recharge, using only 1% of the annual rainfall (runoff) for recharging (Lang 1997; Mapani & Schreiber 2008). Namibia has a number of different aquifers, containing water of different quality. Even though obtaining groundwater is cheaper than alternative sources, such as desalination, measuring the amount of groundwater available, the quality of the water available and other information concerning groundwater supply is costly. As a result, there are no annual reports concerning the current available groundwater, thus there is no data available to predict how long this source of water will be available or when boreholes will become depleted. This is a particular issue for farmers, poor household and other settlers that are dependent on these boreholes for domestic and agricultural water supply.

3.1.5 Population

High population growth is one of the major threats to urban water supply as it increases water demand and can affect water quality. Urban areas consist of streets, concreate or brick pavements and other constructions that limits infiltration and increases runoff (Ooi 2004; Ertsen & van de Ven 2006). Urban areas further limits or restricts the recharging of groundwater and the runoff from the storm water is polluted with chemicals and rubbish (Ooi 2004; Pennington & Cech 2010). This water finds its way into the water system and contaminates or may lower the quality of the water found in and around the city. Rapid urbanisation, as being experienced in most parts of the world, makes it difficult for authorities to keep up with basic services, thus many public utilities, including water supply is under enormous strain. Over extraction of water sources occurs and the lack of proper waste removal services and the increase in poor household causes more than normal pollution levels. Japan, for example, experienced rapid urbanisation as a result of economic development, which resulted in the damage of the natural water cycle of the region (Furumai 2008). Once the natural water cycle is affected it takes a long time to recover, if recovery is even possible.

Namibia’s population is unevenly distributed throughout the country as a result of the lack of water in certain areas, temperature, lack of moisture, better opportunities in urban areas etc. As is expected, Namibia has experienced an increase in the population since 1991. The bar graph in Figure 3.8 shows the population statistics of the year 1991, 2001, 2011 and an estimated statistic for the year 2016. There has been a general increase in Namibia’s population, however the Khomas region, not only has the highest population, but the area is also experiencing high in-migration, especially from rural areas.



Source: adopted from Namibia Statistic Agency (2016)

Figure 3.8 population growth (1991 - 2016)

The growth rate of each region differs, which is a normal occurrence in any country as migration flows from rural areas to urban areas with more favourable socio-economic conditions. However, unlike most other countries, Namibia's fastest growing region, the Khomas region were Windhoek is located, has available land on which to expand, but it does not have the natural water resources. The percentage of the total population found in the Khomas region has increased from 12% in 1991 to 19% in 2016. This seems to be a small increase as population growth is expected. However when comparing this percentage of people found in the Khomas region to the increase or decrease in percentage of the rest of the regions, while considering the availability of water of each region, the significance of this number of increase becomes clearer.

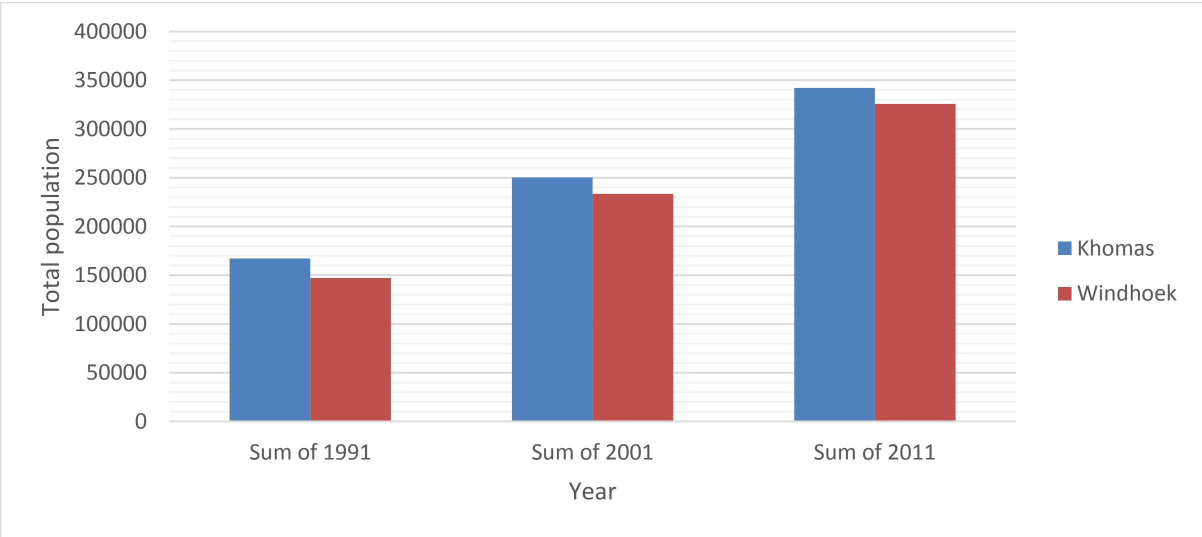
Table 3.1 Population distribution according to percentage

Region	Percentage of total population: 1991	Percentage of total population: 2016	Percentage increase or decrease
Kavango	9	11	2% increase
Ohangwena	13	11	2% decrease
Omusati	14	11	3% decrease
Oshana	10	9	1% decrease
Oshikoto	9	9	No increase or decrease

As seen throughout this section, the north of the country, where the Ohangwena, Omusati, Oshana, Oshikoto and Kavango regions are, has better natural water resources than the centre of the country.

The region receives higher annual rainfall coupled with a lower amount of evaporation and has accesses to large amounts of groundwater and perennial rivers. Naturally there has been an increase in the population of these regions located in the north, however the percentage of the total population found in these regions have generally decreased in the. past 25 years. What can be deducted from this is that migration has resulted in a larger than the natural growth rate in the Khomas region and that the motivation for migration is not based on available water resources. The Khomas region can thus expect a high rate of future population growth, regardless of its limited water resources.

Windhoek and Oshkati are the densest areas while the rest of the country experiences low density levels. According to the census data of 2011, 43% of the total population lives in urban areas, most of which resides in Windhoek (Namibia Statistics Agency 2011). Looking at the total population of the Khomas region, 342 741 people in 2011, 95% of the total population resides in Windhoek. The growth rate, resulting from both the natural increase of the population as well as migration, from 2001 to 2011 amounted to 3.1% annually (Namibia Statistics Agency 2011; 2015).



Source: adopted from Namibia Statistics Agency (2011)

Figure 3.9 Population growth comparison

However, the size of the urban population has increased, and is continuing to increase, at a higher rate than that of the urban region. In fact, the growth rate of the rural area has decreased between the 2001 and 2011, which indicates that a high rate of urbanisation can be expected **(**Bravenboer 2004). In 2011, Windhoek contained 15% of the total population of the country and this number continues to grow annually (Mapani & Schreiber 2008; Namibia Statistic Agency 2011; MET 2013). Windhoek attracts a number of people as it is the national industry and commercial centre of the country as well as the political and administrative hub of Namibia (Peyroux 2002; Namibia Statistics Agency 2015).

3.1.6 Conclusion

This section has shown that the climate of Windhoek is currently stable and the average high and average low temperature of the next five years should remain similar to that of the last eight years, however rainfall is less stable, therefore preparations need to be made to prepare for the worst. Water cannot be wasted and the correct allocation of water is important to ensure the sustainable use of water which increases water savings for future drought periods. The north of Namibia, where Rundu, Tsumeb and Grootfontein lies, has a better water supply and more favourable climatic and geological conditions than the centre, were Windhoek lies. The majority of the population is divided between the capital city and Omusati (refer back to Figure 1.1 Windhoek, and Figure 3.8 population growth (1991 - 2016)), but unlike Omusati Windhoek does not have as high amount water capacity as Omusati and therefore Windhoek needs to work on water supply with the use of good planning tools.

SECTION 4: WATER MANAGEMENT

Water is not restricted to political boundaries and the water management of one are may affect the water supply of another (Feldman 2012). A number of water resources are shared between countries including groundwater and rivers, of which about 60% of all rivers can be classified as transboundary. Water management thus has an international element added to it. Water resources are unevenly distributed across the world and water disputes between countries often occurs. For Semi-arid or Arid regions, especially those that are located in developing countries, water plays an important role in economic development and improving living conditions. In Africa, for example agriculture, mining and fishing are the main economic activities and thus the source of income for many families (Tötemeyer 2014). Because water is an important resource for all and the use of water in one area can negatively affects the water supply of another areas, there is a need for some form of international governance or agreement on water management.

4.1 DEFINING WATER MANAGEMENT

There is no universally agreed upon definition of water management, although several features reoccur in the given definitions which can be divided into four dimensions integrated into water governance (Gunawansa, Bhullar & Hoque 2013). First of all, water has been recognised as a right and basic human need, therefore one of the first sides of water governance focuses on delivering water to all in an equal manner. The second dimension of water governance focuses on power and authority. Power needs to be decentralised between public and private sector entities that co-operate with one another as well as with the community (Gunawansa, Bhullar & Hoque 2013). The third dimension is the administrative part, which is made up of a number of various legal, institutional administrative and technical mechanisms used to facilitate water resource management. The last dimension calls for the sustainable use of water resources (; Gunawansa, Bhullar & Hoque 2013). This entails that the act of water governance, with the administration and authorities co-operating and coordination, should be a process of sustainable water management in terms of economic, environmental and social factors.

4.1.1 International organisations

There are a number of international water organisations, guidelines, action plans and goals, all of which are drawn-up and agreed upon during international conferences. The United Nations (UN) can be identified as one of the biggest international alliances with the most members, including Namibia. There is a water sector, UN Water, which focuses on international water reports and standards[4]. The UN started the mission of setting Sustainable Development Goals in Rio at the Rio+20 conference. The Sustainable Development Gaols 2030 or Agenda 2030 is one of the current international Goals following the Millennium Development Goals that ended in 2015. Goal 6 of Agenda 2030 focuses on ensuring the availability of sustainable management of water and sanitation for all. This sector includes targets and indicators that countries following these goals can use. Issues such as the over extraction of water, poor water quality, water usage, wastewater management and IWRM are included in the goals (UN Water 2015).

4.2 WATER GOVERNANCE AND MANAGEMENT IN NAMIBIA

After Namibia gained its independence new laws and policies where implemented. For the first time the Namibian government was in charge of the country, power was decentralised with the implementation of the Local Authorities Act (1992) and Regional Councils Act (1992) (Becker 2013; Ruppel & Ruppel-Schlichting 2016). However, Namibia's water management is primarily based on the Water Act of 1956, inherited from South Africa, which places the Department of Water Affairs in charge of all water related projects, issues, development etc. (Ruppel & Ruppel-Schlichting 2016). The Water Resource Management Act (24 of 2004), has been approved and published in the Government Gazette, however this act has not come into force yet. Another water act, the Water Resource Management Act (11 of 2013) is meant to replace the previous two water acts. This act provides for the establishment of water advisory council to advise the Minister on water related issues such as policy development (Ruppel & Ruppel-Schlichting 2016).

As a result of the Local Authorities Act, municipalities became in charge of water supply in the major cities as it falls under basic services. Namibia Water Corporation Ltd (Namwater), a state-owned private company, is responsible for the management of the bulk water production and distribution in Namibia (Bravenboer 2004; Pietilä 2005). Towns, villages and cities buy water from NamWater, however those who uses NamWater as their only supply faces the danger of spending more than the allocated budget on water resulting in less finances available for other important developments such as low cost housing, updating much needed infrastructure etc. A lot of municipalities of small towns and villages do not pay their water bill, this has two notable negative impacts, firstly NamWater can cut off the town's water supply and secondly, NamWater does not get the necessary finances it needs to maintain the water supply. Major cities, such as Windhoek supplement its NamWater supply with their own local sources (Pietilä 2005).

[4] Including AGENDA 21, UN World Water Report, Status Report on Integrated Water Resources Management and Water Efficiency Plans, UN Water: Water for a Stainable World 2015 and UN: Water and Energy Report 2014.

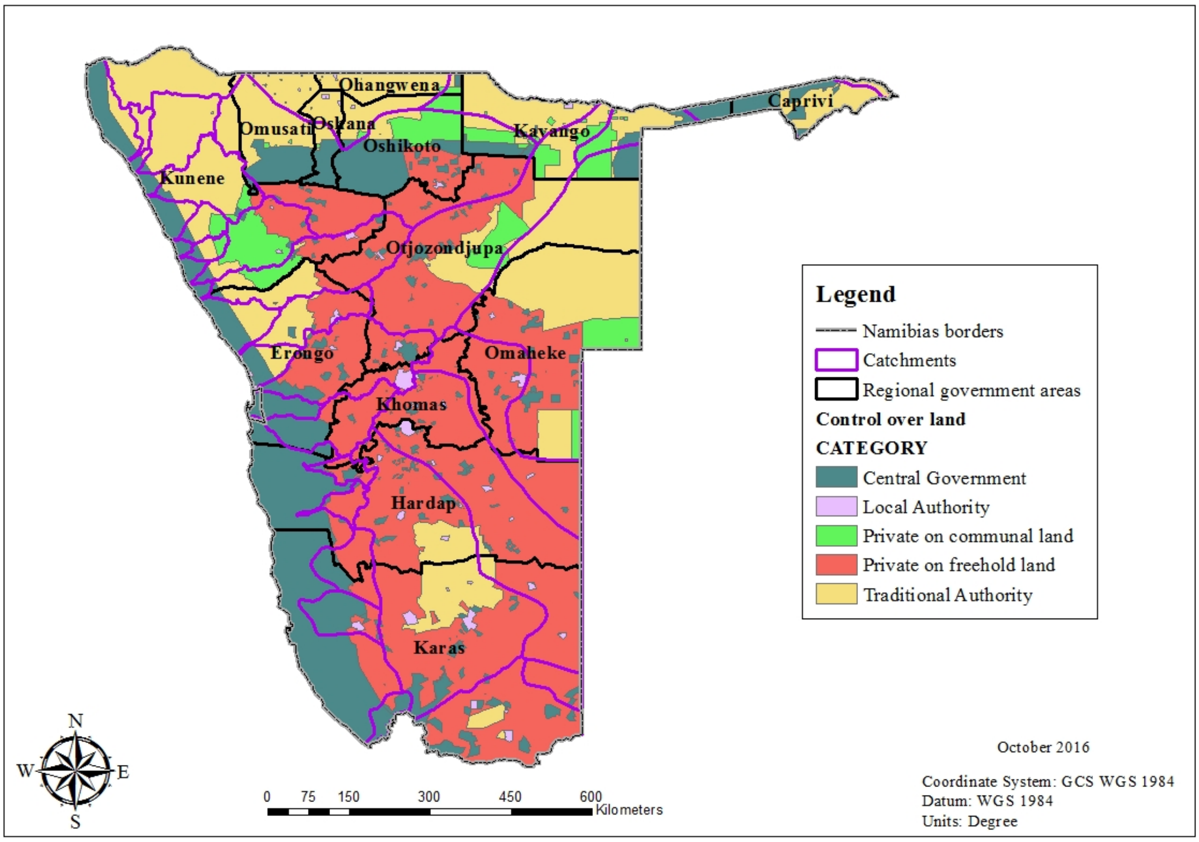
Namibia also has a Water Supply and Sanitation Policy (2008) which principals, including water quality, accessibility and authority are in line with the IWRM plan. This act promotes equitable access to water resources, supply and demand planning in the short and long term, sustainable water utilisation promoting water-efficient technologies and public information (Ruppel & Ruppel-Schlichting 2016). Both the IWRM plan and the Water Supply and Sanitation Policy promotes environment sustainability and community participation. The act also calls for cooperation between responsible parties, namely the government, municipalities, regional authorities and any other ministry department or corporation involved in water or sanitation (MAWF 2010). The Director of water supply and sanitation focuses on clean water supply to both rural and urban communities. Thus, this department is in charge of overseeing the municipal authorities, ensuring that urban citizens are supplied with good quality water.

Namibia is a member of several international agreements and parties. Some of the agreements includes the SADC Protocol on shared water systems, the Zambezi Commission (ZAMCOM), Permanent Okavango River Basin Commission (OKACOM), Permanent Orange-Senqu Commission (ORASECOM) and it is represented on the Permanent Joint Technical Commission (PJTC) for the Kunene River (MAWF 2010). The International River Basin Commissions, the formation of which is enforced in the IWRMA, is in charge of water management at the basin level. All of the commissions includes governing bodies of the neighbouring countries, all of which are involved in decision making. Therefore, Namibia is not in control of these water sources and extraction of water from one of the rivers to distribute to the centre of Namibia takes time. Documents and agreements with terms and conditions first needs to be set up and even then, these terms can change over time, depending on the social, economic, environmental or political[5] conditions of the neighbouring countries.

The governance of water in Namibia is divided amongst different ministry departments and lacks coordination. Figure below demonstrates the different ways in which control over and management of water resources and land are divided between a numbers of authorities. The ministry of Agriculture, Water and Forestry, Ministry of Regional and Local Government, Housing and rural development are working on their own policies. This was recognised in 2013 that these two departments are not in line with one another which lead to the decision to put together a task team consisting of staff member of both ministries as well as NamWater to consider the different submissions and consolidate it into a proposed national policy. This policy will focus on the subsidy

[5] Angola, for example had a prolong war that ended a few years ago, however the city needs water resources to build it back up (Pinheiro, Gabaake & Heyns 2003).

for water supply as well as other essential services for poor household in both rural and urban areas (MAWF 2014/2015).



Source: adapted from Digital Atlas of Namibia (2002)

Figure 4.1 Authority boundaries and control over land

Figure 4.1 demonstrates the complications of water management, the figure shows how the regional government boundaries and the catchment areas' boundaries overlap. Water management falls under the derestriction of the catchment areas, according to the Ministry of Agriculture,Water and Forestry (MAWF), however the cooperation and planning of the regional and local government/authorities can influence the water quality, use, supply and demand and thus can have an influence on water management (Lang 2006). Municipalities of the major cities, such as Windhoek, also has some form of power and control over water management as a result of the Local Authorities Act (1992), however the municipalities and local authorities of smaller towns and cities do not exert any power over Water Resource Management. Thus, the IWRM strategies are not constant across the entire country (Pietilä 2005).

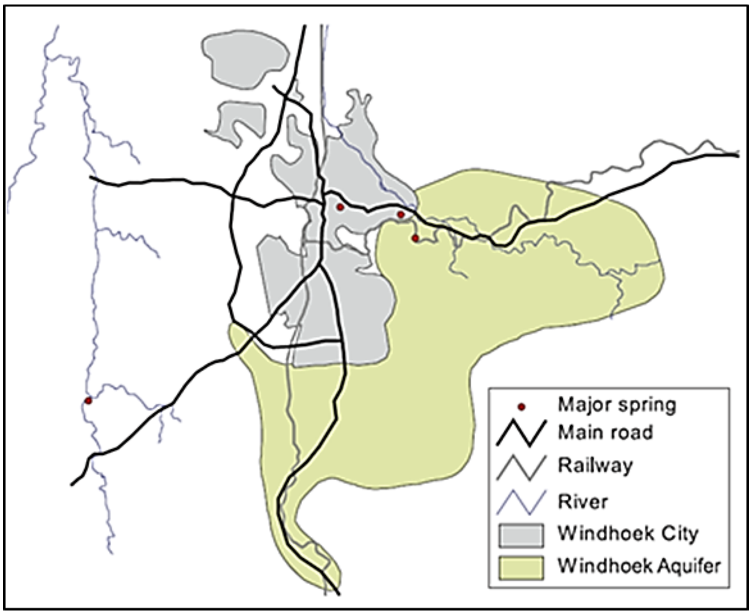
The situation becomes more complicated with the division over the control of land. Traditional authorities and private land owners may not be aware of the ownership status of the water found on their property. This means that they may not follow the water management general guidelines, using the water as they deem necessary. Thus their use and management of water sources may not comply with those of the rest of the country. Limited government management also contributes to this (Lang 2006). What they do with their water sources may also affect the water resources of the rest of the country. It is important to have some type of system in place that ensures that private and traditional land owners share the same water principals or guidelines as local or regional authorities.

In this type of situation where the management, supply and control over water resources is uncertain, mismanagement of land and water resources is inevitable. The accountability of the governing parties involved is questionable as the one will simply blame the other if something goes wrong. This could also result in some issues being overlooked or ignored as it is perceived as “not our responsibility” of that said department. Lack of accountability is not only an issue in water management, generally all countries need a national plan, a local authority that adapts this plan according to the local needs and a regional authority that ensures that the local authority performs. Namibia lacks the basic national set up of laws, policies, guidelines and action plans, however the City of Windhoek has managed to gain control over their water management.

4.3 WATER GOVERNANCE AND MANAGEMENT IN WINDHOEK

Windhoek is locater far away from the ocean, about 400 km, as well as the perennial rivers, >700km, as seen in the discussion of Section 3 (subsection 3.1.3 Rivers). Windhoek is therefore dependent on a number of other water sources including boreholes, treated wastewater and dams. Windhoek’s location was chosen because of the natural springs that were found in the area (Christelis & Struckmeier 2001; Bravenboer 2004). Source: *Christelis & Struckmeier (2001:78)*

Figure 4.2, shows the location of the aquifers found under the city of Windhoek as well as the location of the major springs. Until 1942, Windhoek’s water came mainly from boreholes pumping groundwater from these aquifers (Bravenboer 2004; Mapani & Schreiber 2008). These boreholes became depleted in 1942 as a result of a lack of precipitation for the replenishment of the aquifers as well as the increase water demand as a result of the growing population (Bravenboer 2004; Mapani 2005; Mapani & Schreiber 2008).



Source: Christelis & Struckmeier (2001:78)

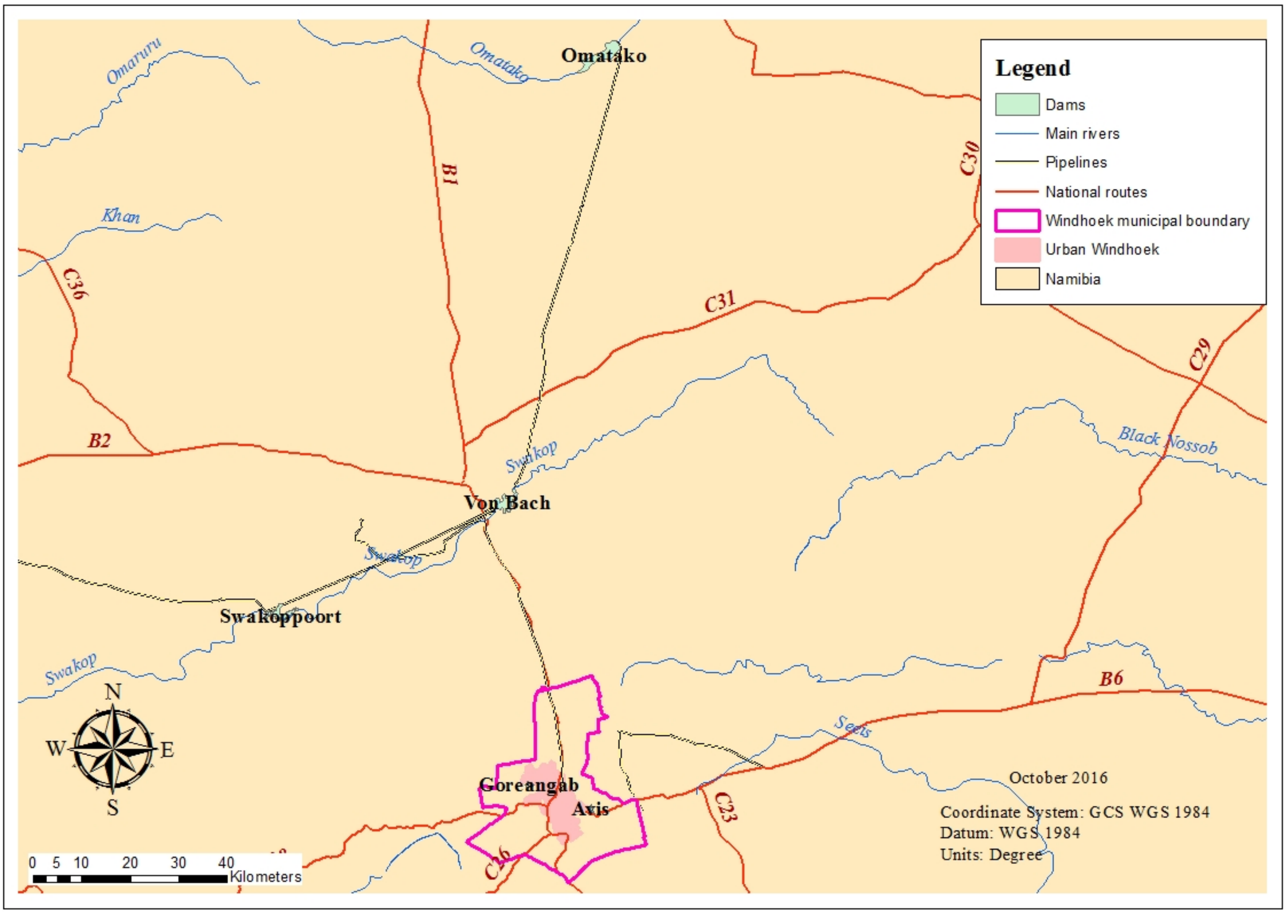
Figure 4.2 Aquifer and springs of Windhoek

The recharge of boreholes is dependent on rainfall of which only 1% finds its way back into the ground (Pietilä 2005; Desert Research Foundation 2009). The extraction of water from these boreholes can therefore be described as unsustainable and not a long term solution for the city of Windhoek (Lang 1997). Surface water from the Avis Dam became the main source of water for the city until the construction and completion of the Von Bach, Swakoppoort and Omatako which are the tree main suppliers of Windhoek's water today (Mapani & Schreiber 2008).

4.4 WINDHOEK'S WATER MANAGEMENT: SUPPLY

Windhoek has only a few local sources of water including groundwater, dams, empherial rivers and treated wastewater (Lahnsteiner & Lempert 2007; Lafforgue & Lenouvel 2015). Windhoek buys water from NamWater while also using local water resources all of which ends up in the three main dams, the Von Bach, Swakoppoort and Omatako. The location of these dams, in terms of their distance from the city's municipal boundaries, as well as the pipelines that transport the water from the dams to the urban area has been included in Source: *adapted from Digital Atlas of Namibia (2002)*

Figure 4.3. The dams fall outside of the municipal boundary, however they form part of the municipal derestriction. All three dams were completed between the year 1970 and 1982 (Sirunda & Mazvimavi 2014). The Von Bach dam forms part of the first phase of the Eastern National Water Carrier (ENWC) project that transfers water from the north to the dams located near Windhoek in order to add to their water supply (Pinheiro, Gabaake & Heyns 2003).



Source: adapted from Digital Atlas of Namibia (2002)

Figure 4.3 water sources, Windhoek

In total, the three dams provide approximately 17 Mm³ of water to Windhoek (Lafforgue & Lenouvel 2015). The Von Bach is the main water supplier as it The Von Bach has a capacity of 48.56 Mm³ which is lower than the capacity of the Swakoppoort dam (63.48Mm³), however the Von Bach loses the least amount of water through evaporation (2 254 mm annually) due to its surface area of 4. 89 km² (Bravenboer 2004; Sirunda & Mazvimavi 2014). Water is therefore transferred from both the Swakoppoort and the Omatako to the Von Bach for storage (Sirunda & Mazvimavi 2014).Figure 4.4 is a summary of the water supply of Windhoek. The three main water sources (surface water, groundwater and wastewater), are indicated and linked to the type of water bodies, including their capacity, which supplies the city with its water. The arrows indicates the direction of the water flow between these sources, including the average amount of rain received by each dam per year (Lafforgue & Lenouvel 2015). The groundwater pumped from the Tsumeb-Otivi-Grootfonteid aquafers is referred to as an outside source, as it falls outside the derestriction of the City of Windhoek.

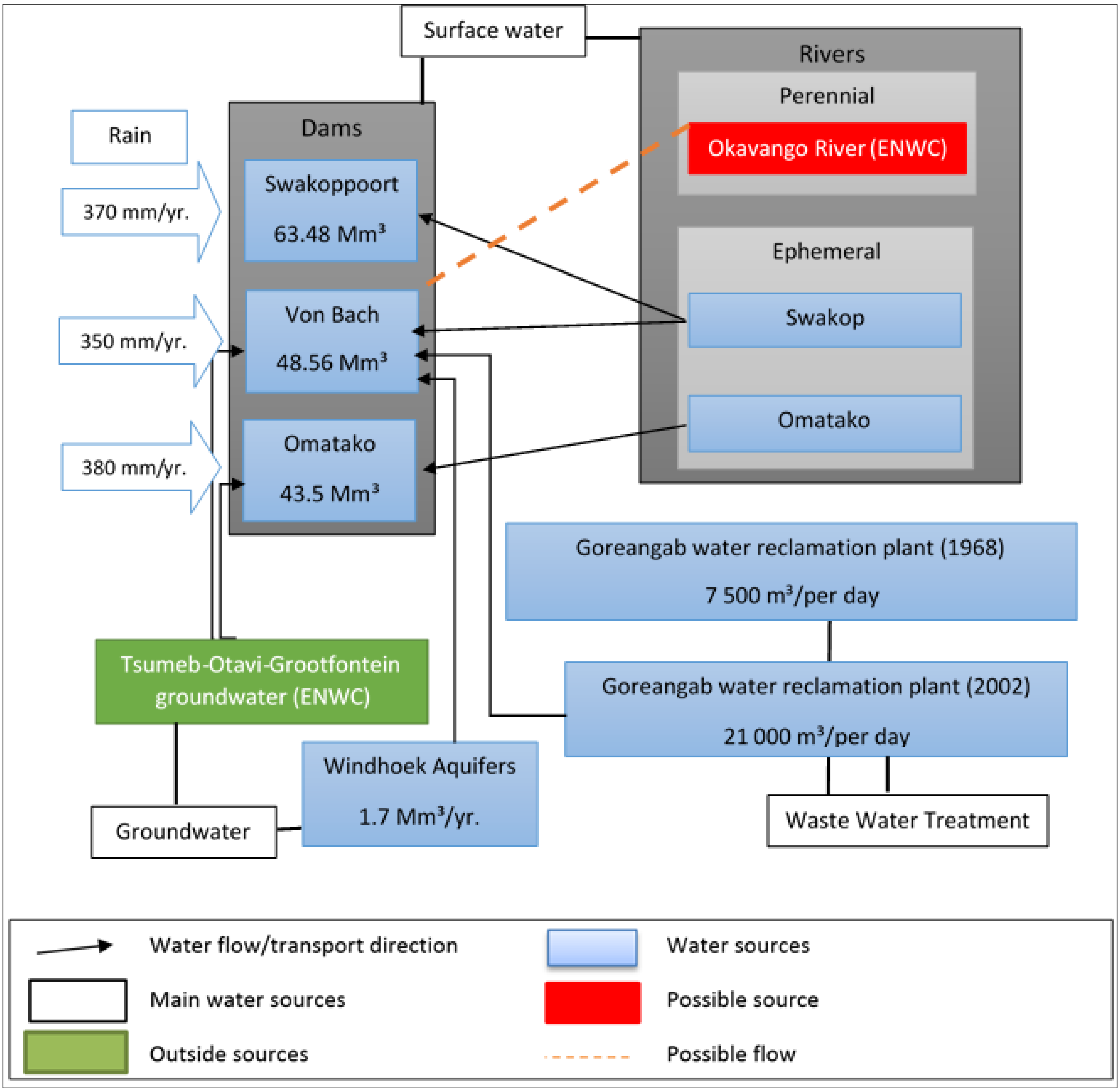
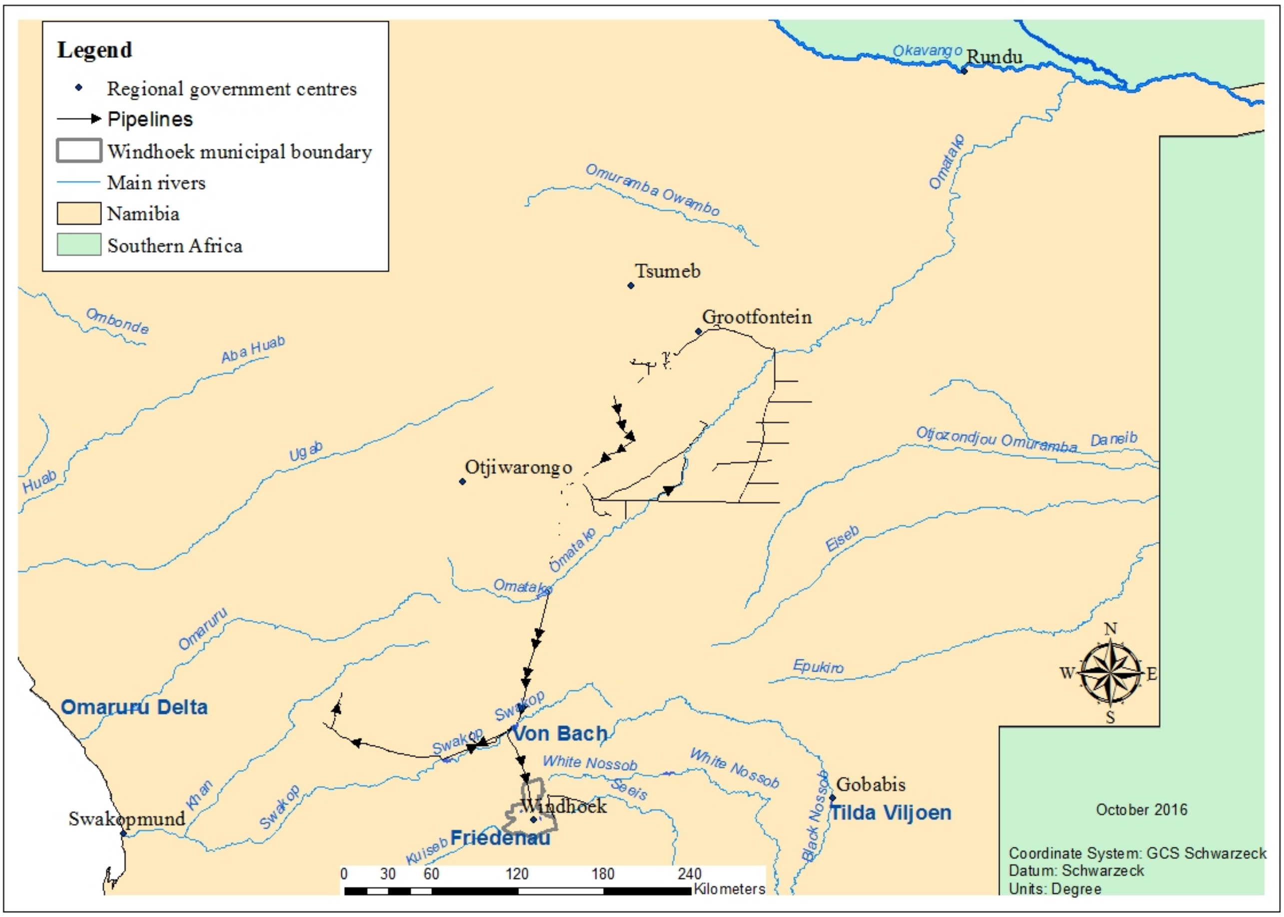


Figure 4.4 water supply resources and its flow

The ENWC has not been fully completed. The construction of a canal between Omatako Dam, located on the Omatako River near Grootfontein, has been completed in 1987 as well as the construction of a pipeline that transports groundwater resources from the Grootfontein basin to the Otavi mountains (Pinheiro, Gabaake & Heyns 2003). The ENMC was originally scheduled for completion in 2003, however the additional water received from the waste water treatment is sufficient for the current demand, therefore the due date has been proposed (Pinheiro, Gabaake & Heyns 2003; Sirunda & Mazvimavi 2014). Windhoek is in need of more water, however the current status and future plans of the ENWC is unknown. The Okavango River is included in f as a possible future water source. Phase five, the construction of a pipeline from Rundu to Grootfontein still needs to be completed (Pinheiro, Gabaake & Heyns 2003). The flow direction of the current pipelines and canals are illustrated below (Source: *adapted from Digital Atlas of Namibia (2002)*

Figure 4.5).



Source: adapted from Digital Atlas of Namibia (2002)

Figure 4.5 water channels' flow direction

Currently the EMNC transports water from Grootfontein to the Von Bach which is then used to supply Windhoek with water. The water flows through pipelines and open channels that also supply water to local farmers and to the Hareoland situated east from the Omatako River (Lafforgue & Lenouvel 2015). Transporting water from such a great distance has several disadvantages. Firstly, it is very costly to construct and maintain the necessary channels. Open channels are constantly obstructed by large objects, including livestock that falls into these channels. The other issue is that evaporation takes place and water is lost in the process of transportation. The second disadvantage of transporting water great distances is that large amounts of water are lost at leakages. It also makes it easy for people to obtain water illegally by tapping into the channels’ water resources.

4.4.1 Groundwater

Windhoek lies on the Damara Sequence geology group. This type of geology has unfavourable aquifer properties with low storage and infiltration levels, however Windhoek is located on top of aquifer and can make use of the available water (Christelis & Struckmeier 2001). Approximately 1.7 Mm^3 of groundwater is extracted annually to add to Windhoek's water supply (Lafforgue & Lenouvel 2015). The age of the groundwater found in and around Windhoek is approximately 12 000 years. Unfortunately, the amount of groundwater that can be used is limited and recharge is slow. Windhoek makes use of artificial recharge methods allowing the city to store water for future use (Mapani 2008).

4.4.2 Recycled water

Reclamation of wastewater is a useful tool in water supply management. Not only does it increase water supply, but it also prevents pollution by treating wastewater before it returns to the water system (van Leeuwen 1996; Chen, Ngo & Guo 2013). Middle income or poor income countries, such as Namibia, are vulnerable to poor water quality as a result of the usage of untreated water. Manny arid regions have begun making use of wastewater treatment in order to increase the water supply. There are different usages of water[6] that results in different types of wastewater, each having a different quality and thus different treatment methods. The end uses of recycled water can be divided into three groups; non-portable, indirect portable and direct portable. Non-portable uses include agricultural uses, forestry, non-portable urban uses, residential uses and recreational and environmental uses. Indirect portable water uses include surface water dilution and reservoir storage. Direct portable water end uses go directly into the water distribution system or is blended in the water supply of the storage reservoirs (Chen, Ngo & Guo 2013).

By 1957, the water purification infrastructure started in Windhoek with the building of the Goreangab Water Reclamation plant, which still functions as one of the main water purification plants today (van Leeuwen 1996; Bravenboer 2004). The plant treats domestic sewage effluent, which has been pumped into the Goreangab Dam, and stored in reservoirs after the proper treatment (van Leeuwen 1996). The treated water is then used for landscape irrigation, supplying water for golf courses and sport fields. Since Namibia's independence (1990), Windhoek has experienced rapid population growth and city expansion, as a result of both the natural increase in the population and urbanisation (Magnusson & van der Merwe 2005; Munier 2007). This lead to an increase in water demand. By 1993 the cities' water managers recognised the dangers of the current water usage. Increasing water supply became a long term goal, leading to the construction of the New Goreangab Water Reclamation Plant (NGWRP), completed in 2002 (du Pisani 2006, Lahnsteiner &

[6] Including industrial, domestic and sewerage.

Lempert 2007). The water outflow from the NGWRP is of a good enough quality to drink. The NGWRP is a successful Public-Private Partnership (PPP) that is run by the Goreangab Operating Company (WINGOC). The plant receives finance from a number of companies including the European Investment Bank, the City of Windhoek and Kreditanstalt fuer Wiederaufbau (Remmert 2016b). This allows the WIGOC to obtain the necessary, up-to-date technology needed to recycle and redistribute the wastewater accordingly.

4.5 WINDHOEK'S WATER MANAGEMENT: DEMAND

Windhoek attempts to curb its water demand by employing a number of strategies, firstly Windhoek educates its citizens making them aware of the limited water supply (Bravenboer 2004). Education is an important step in water sustainability strategies, especially in arid regions (Mapani & Schreiber 2008) Informing people of the situation not only encourages them to use less water, but it can also help them prepare for the worst or come up with creative ways of saving water (Malkina-Pykh & Pykh 2003; Magnusson & van der Merwe 2005). The education of higher institutions may lead to the discovery of new technologies or better ways of maintaining infrastructure that can assist with water supply. The inclusion of more, highly educated, workers also have the potential to assist in better water supply (Malkina-Pykh & Pykh 2003).

Another way in which the City of Windhoek has curbed the demand for water is by implementing block tariffs. As a result of the decentralisation of power, municipalities are able to determine their own mechanism of pricing as well as the amount (Pietilä 2005). Some municipalities charge a set or "flat" prices per cubic meter, while other municipalities, such as Windhoek and Henties Bay, makes use of block tariff, increasing the price per cubic meter as more water is used (Pietilä 2005). Historically Windhoek did not make use of this type of pricing method and people used water in a wasteful manner, the block tariff made people more aware of their usage of water encouraging people to use only a certain amount of water per month in order to save money (Seely 2001). According to Rahaman and Varis (2005), this is a good way of controlling the demand of water and according to Mapani and Schreiber (2008) this type of pricing has had a positive effect as users have decreased the amount of water they use.

Windhoek has a Drought Response Plan, set up by the Department of Infrastructure, Water and Services in 2015. The Drought Response Plan consists of three components, Drought Severity Indicators, Drought Response Actions and Drought Response Program Elements. Drought Response Actions consists of guidelines for augmenting water supplies and reducing water usage during that time (CoW 2015). These action plans consider increasing water supply, by using the Goreangab reclamation plan to its fullest extent and using groundwater, reducing water demand by means of education, monitoring and evaluation and water scarcity tariffs and restrictions. The latest tariff for Windhoek has been released in the Government Gazette No. 6072 on 15 July 2016. Table 6.2 below, shows the current block tariff for domestic use for normal time and times of limited water availability. Municipalities in Namibia can set their own water prices as long as it is send to the Ministry of regional and Local Government to be published in the Government Gazette (Pietilä 2005; Lang 2006).

Table 4.1 Water prices for domestic use

Kl per day	Kl per month	Tariff per Kilolitres (N$)	Total cost (N$)
Domestic			
0 – 0.2 kl	0-6	17.11	0 – 106.62
0.201-1.333	6 – 40	26.47	107- 1058.8
1.334 – 1.666	40-50	48.82	1059 - 2441
>1.666	>50	112.50	>5625
Domestic – times of limited water available			
0 – 0.2 kl	0-6	17.11	0 – 106.62
0.201-1	6 – 30	26.47	107- 794.1
1.01– 1.333	30 - 40	48.82	795 – 1952.8
>1.333	>40	112.50	> 4500

The table demonstrates how water price per kl increases during times when there are limited water available. The first block, 0-6 kl a month, stays at a constant price, as an attempt to allow people to use water for their basic daily needs. After the first block the water price goes up by about 45% per block as indicated in the table. Business consent has a flat tariff of N$ 29.43 per kl. The City op Windhoek realises the importance of businesses and restricting water usage during times of limited water availability could influence the performance of a business. The cost of semi-purified water is cheaper for municipal consumers than the normal block tariff, costing 5.51 per kl (includes 0.72 vat). This encourages people to supplement some of their fresh water use with semi-purified water, increasing the fresh water storage savings for future needs (van Rensburg 2016).

The negative effects of placing economic value on water is that the lower- income groups suffer under the tariffs, if not calculated correctly (Rahaman & Varis 2005). In Windhoek there are a number of low-income (informal settlements) areas, including Katutura, Khomasdal, Wanaheda, Hskahana and Okuryangava (Peyroux 2002). In general, these households use less water than the middle and higher- income households that are found within the city. Most of these communities also use outside taps and therefore share a water source (Tvedten 2011). Windhoek attempts to decrease the prices of water services for these low-income areas. One of the ways in which this is done is by asking lower tariff for sewerage services, a flat price of 22.96, than that of other residential areas, price is charged according to erf size.

Drought Severity Indicators, considers a variety of factors that should be taken into consideration when choosing an appropriate drought response plan. The water availability is one of the main indicators of drought severity. By looking at the current dam levels and comparing that with the population and water usage, the amount of water available to sustain the population can be divided into month. The Drought Response Program, guidelines for water uses during different levels of drought, works on this bases. The guidelines of the Drought Response Plan are summarised in a table explaining water usage and restrictions during different stages of drought (CoW 2015).

Table 4.2 Drought Respons Programme

Water Supply (month of water available	>30	<30	<24	<18	<12
Water availability status	Normal	Water Scarcity	Drought	Severe Drought	Water crisis
Water use	Baseline consumption	Reduced water consumption	Water savings	Increased % water savings	Restrictions
Programme implementation	Do not waste water	Drought watch	Mandatory water savings	Water savings required	Rationing

4.6 URBAN PLANNING

As mentioned in section, Namibia's governing laws are outdated and lacking behind and the planning laws are no exception to this (Remment 2016a). Authorities have tried to curb urban growth since 1990 by developing rural areas and developing the urban areas to handle the growth rate. This has led to a number of housing policies, area developments and zoning land for temporary stay on the boundaries of the city (!Owoses-/Goagoses 2013). Most of the migrants that move to Windhoek live in informal houses on the outskirts of the city where there is a lack of basic services, including proper water pipelines (Mitlin & Muller 2004; Tvedten 2011). Housing has become one of the major priorities of the municipality as citizens, according to the constitution of Namibia, have the freedom of movement and to live were they want as well as the right to housing (!Owoses-/Goagoses 2013). This increase in the population places more and more strain on the municipality as they need to supply all the citizens with basic services, including water (Mitlin & Muller 2004). Citizens have the right to housing and water and the municipalities are in charge of providing these to the citizens in the region. There are no restrictions in terms of migration giving people the right to move into the city. The water supply of the city is therefore under stress and the municipality has to manage the water resources properly to avoid disaster.

In general, urban planning in Windhoek is limited by a lack of funding, specifically for housing that can accommodate the poorer population, poor technical capacity and the outdated regulations that does not cater to the modern urban needs, nor does it consider the sensitive environment of the country (Remmert b 2016). Town planning currently focuses more on market trends that is concerned with property and value than the bigger urban plan. The latest urban developments[7] in Windhoek, for example, is aimed at the higher income groups, thus neglecting the development of more affordable housing. Namibia in general is in need of a National Spatial Development Framework that guides sustainable urban planning (!Owoses-/Goagoses 2013; Remmert 2016a).

[7] Finkenstein, the Grove Mall, Lady Puhamba Hospital and Omeya Golf Estate are all new or in-progress developments. More information on new developments in Windhoek can be found on Property24 (http://www.property24.co.na/property-for-sale-in-windhoek-c2268).

SECTION 5: CONCLUSION AND POLICY IMPLICATIONS

Water is an important resource that is used in all aspects of life and by all life forms. It may be one of the single most important resources on earth, and therefore needs to be well looked after by those that use it. Water scarcity is experienced in the arid-regions found all around the world, making the task of water management particularly difficult for these areas (UN Water 2015). However, events such as climate change, urbanisation, increasing population growth and poor water management can chase any place in the world, regardless of its precipitation, temperature and rainfall, to experience drought or become a water scarce area. Cities in countries that are new to experiencing water shortages can look at cities such as Windhoek as an example of how to manage water supply and demand in such a way that urban development is not negatively affected.

Section 3 explains the temperature, rainfall, groundwater supply and population of the country and how water availability is affected by these factors. In Windhoek, the summer and winter high and low temperatures stays relevantly constant from year to year, however rainfall levels can increase or decrease unpredictably. There is no rain and little cloud cover during the winter period allowing even further evaporation, and thus loss of water. Windhoek's water supply is limited by its climate conditions and its lack of natural water sources, however the city still continues to grow as a result of the natural increase and urbanisation. These characteristics cannot be changed by the municipality, therefore water resource management and city planning should work around these conditions to ensure sustainable development.

The city has a number of ways to increase water supply while simultaneously decreasing the demand for water. Water supply includes dams that receives water from rain, rivers and other sources, groundwater, recycled water and water transported from the north down to the city. The old and new Goreangab Wastewater Treatment plant has played a major role in increasing water supply and providing the city with higher water quality. Water treatment is one of the best ways to increase water supply and decrease the usage of freshwater, as it is a relatively stable source in terms of water availability. Groundwater also contributes to water supply especially in times of need. However, it is important to recharge this water source during rainy seasons when there is a surplus of water. Because of the nature of groundwater and the low recharge rate, artificial recharge is used throughout the world in order to slow down the depletion of groundwater resources. Even though this is a useful way to maintain groundwater resources, it is also a very risky process it can pollute the groundwater, resulting in all the groundwater found in that basin to be of poor quality and unsafe to use directly.

The city has successfully decreased the water usage of the citizens and thus, decreased water demand. Water demand management includes informing the citizens of the current water situation and how to use water scarcely. The Drought Response Plan (2015), further lowers water usage in times of low dam levels. The DRP considers the amount of water available by calculating the number of month of water availability by comparing the water supply to the water demand of the city. The correct policies can then be implemented in order to ensure future water availability. Water has economic value and thus water pricing can be used to lower water usage. The block tariffs encourages lower water usage for domestic purposes. Fresh water is often sublimated for semi-purified water as a result of the lower price, increasing freshwater savings. Unfortunately, poor household suffer under water prices. People living in poverty often turn to water sources that are freely available to them, but have a lower quality, resulting in disease. There is also a lack of sanitation in these areas and the quality of life is low.

Urbanization can be seen as one of the major challenges in both spatial planning and water resource development. The majority of people move to cities in order to have a better live, however this is not always the case, resulting in the urbanisation of the poor. Population growth and migration is inevitable, therefore Municipalities and city planners need to keep up with the housing demands and the supply of basic services. Rapid urbanisation and population growth results in unplanned city growth. Services cannot keep up with the increasing demand and will become unequally distributed amongst the population. Unplanned city growth can have a number of negative effects on the environment as well, including negatively altering the natural water cycle of the entire region (Furumai 2008).

5.1 POLICY IMPLEMENTATIONS

Namibia's laws and policies were inherited from South Africa, however even after its independence in 1990, giving the government the power to implement new laws, the Water Act of 1958 is still the main water governing act. Attempts have been made to replace this act with the Water Resource Management Act (2004) and later the Integrated Water Resource Management Act (2013) , however this has only lead to further divisions in water governance as some local authorities considers the new updated acts while others work on the 1958 Act.

Water resource management and urban growth and town planning policies do not always overlap. On the one hand water resource management is divided different governing bodies, at different levels of authority and different cities. The Windhoek municipality takes charge of water management at a local level. While water management has thus far been relatively successful, the future is uncertain On the other hand, urban planning focuses on available land that can be sold to private investors for housing development and other projects. Water scarcity has the potential to limit development, however there is no city development action plan that considers both water management and urban growth. Drawing up guidelines, that sets creative ways in which urban development can be used to limit water usage or increase water savings, can potentially steer future development, and development policies, in the right direction. Future research can focus on how certain city layout plans and utility distribution can decrease water usage without negatively impact the quality of life of the citizens or economic development.

REFERENCES

!Owoses-/Goagoses F 2013. *Planning Law in Namibia*. Juta: Cape Town.

Agnew C & Anderson E 1992. *Water resources in the arid realm*. Routledge.

Becker F 2013. Spatial planning in urbanisation: observations from an academic perspective. *Journal for Studies in Humanity and Social Sciences*, 2: 1 – 20.

Bravenboer B 2004. *Windhoek: Capital of Namibia. Windhoek*: Gamsberg Macmillan.

Chen Z, Ngo, HH & Guo W 2013. A critical review on the end uses of recycled water. *Critical reviews in environmental science and technology*, 43: 1446-1516.

Christelis G & Struckmeier W 2001. Groundwater in Namibia. *An explanation of the Hydrogeological Map*. John Meinert: Windhoek.

City of Windhoek 2015. *Drought Response Plan*. Department of Infrastructure, Water and Technicla Services: Windhoek.

Desert Research Foundation of Namibia 2009. *IWRM survey and status report: Namibia*. Global Water Partnership Southern Africa. [Online] Available: http://www.gwp.org/Global/GWP-SAf%20Files/Namibia%20IWRM%20report.pdf [accessed: 20 May 2016].

Digital Atlas of Namibia 2002. Director of Environmental Affairs. Ministry of Environment and Tourism. [Online] Available: http://www.uni-koeln.de/sfb389/e/e1/download/atlas_namibia/main_namibia_atlas.html [Accessed 2 June 2016].

Ertsen & van de Ven 2006. Water in the urban environment. In Munier N (ed) 2006. *Handbook on urban sustainability*. Springer.

Feldman LF 2012. *Water*. Polity Press, Cambridge.

Furumai H 2008. Rainwater and reclaimed wastewater for sustainable urban water use. Physical and Chemistry of the Earth 33:340-346.

Gleick 2000. The Changing Water Paradigm. A look at twenty-first century water resource development. *Water International*, 25: 127 – 138.

Gunawansa A, Bhulla L & Hoque SF (ed) 2013. Water Governance: an evaluation of alternative architectures. Edward Elgar: Cheltenham.

Karuaihe S, Wandschneider P & Yoder J 2012. Water bill estimation when pricing is cryptic: experience from Windhoek, Namibia. *South African Journal of Economics*, 80: 264 - 287.

Lafforgue M & Lenouvel V 2015. Closing the urban water loop: lessons from Singapore and Windhoek. *Environmental Science: Water Research & Technology*, 1: 622 – 631.

Lahnsteiner J & Lempert G 2007. Water management in Windhoek, Namibia. *Water Science & Technology,* 55:441-448.

Lange GM 1997. An approach to sustainable water management using natural resource accounts: The use of water, the economic value of water, and implications for policy. *Institute for Economic Analysis*, New York University.

Lang GM 2006. Water accounts and water policy in Namibia. In Lang G & Hassan (ed) 2016. *The Economics of Water Management in Southern Africa: an environmental accounting approach*. Edgard Elgar: Cheltenham.

Magnusson TS & van der Merwe B 2005. Context driven policy design in urban water management. A case study of Windhoek, Namibia. *Urban Water Journal*, 2: 151 – 160.

Malkina-Pykh IG and Pykh I 2003. *Sustainable food and agriculture*. Wit Press.

Mapani BS 2005. Groundwater and urbanisation, risk and migration: the case for the city of Windhoek, Namibia. *Physics and Chemistry of the Earth*, 30: 706 – 711.

Mapani BS & Schreiber U 2008. Management of city aquifer from anthropogenic activities: example of the Windhoek aquifer, Namibia. *Physics and Chemistry of the Earth*, 33: 674 – 686.

Ministry of Agriculture, Water and Forestry (MAWF) 2014/2015. *Annual Report*. Republic of Namibia: Windhoek.

Minisrty of Agriculture, Water and Forestry (MAWF) 2010. Integrated water resources management: plan for Namibia. IWRM Plan Joint Venture Namibia: Windhoek.

Mitlin D & Muller A 2004. Windhoek, Namibia: towards progressive urban land policies in Southern Africa. International Development Planning Review 26: 167 – 186.

Namibia Statistics Agency 2011. *Khomas 2011: census regional profile*. Namibia Statistic Agency FGI House: Windhoek.

Namibia Statistics Agency 2015. *Migration report*. Namibia Statistic Agency FGI House: Windhoek.

Namibia Statistics Agency 2016. *Namibia population prediction 2011 – 2041*. Namibia Statistic Agency FGI House: Windhoek.

Namibia Weather Network 2016. Windhoek, Namibia. [Online] available at: http://www.namibiaweather.info/ [20 May 2016].

Ooi GL 2004. *Sustainability and cities: concept and assessment*. Institute of Policy Studies: Singapore.

Pennington KL and Cech TV 2009. *Introduction to water resources and environmental issues*. Cambridge University Press.

Pereira LS Cordery I and Iacovides I 2009. *Coping with water scarcity: Addressing the challenges*. Paris: Springer Science & Business Media.

Peyroux 2002.Urban growth and housing policies in Windhoek: the gradual change of a post-apartheid town. In Diener I & Graefe O 2002. *Contemporary Namibia: the first landmarks of a post-apartheid society*. Windhoek: Gamsberg Macmillan Publishers.

Pietilä P 2005. Role of municipalities in water services in Namibia and Lithuania. *Public Works Management and Policy,* 10: 53 – 68.

Pinheiro I Gabaake G and Heyns P 2003. Cooperation in the Okavango River basin: The OKACOM perspective. In Tutron A, Ashton P & Cloete (ed) 2003. *Transboundary rivers, sovereignty and development: Hydropolitical drivers in the Okavango River basin*. African Water Issues Research Unit: Pretoria.

Rahaman MM and Varis O 2005. Integrated water resources management: evolution, prospects and future challenges. *Sustainability: Science, Practice, & Policy*, 1.

Remmert D 2016(a). Urban Planning Muddle. *Insight*. July 2016: 14 – 15.

Remmert D 2016(b). Water and Public-Private-Partnership. *Insight*. August 2016: 22

Rubel F and M Kottek 2010: Observed and projected climate shifts 1901−2100 depicted by world maps of the Köppen−Geiger climate classification, Meteorol. Z., 19, 135− 141. DOI: 10.1127/0941−2948/2010/0430

Seely M 2002. Environment: harsh constraints, political flexibility. In Diener I & Graefe O 2002. *Contemporary Namibia: the first landmarks of a post-apartheid society*. Windhoek: Gamsberg Macmillan Publishers.

Sirunda, JJ & Mazvimavi D 2014. The Effects of Water Transfer from Swakoppoort and Omatako Dams on the Water Quality of Von Bach Dam, Namibia. In *Combating Water Scarcity in Southern Africa*. Springer : Netherlands.

Tötemeyer G 2014. Namibia today: challenges and obstacles to reconciliation and stability. Namibia Institute for Democracy: Windhoek.

Tvedten I 2011. *"As Long as They Don't Bury Me Here": Social Relations of Poverty in a Namibian Shantytown,* Vol 11. Basler Afrika Bibliographien.

Van Leeuwen JH 1996. Reclaimed water-an untapped resource. Desalination, 106(1), pp.233-240.

Van Rensburg P 2016. Overcoming global water reuse barriers: the Windhoek experience. *International Journal of Water Resources Development,* 32: 1-15.

World Bank 2015. *A water-secure world for all: water for development.* United Nations: World Bank.

Xu Y & Braune E 2010. The role of ground water in Sub-Saharan Africa. *Ground Water,* 48:229-238.

APPENDICES

A POPULATION DATA

B TEMPERATURE AND RAINFALL DATA

APENDIX A: POPULATION DATA

NAME	ABBR.	CAPITAL	AREA	POPULATION	POPULATION	POPULATION	POPULATION
			A (KM²)	CENSUS (C)	CENSUS (C)	CENSUS (CF)	PROJECTION (P)
				10/21/1991	8/27/2001	8/28/2011	7/1/2016
NAMIBIA	NAM	WINDHOEK	825,615	1,409,920	1,830,330	2,113,077	2,324,400
ERONGO	ERO	SWAKOPMUND	63,539	55,470	107,663	150,809	182,400
HARDAP	HAR	MARIENTAL	109,781	66,495	68,249	79,507	87,200
ǁKARAS (KARAS, //KARAS)	KAR	KEETMANSHOOP	161,514	61,162	69,329	77,421	85,800
KAVANGO (OKAVANGO)	KAV	RUNDU / NKURENKURU	48,742	116,830	202,694	223,352	237,800
KHOMAS	KHO	WINDHOEK	36,964	167,071	250,262	342,141	415,800
KUNENE	KUN	OPUWO	115,260	64,017	68,735	86,856	97,900
OHANGWENA	OHA	EENHANA	10,706	179,634	228,384	245,446	255,500
OMAHEKE	OMA	GOBABIS	84,981	52,735	68,039	71,233	74,600
OMUSATI	OMU	OUTAPI	26,551	189,919	228,842	243,166	249,900
OSHANA	OSA	OSHAKATI	8,647	134,884	161,916	176,674	189,200
OSHIKOTO	OSH	TSUMEB	38,685	128,745	161,007	181,973	195,200
OTJOZONDJUPA	OTJ	GROOTFONTEIN	105,460	102,536	135,384	143,903	154,300
ZAMBEZI (CAPRIVI)	ZAM	KATIMA MULILO	14,785	90,422	79,826	90,596	98,800

NAME	ADM.	POPULATION	
		CENSUS (CF)	
		8/28/2011	
1	WINDHOEK	KHO	325,858
2	RUNDU	KAV	63,431
3	WALVIS BAY	ERO	62,096
4	SWAKOPMUND	ERO	44,725
5	OSHAKATI	OSA	36,541
6	REHOBOTH	HAR	28,843
7	KATIMA MULILO	ZAM	28,362
8	OTJIWARONGO	OTJ	28,249

YEAR	TOTAL POPULATION (MILLIONS OF) - NAMIBIA
1991	1.47
1992	1.51
1993	1.56
1994	1.61
1995	1.65
1996	1.71
1997	1.76
1998	1.81
1999	1.86
2000	1.9
2001	1.93
2002	1.96
2003	1.98
2004	2
2005	2.03
2006	2.05
2007	2.08
2008	2.11
2009	2.14
2010	2.18
2011	2.15
2012	2.26
2013	2.3
2014	2.2

Year	Population Growth (%) - Namibia
1991	3.52
1992	3.19
1993	2.98
1994	2.93
1995	2.97
1996	3.04
1997	3.04
1998	2.9
1999	2.59
2000	2.17
2001	1.74
2002	1.39
2003	1.16
2004	1.11
2005	1.18
2006	1.27
2007	1.34
2008	1.44
2009	1.54
2010	1.64
2011	0.87
2012	0.82
2013	0.75
2014	0.67

APENDIX B: TEMPERATURE AND RAINFALL DATA

AVERAGE HIGH TEMPERATURES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
2016	32.6	33.4	30.2	29.8	25.4	21.0*	---	---	---	---	---	---	30.1*
2015	32.2	33.2	27.3*	26.8	26.6*	21.7	22.6	27.4	28.8*	---	32.8	31.3*	28.0*
2014	30.3	27.9	27.9	25.8	---	22.1	22.7	25.3	29.4	31.8	30.9	33.2	27.9*
2013	33.9	34.0	31.3	27.9	25.5	23.7*	22.7*	---	27.6*	32.2*	31.1*	30.3	28.7*
2012	31.3	28.0	28.2	26.5	25.5*	22.0	22.0	24.9	29.4*	33.5*	29.5*	31.9	27.4*
2011	28.2	27.8*	26.9	25.5	23.5*	21.8	21.0	25.7	30.1	30.1	31.8	31.6	27.1*
2010	28.6	30.9	29.2	27.8	24.3	22.6	21.8	26.3	29.2*	32.0	30.6	31.7	27.9*
2009	31.6*	27.0	27.0*	26.8	24.5	22.0	19.3	25.6	31.2*	30.7	31.1	34.1	27.3*
2008	31.6	28.2	26.4	25.8	24.9	22.2	21.3*	24.9*	29.7*	31.7	30.0*	29.9	27.0*
2007	---	---	---	---	---	---	---	---	---	---	32.7*	32.8	32.8*
AVG	31.1	30.1	28.4	27	25.1	22.2	21.7	25.7	29.4	31.5	31.4	31.9	27.9

AVERAGE LOW TEMPERATURES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
2016	18.6	19.8	15.7	16.1	11.3	8.8*	---	---	---	---	---	---	16.2*
2015	18.7	17.0	15.5*	13.4	10.8*	4.7	5.9	10.9	15.8*	---	16.8	19.8*	12.6*
2014	16.7	17.5	15.6	12.7	---	7.0	6.0	8.7	13.5	15.1	15.6	17.9	13.3*
2013	19.7	19.1	17.6	12.9	10.7	7.5*	7.1*	---	12.0*	15.5*	19.3*	17.3	14.1*
2012	18.3	16.5	14.8	12.0	10.0*	5.2	5.6	8.1	11.1*	17.2*	17.8*	17.4	12.4*
2011	17.0	16.6*	16.3	13.3	10.1*	4.5	5.2	8.8	13.4	13.8	15.8	16.7	12.7*
2010	17.1	17.4	17.4	14.4	10.1	6.6	7.1	9.7	13.8*	16.3	15.9	16.7	13.5*
2009	16.7*	16.8	14.0*	13.2	9.2	6.4	5.3	8.9	16.9*	15.7	15.8	18.6	12.8*
2008	18.2	17.0	14.8	11.6	9.3	5.6	5.0*	9.0*	11.4*	16.1	17.1*	17.1	12.3*
AVG	17.9	17.5	15.8	13.3	10.2	6	5.9	9.1	12.7	15.6	16.3	17.4	13.2

RAINFALL

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
2016	124.8	68.8	47.2	16.2	0.0	0.0*	0	0	0	0.2	---	---	257.0*
2015	82.4	2.2	3.6*	70.4	0.0*	0.0	0.0	2.4	0.0*	---	10.6	25.4*	197.0*
2014	108.6	154.2	127.4	16.6	---	0.0	0.0	0.2	1.6	1.0	21.0	44.2	474.8*
2013	21.6	31.2	79.4	0.8	0.0	0.0*	0.0*	---	12.0*	0.0*	2.8*	95.6	243.4*
2012	59.2	180.2	113.6	0.0	0.0*	0.0	0.0	0.0	0.6*	3.8*	16.0*	43.8	417.2*
2011	384.0	175.1*		296.1	232.2	67.2*	0.0	0.2	0.0	9.4	0.0	12.6	45.0 1221.8*
2010	317.6	25.6	50.2	48.9	11.5	0.0	0.0	0.0	25.4*	0.0	82.7	20.8	582.7*
2009	77.2*	302.3	42.5*	7.8	12.1	0.9	0.0	0.0	6.7*	3.2	5.9	32.9	491.5*
2008	53.1	193.2	195.2	11.6	2.9	0.3	0.0*	0.0*	0.0*	33.1	43.2*	42.7	575.3*
2007	---	---	---	---	---	---	---	---	---	---	18.2*	20.8	39.0*