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An investigation of the rainfall-related and human-induced risk drivers that contributed to acute urban water scarcity: A case study of the urban water scarcity in the George Municipality from 2009 - 2010



MPhil Thesis

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December 2011

An investigation of the rainfall-related and human-induced risk drivers that contributed to acute urban water scarcity: A case study of the urban water scarcity in the George Municipality from 2009 - 2010

A Thesis Submitted to the Faculty of Science

Department of Environmental and Geographical Science

University of Cape Town

For The Fulfilment of the Requirements for the Degree of Master of Philosophy in
Environmental and Geographical Science (Disaster Risk Science)

By

Laura Marie Barrett

UNIVERSITY OF CAPE TOWN

PLAGIARISM DECLARATION

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ACKNOWLEDGEMENTS

Firstly, I would like to extend a heartfelt thanks to my supervisor Dr. Ailsa Holloway for supporting me throughout the study. She has committed a lot of time and energy to this study and has been patient and kind whilst providing vital constructive criticism. Her extensive knowledge has not only helped me through this study but has taught me a way of thinking, writing and analysing problems for the rest of my years in research. This study would not have been possible without her.

To Arthur Chapman, who was always willing to lend a hand with data analysis and discussion. He always provided a clear and concise way of dealing with problems.

Thank you to the staff at DiMP: Sylvia Prime, Gillian Fortune, Wilma Roux and Patricia Zweig for their unwavering support and assistance at all times.

Special acknowledgement and thanks to the Cape Higher Education Consortium and USAID for financially supporting the research.

I am also grateful to all the key informants for their vital contributions in providing important research information, material sources and contact persons. The Department of Water Affairs, Eden District Disaster Management Centre, Provincial Disaster Management, George Municipality and The South African Weather Service, without which the study would not have been possible.

My appreciation and thanks goes to Dr. Joy McCarthy for editing my thesis

My special thanks to my family and friends for all their love and support, in particular to my two pillars of strength - ever gracious and humble parents, Justin and Helen Barrett. Huge thanks to my kind brother, Daniel for taking out so much time to help me with the data consolidation and analysis. To Simon Marshall for always being available to assist, offer advice and reading through my draft thesis.

Lastly, thanks go to my best friend and sister, Nicola, who has supported me throughout my Master's degree.

ABSTRACT

In 2009, severe water scarcity in the Eden District resulted in seven municipalities being declared “drought zones”. This was largely attributed to the lowest rainfall recorded in 132 years and widely recognised as a climate change problem (SABC News, 2009). The Eden District administrative centre, the municipality of George, was also identified as significantly drought affected with water storage declining in the Garden Route Dam to 26.86% of Full Capacity Storage (Department of Water Affairs, 2010). The declaration of the drought emergency in South Africa’s Eden District in 2009 illustrates the increasing episodes of urban water scarcity in rapidly growing urban centres in Africa that are also exposed to climate variability.

Specifically this study sought to investigate the atmospheric and human-induced risk drivers that contributed to the acute urban water scarcity in the George Municipality from 2009 - 2010. Such understanding is viewed as central to sustainable urban development in rapidly growing Africa cities already exposed to climate extremes.

The methodology used for data collection and analysis comprised a “mixed-methods” research design that incorporated both quantitative data, including rainfall, population, urban water consumption and recorded dam levels for the Garden Route Dam and qualitative information sourced from drought workshops and the district and provisional disaster management centres.

The findings of this study suggest that the disaster event was a meteorological and hydrological drought. They also point to a downward trend in rainfall, highly variable rainfall and shifting seasonality in the George Municipality. Garden Route Dam storage levels show an overall downward trend and Garden Route Dam consumption levels show the opposite, with an increasing trend over the last ten years.

Severe weather events, management interventions and an increase in rainfall are the three variables that contributed to the end of the drought event. However, the challenges facing the municipality are complex and highly variable. The results indicate the need for improved understanding and implementation of integrated water resource management.

ABBREVIATIONS AND ACRONYMS

| | |
|--------|--|
| AWC | Available Water Content |
| DWA | Department of Water Affairs |
| EDM | Eden District Disaster Management |
| FCS | Full Capacity Storage |
| GDP | Gross Domestic Product |
| GRD | Garden Route Dam |
| IDP | Integrated Development Plan |
| kl | Kilolitres |
| IWRM | Integrated Water Resource Management |
| LM | Local Municipality |
| MI | Megalitres |
| PDSI | Palmer Drought Severity Index |
| PHDI | Palmer Hydrological Drought Index |
| SAWS | South African Weather Service |
| SPI | Standardised Precipitation Index |
| UNDP | United Nations Development Programme |
| UNISDR | United Nations International Strategy for Disaster Reduction |
| WMA | Water Management Authority |
| WRC | Water Research Commission |

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CHAPTER ONE

INTRODUCTION

1.1. Introduction

Africa is rapidly urbanising, evidenced by the doubling of its urban population from 205 - 400 million people between 1990 and 2010 (Mafuta *et al*, 2011). This rapid growth of cities and towns in Africa is also reflected by a changing disaster risk profile that is driven by both exposures to increased climate variability as well as limited government capacity for provision of essential services including water supplies (Satterthwaite, 2011).

However, some authors (Pelling and Wisner, 2009: 6) suggest that an accurate understanding of Africa's changing disaster risk profile is distorted by entrenched beliefs that the continent's disasters are caused by drought. They also argue that this perception is unhelpful in informing both research and policy development (ibid, 2009: 6). This underlines the value of research that examines contemporary urban risks in African cities facing the dual challenges of climate variability and population growth.

This chapter introduces the background to the study, which was prompted by an urban water emergency widely attributed to meteorological drought (Pers. Communication, Eden District Disaster Management, 2011). The chapter also presents the study aim and research objectives, along with the constraints which affected the research results. The chapter concludes by outlining the organisation of the thesis.

1.2. Background

The declaration of a drought emergency in South Africa's Eden District in 2009 demonstrates the difficulties associated with accurately characterising episodes of acute water scarcity in rapidly growing urban centres in Africa. This especially applies to urban areas exposed to climate variability. In 2009, severe water scarcity in the Eden District resulted in seven municipalities being declared "drought zones". This was largely attributed both to the lowest rainfall recorded in 132 years as well as to climate change (SABC News, 2009). The Eden district administrative centre, the municipality of George, was also identified as significantly drought-affected, with water storage in the Garden Route Dam (GRD) declining to 26.9% of Full Capacity Storage (FCS) (Department of Water Affairs, 2010).

Concerted drought risk management interventions and water consumption controls implemented in 2009 gradually improved water security in the George Municipality, with GRD storage levels

returning to 72.4% by November 2010 (Department of Water Affairs, 2010).

However, while this episode of acute water scarcity was largely attributed to meteorological conditions, the municipality's population had also increased dramatically from 135,000 in 2001 to 200,000 in 2009 (George Local Municipality IDP, 2011/2012, 2011), resulting in significant additional demand on local dam storage. This raises questions about the respective contributions of declining water supply and increasing demand as risk drivers of the acute urban water scarcity in the George Municipality.

1.3. Study Rationale and Aims

Although Africa is increasingly an urban continent, there has been inadequate development of reliable urban water supplies (Mafuta *et al*, 2011: 6). Moreover, Sub-Saharan Africa's water storage capacity is significantly underdeveloped with an annual average storage capacity of 200m³ per person compared to 5,961m³ per person in North America (Grey and Sadoff, 2006; Foster and Briceno-Garmendia, 2010 cited in UNISDR, 2011: 62).

This particularly constrained availability of urban water storage increases the exposure of Africa's growing human settlements to rainfall failure. It is particularly the case, given that large areas of the continent are widely viewed as exposed to meteorological, hydrological and agricultural drought.

In this context, this study's focus on the recent drought experienced by the George Municipality in South Africa's Eden District afforded an opportunity to investigate the relative contributions of both climatic and human-induced risk drivers to the municipality's urban water shortage in 2009 - 2010. Moreover, by including an emphasis on rainfall and urban water consumption levels in years prior to the drought, the study sought to identify accumulating natural and human-induced risk factors prior to drought episode that increased the likelihood of severe water shortages.

Consistent with the disaster risk lens applied in this research, the study combined elements of hazard and vulnerability to identify factors that increased the risk of urban water scarcity. This approach incorporates prevailing views that stress the role of poor urban water demand as the major driver of water scarcity (Mafuta *et al*, 2011:7). In this context, the study's explicit focus on George's rising water consumption patterns, that were associated with the municipality's rapid growth, addressed a previously overlooked factor related to the social construction of water scarcity risk.

This rationale is also consistent with observations made by Vogel *et al* (2010). They cite experience

from Northeast Brazil where repeated attempts to 'manage' drought risks through improved water schemes, alongside a strong science of drought and post-drought response, 'missed their mark'. In this example, the author argues, the focus should have been on 'better understanding the processes causing vulnerability to drought and heightening drought risks' (Lemos, 2007: 16). The study locates itself in this space, with a particular focus on examining the role played by rapid urban expansion in exacerbating the risk of acute water scarcity.

Specifically, the study was informed by three research objectives. These were to:

- Investigate annual rainfall, trend, seasonality and intensity to characterise the precipitation drivers for the 2009 - 2010 episode of acute water scarcity in the George Municipality.
- Investigate increasing water scarcity and hydrological drought conditions by examining change in GRD storage levels and their relationship with both rainfall and urban water consumption
- Examine the respective contributions of severe weather events and purposive urban water demand interventions on dam storage levels prior to and during the episode of severe water scarcity.

Specific research questions that were addressed in the study asked:

- Was the 2009 – 2010 episode of acute water scarcity in George associated with meteorological drought conditions?
- Was the episode of acute rainfall scarcity associated with changing annual rainfall (supply) conditions in the years prior to 2009 - 2010?
- Was the episode of acute rainfall scarcity associated with changing annual water consumption (demand) in the years prior to 2009 – 2010?
- During 2009 – 2010, was the progression of rising urban water scarcity contained/reversed by meteorological conditions and/or improved by urban water demand strategies?

1.5. Ethical Considerations

There were important ethical considerations which informed this research. Confidentiality,

transparency and the inclusiveness of participating respondents and key informants were respected. These were achieved by referring to informants by their official designation rather than names. In addition, study results will be shared with government departments and private companies who assisted with data access.

A copy of the final thesis will be provided to both the Provincial and Eden District Disaster Management Centres.

1.6. Limitations

During the course of the study, the researcher received numerous reports and other data, provided generously by government and other officials eager to better improve local drought risk management. However, she also encountered numerous constraints which included difficulty in accessing data due to institutional limitations, as well as access to the area.

Because of the nature of this study and the slow onset of the drought over the period of a year, historical data were needed to understand both the climate variability and the management of water usage in the area. These data were at times difficult to obtain and missing data constituted a limitation. For instance, during the study period the location of rain gauges shifted. In addition, although extrapolated population data were obtained from the George IDP, there were limited accurate recent population data available for the George Municipality. In this context, the researcher relied on socio-demographic information provided by extrapolated from the 2001 census. This unfortunately did not reflect an accurate population estimate for 2010.

In addition, because of the nature of the disaster risk domain, the focus can shift quite substantially when another disaster event occurs. For instance, pressure generated by wild-fires shortly after the drought declaration significantly constrained the researcher's access to local disaster management officials in the initial stages of this study.

A further study constraint was related to the distance of the study site from Cape Town. As the George Municipality is located 400km away from Cape Town, this made the researcher's travel to the study area expensive and time-consuming. Moreover, unlike other disaster events, a drought emergency is a prolonged process. This necessitated collecting and compiling records over long periods and slowed the research process.

1.7. Organisation of the thesis

This thesis is organised into six chapters. It begins by introducing and outlining the research as well as

the study's aims and objectives, ethical considerations and limitations. Chapter Two provides an overview of the literature that guided this study along with the conceptual framework applied. Chapter Three, the Study Context, contextualises the research and introduces the George Municipality. Chapter Four describes the methods followed and applied. The thesis continues in Chapter Five by presenting the study's findings and analysis. Chapter Six concludes the thesis by discussing the findings and suggesting future research directions.

1.8. Summary

This chapter introduced the research problem and outlined the study's aims and objectives. It continued by describing the ethical considerations that guided the research project as well as important constraints to the research. The chapter concluded by presenting the organisation of the thesis.

University of Cape Town

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

This study's focus on the determinants of the 2009 – 2010 urban water scarcity in the George Municipality necessitated reviewing relevant literature related to drought, urban risk and integrated water resource management.

This chapter begins by examining drought as a global disaster risk, including its spatial extent and projected loss. It also examines contemporary definitions of drought, including their constraints. The chapter continues by characterising drought as a disaster risk in Africa and its occurrence in South Africa. It then examines hydrological drought as a contemporary urban risk in Africa, with a particular focus on sustainable urban water supplies. It concludes by providing an overview of methods conventionally applied to drought assessment and by introducing the conceptual framework for this study.

2.2. Drought as global disaster risk

This section introduces the concept of drought as a “creeping” disaster and details its losses and impacts on a global scale.

2.2.1. Drought as a “creeping” disaster

Although drought is a well-recognised natural hazard, it differs significantly from other sudden onset threats. For instance, hydro-meteorological drought is often referred to as a “creeping phenomenon” (Sivakumar *et al*, 2010). Although its slow-onset characteristics permit (in principle) timely pre-emptive intervention, severe droughts have reportedly affected over 2 billion people since 1900 (EM DAT 2010, cited in UNISDR, 2011: 59). However, although drought is a well-documented threat (Wilhite, 2005), it still remains “poorly understood”, especially hydrological and agricultural drought (UNISDR, 2011: 56). The Global Assessment of Risk (ibid, 2011: 56) further argues that although meteorological drought can be determined and measured, robust measurement of hydrological and agricultural drought requires further study.

2.2.2. Global estimates of drought loss and impacts

Recent research on the scale and extent of drought impacts suggest that more than 11 million people have died in internationally reported droughts since 1900, with over 2 billion affected (EM-DAT, 2010b, cited in UNISDR, 2011: 59). Figures 2.1 and 2.2 respectively indicate the global occurrence of reported drought disasters between 1970 and 2008. Figure 2.1 shows significant areas of South America, Africa and Asia being affected, with over 10 million persons affected. For instance, in regions such as Southern Africa, Asia and parts of Latin America. Figure 2.2 shows a similar trend in the number of drought events, with countries located in South America, Africa and Asia again the most affected (UNISDR, 2009: 4-5). However, although drought generates extensive effects, unlike other natural hazards, its impact on mortality is less clear. For instance, the same report refers to only 4,472 deaths from 1990-2009 that are officially attributed to drought (ibid, 2011: 59).

This considerable disconnect between the scale of population-wide drought effects and documented mortality that can actually be linked to drought highlights the difficulties in recording, reporting and interpreting drought impacts. For instance, the UNISDR's Drought Risk Reduction Framework and Practices notes that although drought disasters explain less than 20% of reported disaster events in Africa, they are associated with 80% of those affected in reported disaster occurrences for the continent (ibid, 2009).

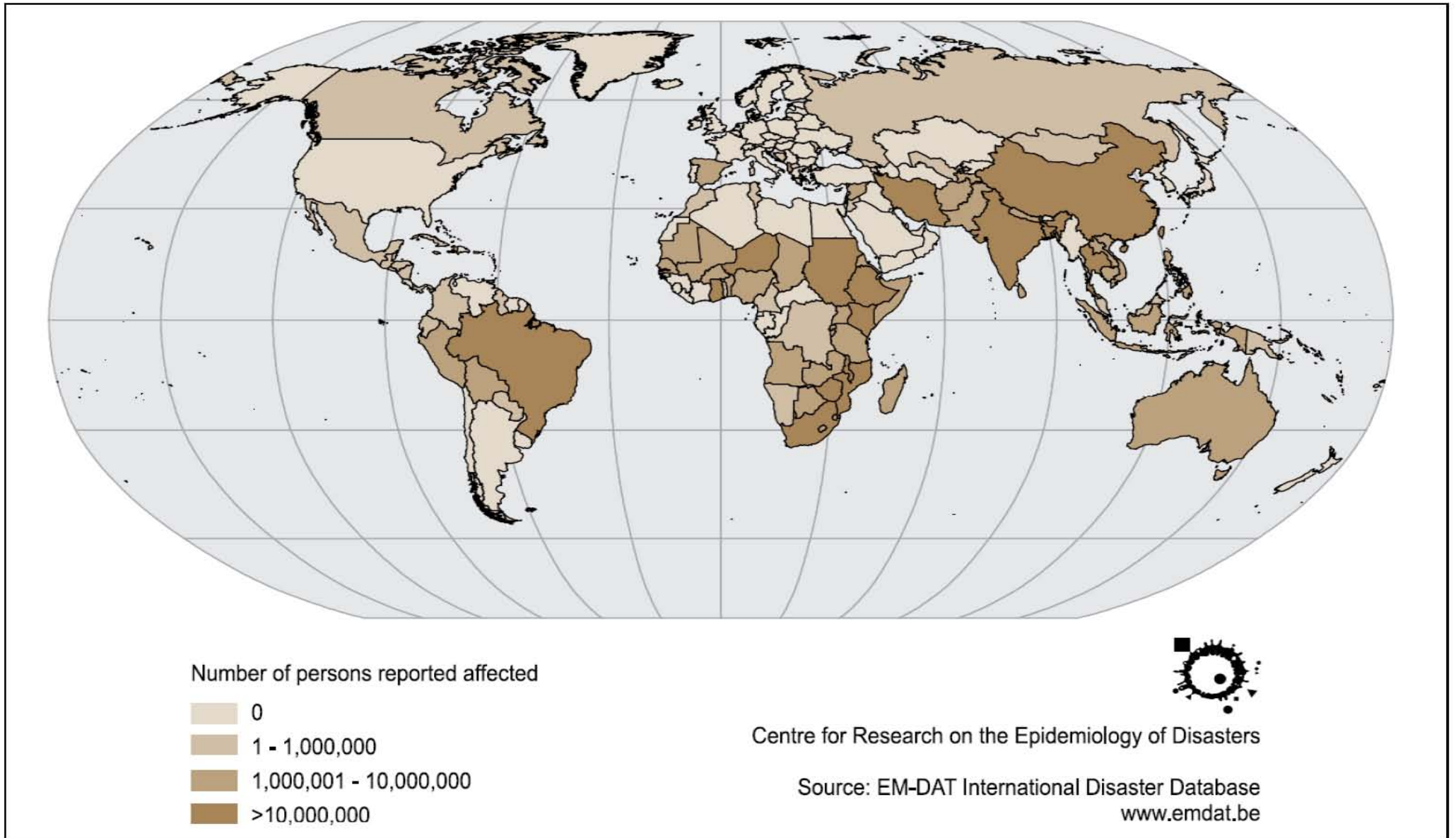


Figure 2.1: Number of drought disasters reported by country: 1970 – 2008 (UNISDR, 2009: 4)

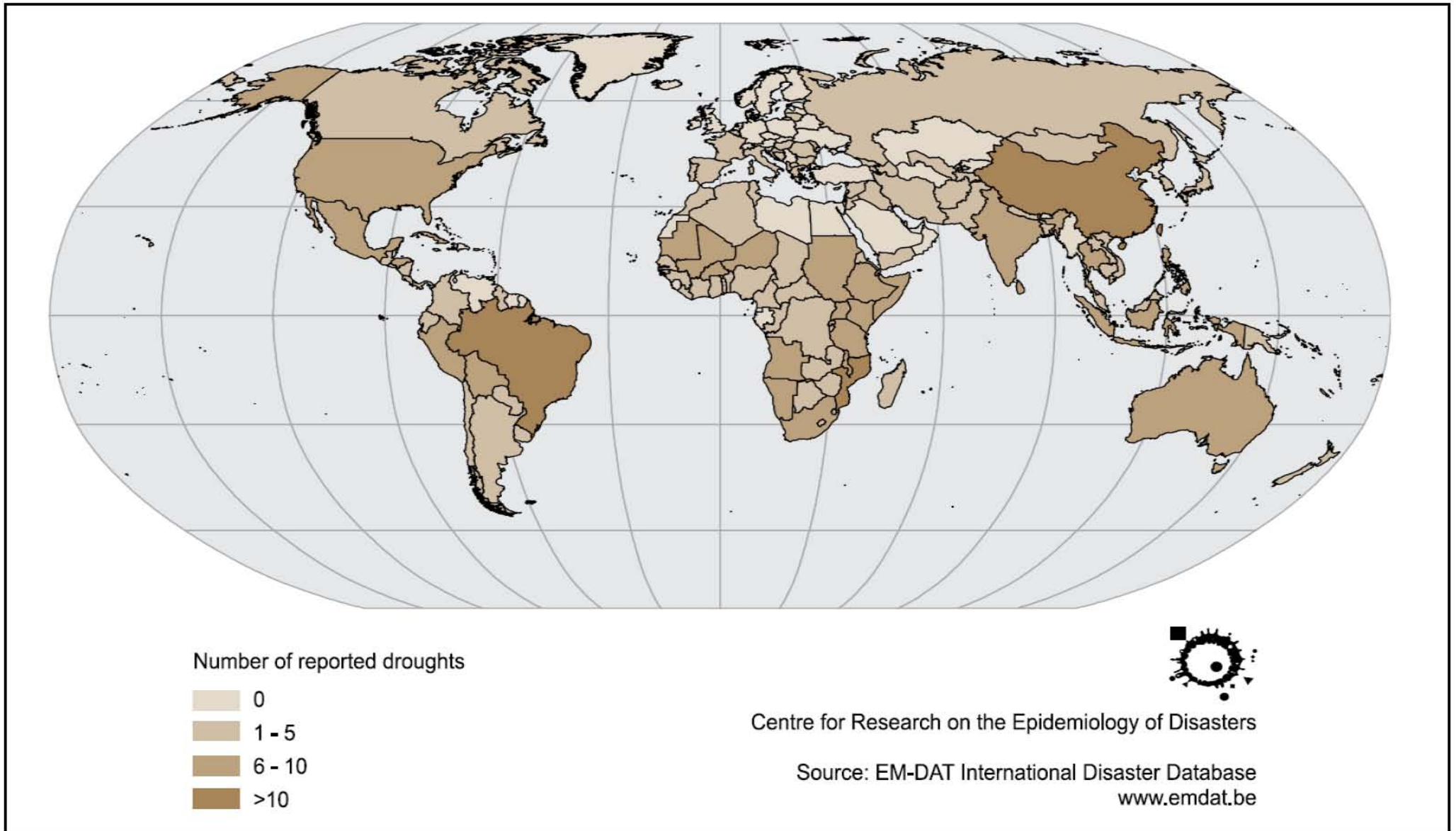


Figure 2.2: Number of persons reported affected by drought disasters: 1970 – 2008 (UNISDR, 2009: 5)

2.2.3. Types of drought

A recurrent challenge in characterising drought is its diverse forms. Conventionally, drought is viewed as a reduction in precipitation over an extended period of time (Sivakumar, 2010: 3). However, as there is not one universally accepted definition of drought, this has led to difficulties in identifying specific drought events and their associated severity and duration (Wilhite, 2005).

Figure 2.3, (Sivakumar *et al*, 2010: 6) illustrates currently recognised forms of drought and their progression. This process usually begins with a meteorological drought due to reduced rainfall. However, as human influence increases, the drought typology changes, first generating agricultural, and then hydrological drought effects. Socio-economic drought conditions eventually become apparent, and are reflected in impacts on sectors relating to health and food security.

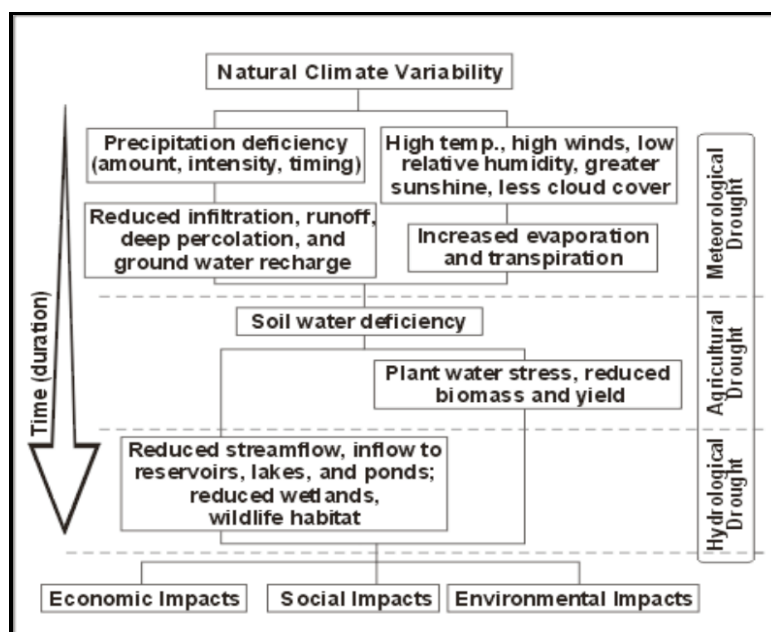


Figure 2.3: Types and progression of drought over time (Sivakumar *et al*, 2010: 6).

Meteorological Drought, as defined by Wilhite (2005), is a drought that usually precedes all other types of drought. It is caused by a deficit in rainfall, a departure from the normal, over an extended period of time. According to Muller *et al* (2009: 10), a climatic drought, or meteorological drought is one year or more of low rainfall compared with annual averages. For the purposes of this study, the SAWS (2011) definition of meteorological drought was used. This is when rainfall falls below 75% of the normal and is calculated over a period of at least 30 years (www.saws.co.za, 2011).

Agricultural Drought, on the other hand, involves more than just a deficit of rainfall. It occurs when the drought affects crop production and the ecology of agriculture and from poor management of water supply and poorly planned agricultural programmes - such as soil conditions and erosion by causing a shortfall in water available to the crops (Wilhite, 2005). Conventionally, agricultural drought results from an extended

period of below 75% of average precipitation (SAWS, 2011) leading to an imbalance in the moisture content of the soil during the growing season (Moorsom *et al*, 1995 cited in Wilhite, 2005). However, there is no direct relationship between precipitation levels and the 'infiltration' of the precipitation into the soil (Sivakumar *et al*, 2010: 5). This is because there are many other variables that should be considered, including groundwater availability, soil moisture and temperature.

Hydrological Drought is related to the effects of periods of precipitation shortfalls on surface or subsurface water supply. The frequency and severity of hydrological drought is often defined on a watershed or river basin scale. Although all droughts originate with a deficiency of precipitation, a hydrological drought is concerned with the hydrological cycle and usually lags a meteorological drought and agricultural drought. This is because the precipitation deficiency that initially takes place takes a while (up to 2 months) to show in the hydrological components, such as soil moisture, stream flow and groundwater. (www.drought.unl.edu, 2011)

While all forms of drought are associated with reduced precipitation, the occurrence of agricultural and hydrological drought are not exclusively informed by rainfall, but also by other key risk drivers – including rural poverty, urbanisation, inappropriate soil and water management or ineffective risk governance (UNISDR, 2011: 62-66). For instance, India experienced a severe drought in 2000. This prompted wide scale state awareness and infrastructure development. Contingency plans were formulated and although these responses constituted a reactive process to the drought, they have also reduced the livelihood vulnerability of the affected communities to subsequent droughts (ibid, 2011:68).

Although *Socio-economic drought* is not specifically identified in Figure 2.3, authors such as Benson and Clay (1998: 7), stress its significance. It relates to the "impact of drought on human activities, including indirect as well as direct impacts." (ibid, 1998: 7). It refers to a combination of economic, social and environmental impacts. This type of drought is concerned with the consequences of the reduction of rainfall on human activities which includes the delivery of urban water rather than just the water availability itself (ibid, 1998: 7).

2.3. Drought as disaster risk in Africa

On an international scale, drought has become synonymous with Africa due to its association with recurrent famine and conflicts. This section underlines drought as a recurring threat and its stereotypic interpretations as complex emergency within Africa.

2.3.1. Drought as recurrent threat

Drought is a recurrent threat across sub Saharan Africa and, together with floods, accounts for 80% of loss of life associated with natural hazard occurrences on the continent (Bhavnani, R. *et al*, 2008). The

widespread distribution of drought impacts is shown in Figure 2.4 below. Particularly serious drought events have been recorded in sub Saharan Africa between 1960 and 2000, including occurrences in 1965-66, 1972-74, 1981-84, 1986-88, 1991-92 and 1994-95 (ibid, 2008). However, many of such reported drought events have also occurred in countries experiencing civil or political conflict (UNISDR, 2011: 59). This creates difficulties in correctly attributing hardship, damage and loss to drought where other structural factors exist (such as armed conflict or economic disruption). Moreover, as argued by Benson and Clay (1996: 51), country-specific vulnerability to drought shocks is significantly determined by structural factors that are internal to the country's economy.

For instance, they propose a typology, identifying four distinct country profiles associated with different drought impacts. These include simple, intermediate, complex and dualistic economies, signalling different levels of exposure to drought shocks, as well as capacity to absorb and redistribute the impacts. This configuration "counter intuitively" indicates that intermediate economies with high dependence on agriculture such as Zimbabwe and Malawi are more vulnerable to drought shocks due to inter-sectoral linkages to and from water-intensive sectors, than those characterised by either weak links or economic diversification such as South African or Botswana (Benson and Clay, 1996: 52).

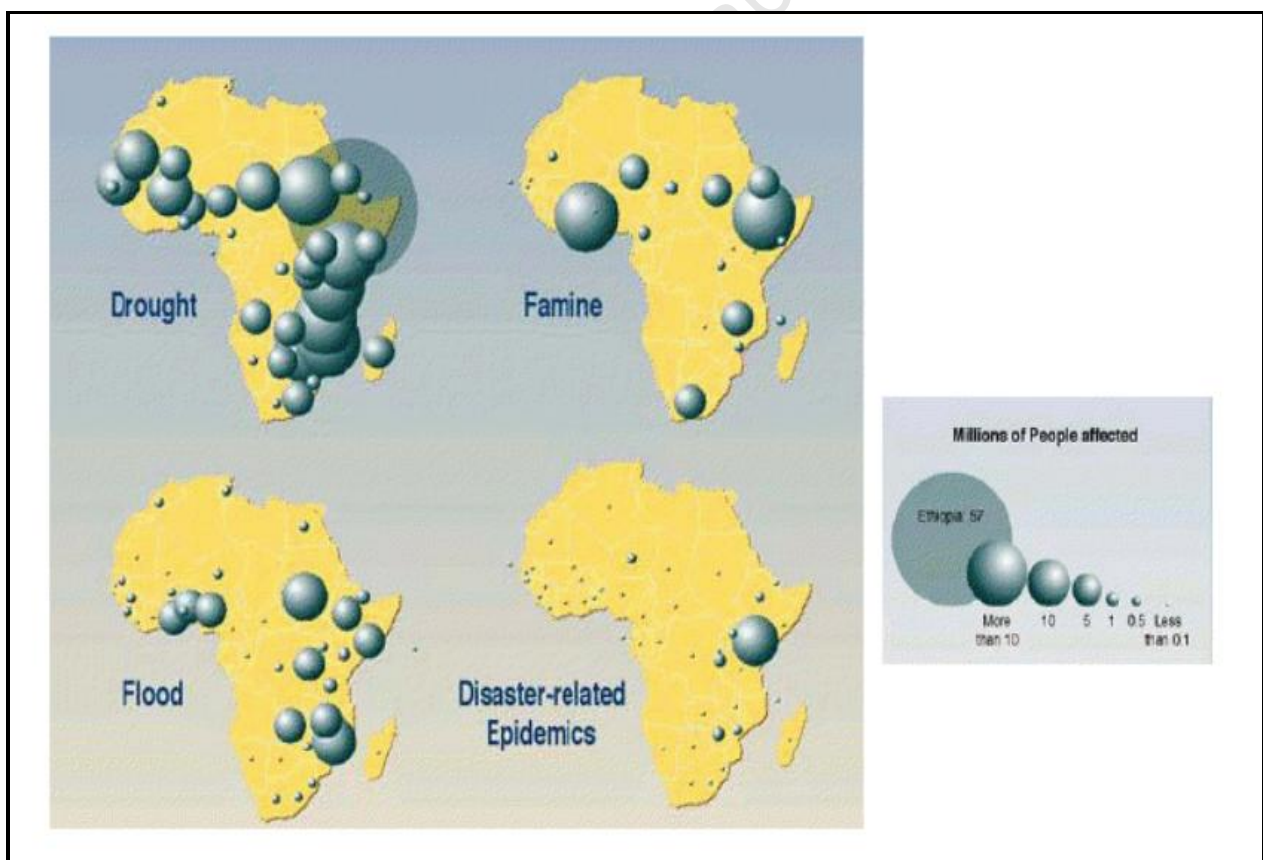


Figure 2.4: Number of Persons affected by natural disasters, 1971 – 2000 (UNISDR, 2008, cited from Bhavnani, R. *et al*, 2008)

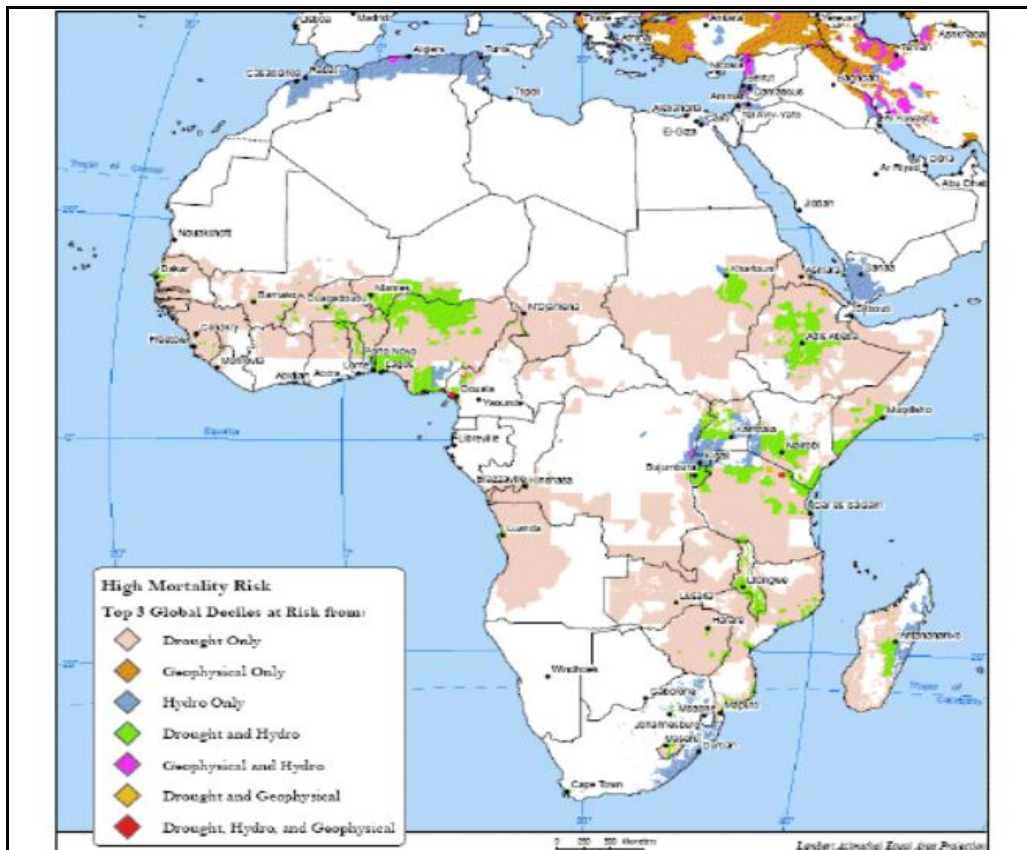


Figure 2.5: Distribution of Hazard Risk Spots in Sub Saharan Africa (Bhavnan, *et al*, 2008)

2.3.2. Drought in Africa: complex emergency

A recurrent difficulty in characterising drought within Africa is its association with humanitarian crises that may be largely attributed to other causes. In this context, Benson and Clay (1996: 12) caution that drought may “become the automatic scapegoat for any contemporaneous economic woes and will probably delay the implementation of appropriate measures to address other, possibly more fundamental economic problems.” (ibid, 1996: 12). They specifically refer to instances in 1982 – 1984 and 1991 – 1992 when Zimbabwe sought external aid for drought. However these requests occurred when the government was also under pressure due to severe balance of payments and structural adjustment difficulties (ibid, 1996: 12).

The humanitarian crisis that unfolded in Southern Africa a decade later was similarly attributed to climatic factors at its onset. However, Darcy *et al*, (2003) note that “the characterisation of a crisis primarily in terms of supervening climatic factors can be a convenient fiction, one that allows both host government and the international aid community to avoid direct reference to more intractable and politically sensitive issues.” On one hand, the inaccurate attribution of an impending emergency to drought may expedite humanitarian operations. However, it also constrains accurate understanding of the causal pathways from meteorological drought through to realised outcomes in human hardship and loss. In Southern Africa, these

outcomes may be further blurred by disproportionate high levels of food assistance relative to non-food assistance, in times of emergency. For instance, in the 2002 - 2003 Southern African crises, 83% of the Consolidated Appeal Process (CAP) was for food commodities. While more than 75% of this relief component was funded, a mere 31% for other sectors (including water and health) were successfully resourced (Darcy *et al*, 2003)

Such responses reinforce perceptions of drought as the primary cause of crop failure which necessitates international food relief – even though environmental stressors may constitute just one of many risk factors for production shortfalls (Holloway, 2003).

2.4 Drought occurrence in South Africa

This section examines the history of drought, the formation of drought policy and the atmospheric drivers of drought in South Africa.

2.4.1. History of drought in South Africa

South Africa has a history of drought exposure, with more than 90% of South Africa experiencing arid and semi-arid conditions (Hoffman, 2009) at some point. Drought is a regular feature of the South African climate, with records of severe droughts dating back to as early as 1698 to 1704 when an extended drought occurred over most parts of the country (Turton *et al*, 2004: 31). Droughts were also recorded from various sources in the early 1800s and the mid-1820s. For instance, an “unusually harsh” drought was noted in the 1860s, 1874 and again in 1875 (Vogel, 1989: 292 - 294). Other droughts were recorded in 1895 to 1896 also known as the “Year of troubles”, during World War I, in 1916 and from 1927-1928, during the Great Depression. More recent drought events were reported in 1930 to 1933, 1960 to 1965, 1978 to 1987, 1991 to 1995 (Turton *et al*, 2004: 35 - 294).

2.4.2. Drought Policy in South Africa

The recurrence of droughts in South Africa is unsurprising given its profile as a highly water scarce country. For instance, South Africa was recently ranked the 29th driest country out of 193 countries (Muller *et al*, 2009) with unevenly distributed water resources and an annual average of 490mm rainfall, well below the global average of 876mm. The country’s water scarce profile has resulted in a long established involvement in managing drought – especially as this applies to agriculture. This extends as far back as 1916 when findings from the first formal investigation on soil conservation were released (O’Farrell *et al*, 2009: 37).

In South Africa, as is the case in many countries, drought policies have been focussed mainly on agriculture and soil conservation. Government financial support for commercial farmers can be traced back to 1930 and has been continued since (ibid, 2009: 37). However, with increasing recognition that drought events are expected natural occurrences in South Africa, government policy has shifted since the 1980s (ibid,

2009: 37). This is reflected in an increasing policy emphasis on sustainable farming practice. Although drought affects water supplies, for urban as well as rural areas, past policy emphasis has primarily viewed drought as a rural and agricultural risk, managed by financially supporting farmers.

2.4.3. Atmospheric drivers of drought conditions in South Africa

South Africa's exposure to recurrent meteorological droughts is significantly influenced by its climate. This includes expected climate conditions as well as oceanic-atmospheric processes such as El Niño and long term influences associated with climate change.

South African Climate

South Africa lies in the subtropical high pressure belt at approximately 30 degrees south and is affected by circulation systems which prevail in the tropics (north) and the temperate latitudes (south) (van Zyl, 2003; Tyson and Preston-Whyte, 2000). The country experiences four distinct seasons with the south western region receiving a winter rainfall and the rest of the country a summer rainfall. South Africa receives only half of the world's annual average rainfall with just 35% of the country receiving more than 500mm annually (van Zyl, 2003). Because the country spans 1, 2 million kilometres², the altitude, latitude and effects from the sea currents are vastly different. This results in five main aridity zones as shown in Figure 2.6:

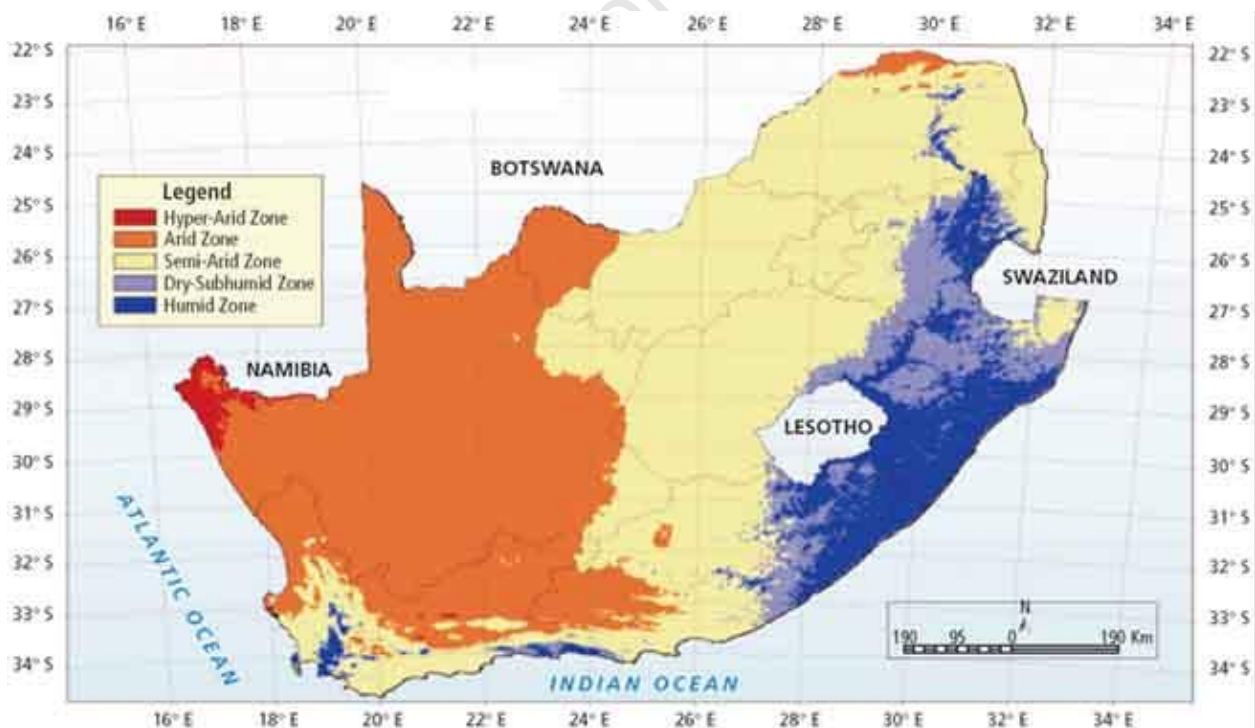


Figure 2.6: Map of aridity zones in South Africa (<http://www.fao.org>)

Tyson and Preston-Whyte argue that more than half of South Africa is rated as a potential desert zone because of its climatic conditions. They further note that areas of the central and northern regions of the

country have extremely high risk conditions of becoming permanent drought zones (ibid, 2000: 325).

El Niño/La Niña

The South African climate is also affected by “decadal and multi-decadal variability, notable with El Niño-dominated years.” (Midgley *et al*, 2010: 5). They further note that El Niño phenomena are attributed to the Walker circulation system that is located over the Pacific Ocean and is directly responsive to sea-surface temperatures over the Eastern and Western Pacific Ocean (Tyson and Preston-Whyte, 2000). Because the sea surface temperatures change, a major pressure oscillation occurs in the atmosphere which is termed the Southern Oscillation (UNDP, 1997). The water over the eastern Pacific Ocean undergoes warming and the pressure falls, resulting in a cell over the ocean which reverses the trade winds and causes the El Niño-Southern Oscillation (ENSO) event (Tyson and Preston-Whyte, 2000). The converse of this is called the non-ENSO or La Niña event.

El Niño has a global atmospheric influence and it has the ability to change climatic conditions along the coasts of countries. It tends to cause increased rainfall and often severe floods in countries such as Chile, Peru and parts of the USA. But because of the movement of rainfall bands offshore, the effect that El Niño has on South Africa is that of a drying trend on the summer rainfall region (UNDP, 1997). In the past, El Niño has been associated with severe drought in Southern Africa specifically 1982/83 and 1991/92 (UNDP, 1997)

Climate Change

Climate change has been identified in scientific studies as “significant threat to human livelihoods and sustainable development of the world” (IPCC 2001a, cited in Midgley *et al*, 2005). The Intergovernmental Panel of Climate Change (IPCC, 2011) refers to climate change as, “A change in the state of the climate that can be identified (statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.” (www.thegwpc.org, 2011)

Studies of anthropogenic climate change argue that the global warming trends are accompanied by changes in rainfall variability, intensity and cyclicity, the duration of dry periods and the frequency of extreme weather events (Midgley *et al*, 2005). In the specific context of meteorological drought, climate change also alters the hydrological cycle by increasing the frequency of magnitude of drought with the underlying assumption that a diminished water supply will lead to social, economic and ecological hardships (Wilhite 2005).

According to Midgley *et al*, (2010: 16), the climate change that will be experienced in South Africa will

result in increasing intensity of extreme rainfall, lengthening of dry periods between the extreme rainfall events, warmer temperatures and extreme hot days (ibid, 2010: 47). The same report also cited studies that indicate the southwest will experience a visible drying trend, with the area receiving less winter rainfall in the future (Hewitson *et al*, 2009 cited in Midgley *et al*, 2010: 41) The forecasted rainfall changes also include a wetter east coast in summer months with drier conditions over the western regions of the country (Hewitson and Crane, 1996 cited in Midgley *et al*, 2010)

Development Challenges facing the water sector

While projected changes in climate are expected to add "... one more layer to the already challenged water sector." (Midgley *et al*, 2010: 61), the South African water sector is already overstretched. For instance, "by 2000, 5 of the 19 water management areas were already over-allocated and were experiencing water stress" (ibid, 2010: 50) and a decade later, available surface water resources are almost fully allocated.

This constrained availability of water in South Africa, along with its low annual rainfall, highlights the need for careful management of the country's water resources. South Africa, under the National Water Act of 1997, is divided into 19 Water Management Areas (WMAs) (DWA, 1998). Although this differentiation sought to strengthen local management of water resources the country's water sector faces many difficulties, including inadequate funding, resource constraints and outdated infrastructure. This, coupled with severe shortages with respect to science, engineering and technical areas and the "huge losses in institutional memory and strategic and operational decision-making capabilities", makes South Africa's water management sector complex (DWA, 2011: 18).

2.5. Drought as a driver of urban risk: Focus on urban water supplies

2.5.1. Africa: rising urban risk

On one hand, established responses to drought emergencies within Africa have alleviated immediate hardships and food insecurity. However, their prolonged and highly visible character has also helped to entrench perceptions that drought is a rural phenomenon and primarily associated with rain-fed agriculture and food insecurity (Holloway, 2003).

Pelling and Wisner (2009: 6) argue that such perceptions are at variance with Africa's emerging development profile. Specifically, they note three "predominant images" which they suggest represent a "false vision of Africa" (ibid, 2009: 6). These include images of Africa as a primarily rural continent where disasters are due to drought and which also receives international relief in times of duress. Along with Satterthwaite (2011), they counter this by emphasising the rapid pace of urbanisation, specifically Africa's emergence as the most rapidly urbanising continent.

2.5.2 Africa's urban growth trajectory: Consequences for urban risk

Although Africa is still the least urbanised region globally, its urban population doubled from 1990-2010, rising from 205 million to 400 million (Mafuta *et al*, 2011). Moreover, by 2030 and 2050 respectively, the continent's urban residents are projected to contribute 50 and 60% of Africa's total population. Figure 2.7 indicates the extent of the continent's urbanising profile with numerous cities exceeding 5 million inhabitants.

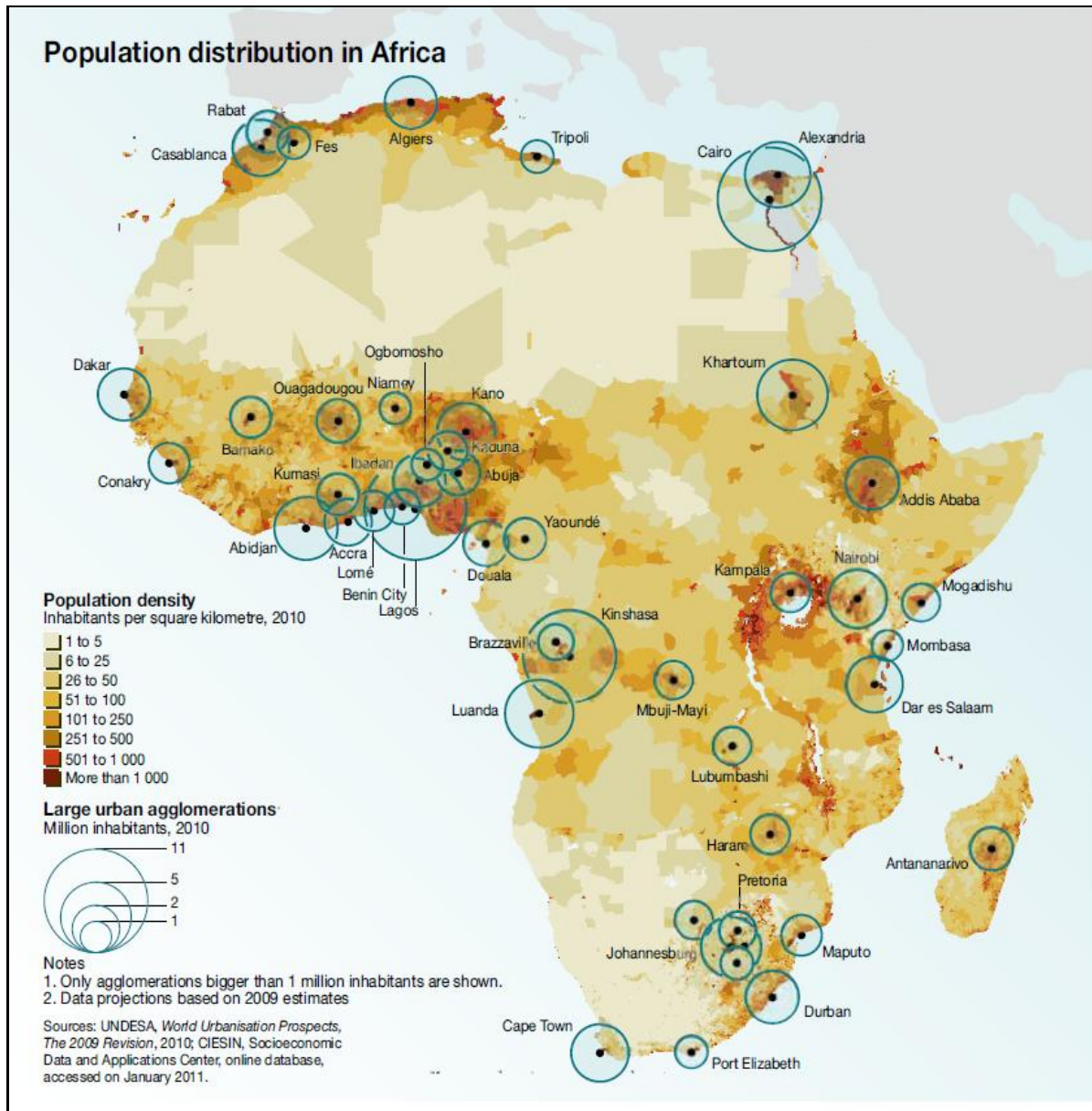


Figure 2.7: Population Distribution and Density in Africa (Mafuta *et al.*, 2011)

The rapid pace with which Africa is urbanising also challenges prevailing beliefs that “drought is a driver for disaster through a direct link to food insecurity”. (Pelling and Wisner, 2009: 6). These authors note that African towns and cities experience diverse disaster risks, including floods, urban fire and public health concerns. Along with Satterthwaite (2011: 33), they highlight this rising, previously unrecognised risk profile

within urban Africa. Recognising the diversity of risks that face African cities, they advance a continuum of urban risk that ranges from highly frequent everyday hazards (i.e. informal settlement fires) to infrequent large or catastrophic events (i.e. earthquakes) (Satterthwaite, 2011: 33).

2.5.3. Urban Risk: Focus on hydrological drought

In their review of 166 documented urban disasters in Africa that occurred between 1997 and 2008, Pelling and Wisner (2009: 25) also include “urban drought” (ibid, 2009: 25). This represents one form of hydrological drought due to reduced availability of ground and surface water supplies to an urban population. However, unlike meteorological drought, which is attributed to atmospheric conditions, hydrological drought may be driven by urbanisation, tourism, industrialisation and growth of agribusiness (UNISDR, 2011: 63). For instance, the rapid growth of urban populations across much of Africa, including in already water-stressed areas has outstripped available supply. This is evidenced by the significant underdevelopment of sub-Saharan Africa’s water storage facilities. These reportedly (UNISDR, 2011: 63) provide an average per capita storage capacity of 200m³ per year. This contrasts with values of 1,277m³ and 5,961 m³ in Thailand and North America respectively. Moreover, the projected costs for capital expansion of water infrastructure in sub-Saharan Africa (2006-2015) were estimated at US\$ 15 billion (Foite and Briceno-Gamendia, cited in UNISDR, 2011: 62).

A related, emerging concern, not only limited to growing African cities, is the management of risk associated with *water scarcity* and *water shortage*. These two concepts have been developed because of the “multi-dimensional” repercussions of drought on a community (Iglesias *et al*, 2007). While the concepts of *water shortage* and *water scarcity* both refer to a shortfall in water, Applegren (1998) defines *water shortage* as an absolute shortage, where the amount of water available does not meet the requirements it must fulfil. *Water scarcity*, however, refers to the relationship between the amount of water available and the overall demand for it (Applegren, 1998). He further argues that as *water scarcity* is more socially constructed influenced both by consumption and supply, it may also be generated by development that is accompanied by poor water demand management.

Other authors have proposed specific indicators of *water scarcity*. For instance, Falkenmark (1986 cited in Muller *et al*, 2009) suggests that *water scarcity* occurs when water resources fall below 1,000m³ per capita per year while ‘absolute water scarcity’ is when these drop below 500m³ per capita per year. He further proposes that ‘water stress’ refers to conditions when a region’s available water resources fall below 1,667m³ per capita per year.

2.5.4. Integrated Water Resource Management in Africa

Africa’s growing urban population illustrates the difficulties in managing urban water scarcity. For instance, it is reported that service delivery of water and sanitation in Africa is “characterised by deficient, ageing

and overloaded networks ...” which are associated with poor management and degradation of water quantity and quality (UNISDR, 2011: 6). This is evidenced between 1900 and 2008, when Africa’s urban population increased from 29 million to 59 million people, without any advances in water resources (WHO/UNICEF 2010 cited in Mafuta *et al*, 2011: 13).

Until recently, engineering solutions have been used to counter the rapidly increasing demand for urban water supplies in Africa. However, Mafuta *et al* (2011: 7) argue that an over-emphasis on such water supply approaches does not enable fully integrated water resources management because it is expensive and does not address the fast degradation of existing water infrastructure. Moreover, they also note that a primary focus on urban water supply diverts attention away from the importance of managing urban water demand (ibid, 2011: 7).

The value of improved urban water demand management is illustrated through the application of Integrated Water Resource Management (IWRM) approaches which are increasingly promoted world-wide. IWRM is a “process that promotes the co-ordinated development and management of water, land and related resources in order to maximise the economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (Mafuta *et al*, 2011: 19). It was first introduced in 1992 at the World Conference on Environmental and Development (ibid, 2011: 19). However, it was only adopted by South Africa following the World Summit on Sustainable Development in 2002. IWRM combines equity, efficiency and sustainability while broadening the focus on water use to include all the related water practises which include agriculture, forestry and urban planning (ibid, 2011: 19). In this context, the approach is all-encompassing and includes not only urban water supply, but also urban water demand.

2.6. Methods for determining drought

A key element for effective IWRM is balancing water demand and supply. This necessitates methods for assessing as well as monitoring availability and utilisation of water, including during drought periods. While the methods listed below have been conventionally applied to meteorological and agricultural drought, they have proved to be less effective in monitoring the risk of hydrological or urban drought.

This section details the frequently used drought indicators to determine the type, onset and extent of a drought. It explains the reasons these indicators are used as well as their major constraints in application.

2.6.1. Major methods used

Drought indicators are variables that help explain the magnitude, duration, severity and spatial extent of drought (Wilhite, 2005). Most indicators use hydrological and meteorological data such as precipitation, stream-flow, soil moisture, reservoir storage and groundwater. Indicators often combine several variables into a single index to describe a process and are commonly referred to as ‘drought indices’ (ibid, 2005). The

importance of drought indicators to determine and monitor drought conditions, generate the level of drought response needed and lastly, to measure the drought to compare it to future droughts (ibid, 2005).

While prevailing meteorologically-oriented indicators (such as the Percent of Normal method and the Standardised Precipitation Index) may usefully signal meteorological drought, some authors argue that these are less appropriate for hydrological droughts (Iglesias, *et al*, 2007). They note that meteorological indices do not adequately incorporate the management and storage processes of the hydrological components (ibid, 2007). In addition, these indicators are difficult to measure and Wilhite (2005) notes that appropriate data are not always reliable, consistent or available. He adds that weightings of each indicator may vary according to region and argues that they do not assist in proactive measures. Moreover, they only address hydrological and meteorological drought (Wilhite, 2005).

Despite these constraints, several approaches have been used in conventional drought analysis. These include, but are not limited to the following: The Percent of Normal method, Standard Precipitation Index (SPI), Palmer Drought Severity Index (PDSI) and Palmer Hydrological Drought Index (PHDI).

The *Percent of Normal* approach is the simplest measurement of rainfall for a region. It is calculated by dividing actual annual precipitation by a 30 year annual average and multiplying it by 100 to reach a percentage of normal (Sivakumar *et al*, 2010: 8). The average annual precipitation is considered to be 100%. The disadvantage of this measurement is that the mean is often not the same as the median precipitation “which is the value exceeded by 50% of the precipitation occurrences in a long term climatic record” (ibid, 2010: 8).

From the perspective of consensus, the *Standardised Precipitation Index* (SPI) is the most accessible and simplest method to use for determining meteorological drought (Sivakumar *et al*, 2010: 9). It was developed by McKee *et al* (1993) and was designed to “...quantify precipitation deficits for multiple timescales, such as 3-, 6-, 9-, 12- month...” prior periods relative to the same months the years before. SPI assists in addressing constraints associated with applying the Palmer Drought Severity Index, which is explained below (Wilhite, 2005).

A widely used approach for determining drought magnitude is the *Palmer Drought Severity Index*. Developed in 1965, this method sought to standardise measurements of moisture conditions that would allow values to be compared between locations and months. The PSDI is a meteorological drought index, able to measure both unusually wet as well as dry conditions (Sivakumar, 2010). Therefore, when weather conditions revert to normal, the drought ends (as determined by the PDSI), however this excludes indicators such stream-flow, lake and reservoir levels (ibid, 2010).

The PDSI examines both water supply and demand, and is derived from a moisture balance model, which incorporates temperature and precipitation data, as well as the available water content (AWC) of the soil (Wilhite, 2005; Sivakumar, 2010).

Sivakumar (2010: 13) notes in “near-real-time, Palmer’s index is no longer a meteorological index”, but is more correctly viewed as a hydrological index. This is known as the Palmer Hydrological Index (PHDI), as it assesses longer-term moisture anomalies that effect stream-flow, groundwater and water storage (Wilhite, 2005).

The Palmer indices, both the PDSI and the PHDI (further revised in 1989) have been widely used, especially in the United States. They are viewed as useful for measuring impacts related to soil moisture that are relevant to agriculture. However, they are not generally regarded as a robust measure of hydrological effects of longer term droughts (Sivakumar, 2010). Moreover, they are not viewed as robust or applicable in regions characterised by extreme rainfall and run-off availability (i.e. Australia and South Africa).

Although indices such as PDSI and SPI have proved useful for determining the scale and magnitude of meteorological drought, their effectiveness is constrained when applied to hydrological drought and historical drought impacts. This is due to the influence of storage availability (Iglesias *et al*, 2007).

For the purposes of this specific study, a mixed-methods approach was used because of the role management interventions played in the drought process. On one hand, the researcher applied ‘Percent of normal’ methods to rainfall and dam storage levels to determine the extent to which rainfall storage levels varied from average values in 2009 and 2010. However, recognising the key contribution that urban water demand played, the researcher also related annual water consumption values to ‘Historical Firm Yield’ estimates. Firm yield is defined as the “the maximum yield that can be delivered by the reservoir, even through a severe drought. Ideally, the firm yield would be determined from a period of record that included the worst drought likely to affect the reservoir.” (Waldron and Archfield, 2006: 1). The researcher applied this indicator to determine the extent that local consumption also contributed to the “draw-down” on the maximum available water storage foreseen to avert a hydrological drought emergency.

2.7 Conceptual Framework for this study

2.7 1 Introducing key concepts

As this study is situated within the disaster risk domain, it gives particular emphasis to the concepts of hazard, vulnerability and disaster risk.

This allows for distinctions to be made between extreme hazards and extreme risks, as the occurrence of hazard processes does not automatically translate into realisation of extreme risks, reflected in identifiable losses and impacts (UNISDR, 2011).

It also argues that the progression of risk under hazard exposures is exacerbated by vulnerability conditions. In the context of this study therefore, exposure to the hazard of meteorological drought did not automatically imply a severe drought “risk” or drought “disaster”.

Specifically for the purpose of this study, disaster risk was viewed as:

“The potential disaster losses in lives, health status, livelihoods, assets and services which could occur to a particular community or a society over some specified future time period.” (UNISDR, 2009: 9)

This conceptualisation frames disaster risk as the outcome of the interplay between external hazard exposures and internal vulnerability conditions. It adopts the widely held argument made by disaster scholars (Wisner *et al.*, 2004) that natural hazard processes such as drought translate into disaster events only under conditions of internal vulnerability. In this context, the concept of a physical hazard, such as a meteorological drought, is defined as:

“...a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.” (UNISDR, 2009: 17).

While such processes clearly have potential to trigger losses, subsequent impacts vary significantly depending on the levels of vulnerability for those exposed. For instance, recent earthquakes in Haiti, Chile and New Zealand (GAR, 2011) illustrated how lower magnitude hazard events (i.e. the Haiti earthquake) may result in catastrophic losses, compared to higher or same magnitude occurrences respectively in Chile and New Zealand, which were associated with much lower mortality (number of deaths). While in Haiti, a 7.0 magnitude (USGS, 2011) earthquake resulted in the loss of 222,570 lives (ONEMI, 2010), an 8.8 magnitude earthquake event in Chile shortly thereafter led to 525 deaths (ibid, 2011). The dramatically lower mortality in Chile was significantly attributed to risk governance interventions that reduced infrastructure vulnerability by enforcing earthquake-resistance building codes.

A central concept in prevailing thought on disaster risk is the contribution of vulnerability to the escalation of risk conditions. This is defined as:

“...The characteristics and circumstances of a community, system or asset that makes it susceptible to the damaging effects of a hazard” (UNISDR, 2009:30).

Therefore a disaster cannot occur in the absence of either hazard, or vulnerability conditions. The relationship between disaster risk, vulnerability and hazard is represented in the following equation (Blaikie *et al*, 1994):

$$\text{Disaster Risk (DR)} = \text{Vulnerability (V)} \times \text{Hazard (H)}$$

Although in this research project, the term “drought” was widely used by officials and the media to define the water emergency in the George municipality, it provided a limited explanatory framework for the study. As the study progressed, and as findings on urban water consumption became available to the researcher, it became clear that the research problem extended well beyond a narrow focus on drought, associated with reduced rainfall. As a result, the researcher reframed the study as an investigation of an episode of acute urban water scarcity.

2.7.2. Application of disaster risk concepts in this study

Therefore, this study applied and classified the concepts of hazard, vulnerability and risk to urban water scarcity in George. While the meteorological drought that occurred was viewed as the hazard, the researcher also recognised that ineffective urban water demand management would also have increased vulnerability conditions within the George Municipality, increasing the risk of urban water scarcity. The risk was realised through the experience of urban water scarcity that occurred from 2009 - 2010 in the George Municipality and that was measurably reflected in declining storage levels at the GRD. The relationship between the risk concepts used in the study and the indication applied to examine their progression are represented below in Table 2.1 and Figure 2.8.

| Concept | Application | Indicator |
|---------------|------------------------|--|
| Hazard | Meteorological Drought | Rainfall (mm) |
| Vulnerability | Urban Water Demand | Urban Water Consumption (MI) and Urban Water Consumption/Historical Firm Yield |
| Risk | Urban Water Scarcity | GRD Storage Levels (%) FCS |

Table 2.1: Application of disaster risk concepts to urban water scarcity in the George Municipality from 2009 – 2010.

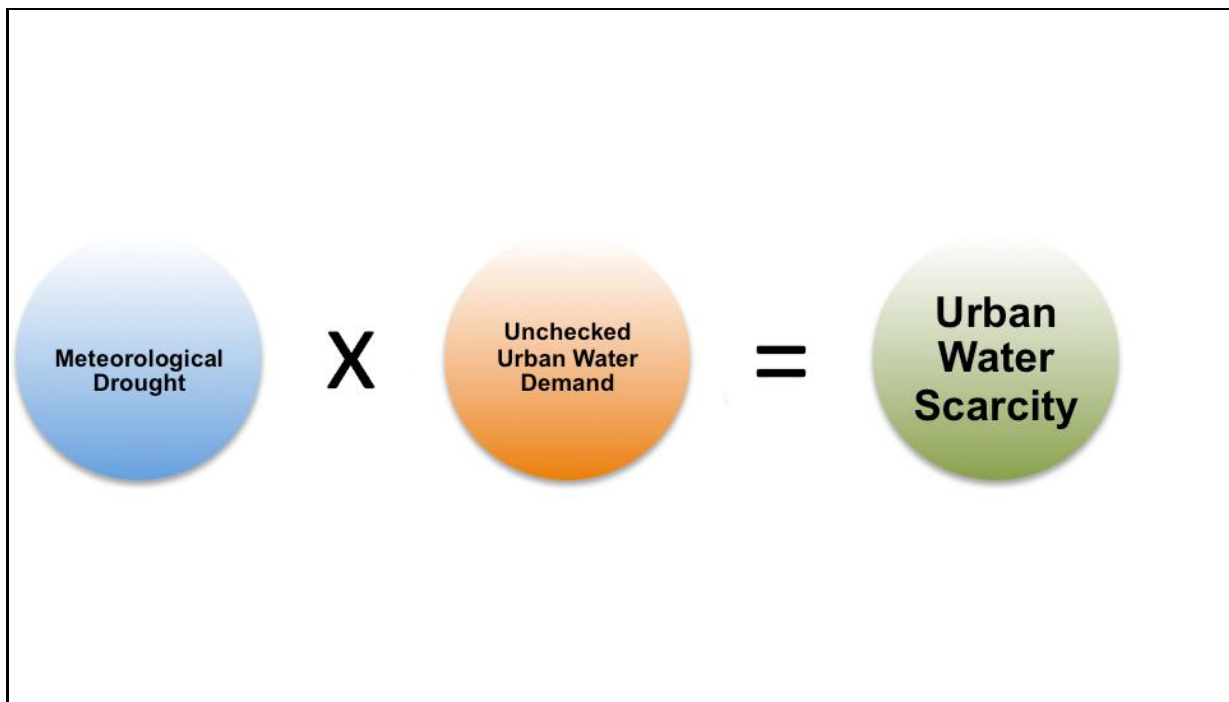


Figure 2.8: Schematic representation of the application of disaster risk to the urban water scarcity in the George Municipality from 2009 - 2010

2.8. Summary

This chapter began by introducing drought as a global risk, focusing on the slow, protracted nature of drought, types of drought and the loss estimates associated with the drought disasters. It then described drought in Africa as a recurrent threat and 'complex emergency'. Because of the history of drought occurrence, South Africa has developed policies for drought mitigation. An overview of the atmospheric drivers and the water resources in the country were given.

The chapter then continued by examining drought as an urban risk, and focusing on urban water supplies. It outlined the methods that are frequently used to determine drought severity, and concluded with the conceptual framework for the study.

CHAPTER THREE

RESEARCH CONTEXT

3.1. Introduction

The geographic context for this study was the George municipality within the Western Cape Province of South Africa. The chapter begins by providing an overview of the George Municipality, including its location, area extent, history and socio-economic characteristics. It continues by describing the important climatic and topographic features that characterise the area. Given the study's focus and the municipality's experience of acute water scarcity from 2009 - 2010, the chapter then outlines urban water supply provision for the municipality. It concludes by reviewing the municipality's flood and drought history, followed by a description of the 2009 - 2010 drought that affected the city.

3.2. The George Municipality: Location, area extent and socio-economic profile

Nestled between the Outeniqua Mountains and the Indian Ocean, along the south coast of the Eden District, the George Municipality is a popular holiday and conference centre. It also forms the backbone of the administration and commercial activities in the Eden District and is rapidly developing into a significant metropolis of the Western Cape (George Local Municipality IDP, 2009/2010).

George was the first town in South Africa to be founded under British rule and was named after the reigning monarch, King George III (www.george.co.za, 2010). It is also the sixth oldest town in South Africa, being established on 23 April 1811.

Initially the town of George was established to serve as an administrative centre in the underdeveloped area of the Southern Cape Coast (van Niekerk, *et al*, 2009). Local timber production subsequently boosted industrial and commercial growth development of the town, resulting in population growth and its eventual municipal status in 1837 (George Local Municipality IDP, 2011/2012). It has become the second largest urban settlement after Cape Town in the Western Cape (Thomas, 2005). With escalating growth, the municipality now has approximately 200,000 inhabitants.

The Eden District, within which the George Municipality is located, is a major provincial growth node (DiMP, 2006). It is sometimes referred to as the 'Southern Cape' or the 'Garden Route'. It shares borders with the Overberg, the Winelands and Central Karoo. The district comprises seven municipalities: Bitou, George, Hessequa, Kannaland, Knysna, Mossel Bay and Oudtshoorn (Eden District Municipality IDP, 2010/2011).

The Eden district, reliant on tourism and agriculture, is the third largest district in the Western Cape and is home to significant rural activity (Eden District Municipality IDP, 2010/2011). However, more recently rapid

population and urban growth have also brought new development opportunities in the Eden district (Thomas, 2005).

3.2.1. Location and areal extent

The exact geographical location of the George Municipality is 34°00'S; 22°23'E as shown in Figure 3.1. The municipality covers a total area of 1,068 km², which is less than one percent of the total provincial area (Thomas, 2005). It includes the City of George, the villages of Wilderness and Herolds Bay as well as the coastal resorts of Kleinkrantz, Victoria Bay and Wilderness National Park as shown in Figure 3.2. It also includes the rural areas of Rondevlei, Geelhoutboom, Herold, Hansmoeskraal and Waboomskraal (George Local Municipality IDP 2009/2010

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Figure 3.1: The George Municipality in the Eden District located within the Western Cape (Asisbiz, 2011)

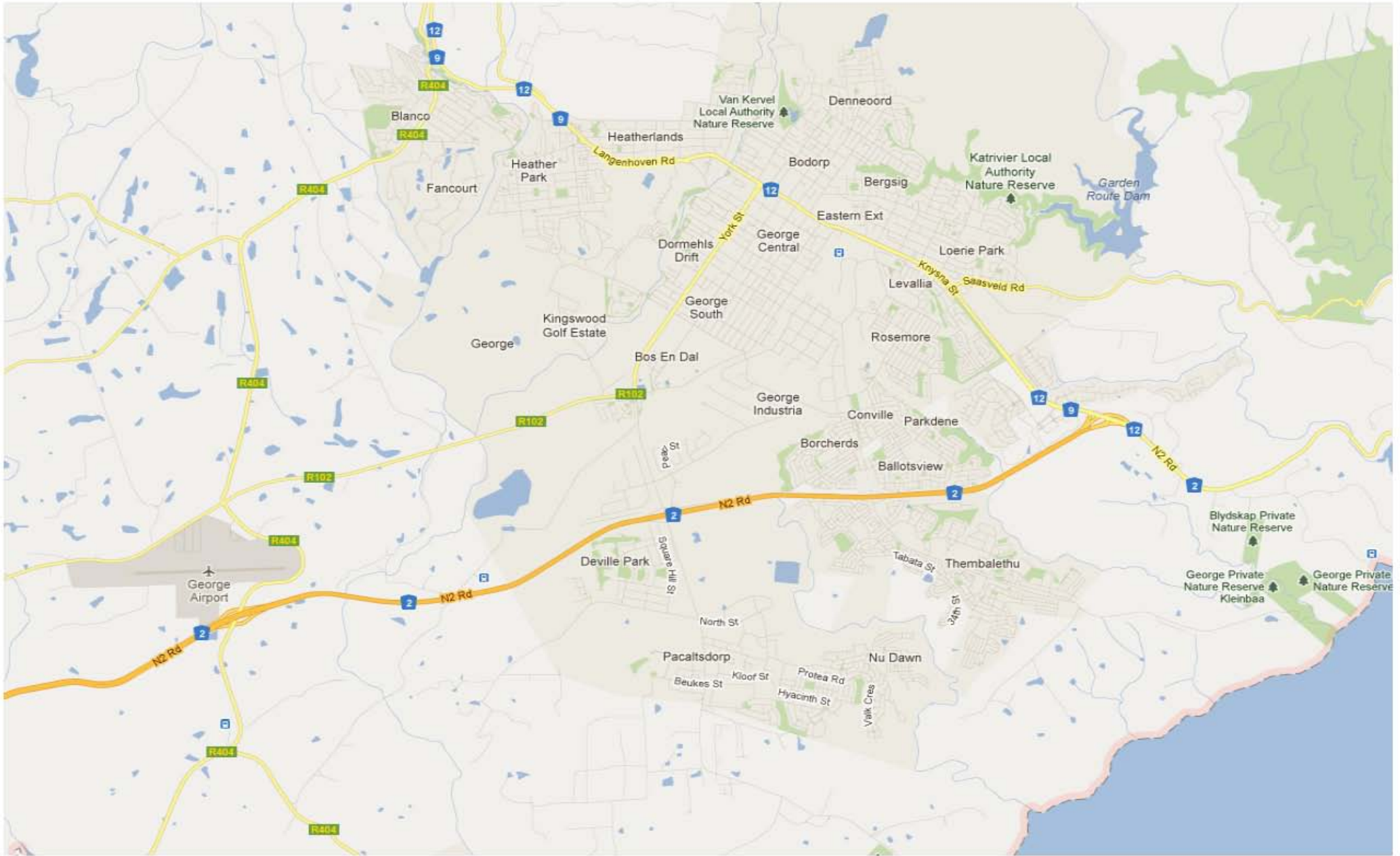


Figure 3.2: The George Municipality (Google Maps, 2012)

3.2.2. Current socio-economic profile

While it is clear that the George Municipality's population has increased significantly, the scale of growth is still unclear. For instance, Stats SA and a 2007 George Municipality Community Survey (George Local Municipality IDP, 2009/2010) estimate that the municipality's population has increased from 80,645 in 1991 to 177,352 in 2007.

Similarly, 2001 census data and community surveys indicate that household totals increased from 25,427 (1996) to 35,520 (2001) and then to 42,793 (2007). However, George Municipality argues that this represents an underestimate of true population growth (George Local Municipality IDP, 2011/2012).

The Draft Spatial Development Framework of George Municipality assumed a growth rate of 4.6% annually between 1995 and 2001. This has generated higher population estimates than those provided by SA Stats. This was reflected in differences of approximately 40,000 people between the (2007) community survey and municipal projections for the same year. Table 3.1 presents municipal population estimates from 2001-2009.

| Year | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Population | 135,409 | 141,638 | 148,153 | 154,968 | 162,097 | 169,553 | 177,352 | 185,511 | 194,044 |

Table 3.1: Projected Population of George Municipality 2001 - 2009 (George Local Municipality IDP, 2011/2012).

The George Municipality accommodates about one-third of the population of the Eden District Municipality and contributes between 30 to 35% to the District's Gross Regional Product (Thomas, 2005). This is attributed to the large population with the high in-migration of black Africans from the Eastern Cape combined with the movement of retirees from Gauteng that, by 2005, had resulted in an estimated population of 160,000 (ibid, 2005). This growth was attributed to the attractive characteristics of the area, including its standard of living and employment opportunities (Thomas, 2005).

The service sector contributes the largest part of the economy of the George Municipality (George Local Municipality IDP, 2011/2012) with wholesale, retail, catering and accommodation providing 21.5% of the Gross Geographical product (GGP). Finance and business services comprise a further 20.8% of the GGP. This is indicative of the conference, administrative and service nature that the municipality of George has become. This 'service sector' also experienced a 14.7% growth rate. Agriculture reportedly showed a 2.3% increase while electricity and water reflected 5% growth rates. In contrast, mining and manufacturing are decreasing in importance (ibid, 2011/2012).

3.3 The George Municipality: Climate and Topography

3.3.1. Climate

In the context of the Western Cape Province, George Municipality falls under the region known as the Cape South Coast. The South Coast receives predominantly winter rainfall, but this trend changes towards the east of the South Coast region where rainfall is characterised by a tendency towards summer rainfall (Tummon cited in DiMP, 2007). The precipitation cycle for the municipality is bimodal with the majority of rain falling in two main periods of the year, specifically from March to April and August to November respectively (Tummon in DiMP, 2007). The difference between the George Municipality and the broader rainfall region is attributed to the Outeniqua Mountains, which are higher than 1,500 metres above sea level (oudtshoorninfo.com, 2010) and cause orographic (forced upward movement of air caused by relief) uplift resulting in rainfall. Annual rainfall is reportedly 850mm and is spread throughout the year with the mid-year months, May June and July receiving the least rainfall (George Local Municipality IDP, 2011/2012).

Other significant weather systems in the Western Cape that affect the George Municipality directly include the coastal low pressure systems and the cut-off low. Coastal low pressures are areas of low pressure which cause atmospheric lift and hence cloud cover through adiabatic cooling. In the Cape South Coast these coastal lows result in berg winds, which are warm dry winds that move from the escarpment down to the coast and are usually associated with veld fire risk (Tyson and Preston-Whyte, 2009). The cut-off low is another frequent feature of the Western Cape climate. Cut-off lows are cold low frontal depressions that have been isolated from the coastal pressure system and occur in the mid-latitudes. They are characterised by heavy rainfall and gale force winds (SAWS, 2007). These cause extreme rainfall and are associated with flooding in the province, resulting in R2,540,626,042 in direct damage cost from 2003-2008 alone (Holloway *et al*, 2010).

3.3.2. Topography and hydrological profile

The topography of the area is varied but is predominantly comprised the coastal plateau that is bordered by the Outeniqua Mountains that reach 1,600m above sea level. The coastal region, one of the George Municipality's tourist attractions, is rugged with deep valleys and river gorges (van Niekerk *et al*, 2009).

The George Municipality contains within its borders both small and large river catchments. Amongst the most important are the Swart, Kaaimans, and Malgas River Catchments (George Local Municipality (c), 2005). In the context of this study, the Swart River is particularly relevant as the largest dam within the George Municipality, the Garden Route Dam (GRD), is located on this river (refer to section 3.4.2).

3.4. The George Municipality: Municipal Service Provision

This section outlines the basic services provided by the municipality including water and electricity. It also describes the water supply mechanisms within the area.

3.4.1. Access to basic services

In addition to formal neighbourhoods, in 2011, the George Municipality had 24 informal settlements, comprising 5,000 households (George Local Municipality IDP 2011/2012). With 5 people estimated per household, it is estimated that 25,000 people currently reside in informal settlements, with a further 4,200 families reportedly living in backyard dwellings. Most of these structures are vulnerable to threats such as flooding and fires and more recently, drought conditions (George Local Municipality IDP 2011/2012).

Table 3.2 presents data reflecting rising water provision from 1996-2008 within the George municipality. This signals impressive coverage across the municipality, as, even in 1996, 94% of all households had access to clean water. According to Stats SA, eleven years later, in 2007, although the number of households had almost doubled, the proportion with access to potable water had increased further to 98.4% (George Local Municipality IDP, 2011/2012).

| Category | 1996 (Stats SA) | | 2001 (Stats SA) | | 2007 (Stats SA) | | 2008 (DWA) | |
|------------------------------------|--------------------|------|--------------------|--------|--------------------|--------|---------------|--------|
| | Number | % | Number | % | Number | % | Number | % |
| Households with access to water | 24,151 | 94% | 34,170 | 94.60% | 42,091 | 98.40% | 42,000 | 95.20% |
| Households without access to water | 1,549 | 6% | 1,969 | 5.40% | 702 | 1.60% | 2,111 | 4.80% |
| Total | 25,700 | 100% | 36,139 | 100% | 42,793 | 100% | 44,111 | 100% |

Table 3.2: Access to Water in the George Municipality 1996 - 2008 (George Local Municipality IDP 2011/2012)

Access to electricity shows a similar trend, with 83% of households 25,700 having access to the grid in 1996. Twelve years later, in 2008, and despite an increase in households to 39,226, access to electricity remained high at 85%. On one hand, this shows a very high level of delivery in the George Municipality; on the other it shows the significant increasing demand for basic services.

3.4.2. Urban Water Supply Mechanisms

The George Municipality owns and operates the Garden Route Dam (GRD), also known as the George Dam or the Upper Swart Catchment Dam (George Local Municipality IDP, 2011/2012). This dam is located in the

coastal area of the Gouritz Water Management Area (WMA 16) close to the George Municipality (IWR, 2011). It was constructed in 1979 and has a catchment area of 35.5 km². The Full Capacity Storage (FCS) is 9.03 million m³ (Department of Water Affairs, 2011). GRD is the main source of water for the George Municipality and during 2009 to 2010 provided the municipality 9.22 million m³ of water (IWR, 2011).

The George Bulk Water System consists of the GRD system, which is linked to the Kaaimans and Malgas (K30B) River catchments via run-off-river abstractions or diversions that contribute to the system. The Touws (K30D) River abstraction that supplies to the Wilderness area is also part of this system (IWR, 2011).

The George Municipality built the GRD. Moreover, because it is the responsible Water Services Authority, the municipality maintains and operates GRD and has the licensed extraction rights. However, day-to-day management of the GRD is outsourced to a private service provider (Pers. Communication, the George Municipality, 2011).

With specific respect to monitoring dam water levels, the Department of Water Affairs (DWA) monitors water volumes telemetrically three times a week. However, actual weekly and monthly consumption is monitored by the George Municipality. Currently, weekly dam level readings are emailed to the Provincial Disaster Management Centre (PDMC) that in turn sends it to the relevant stakeholders (Pers. Communication, the George Municipality, 2011).

Figure 3.3 shows the location of the GRD in relation to the municipality.

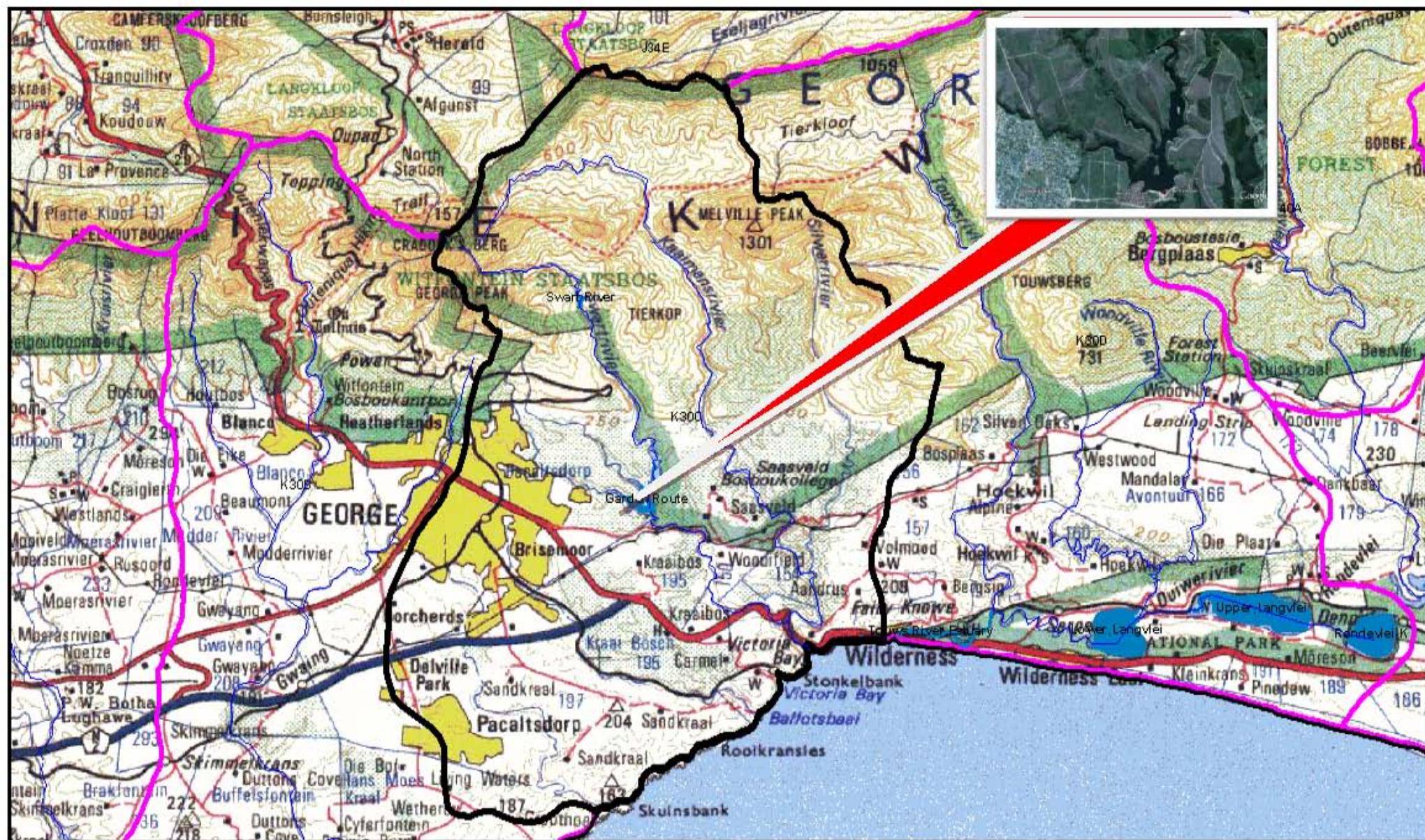


Figure 3.3: Location of GRD in the K30 Quaternary Catchment (GRD Operations Analysis Report, 2011 and Google Earth, 2011)

3.5. George: Disaster risk context: focus on water scarcity

The George Municipality is exposed to multiple threats (such as flooding, drought and veld fire) and has sustained approximately R59 million in flood losses since March 2003 (Holloway *et al*, 2010). In the past 10 years there have been four severe weather events that significantly affected the George Municipality. The area also experiences recurrent wildfires and is exposed to recurrent drought threats.

The recent increase in severe weather-events however, has not reversed conditions of progressive water scarcity in the George Municipality. For instance, in 2000, the former Department of Water Affairs and Forestry examined the national water balance (supply/demand) scenario for South Africa's Water Management Areas (WMAs). This scenario, reflected in Figure 3.4 below, anticipated that four WMAs would experience water surplus conditions while five WMAs would experience water shortages. Even ten years ago, in 2000, ten years water shortage conditions were anticipated for the entire WMA 16 area which includes George Municipality.

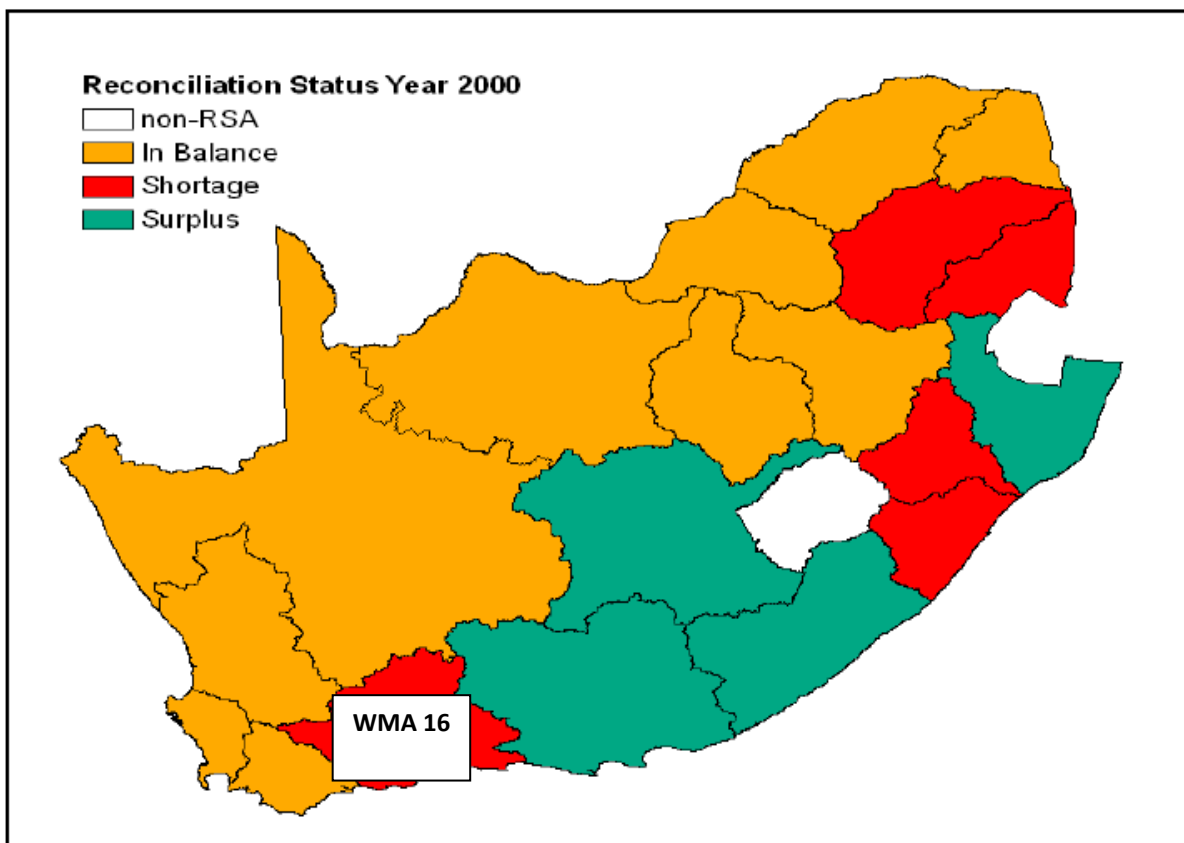


Figure 3.4: Water demand and supply scenarios for 2000 in South Africa (DWAf, 2010: 2)

The district's recurrent exposure to severe weather events, floods and wildfire has highlighted the need for robust disaster risk management. Although the district disaster management centre was

officially established in 2008, efforts to build this capacity date back to 1988 (Pers. Communication, Eden District Disaster Management, 2011)

3.6. The 2009 – 2010 Drought

This study's focus, the 2009 to 2010 Eden District drought, was declared on the 10 November 2009 in terms of the section 23 (1) (b) of the National Disaster Management Act, 2002 (Act No 57 of 2002). It was described as a meteorological, agricultural, hydrological and socio-economic drought and was attributed to be the lowest recorded annual rainfall in 132 years (George Herald, October 2009). A further declaration to extend relief was made in May 2011 (Pers. Communication, Provincial Disaster Management, 2011). The drought coincided with global El Niño conditions (NOAA, 2009), which existed in the equatorial Pacific Ocean from June 2009 and in May 2010, and which were associated with increased storminess in southern United States and drought in Indonesia (ibid, 2009)

Several months before the drought was formally declared in November 2009, dam storage levels had already dropped to 44% capacity (July 2009). However the drought declaration led to wide-reaching public awareness campaigns and other measures to reduce water usage and conserve resources. These included drought management strategies that sought to simultaneously control the local water demand and increase the water supply.

Efforts to reduce water demand included public awareness campaigns, augmented by the introduction of strict water tariffs. These measures reduced water and consumption levels by 40% from 34MI/day in January 2009 to 22.4MI/day in October 2010. Together with rainfall, it resulted in FCS being restored by January 2011 (Department of Water Affairs, 2011). A reporting and risk rating system was also developed for the Eden District to convey comprehensive but simple drought messages to the public as well as government.

Measures to increase water supply for the long term (i.e. to 2030) sought to 'spread the risk' to other water sources including groundwater and re-use of effluent. Other longer term measures are still to be implemented. These included raising the GRD wall and the treatment of reclamation plant. These measures are shown in Figure 3.5.

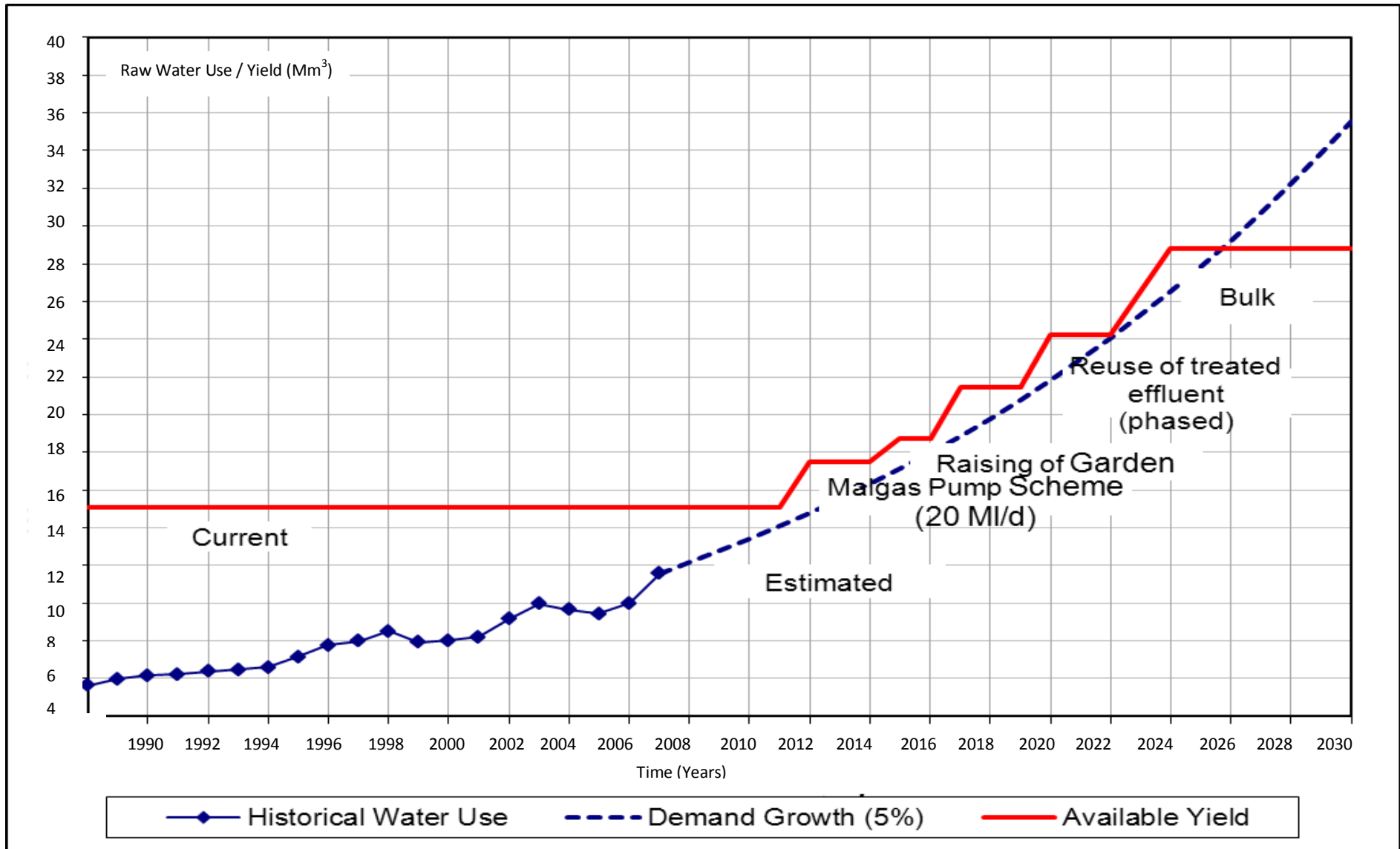


Figure 3.5: Projected water supply strategies for George Municipality for 1981 – 2030 (Presentation George Debriefing 5 May 2011)

The National Treasury mobilised R53.8 million for the first drought declaration for the entire Eden District, with R15.2 million being distributed to the George Municipality. The remaining municipalities received R38.7 million, with Knysna and Mossel Bay Municipalities being allocated R22 million and R 16.5 million respectively (Pers. Communication, Provincial Disaster Management, 2011).

Although water restrictions were lifted in February 2011, consumption in April was recorded at a low of 25.8MI/day. This indicates an encouraging shift in responsible water usage in the George municipality. The drought was declared over in June 2011 when the flooding occurred (Pers. communication, Eden District Disaster Management, 2011).

Following the drought event, concerted attention was applied by drafting an integrated provincial water resource strategy. This strategy is still in process and aims to guide water resource activities to meet growth and development goals of the province (Department of Environmental Affairs and Development Planning, 2010).

3.7. Summary

This chapter introduced the geographical location of George, showing how its unique natural environment and strategic location are key components for its recent, rapid development. In addition, George's location also exposes the municipality to severe weather, including frontal systems that cause heavy downpours and contribute to flash floods. Similarly the George municipality is exposed to berg winds that contribute to endangering veld fires.

The chapter has outlined the significant population expansion experienced in recent years, including rising demand for basic services, such as electricity and water. It concludes by providing a brief overview of the 2009 to 2010 drought and measures taken to address the acute water shortage experienced during this period by the George Municipality.

CHAPTER FOUR

METHODOLOGY

4.1. Introduction

This study sought to investigate the 2009 - 2010 Eden District drought, with a particular focus on the conditions that generated acute urban water scarcity in the Municipality of George. This necessitated a “mixed-methods” research design that incorporated both quantitative data, including rainfall, population, urban water consumption and recorded dam levels for the GRD and qualitative information sourced from drought workshops and the district and provisional disaster management centres.

The chapter begins with an overview of the methods used and reasons for their selection. It continues by describing steps taken to collect and organise rainfall and dam level from 2000 - 2010 into discrete datasets, along with information on the George Municipality’s urban water consumption and population. Then, detailed descriptions of steps taken to collect and consolidate the numerous newspaper articles and documentary information related to the identification and management of the drought are shown.

The chapter continues by outlining methods used to examine time-series data respectively for rainfall and dam levels in the George Municipality. It concludes by describing a three step analysis process, which first integrates rainfall, then dam level data, over time and relates these values to urban water supply management processes affected prior to and during the drought.

4.2 Overview

This research project constituted a case study of the urban water scarcity that seriously affected seven municipalities in the Southern Cape. However, the research specifically focused on the experience of urban water scarcity in the George Municipality, which was associated with declining water availability in the GRD.

Although the precipitous reduction in dam water supply from 2008 - 2010 was widely attributed to meteorological drought conditions across the Southern Cape, this study recognises that acute urban water scarcity may also be attributed to high and unregulated urban water demand (Wilhite, 2005). Moreover, given the recent rapid development of the George Municipality and its associated population growth since 2001, the study acknowledged that rising urban water demand may have contributed to declining dam water levels and the subsequent hydrological drought.

As it was unclear whether hydrological drought conditions that affected the George Municipality were attributed to a reduction in annual rainfall or increased urban water demand or a combination of both, the research design drew on methods from the fields of meteorology, hydrology, integrated water management and disaster risk.

Specific methods applied included historic analysis of rainfall from six stations spatially associated with the GRD as well as population statistics for the George Municipality associated with urban water consumption. In addition, recorded dam level data from 2000 - 2010 as well as urban water consumption values were collected for the GRD, recognising that this information indicates imbalances in water supply and demand.

In addition to methods that analysed quantitative time-series data such as rainfall and dam levels, the research design incorporated information derived from numerous qualitative data sources. These included official documents relating to the declaration and management of the drought as well as meeting reports and newspaper accounts that recorded its progression. Additional qualitative data were gathered through primary data collection in the George Municipality, interviews with key informants and the researcher's attendance in drought management meetings.

This combination of quantitative and qualitative methods enabled the researcher to identify the underlying physical causes of the 2009 - 2010 drought, as well as the risk management interventions that reversed it. The research process took place over 16 months from January 2010 - May 2011 and is shown in Table 4.1.

| Research Process | | |
|----------------------------|---|---|
| Date | Purpose | Method |
| February 2010 - April 2010 | Scoping, Identification of research question and Site selection | Meetings and semi structured interviews, research into the disaster event |
| March 2010 - August 2011 | Secondary Data Collection | Contact with relevant departments and key informants |
| March 2010 - May 2011 | Primary Data Collection | Ongoing primary data collection from meetings and workshops |
| May 2011 - August 2011 | Secondary Data Consolidation and Analysis | Application of methods for rainfall, hydrological and population analysis |
| May 2011 - August 2011 | Primary Data Consolidation and Analysis | Documentation of the drought |

Table 4.1: Research Process for the Study

4.3 Site Selection

The rationale for selecting the George Municipality for this study was justified for several reasons. Firstly, from a disaster risk perspective, the George Municipality has a complex weather risk profile. This is evidenced by the municipality's exposure to severe weather events, which from 2003 - 2008 generated losses of R59 million (Holloway *et al*, 2010). Secondly, as the George Municipality is the second-largest urban centre in the Western Cape, with a rapidly growing population, it provided a useful research site to examining challenges related to sustainable water supplies. Thirdly, the Eden District Disaster Management

Centre is located in the George Municipality where drought management meetings and workshops were held. Similarly, daily rainfall records, annual population data, monthly and weekly urban water dam consumption values and weekly dam records, along with relevant drought reports were readily obtained for the George Municipality through relevant government and related sources.

4.4. Secondary Data Collection

Given the study's focus on identifying the causal factors for the George Municipality's drought, secondary data sources were consulted. These included qualitative, quantitative and spatial sources and are summarised below in Table 4.2.

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| Summary of Secondary Data Sources | | | |
|--|--|---|------------------|
| Data Source | Data Type | Rationale | Date |
| Quantitative | | | |
| The South African Weather Service | Daily Rainfall Records | Trends in rainfall prior to the drought, Seasonality shifts in rainfall, Intensity and Frequency of rainfall changes | 1900 - 2010 |
| The Department of Water Affairs | Weekly Dam Level Records | Trends prior to the drought, Trends in annual dam levels, Trends in monthly dam levels | 2000 - 2010 |
| Stats SA together with George Municipality | Census Data | General population trend prior to during and after the drought. | 2000 - 2009 |
| The George Municipality | Urban Water Consumption Data | Urban Water Consumption levels of the Garden Route Dam | 2000 - 2010 |
| Chief Directorate of Surveys and Mapping | Spatial Data | Initial identification of municipality boundaries, Dam location and catchment information | 2008 |
| Qualitative | | | |
| The Eden District Disaster Management Centre | Drought Management Reports, Relevant action policies related to urban water management | Identification and examination of pre-, post- and management of the drought. Legislation and policies in place for understanding of urban water management in the George Municipality. | 2008, 2009, 2010 |
| Eden and the George Municipality Districts | Drought Management Reports, Relevant action policies related to urban water management, Municipal development planning documents | Identification and examination of pre-, post- and management of the drought. Legislation and policies in place for understanding of urban water management in the George Municipality. Background information for the George Municipality | 2007 - 2011 |
| The George Herald | Drought-related Newspaper articles | The role of public awareness campaigns and key information | 2009, 2010, 2011 |
| SAWDIS | Drought-related reports from websites | The role of public awareness campaigns and key information about management and the stages of the drought | 2009 - 2011 |

Table 4.2: Summary of Secondary Data Sources

4.4.1. Rainfall Data

Daily rainfall records for the six rainfall stations within the George Municipality were sourced from the South African Weather Service (SAWS). These data proved difficult to collect as the location of rainfall stations had shifted during the study time frame. In addition, the station datasets were incomplete and contained numerous missing records. The locations of specific stations are shown below in Table 4.3 and Figure 4.1.

| Station | Code | Co-ordinates and Altitude | Date | Period | Missing Data |
|-----------------------------|-----------|------------------------------|-------------------------------------|-----------|--|
| George P.W. Botha | 0012661_W | 34 01.2 S, 22 22.8 E 191m | 1 September 1992 - 31 December 2010 | 18 years | Nil |
| P.W. Botha Lughawe | 0028690_W | 34 00.00S, 22 22.08E 180m | 1 June 1977 - 31 August 1992 | 15 years | 1987, 1988 |
| Herold (Pol) | 0028771_W | 33 51.00S, 22 27.0E 610m | 1 March 1924 - 30 April 2007 | 83 years | September 1924, April 1929, April 1931, October 1935, March 1960, February 1967 |
| Witfontein Bos | 0028775_W | 33 55.2S 22 27.0E 510m | 1 September 1954 - 30 April 2007 | 53 years | December 1963 |
| George Dorp | 0028808AW | 33 55.02S, 22 22.58E 197m | 1 November 1877 - 30 September 2004 | 104 years | September 1905, June 1911, May and October 1917, June 1927, August 1985 - end of December 1989, August 1994- end June 1995 |
| George Bosleliesteeg | 1128836_W | 33 55.8S, 22 28.2E 244m | 1 October 1994 - 30 April 2007 | 13 years | Nil |

Table 4.3: Rainfall Station Information

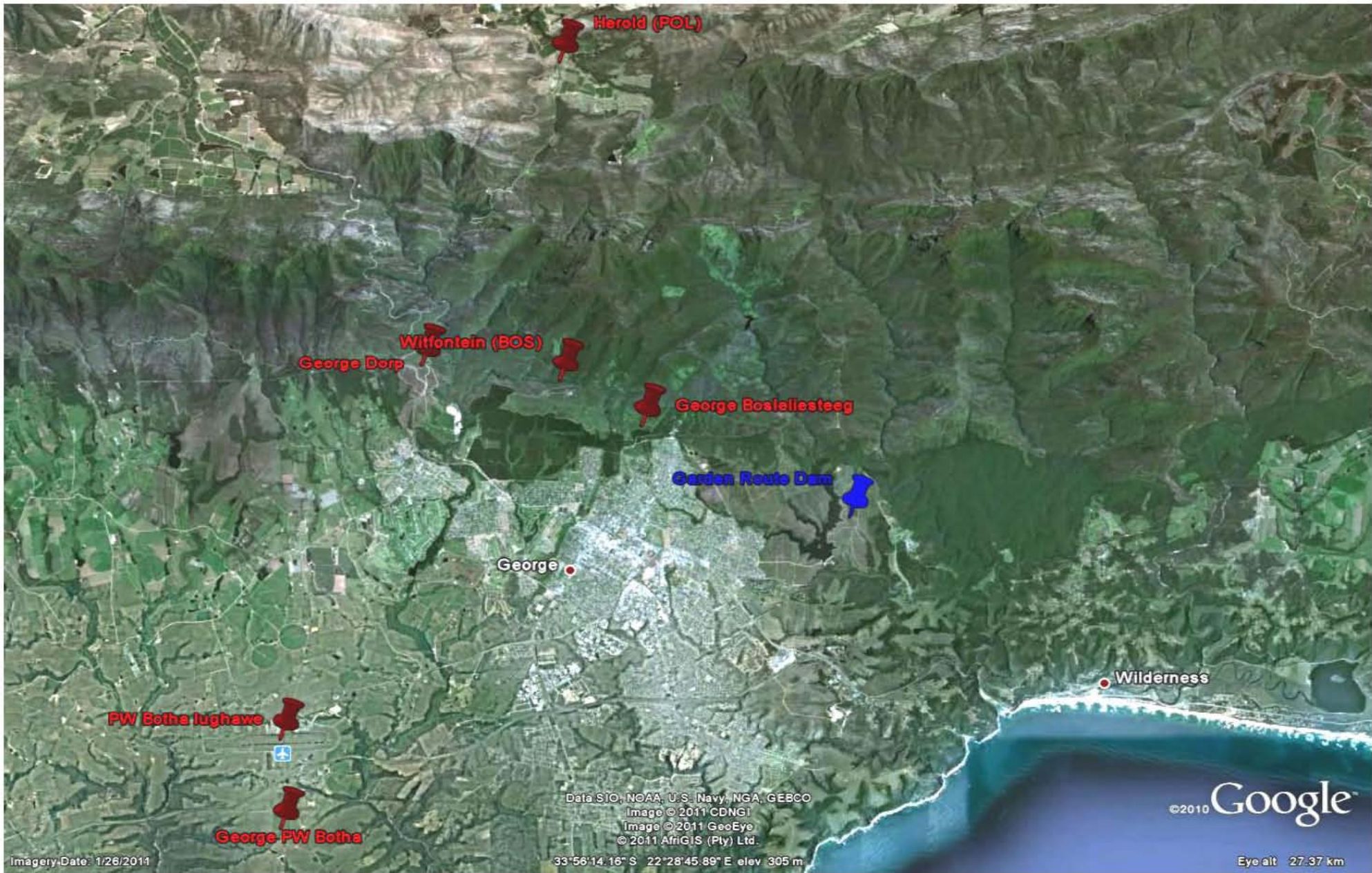


Figure 4.1: Location of Rainfall Stations in the George Municipality

4.4.2. Hydrological Records

Weekly hydrological records for the GRD were sourced electronically from the DWA in the George Municipality. The data obtained reflected weekly percentages of FCS and dam storage levels (kl) for the years 2000 - 2010.

4.4.3. Population Data

These data were obtained from the George Municipality. The 2001 data were sourced from Stats SA and 2007 data derived from a Community Survey done by the George Municipality (George Municipality, 2011). The remaining population data were drawn directly from the George Municipality Draft Spatial Development Framework, which extrapolated population growth based on an annual 4.6% increase between 1995 and 2001.

4.4.4. Urban Water Consumption Data

Urban water consumption data were sourced electronically from the George Municipality. The data were provided in monthly and weekly consumption levels (kl) for the GRD for the time period, 2000 - 2010.

4.4.5. Spatial Data Source

Maps were accessed from the Chief Directorate of Surveys and Mapping in Mowbray, Cape Town. These maps identified the river basin, catchments and dam location. They also identified the boundaries of the George Municipality within which the study is located.

4.4.6. Qualitative Secondary Data Sources

In addition to the quantitative and spatial sources identified above, the researcher also consulted diverse sources of qualitative data. These included drought management reports, municipal development planning documents (Integrated Development Plans), relevant action policies related to urban water management, drought related newspaper articles and reports from websites.

Drought Management Reports

Monthly and weekly drought reports and documents were sourced from the Department of Water Affairs and the Eden District Disaster Management Centre. The Eden District Disaster Management Centre compiled the monthly reports which included Water Crisis Management progress reports. These provided the following information:

- Water Crisis Status, which was shown in the form of a risk-rating chart. This summarised the

priority municipalities in the Eden District.

- Regional drought and water supply indicators such as rainfall, dam levels, river flow volumes and seasonal forecasts.

Municipal Development Planning Documents

Integrated Development Plans from 2007-2011 were collected for the George Municipality and the Eden District Municipality. These provided information for the context of the study as well as important population data.

Relevant action policies related to urban water management.

The following legislation and policies surrounding urban water management were collected electronically:

The South African National Disaster Management Act (Act 57 of 2002)

The South African National Disaster Management Framework of 2005

The South African National Water Services Act (Act 108 of 1997)

Constitution of the Republic of South Africa: Chapter 7

Drought - related newspaper articles

The George Herald newspaper provided useful accounts of the drought progress in both electronic and hardcopy format. The newspaper provided feedback for the public and helped create and manage the awareness campaigns. The Eden District Disaster Management Centre, in collaboration with the Western Cape Disaster Management Centre guided the release and content of information.

Drought- related reports from websites

The following websites provided reliable information on drought related data:

- www.sawdis.co.za
- www.georgeherald.co.za

4.5. Primary Data Collection

The secondary data sources were complemented by primary data collection. This entailed three visits by the researcher to the George Municipality during the course of the study.

The data collection methods were field observation, participant observation at drought-related meetings and key informant interviews.

4.5.1. Field Observation

Field observation took place through three site visits to the George Municipality from 2010 - 2011. These occurred on the 12 March 2010, 29 March to 1 April 2010 and 5 May 2011. The visits enabled collection of drought related records as well as observation of drought-response interventions. These included observation of municipal desalination plants and waste water treatment facilities. They also allowed for visits to the GRD in March 2010 when it was reportedly 33% full (DWA, 2010). In addition, the researcher was able to observe the controlled burning exercise undertaken in March 2010 to expedite surface run-off.

4.5.2. Participant observation at drought meetings and workshops

As the study progressed, the researcher's active participation in organised drought management meetings and workshops emerged as a key component of the field research.

The researcher participated in three such processes; a monthly drought committee meeting on 12 March 2010, a FETWater Workshop on water-related Disasters from 29 March - 1 April 2010 and a drought debriefing on 5 May 2011 in the George Municipality.

During these meetings and workshops, a diverse range of governmental and non-governmental stakeholders provided factual information on the progression of the drought and its management. They also afforded access to key informants and resource people who provided both qualitative insights as well as quantitative information.

4.5.3. Key Informant Interviews

Key informant interviews were conducted with private consultants, as well as representatives of municipal and district departments and the Department of Water Affairs. These included disaster managers from affected areas as well as the head of the Eden District Disaster Management Centre. Interviews undertaken provided insight into the management of the drought, the contributing risk drivers prior to its onset, challenges faced and lessons learned.

4.6. Data Organisation and Consolidation

The protracted nature of drought management processes result in vast amounts of both qualitative and quantitative data. Moreover, the study's dual focus on the pre-conditions that drove the drought and the drought management response, required organisation of diverse datasets of uneven quality and reliability.

This necessitated the evaluation and organisation of rainfall, dam level and urban water consumption

data. It also required extrapolation of population data for the George municipality over the study period. In addition, the researcher was required to organise numerous drought management reports generated over the disaster time frame and which were derived from multiple sources.

4.6.1. Organisation of Rainfall Data

Daily rainfall data from the six rainfall stations listed in Table 4.3 were systematically organised into discrete time series. These were then evaluated for completeness of records and missing values. Data were then entered into MS Excel to generate weekly, monthly and annual rainfall values.

Annual rainfall values for all stations were then graphed to represent trends from 1901 - 2010. The researcher limited more detailed analysis of rainfall to data collected from the two airport stations, P.W Botha Lughawe and George P.W. Botha, due to the 31 - year duration of the record. Although the rainfall station relocated from P.W. Botha Lughawe to George P.W. Botha in 1992, the combination of sites provided the most robust time series for the purposes of the study. Although there were stations located in closer proximity to the GRD, regrettably these rainfall records were incomplete.

4.6.2. Organisation of Hydrological Records

Weekly data from 2000 - 2011 for GRD storage, obtained from the Department of Water Affairs, were imported into MS Excel. These were subsequently totalled to provide monthly and annual values and averages, which were graphically represented.

4.6.3. Organisation of Population Data

The George Municipality provided population data for the study. Unfortunately, as accurate annual population data were not available, the researcher was limited to extrapolated population data. This information was organised into a table and used to graph trends in the local population

4.6.4. Organisation of Urban Water Consumption Data

The municipality provided the data for the GRD's urban water consumption levels from 2000 to 2010. These data were also entered into MS Excel to generate monthly, then annual water consumption totals and subsequently to examine trends and patterns and combine the data with other variables.

4.6.5. Organisation of Qualitative Secondary Data Sources

Written reports, newspaper articles, management strategies and policy documents that were obtained from the Eden District Disaster Management, were organised by type of source (i.e.

municipal drought reports). These were then organised to determine the sequence of the response.

4.7. Data Analysis

As this study sought to investigate changing rainfall (water supply) and urban water consumption (urban water demand) in relation to the 2009 - 2010 drought in the George Municipality, the analysis focused specifically on these two variables.

4.7.1. Determination of meteorological drought and declining rainfall trends

The researcher applied several complementary methods to examine local rainfall in the year immediately prior to the onset, during the declared drought and over the recent climate record.

Determining occurrence of meteorological drought

Although there are many different methods for determining meteorological drought, the researcher applied the definition proposed by the South African Weather Service (SAWS) (www.saws.co.za, 2011). It defines drought on the *“basis of the degree of dryness in comparison to “normal” or average amounts of rainfall for a particular area or place and the duration of the dry period.*

For the purposes of this study, the researcher sought to determine whether rainfall in 2009 was less than 75% of normal, as the SAWS views this as an indicator of severe meteorological drought (SAWS, 2011). SAWS, further proposes that *“normal rainfall for a particular places is calculated over a 30 year period using rainfall figures for at least 30 years.”* (www.saws.co.za, 2011). Rainfall in the suspected drought year is then related to the 30-year rainfall ‘norm’ to determine the extent of shortfall from the annual rainfall average.

The researcher applied a two-step method for determining the extent of meteorological drought conditions in 2008 and 2009. First, she established the average annual rainfall for the P.W. Botha Lughawe and George P.W. Botha stations as shown below.

$$\sum x/n = z$$

Where:

x = Annual rainfall for years 1978 - 2010

n = 31 years

Z = Average annual rainfall over 31 year period (mm)

Second, she expressed the annual rainfall for 2008, 2009 and 2010, respectively as a percentage of the average rainfall determinants for the preceding 31 years.

Examining annual rainfall trends, seasonality and variability

While the 2009 - 2010 drought constituted a period of acute water scarcity, the researcher sought to investigate whether the occurrence of a meteorological drought was associated with changing trends in the annual rainfall as well as changes in rainfall intensity and seasonal distribution. While overall temporal and spatial distribution of rainfall in the George Municipality was assessed by viewing data from all six rainfall stations, more specific attention to variability was limited to the airport station.

Rainfall Trends: 1901 - 2010

The researcher initially used all six rainfall stations to plot annual rainfall over time to determine the general trend in annual rainfall across the George Municipality.

Variability

Variability in the rainfall data was examined with monthly rainfall graphs. The data was also organised into a matrix where the monthly rainfall could be analysed. From here, the average monthly and average annual rainfall was determined for each year over a 31 - year period, 1978 to 2010 for stations P.W. Botha Lughawe and George P.W. Botha. These data were then colour coded to examine the variability of the rainfall data.

Seasonality

Rainfall data from the two airport stations were divided into two equal 12-year periods. These time periods were chosen with the only available data to show how the seasonality had changed over a time period. These were P.W. Botha Lughawe from 1978 - 1991 and the second George P.W. Botha from 1998 - 2009. These data were consolidated to provide rainfall totals for the 2 (12 year) periods to identify shifts in seasonality.

4.7.2. Determinants of hydrological drought

Wilhite (2005) defines hydrological drought as: *“This drought occurs when water reserves fall below the average.* Hydrological drought tends to occur slowly because it involves using stored water” Furthermore, hydrological drought is *“...the lag between the amount of precipitation fallen and the available groundwater”* (Moorsom, *et al*, 1995: 21).

The researcher adopted the same two-step process as with meteorological drought. First she established the average annual storage levels for the GRD from 2000 to 2010. Then she expressed the GRD levels for 2008, 2009 and 2010 as a percentage of the eleven-year average.

$$\sum x/n = Z$$

Where:

x = Annual GRD storage levels for years 2000 - 2010

n = 11 years

Z = Average GRD storage level for 2000 - 2010

Weekly records were sorted into monthly and annual records. These records were then used to generate monthly and annual GRD storage level graphs.

Then the monthly rainfall values were used together with the GRD storage levels to produce a graph with both variables to examine the lag in time between the two variables.

4.7.3. Determinants of causal factors for the hydrological drought

Urban water consumption values obtained from the municipality were graphed over time and the trend was analysed. This information was imported into other graphs that were used to examine the relationship between the rainfall data, GRD storage level data and GRD consumption data. Annual consumption data were also expressed as a proportion of Historical Firm Yield (HFY) for the GRD that was derived from the Garden Route Dam Operations Analysis Report (IWR, 2011). As Historical Firm Yield represents the maximum yield possible, even through severe drought, annual consumption (expressed as proportion of HFY) was viewed as a useful indication of imbalanced demands that would increase municipal vulnerability to meteorological drought events.

4.7.4. Identification of other intervening factors and measures

This study's specific focus on the experience of urban water scarcity in the George Municipality due to reduced storage levels in the GRD also required examination of the role of other intervening factors. These included the contributory role played by cut-off low systems in replenishing the dam. They also included the role played by drought management strategies introduced in 2009 and 2010.

To explore possible relationships between severe weather events and dam storage levels, the researcher identified rain days associated with recent recognised cut-off low systems, which affected the George Municipality and graphed the associated rainfall with GRD storage information.

She also sequenced the specific drought risk management strategies and measures implemented between 2009 and 2010 and graphed them in relation to GRD storage and rainfall levels.

4.8. Constraints and limitations

There were many data constraints encountered in the course of this research. These included

sourcing reliable and complete rainfall records, uneven and extrapolated population figures for the George Municipality. Lastly, accessing accurate actual dam consumption data for the GRD proved particularly difficult. Specifically the limitations included:

Rainfall Data

Although the data covered more than 100 years, these were drawn from six rainfall stations and could not be integrated due to location. The data that were derived were from two rainfall stations situated at the airport. These stations, P.W. Botha Lughawe and George P.W. Botha have an 11 metres difference in altitude which may alter the rainfall records - refer to Table 4.3. Unfortunately, there were also missing values, specifically at P.W. Botha which was missing two full years of rainfall data. Rainfall data for 1987 and 1988 were also missing from the P.W. Botha rainfall station.

Population and Urban Water Consumption Data

Population data were extrapolated with an average estimated growth rate. As described earlier George's actual population was unclear during the study period. Although population data were extrapolated, actual dam consumption data were obtained from the municipality to gauge a more accurate demand on urban water supplies.

Drought Management Data

The diverse range of role-players and varied data sources resulted in occasional reporting inconsistencies (i.e. in dates). In addition, some quantitative data was unreferenced, with sources that could not be determined.

4.9. Summary

The chapter detailed the mixed methods approach used by the researcher. The collection, organisation and analysis of rainfall, GRD storage levels, GRD consumption levels and population data for the George Municipality, along with approaches for handling qualitative information data were described. Limitations and constraints that were specifically experienced in the research were explained.

CHAPTER FIVE

FINDINGS AND ANALYSIS

5.1. Introduction

This study sought to investigate the risk drivers that generated the urban water scarcity within the George Municipality from 2009 - 2010.

Chapter Five presents findings and relates these to the onset and management of the episode of acute urban water scarcity. Meteorological drought conditions in 2008, 2009 and 2010 as well as rainfall trends, variability and seasonality that increased the likelihood of water scarcity conditions were also investigated. It continues by examining GRD annual and monthly storage levels in relation to consumption data from 2000 - 2010.

The chapter concludes by relating recent severe weather events to GRD storage levels as well as the sequence of drought risk management interventions that reversed acute water scarcity in George.

5.2. Characterising meteorological drought, rainfall trends, variability and seasonality

A central question for this study was to determine the intensity of the meteorological drought that affected George. Associated questions sought to determine whether the 2009 - 2010 drought reflected a downward trend in annual rainfall as well as changing patterns in rainfall seasonality and variability.

5.2.1. Determining the occurrence of meteorological drought

As described in Chapter Four, the researcher applied the South African Weather Service's definition of a meteorological drought (SAWS, 2011), to determine whether rainfall within the George Municipality met recognized drought conditions. She calculated annual rainfall for the years 1978 - 2010. She then expressed this as a percentage of the average annual rainfall for the 31 study period (1978 - 2010) to demonstrate deviations from the annual mean rainfall over the 31 years period. Table 5.1 represents annual rainfall for the 31 years from 1978 - 2010, from P.W. Botha Lughawe and George P.W. Botha stations.

It shows an average annual rainfall of 702mm with a range between 1,214mm (1981) and 371mm (2009). It also shows recorded rainfall for 2008 and 2009 was 566mm and 371 mm respectively. These results indicate that 2008 rainfall (566mm) was 80.6% of average annual rainfall while recorded rainfall in 2009 fell to 52.8% of average annual rainfall.

As the 2009 value of 52.8% of average annual rainfall falls well below the SAWS threshold for meteorological drought (75% of average annual rainfall) it is clear that this constituted a severe meteorological drought event. In addition, the lower than average rainfall value of 566mm in the previous year, 2008 also imposed significant pressure on municipal water supplies. Table 5.1 shows that for the 31-year climate period under study, there is no previous record of two such low rainfall years occurring 'back-to-back'.

Although not the focus of this study, analysis of rainfall data further indicated that 2005 also constituted meteorological drought, with annual rainfall falling to 457mm or 65.1% of the normal mean for the study period. Although SAWS suggests that "other climatic factors such as high temperature, high wind, low soil moisture and low relative humidity can significantly aggravate the drought conditions", investigating these exceeded the scope of the study.

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| | Annual Rainfall (mm) | Percentage (%) of Average Annual Rainfall over the 31 Year Period (702mm) |
|------------------|----------------------|---|
| 1978 | 588 | 83.8 |
| 1979 | 570 | 81.2 |
| 1980 | 643 | 91.6 |
| 1981 | 1214 | 172.9 |
| 1982 | 760 | 108.3 |
| 1983 | 687 | 97.9 |
| 1984 | 560 | 79.8 |
| 1985 | 740 | 105.4 |
| 1986 | 544 | 77.5 |
| 1989 | 692 | 98.6 |
| 1990 | 626 | 89.2 |
| 1991 | 576 | 82.1 |
| 1992 | 893 | 127.2 |
| 1993 | 872 | 124.2 |
| 1994 | 835 | 118.9 |
| 1995 | 817 | 116.4 |
| 1996 | 796 | 113.4 |
| 1997 | 705 | 100.4 |
| 1998 | 549 | 78.2 |
| 1999 | 603 | 85.9 |
| 2000 | 710 | 101.1 |
| 2001 | 747 | 106.4 |
| 2002 | 561 | 79.9 |
| 2003 | 825 | 117.5 |
| 2004 | 753 | 107.3 |
| 2005 | 457 | 65.1 |
| 2006 | 871 | 124.1 |
| 2007 | 951 | 135.5 |
| 2008 | 566 | 80.6 |
| 2009 | 371 | 52.8 |
| 2010 | 665 | 94.7 |
| Total Ave | 702 | 100 |

Table 5.1: Annual Rainfall and Percentage of Average Annual Rainfall for 31 years from 1978 – 2010.

5.2.2. Examining annual rainfall from 1901 - 2010 for George Municipality

Figure 5.1 graphically represents annual rainfall data from the six rainfall stations within the George Municipality. As previously explained in Chapter 4, rainfall data were highly uneven, with missing values and incomplete rainfall records. All rainfall stations had variations in altitude and time scale.

However, Figure 5.1, drawing on available data, shows annual rainfall across all stations. Although recorded rainfall volumes are clearly affected by the location and altitude of the stations concerned (for instance the higher volumes of rainfall from George Bosleliesteeg, located at a higher altitude from 1995 to 2006), they are all shown in the figure below.

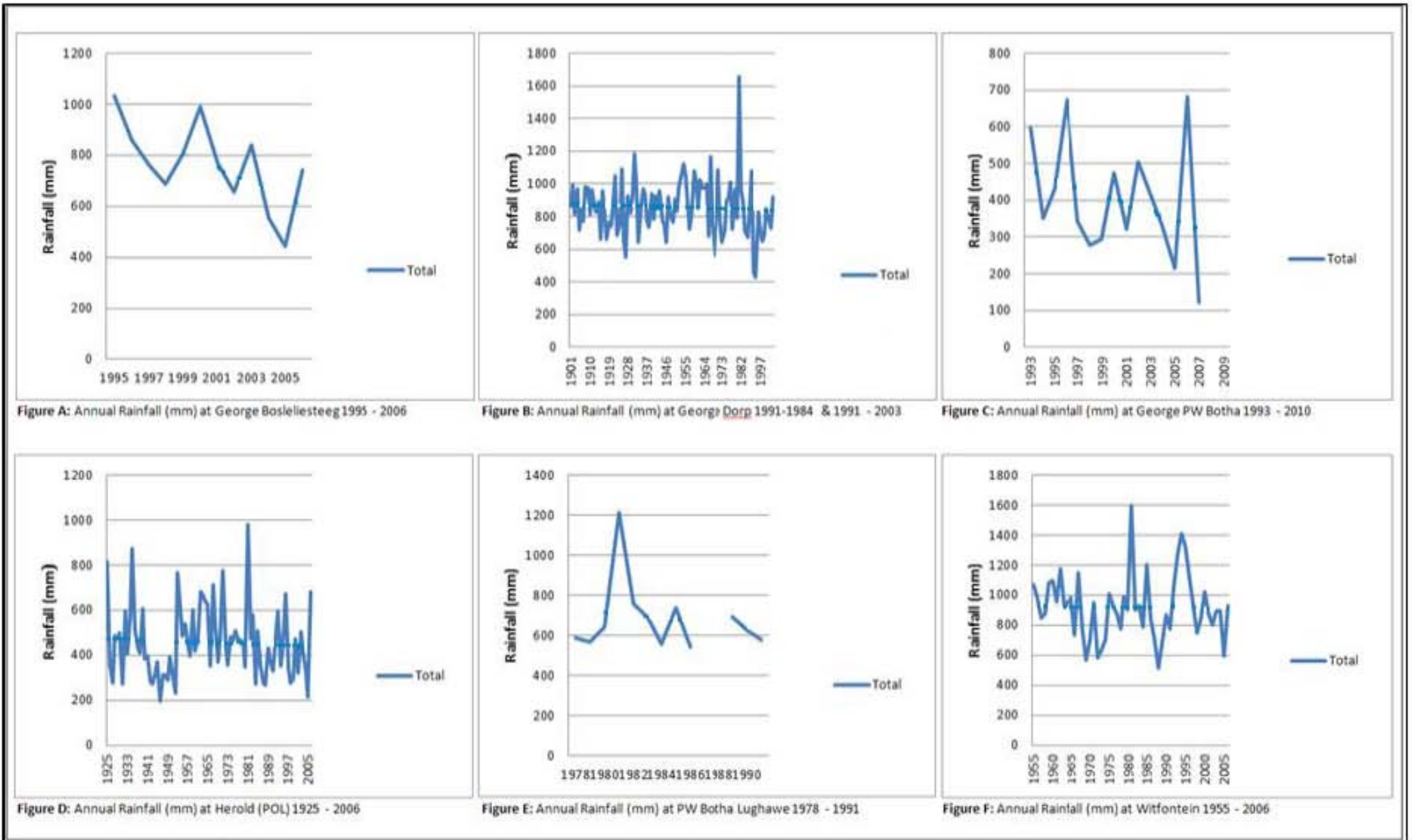


Figure 5.1: Annual Rainfall (mm) at George Bosleliesteeg, George Dorp, George P.W. Botha, Herold (POL), P.W. Botha Lughawe, Witfontein from 1901 – 2010.

5.2.3. Rainfall variability and seasonality

As the Southern Cape is noted for its exposure to weather extremes, the researcher investigated rainfall variability for the 31 year period. This was undertaken by examining annual rain days for the study period as well as the intensity of daily rainfall.

Table 5.2, represents the rainfall data clustered into five year periods. This illustrates marked changes in variability over time. Average annual rainfall, average number of rain days and average rainfall per rain day were each calculated over 5 year intervals. The period 2005 – 2009 shows the lowest average annual rainfall of 643.2mm. 1983 – 1989 also had a low annual average rainfall of 644.6mm. Average number of rain days was lowest in the 2005 – 2009 period with only 86.6 rain days on average each year. This corresponds with the second-lowest rainfall value per rain day at 7.3mm.

Table 5.1, also suggests increasing variability in more recent years of the rainfall record. For instance, over the 31 year period, there were seven years in which rainfall fell below 80% of normal. Three of these years, 2005, 2008 and 2009 occurred recently, with annual values of 457mm, 566mm and 371mm respectively. Similarly, only 4 years of rainfall that exceeded 120% of normal were noted. Two of these, 2006 and 2007, also occurred in the past 5 years, with 871mm and 951mm respectively. These findings suggest increasing inter-annual rainfall variability in the recent rainfall record, with three of the lowest and two of the highest rainfall years occurring from 2005 onwards.

The effect of El Niño on the southern parts of Africa is one of a drying trend (SAWS, 2011). The 2009 meteorological drought in the George Municipality coincided with a global El Niño. Therefore the drying in the years 2008 and 2009 could also be possibly attributed to El Niño.

Data on rainfall seasonality also indicate recent change. Figure 5.2 compares the 1978 - 1991 monthly distribution of rainfall for P.W. Botha Lughawe with the 1998 - 2009 monthly distribution at George P.W. Botha rainfall station. While both rainfall graphs indicate bimodal distributions, the most recent data derived from the P.W. Botha Lughawe station from 1998 - 2009 suggest seasonal shift towards the latter months of the year. Mid-year rainfall (May - July) remains modest compared to the recorded rainfall in November.

| Five Year Periods | Average Annual Rainfall over Five Year Period (mm) | Average Number of Rain Days over Five Year Period (days) | Average Rainfall per Rain Day over Five Year Period (mm) |
|--------------------|--|--|--|
| 1978 - 1982 | 755.0 | 95.8 | 7.8 |
| 1983 - 1989 | 644.6 | 90.8 | 7.1 |
| 1990 - 1994 | 760.4 | 94.2 | 8.0 |
| 1995 - 1999 | 694.0 | 90.4 | 7.7 |
| 2000 - 2004 | 719.2 | 91.2 | 7.9 |
| <i>2005 - 2009</i> | <i>643.2</i> | <i>86.6</i> | <i>7.3</i> |

Table 5.2: Count of Rain Days per annum, Average Count of Rain Days per month and Average Monthly Rainfall (mm) from 1978 - 2010.

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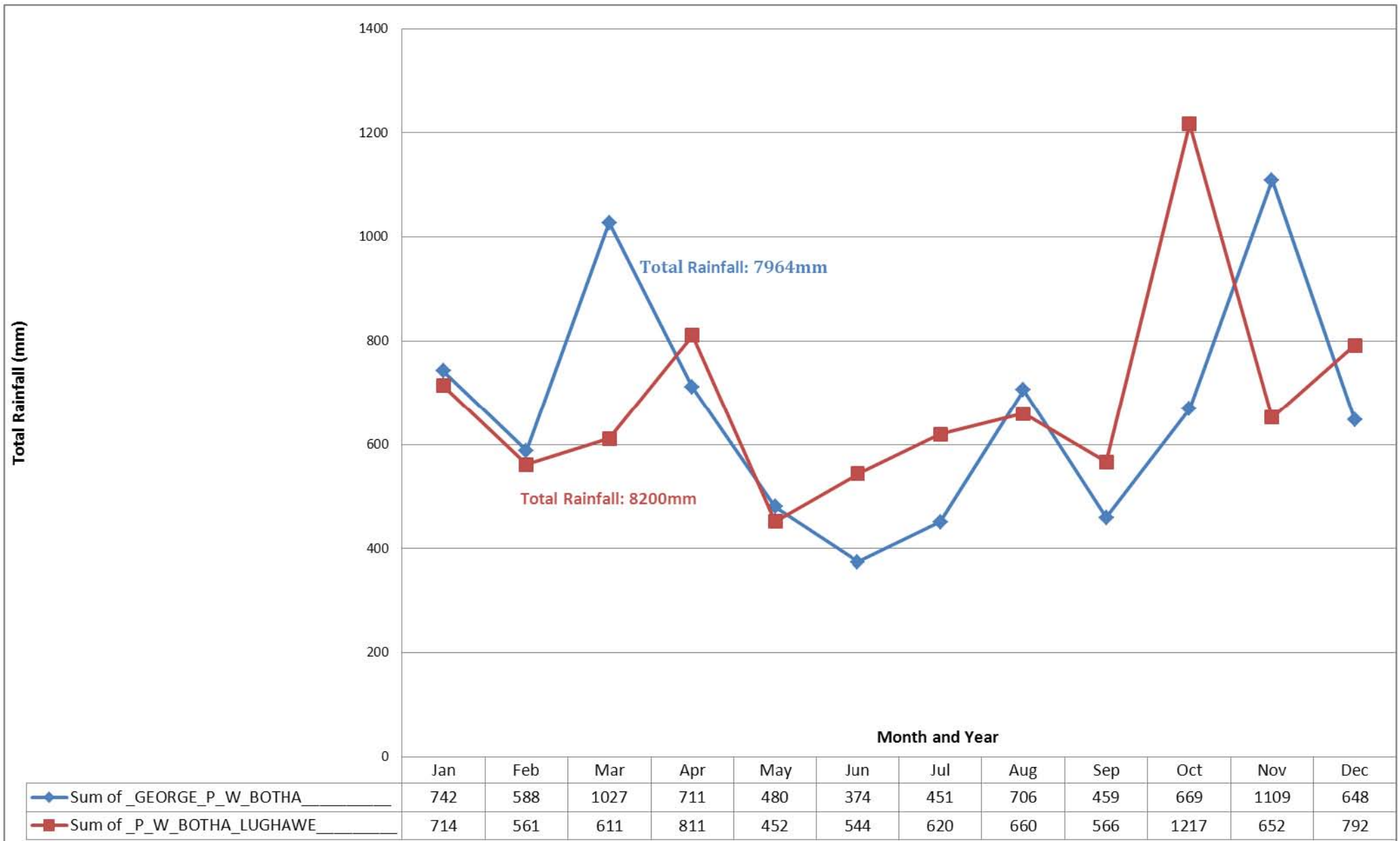


Figure 5.2: Monthly Rainfall (mm) over a 12 year period at P.W. Botha Lughawe (1978 - 1991) and a 12 year period at George P.W. Botha (1998 - 2009).

5.3. Determinants of hydrological drought

This study's focus was on the experience of the urban water scarcity in the George municipality associated with declining reservoir levels in the GRD. This necessitated investigating the intensity of the hydrological drought that affected the George Municipality, specifically the degree to which GRD storage levels fell below the monthly and annual average storage levels (Moorsom *et al*, 1995). This section presents findings on storage levels recorded at the GRD from 2000 - 2010 and relates these to annual rainfall prior to and during the drought.

5.3.1. Determining occurrence of hydrological drought

The researcher calculated the average annual GRD storage levels from 2000 - 2010 from weekly then monthly GRD storage level records supplied by Department of Water Affairs (DWA, 2011). These results are reflected in Table 5.3 and indicate that on average, the GRD reached 80.2% of Full Capacity Storage for the decade under study. The table also shows that in 2006, 2009 and 2010, annual dam levels respectively recorded 78.7%, 51.7% and 45.8% of FCS, which are lower than the average storage levels for the decade.

When these values are related to the annual storage mean of 7,281MI over the decade under study, it shows the GRD was 106.8% full in 2008. This dropped significantly to 63.6% of its average annual storage level within in a year, in 2009. And in 2010, it dropped even further to 60.6%. This is evidenced by the occurrence of markedly reduced GRD storage levels in 2009 (51.7%) and 2010 (45.8%) which lagged behind reduced rainfall in 2008 and 2009.

These low storage values and their lagged occurrence after reduced rainfall in 2008 and 2009 indicate that the George Municipality was affected by a hydrological drought.

| Year | Average Annual GRD Storage (MI) | Percentage (%) of Average Annual GRD Storage for the 10 year period (7,281MI) | Percentage (%) of FCS over 10 year period (9000MI) |
|----------------------|---------------------------------|---|--|
| 2000 | 7,872 | 108.1 | 87.9 |
| 2001 | 8,359 | 114.8 | 93.4 |
| 2002 | 8,139 | 111.8 | 90.9 |
| 2003 | 8,284 | 113.8 | 90.9 |
| 2004 | 7,225 | 99.2 | 80.7 |
| 2005 | 7,618 | 104.6 | 85.1 |
| 2006 | 7,888 | 108.3 | 78.7 |
| 2007 | 7,888 | 108.3 | 90.1 |
| 2008 | 7,775 | 106.8 | 86.8 |
| 2009 | 4,633 | 63.6 | 51.7 |
| 2010 | 4,414 | 60.6 | 45.8 |
| Total Average | 7,281 | 100 | 80.2 |

Table 5.3: Average Annual GRD Storage (MI), Percentage (%) of Average Annual GRD Storage and Percentage (%) of GRD FCS from 2000 - 2010

5.3.2. Annual cyclicity of GRD storage and storage trend

As the GRD constitutes the primary water supply source for the George Municipality, the sustainability of the town's water supply depends on seasonal rainfall to fill the dam. This generates an expected cyclicity in GRD storage levels, with full storage coinciding with heavier summer rainfalls followed by declining levels during the mid-year months, May, June and July.

Figure 5.3 shows this cycle changing markedly from 2005, with evidence of a dramatic reduction in storage to 50.5% of FCS by March 2006. A similar but more severe decline in storage levels is represented from 2009. This steep reduction in storage reached 26.9% FCS in February 2010. The Figure also shows the two highest average storage levels are earlier in the decade, in 2001 and 2003 while the two lowest were at the end of the decade in 2009 and 2010.

Figure 5.4 shows the trend of the average annual GRD storage levels over the ten year period from 2000 - 2010. Despite an indication of improved storage between 2007 and 2011, the graph represents an overall downward trend.



Figure 5.3: Monthly GRD Storage Level Percentages (%) from January 2000 - June 2011

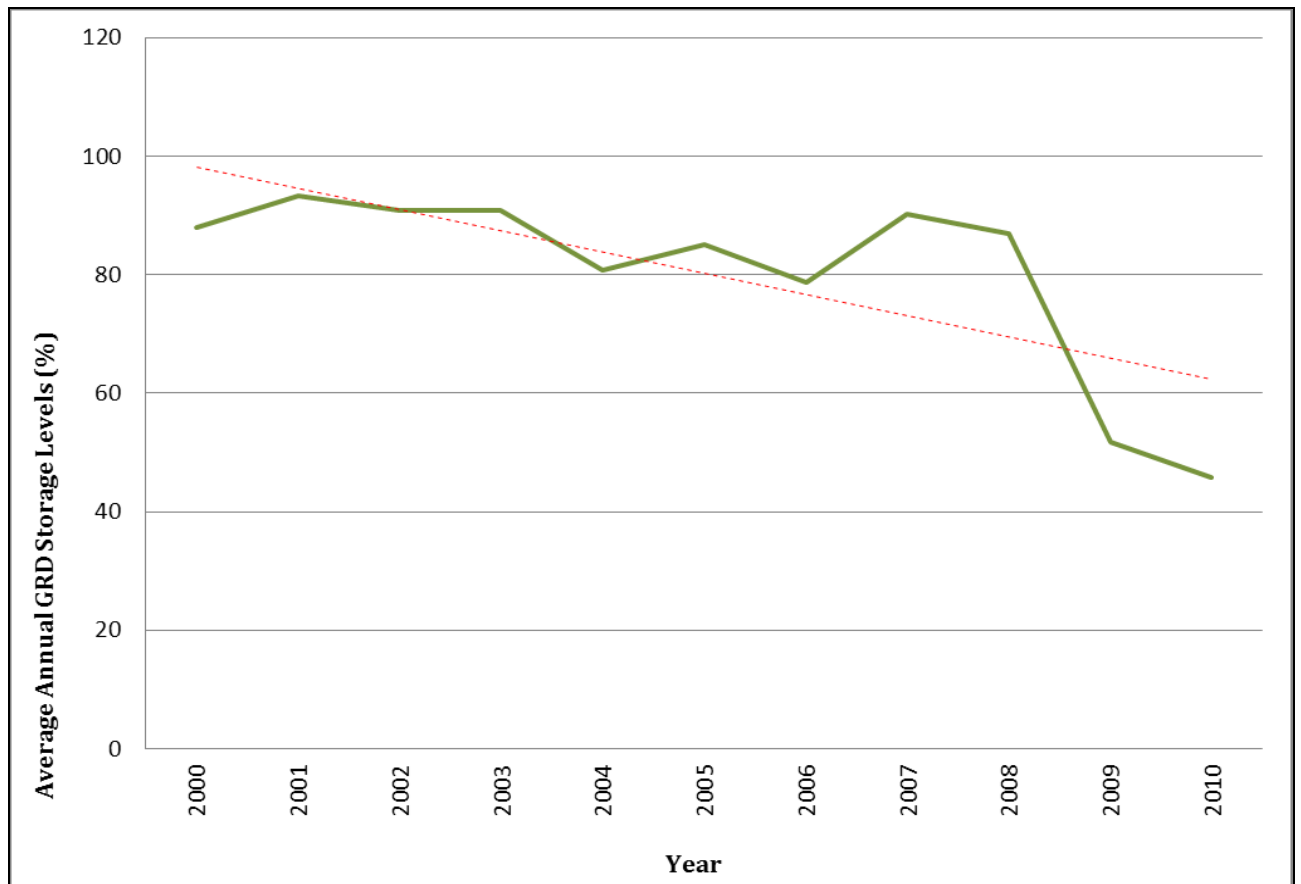


Figure 5.4: Average Annual GRD Storage Levels (%) from 2000 - 2010

5.3.3. GRD storage level and rainfall

The tight relationship between rainfall and dam storage levels is illustrated in Figure 5.5 and Table 5.4. This shows the close association between rainfall and lagged increase in GRD storage levels. It particularly is illustrated in March 2003, December 2004, and November 2008 when GRD storage levels were 90.3%, 76.3% and 84.0% respectively.

Table 5.4 shows that in March 2003, the GRD was at 90.28% FCS. Following a cut off low event that month (252mm rain) and further monthly rainfall of 144mm in May, the dam reached full capacity. It remained full for June and July 2003 with 100.07% and 97.01% FCS respectively, despite monthly rainfall of 28mm and 43mm for these months. In December 2004, although, GRD storage was at 76.3% FCS, following a 145mm event, storage levels again reached 100.2% by February 2005. In November 2008, the GRD storage levels were recorded at 84%. Following 161mm rainfall that month due to another cut off low, GRD storage levels rose to 97.16% in December (without any December rainfall). These examples indicate the effect heavy rainfall events have on dam storage levels, suggesting a modest 1-2 month lag between robust rainfall and dam response.

| Pre - Rainfall GRD Storage Level (%) | | | Post - Rainfall GRD Storage Level (%) | |
|--------------------------------------|------------------------------|----------------------|---------------------------------------|------------------------------|
| <i>Month and Year</i> | <i>GRD Storage Level (%)</i> | Rainfall (mm) | <i>Month and Year</i> | <i>GRD Storage Level (%)</i> |
| Nov-01 | 87.1 | 169 | Dec-01 | 99.98 |
| Mar-03 | 90.3 | 252 | Apr-03 and May-03 | 79.9 and 100.5 |
| May-03 | 100.5 | 144 | Jun-03 | 100.1 |
| Dec-04 | 76.3 | 145 | Jan-05 and Feb-05 | 76 and 100.2 |
| Aug-06 | 100.6 | 196 | Sep-06 | 100.23 |
| Nov-07 | 100.4 | 389 | Dec-07 | 100.4 |
| Nov-08 | 84 | 161 | Dec-08 | 97.16 |

Table 5.4: Pre-Rainfall GRD Storage Levels and Post-Rainfall GRD Storage Levels after Heavy Rainfall Events from 2001 - 2008

Figure 5.5 shows how the dam fills after a rainfall event, however the last 18 months is most valuable in understanding the increased consumption levels. Even after the November 2007 event of 389mm, the dam still managed to fall down to 60% FCS less than a year later. The same occurred in November 2008, when 161mm fell and 6 months later the dam storage levels were at 50% FCS.

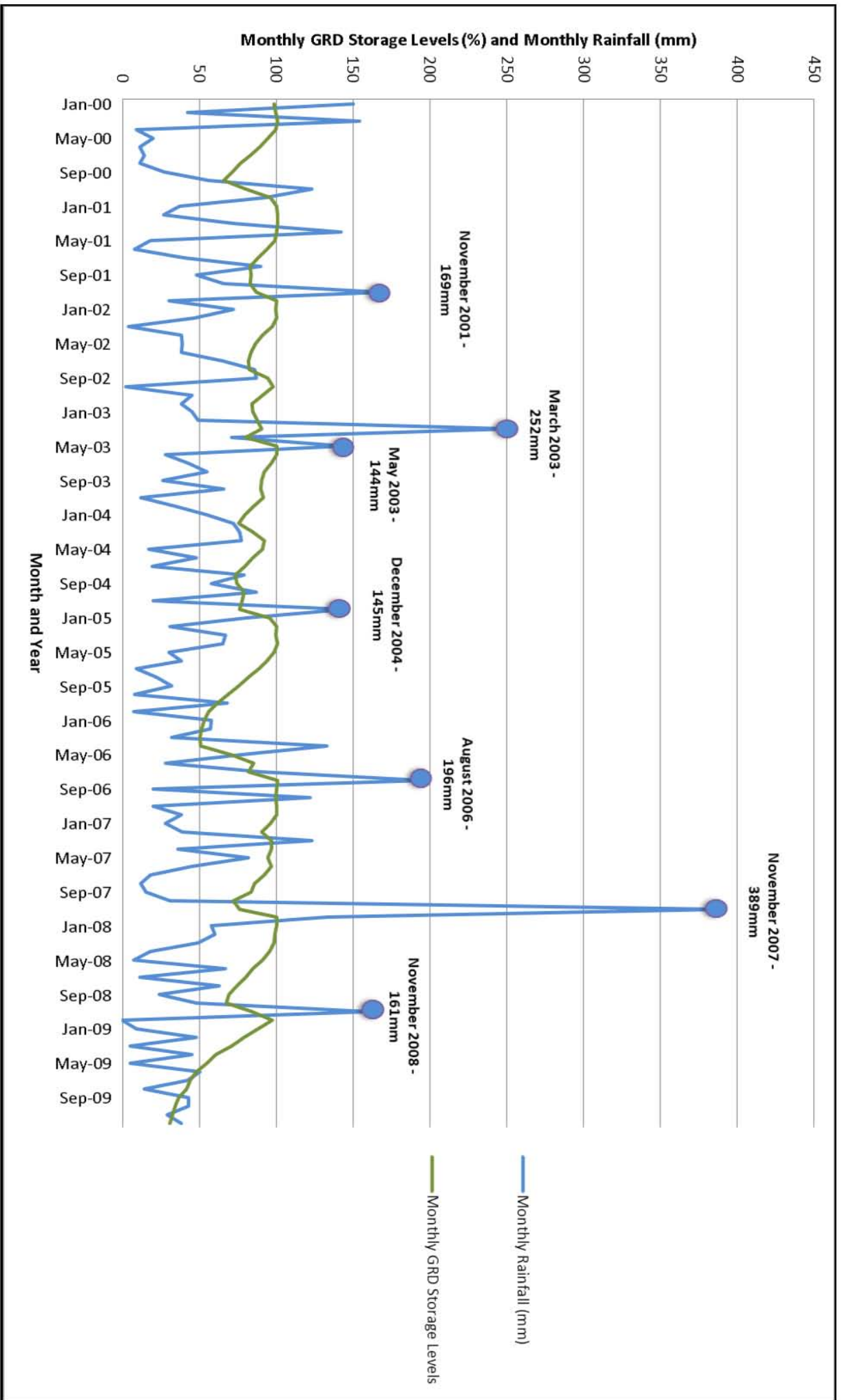


Figure 5.5: Monthly Average Rainfall (mm) and Monthly Average GRD Storage Percentage (%) Levels from January 2000 - December 2010

5.4. Determinants of urban water scarcity

Balancing urban water demand and supply in areas exposed to rainfall variability requires an understanding of urban water consumption patterns. Therefore the study also sought to quantify urban water consumption within the George Municipality to determine its contribution to the urban water scarcity experienced in 2009 – 2010.

5.4.1. GRD consumption levels

Annual and monthly GRD consumption levels are reflected in Table 5.5 and Figure 5.6. GRD consumption levels show a steady increase throughout the 11 years, but a steep incline is shown between 2006 and 2007, rising from 9,974.5MI to 11,606.0MI. This trend has continued rising, with the highest annual consumption of 12,650.1 MI (2008), recorded in the 10 year period. Figure 5.6 represents the increase graphically, indicating periods of sharp growth.

| Year | Annual GRD Consumption (MI) | Average Monthly GRD Consumption Levels (MI) | Percentage difference from previous year (%) | Average Monthly GRD Storage Levels (%) |
|-------------|-----------------------------|---|--|--|
| 2000 | 8,003.1 | 666.9 | | 87.5 |
| 2001 | 8,187.6 | 682.3 | 2.3 | 92.9 |
| 2002 | 9,164.2 | 763.7 | 11.9 | 90.4 |
| 2003 | 9,976.6 | 831.4 | 8.9 | 92.0 |
| 2004 | 10,105.2 | 842.1 | 1.3 | 80.3 |
| 2005 | 10,175.2 | 847.9 | 0.7 | 84.6 |
| 2006 | 9,974.5 | 831.2 | -2.0 | 78.3 |
| 2007 | 11,606.0 | 967.2 | 16.4 | 87.6 |
| 2008 | 12,650.1 | 1,054.2 | 8.9 | 86.4 |
| 2009 | 11,975.1 | 997.9 | -5.3 | 51.5 |
| 2010 | 7,741.4 | 645.1 | -35.4 | 49.0 |

Table 5.5: Annual GRD Consumption (MI), Average Monthly GRD Consumption Levels (MI), Percentage difference from the previous year (%) and Average Monthly GRD Storage Levels (%) from 2000 - 2010

Table 5.5 illustrates the growth of the consumption levels by calculating the percentage growth from the previous year. From 2006 to 2007, annual water consumption markedly increased by 16.4%. This rose further in 2008 by 8.9%.

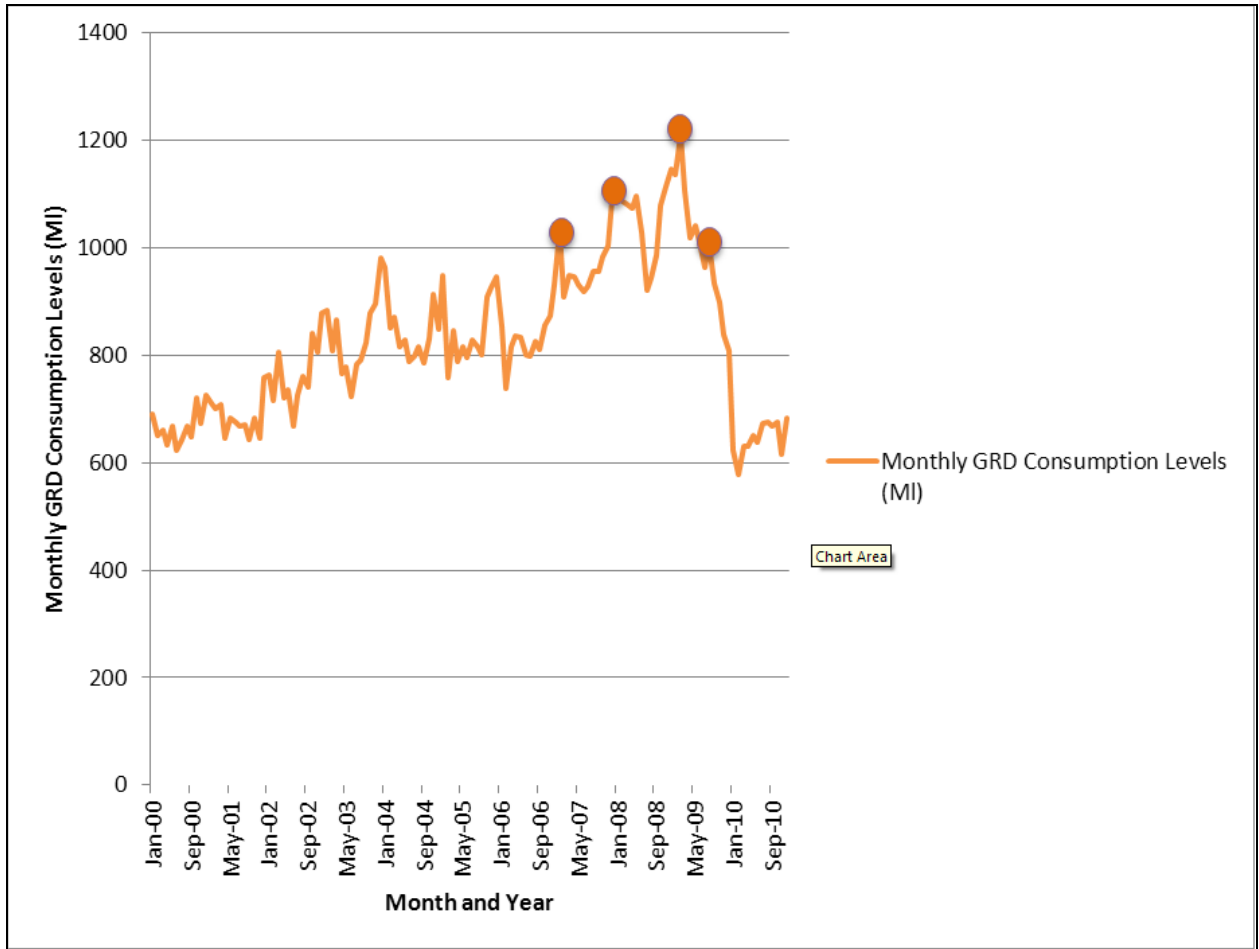


Figure 5.6: Monthly GRD Consumption Levels (MI) from January 2000 - December 2010

Figure 5.7 relates the monthly GRD consumption levels to GRD storage levels. Rising consumption levels are associated with a corresponding decline GRD in storage levels. Encouragingly however, the graph indicates that storage levels began to improve in June/July 2010, after consumption levels were driven down at the beginning of 2010. Trend lines have been added to the graphs to Figure 5.7 to represent the intercept in early 2007, when monthly consumption exceeded monthly storage availability. The large dots represented in the graph are to show when the monthly GRD consumption levels exceeded 1000MI.

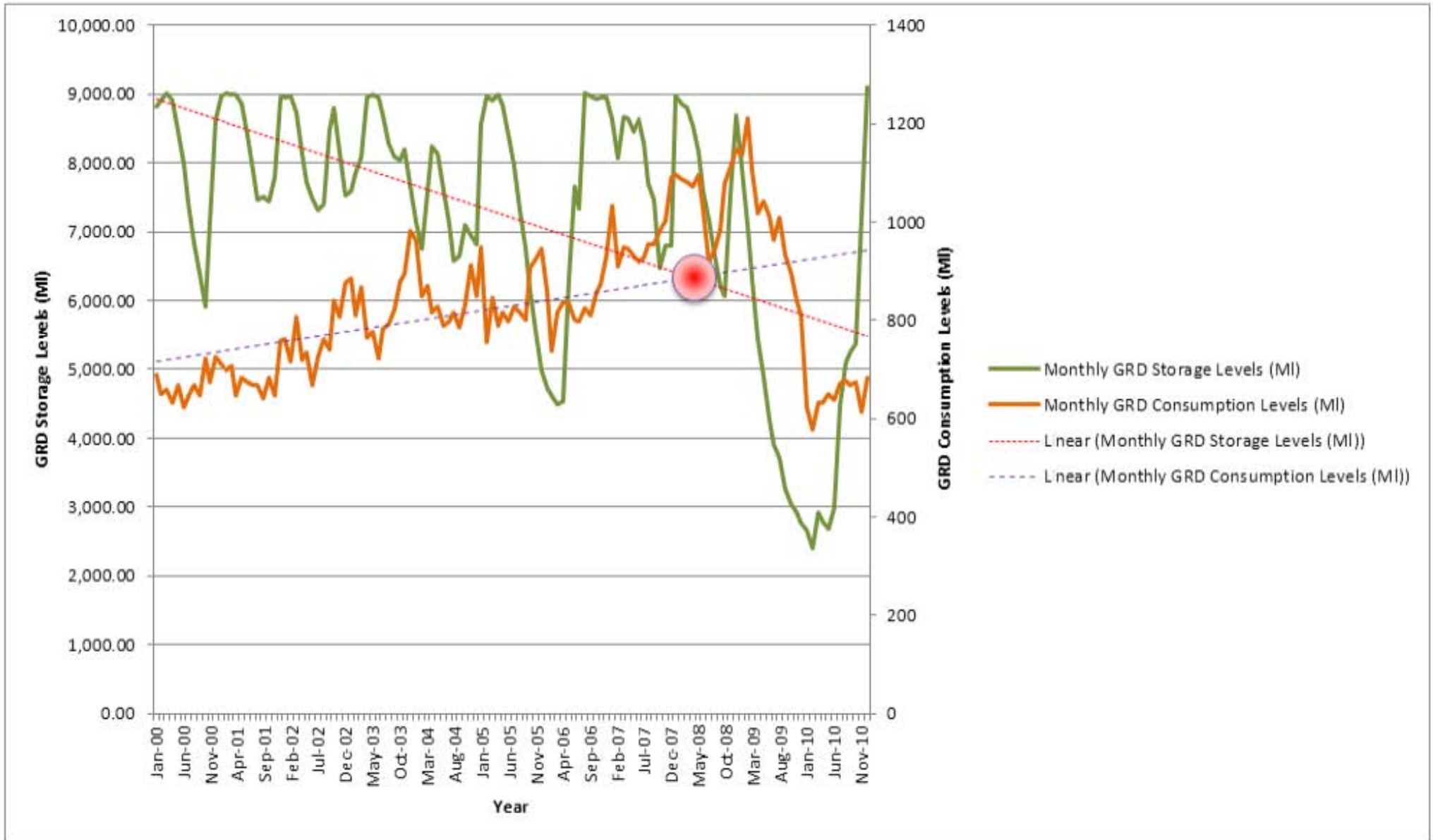


Figure 5.7: Monthly GRD Consumption Levels (MI) and Average Monthly GRD Storage Levels from January 2000 - December 2010.

5.4.2. The causal factors for urban water scarcity: reduced rainfall and escalating urban water consumption

This study sought to investigate the respective contributory roles of reduced rainfall and urban water consumption in the acute urban water scarcity experienced in George.

Figure 5.8 illustrates these relationships graphically. Specifically it represents annual rainfall, average annual GRD storage levels and annual GRD consumption levels from 2000 – 2010, as these are applied to its FCS value of 9000MI.

Annual rainfall reached its maximum over the 10-year record with close to 1,000mm in 2007 and subsequently decreased steeply to less than 400mm in 2009. However, in 2007, annual GRD consumption levels also began to increase rapidly, rising from 9,974.5MI in 2006, to 11,606.0MI in 2007 and the highest recorded in the 10 year period, 12,650.1MI in 2008. Fortunately, sharply reduced consumption reversed this trend in 2009, with increased public awareness along with strict water tariffs and restrictions (Pers. Communication, Eden District Disaster Management, 2011).

However, these interventions did not achieve significant improvements in urban water storage, with 2009 and 2010 recording the lowest average monthly GRD storage levels in the ten year period at 51.5% and 49% respectively. They did, however, reduce the rate of the GRD consumption levels by curbing the urban water usage. Table 5.6 and Figure 5.8 illustrate the prevailing complexity of managing the risk of urban water scarcity within the George municipality, under local conditions of highly variable rainfall, combined with sustained water demand.

Figure 5.8 specifically shows the reduction in rainfall from 2007 onwards, simultaneously with an increasing trend in GRD consumption levels. Reservoir storage levels decline markedly in both 2009 and 2010.

| Year | Annual Rainfall (mm) | Annual GRD Consumption (MI) | Average Monthly GRD Consumption Levels (MI) | Average Monthly GRD Storage Levels (MI) | Average Monthly GRD Storage Levels (%) |
|----------------------|----------------------|-----------------------------|---|---|--|
| 2000 | 710 | 8,003.1 | 666.9 | 7,872.4 | 87.5 |
| 2001 | 747 | 8,187.6 | 682.3 | 8,359.3 | 92.9 |
| 2002 | 561 | 9,164.2 | 763.7 | 8,138.7 | 90.4 |
| 2003 | 825 | 9,976.6 | 831.4 | 8,283.7 | 92.0 |
| 2004 | 753 | 10,105.2 | 842.1 | 7,224.8 | 80.3 |
| 2005 | 457 | 10,175.2 | 847.9 | 7,617.9 | 84.6 |
| 2006 | 871 | 9,974.5 | 831.2 | 7,043.2 | 78.3 |
| 2007 | 951 | 11,606.0 | 967.2 | 7,887.7 | 87.6 |
| 2008 | 566 | 12,650.1 | 1,054.2 | 7,775.4 | 86.4 |
| 2009 | 371 | 11,975.1 | 997.9 | 4,633.0 | 51.5 |
| 2010 | 665 | 7,741.4 | 645.1 | 4,413.8 | 49.0 |
| Total Average | 679.7 | 9,959.9 | 830.0 | 7,204.5 | 80.1 |

Table 5.6: Annual Rainfall (mm), Annual GRD Consumption (MI), Average Monthly GRD Consumption Levels (MI), Average Monthly GRD Storage Levels (MI) and Average Monthly GRD Storage Levels as percentage of FCS (%) from 2000 - 2010

The combined effect of decreased rainfall and increased GRD consumption levels is reflected in the downward trend of GRD storage levels in Figure 5.8.

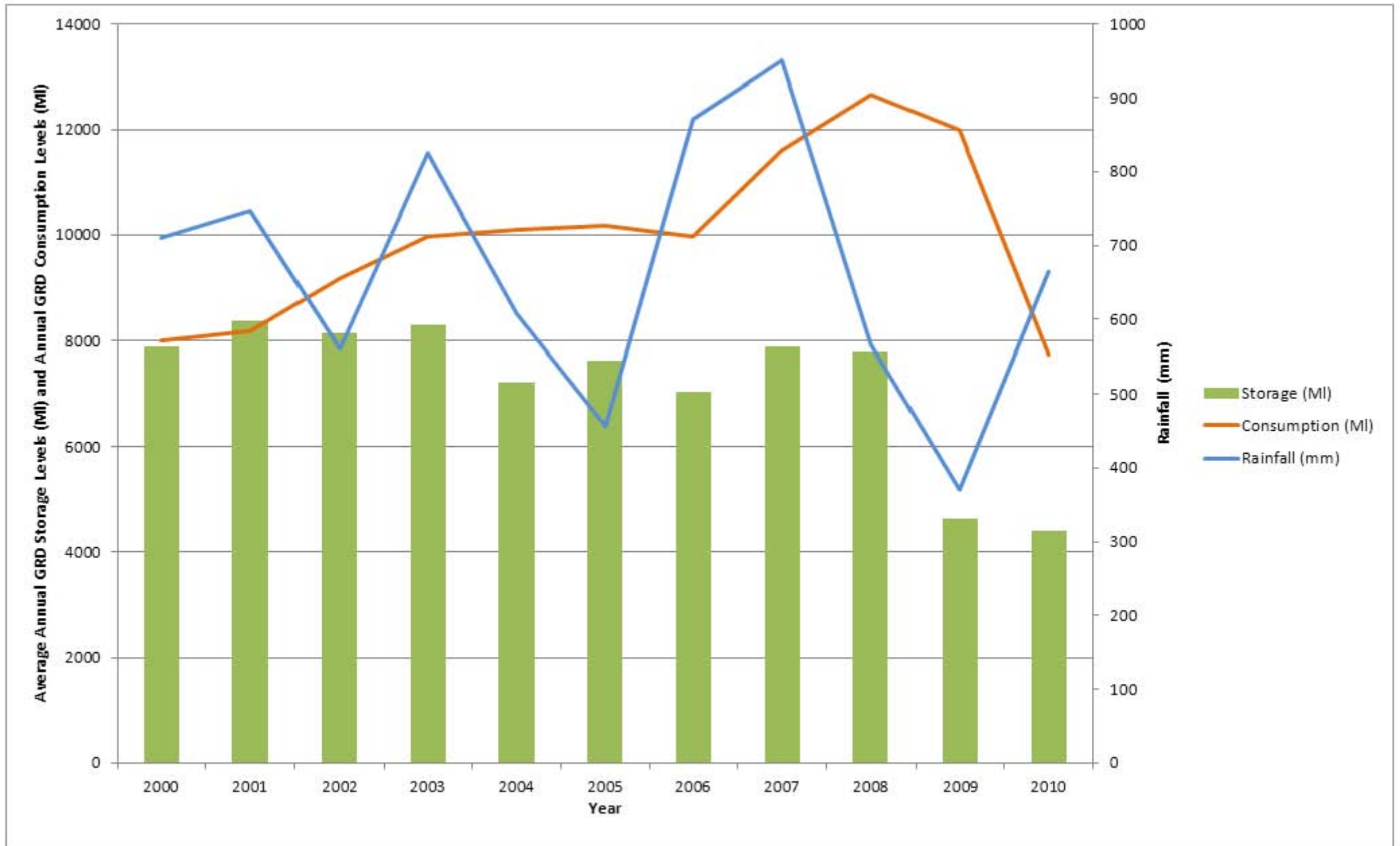


Figure 5.8: Average Annual GRD Storage Levels (MI), Annual GRD Consumption Levels (MI), George P.W. Botha Rainfall (mm) from 2000 - 2010

The contributory role of escalating urban water consumption to declining storage levels is further illustrated in Table 5.7 and 5.8. Table 5.7 adjusts annual consumption and average storage for population. It shows that over the ten year period from 2000 to 2009, per capita consumption remained steady at approximately 174 litres/person/day. However, actual dam storage declined markedly. This is unsurprising given that overall demand increased from 8,003MI in 2000 to 12,650MI in 2008, reflecting approximately a 60% increase in supply requirements.

Table 5.8 relates the same consumption values to the Historical Firm Yield (m³/year) estimated in the Garden Route Operation Analysis Report (IWR, 2011). When annual consumption is related to the HFY of 12.1m³/year a markedly escalating trend emerges. For instance, while annual consumption constituted only 66% of HFY in 2000, it rose to 105% in 2008 (the year prior to the meteorological drought).

The lagged effect of this elevated consumption increased the George Municipality's vulnerability to the low rainfall year that followed in 2009.

| Year | Annual Consumption (MI) | Average Annual Storage (MI) | Rainfall (mm) | Population | Consumption of FCS (MI/Capita) | Consumption: l/Capita/Day | Storage/Capita (MI/capita) | Storage/Capita /Day |
|------|-------------------------|-----------------------------|---------------|------------|--------------------------------|---------------------------|----------------------------|---------------------|
| 2000 | 8,003 | 7,872 | 710 | 129180 | 0.062 | 170 | 0.061 | 167 |
| 2001 | 8,188 | 8,359 | 747 | 135,409 | 0.060 | 166 | 0.062 | 169 |
| 2002 | 9,164 | 8,139 | 561 | 141,638 | 0.065 | 177 | 0.057 | 157 |
| 2003 | 9,977 | 8,284 | 825 | 148,153 | 0.067 | 184 | 0.056 | 153 |
| 2004 | 10,105 | 7,225 | 608 | 154,968 | 0.065 | 179 | 0.047 | 128 |
| 2005 | 10,175 | 7,618 | 457 | 162,097 | 0.063 | 172 | 0.047 | 129 |
| 2006 | 9,975 | 7,043 | 871 | 169,553 | 0.059 | 161 | 0.042 | 114 |
| 2007 | 11,606 | 7,888 | 951 | 177,352 | 0.065 | 179 | 0.044 | 122 |
| 2008 | 12,650 | 7,775 | 566 | 185,511 | 0.068 | 187 | 0.042 | 115 |
| 2009 | 11,975 | 4,633 | 371 | 194,044 | 0.062 | 169 | 0.024 | 65 |
| 2010 | 7,741 | 4,414 | 665 | 202,870 | 0.038 | 105 | 0.022 | 60 |

Table 5.7: Annual Consumption (MI), Average Annual Storage (MI), Rainfall (mm), Population, Consumption of FCS (MI/Capita), Consumption: Litres per day per person (l/capita/day), Storage/Capita (MI/Capita) and Storage per day per person (St/Capita/Day) from 2000 - 2010

| Year | Annual Consumption (MI) | Historical Firm Yield (m ³ /a) | Percentage (%) of Historical Firm Yield | Percentage (%) Increase per Annum |
|------|-------------------------|---|---|-----------------------------------|
| 2000 | 8,003 | 12.1 | 66 | |
| 2001 | 8,188 | 12.1 | 68 | 2 |
| 2002 | 9,164 | 12.1 | 76 | 12 |
| 2003 | 9,977 | 12.1 | 82 | 9 |
| 2004 | 10,105 | 12.1 | 84 | 1 |
| 2005 | 10,175 | 12.1 | 84 | 1 |
| 2006 | 9,975 | 12.1 | 82 | -2 |
| 2007 | 11,606 | 12.1 | 96 | 16 |
| 2008 | 12,650 | 12.1 | 105 | 9 |
| 2009 | 11,975 | 12.1 | 99 | -5 |
| 2010 | 7,741 | 12.1 | 64 | -35 |

Table 5.8: Annual Consumption (MI), Historical Firm Yield (m³/annum), Percentage of Historical Firm Yield and Percentage Increase per Annum from 2000 - 2010

5.5. Identification of other intervening factors and measures

This section examines the intervening factors that either reduced exposure to low rainfall, or reversed acute urban water scarcity in this case study. These include severe weather events that played a protective role in replenishing dam storage levels. They also include critical drought management interventions during the drought period when the natural 'protective processes' such as severe weather events failed to occur. These intervening factors and measures are presented in Figures 5.9, and 5.10 as well as Table 5.9.

5.5.1. Severe weather events play a protective role

During the past seven years, the Southern Cape has also been affected by numerous severe weather events (Holloway *et al*, 2010) While these have generated severe flood-related property losses, they have also conferred protective benefits by replenishing reservoir levels. Figure 5.9 illustrates this protective relationship by relating the dates of recorded severe weather events to monthly GRD storage levels.

This suggests that severe weather events are playing a protective role in dam level storage. This relationship is clearly evidenced in 2006. During this period, dam levels decreased rapidly, falling to 50% of FCS in March 2006. In August 2006, the George Municipality experienced a cut off low, a severe weather event which resulted in rainfall of 196mm that subsequently increased storage levels to 100.62%. However three months prior to the August 2006 event, there was unusually higher rainfall which helped to raise the GRD storage levels. This pattern recurred in November 2007 and

November 2008 resulting in 389mm and 161mm rainfall respectively. These events raised dam levels from 76.03% in November 2007 to 100% FCS in December 2007. However in 2009, in the absence of any heavy rainfall events, and exacerbated by high urban water demand, GRD storage levels plummeted to 26.9% of FCS.

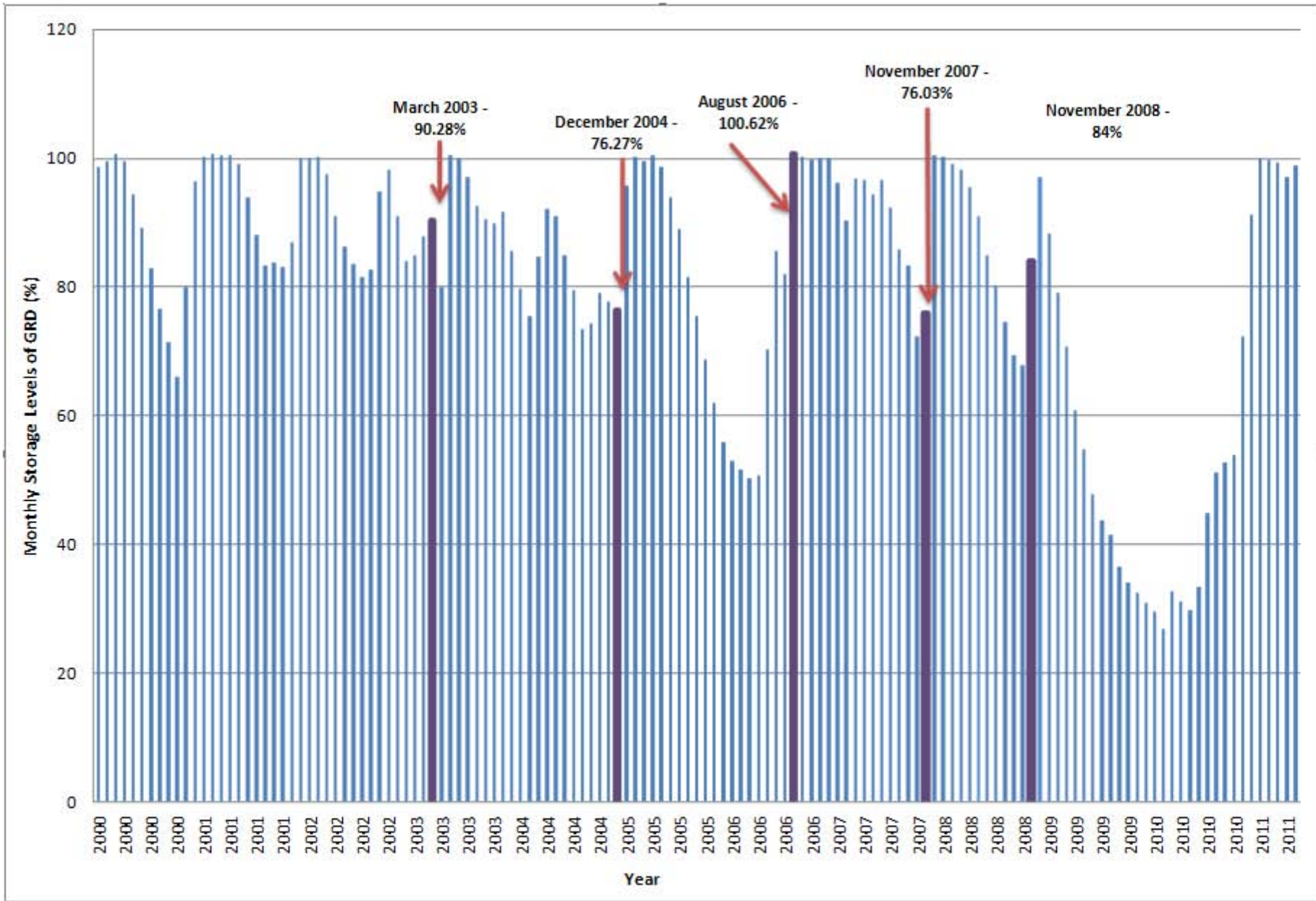


Figure 5.9: Monthly GRD Storage Levels from January 2000 - May 2011 with Severe Weather Events

5.5.2. Municipal and District Drought Management Strategies

From January 2009 - May 2010, numerous interventions were undertaken to avert a water emergency. These are presented and sequenced in Figure 5.10 and Table 5.9. For instance, the first water restrictions and monetary fines were introduced in April 2009 and subsequently strengthened twice during the course of that year. From December 2009 to June 2010, water tariffs, water restrictions and public awareness campaigns were at full strength.

However, despite these interventions initiated in January 2009, GRD storage levels continued to drop from a December 2008 high of 97.2% to 47.8% in June 2009. This was exacerbated by low rainfall as well as sustained high water consumption.

Figure 5.10 further shows that declining GRD storage levels only began improving from June 2010. This followed the activation of the Outeniqua Waste Water Treatment Works in May 2010 and welcome rainfall of 100mm in June 2010. The blue clouds shown on the figure shows significant (over 100mm) rainfall within a month.

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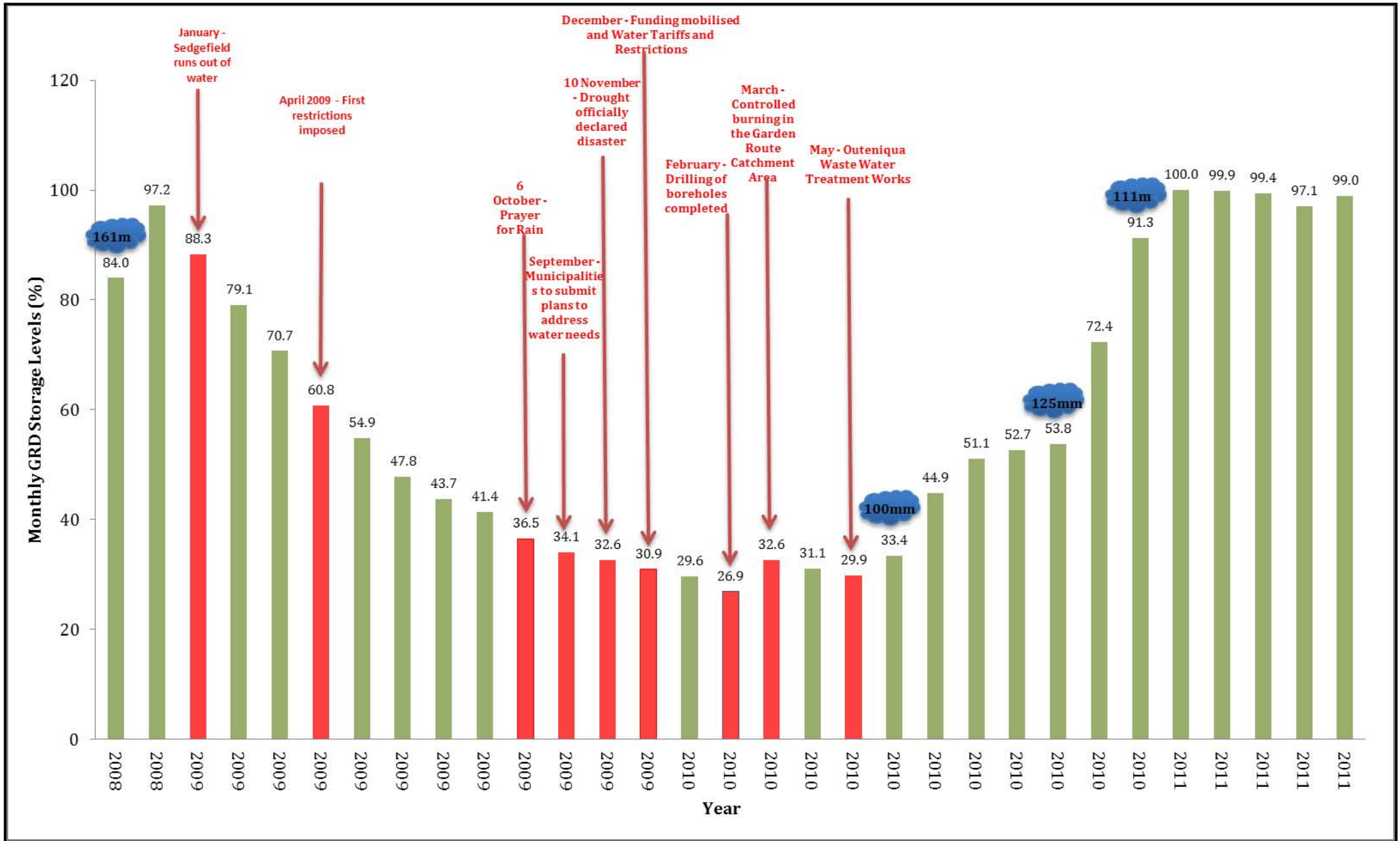


Figure 5.10: Monthly GRD Storage Percentage (%) Levels November 2008 to May 2011 with detailed management strategies timeline

| <i>Phase</i> | <i>Month</i> | <i>Action Taken</i> | <i>Government/Private (District/Provincial/National)</i> | <i>Description</i> |
|--|---------------------------|---|---|---|
| First Alert | January 2009 | Authorities warned of low levels of rainfall in coming months | | Sedgefield ran out of water. Water had to be trucked from George to Sedgefield. Knysna also experienced severe water scarcity |
| Proactive Measures | April 2009 | First restrictions imposed - Strengthened twice | George Municipality | |
| Proactive Measures | October 2009 | Prayer for rain at Outeniqua Stadium | George Municipality | |
| Proactive Measures | August 2009 | Situation in Sedgefield. Meetings started being held and drought management plan was drawn up in George | George Municipality, Eden District Disaster Management, Western Cape Disaster Management Centre, Department of Water Affairs, South African Weather Service | George Municipality called on the Province to have GRD raised. Reports devised to engage National Disaster Management and the National Treasury. SAWS did a historical climatic analysis and DWA did a historical analysis of rivers |
| Emergency Management/ Impact verification | September 2009 | Municipalities to submit business plans to address current needs, Emergency tariffs, monitor high water usage, district-wide awareness campaigns, re-prioritise capital budget, implement short and medium-term solutions, commit human and financial resources required to address crisis, | Western Cape Disaster Management Centre, Eden District Disaster Management Department of Water Affairs, South African Weather Service, Agri SA | Implemented emergency tariffs immediately. Installed low pressure water systems immediately. Monitored consumers with high water consumption & took appropriate steps to limit their water use. Committed financial & human resources to Joint District Communications Team (with a district-wide public awareness campaign). Reprioritised the operational budget for law enforcement, public awareness, water flow control. Reprioritised capital budget and implemented short medium-term solutions. Committed human financial resources needed to address crisis. |
| Classification and Declaration of Local Disaster | 10 November 2009 | Declaration of disaster | Act. Executive Municipal Manager requests for the Eden District to be declared as a local disaster | |
| Funding mobilised | December 2009 | | National Treasury | |
| Proactive Measures | December 2009 - June 2010 | Restrictions | George Municipality | An increase in water tariffs. Current use of grey water only for garden irrigation filling of swimming pools with potable water prohibited for irrigation of sports fields, washing of vehicles and cleaning of hardened surfaces. If contravened, the person(s) is subject to fines/imprisonment |
| Proactive Measures | February 2010 | Increase Water Supply - Drilling Bore holes | George Municipality | |
| Proactive Measures | March 2010 | Increase Surface Run-off - Controlled burning | George Municipality | |
| Proactive Measures | May 2010 | Increase Water Supply - Outeniqua Waste Water Treatment Works | George Municipality | Re-use of waste water, completion in May 2010 |

Table 5.9: Sequence of Drought Management Interventions George Municipality 2009-2010

5.5.3. Managing urban water supplies under complex conditions

The management of this episode of acute urban water scarcity illustrates the complexity of relationships between highly variable rainfall and unregulated water consumption. For instance, Figure 5.11 and Table 5.10 represent values for monthly rainfall, GRD storage levels and consumption from January 2008 – December 2010. Annual water consumption levels prior to the water crisis had progressively increased, rising to 11,606.0MI in 2007.

Moreover, despite reduced rainfall in 2008, high consumption levels persisted for much of 2009. These began to decrease only in the latter months as awareness of drought conditions increased, followed by the official declaration of the drought in November 2009. This was measurably reflected in a monthly consumption of only 615,3MI in November 2009 compared with a high of 1,146.3MI in December 2008.

GRD storage levels reflected the combined impact of variable rainfall and rising, then falling urban water consumption. For instance, GRD storage levels fell to an historic low in February 2010, with only 2,404.7MI in the GRD. However, by December 2010, the GRD had filled to 9,112.5MI (or more than 100% FCS). This replenishment occurred despite lower than average annual rainfall in 2010 of 655mm (compared with an expected average annual of 702mm). It is explained by sustained low consumption levels of under 700MI per month.

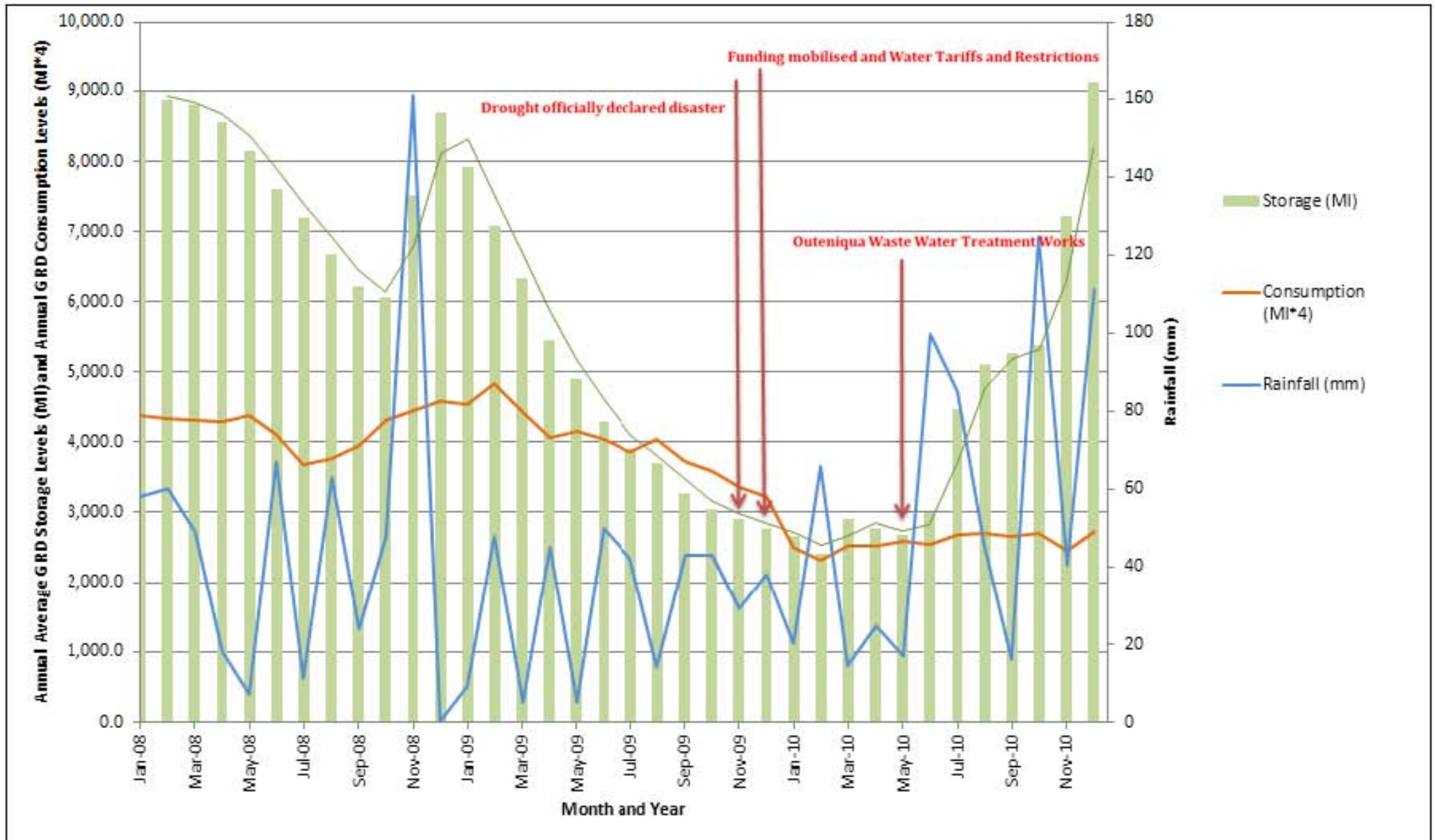


Figure 5.11: Combination of Annual Average GRD Storage Levels (MI), Annual GRD Consumption Levels (MI*4), Rainfall Levels (mm) and Major Management Strategies focused in on the Period 2008, 2009 and 2010.

| Year | Monthly GRD Consumption (MI) | Increase/Decrease GRD Consumption from previous month | Average Monthly GRD Storage (MI) | Increase/Decrease GRD Storage from previous month | Monthly Rainfall (mm) | Stage of Process/ Local Management Response |
|------------------|------------------------------|---|----------------------------------|---|-----------------------|--|
| 08-Jan | 1,097.8 | | 8,974.5 | | 58.0 | |
| 08-Feb | 1,086.8 | Decrease | 8,874.7 | Decrease | 60.0 | |
| 08-Mar | 1,080.3 | Decrease | 8,800.3 | Decrease | 49.0 | |
| 08-Apr | 1,072.8 | Decrease | 8,547.2 | Decrease | 18.0 | |
| 08-May | 1,095.9 | Increase | 8,150.9 | Decrease | 7.0 | |
| 08-Jun | 1,028.3 | Decrease | 7,595.8 | Decrease | 67.0 | |
| 08-Jul | 919.8 | Decrease | 7,188.3 | Decrease | 11.0 | |
| 08-Aug | 943.9 | Increase | 6,675.9 | Decrease | 63.0 | |
| 08-Sep | 985.7 | Increase | 6,213.5 | Decrease | 24.0 | |
| 08-Oct | 1,079.5 | Increase | 6,065.4 | Decrease | 48.0 | |
| 08-Nov | 1,112.9 | Increase | 7,520.3 | Increase | 161.0 | |
| 08-Dec | 1,146.3 | Increase | 8,698.5 | Increase | 0.0 | |
| Sub Total | 12,650.0 | Increase | 7,775.4 | Decrease | 566.0 | |
| 09-Jan | 1,135.4 | Decrease | 7,908.6 | Increase | 9.0 | Sedgefield runs out of water |
| 09-Feb | 1,211.5 | Increase | 7,081.5 | Decrease | 48.0 | |
| 09-Mar | 1,105.7 | Decrease | 6,329.6 | Decrease | 5.0 | |
| 09-Apr | 1,017.6 | Increase | 5,446.4 | Decrease | 45.0 | First restrictions imposed |
| 09-May | 1,041.7 | Increase | 4,913.3 | Decrease | 5.0 | |
| 09-Jun | 1,010.8 | Decrease | 4,280.8 | Decrease | 50.0 | |
| 09-Jul | 964.2 | Decrease | 3,915.9 | Decrease | 42.0 | |
| 09-Aug | 1,008.1 | Increase | 3,709.5 | Decrease | 14.0 | |
| 09-Sep | 933.3 | Decrease | 3,270.6 | Decrease | 43.0 | Submission of municipal water plans |
| 09-Oct | 898.6 | Decrease | 3,053.6 | Decrease | 43.0 | Prayer for Rain |
| 09-Nov | 839.4 | Decrease | 2,918.3 | Decrease | 29.0 | Drought officially declared |
| 09-Dec | 808.7 | Decrease | 2,768.0 | Decrease | 38.0 | Funding mobilised and Water tariffs and restrictions |
| Sub Total | 11,975.0 | Decrease | 4,633.0 | Decrease | 371.0 | |
| 10-Jan | 623.4 | Decrease | 2,653.1 | Decrease | 20.0 | |
| 10-Feb | 577.4 | Decrease | 2,404.7 | Decrease | 66.0 | Drilling of boreholes |
| 10-Mar | 631.0 | Increase | 2,920.4 | Increase | 15.0 | Controlled burning |
| 10-Apr | 631.2 | Increase | 2,783.8 | Decrease | 25.0 | |
| 10-May | 650.5 | Increase | 2,674.2 | Decrease | 17.0 | Outeniqua WWTW |
| 10-Jun | 638.3 | Decrease | 2,989.6 | Increase | 100.0 | |
| 10-Jul | 672.3 | Increase | 4,477.9 | Increase | 85.0 | |
| 10-Aug | 676.0 | Increase | 5,099.9 | Increase | 46.0 | |
| 10-Sep | 667.2 | Decrease | 5,255.0 | Increase | 16.0 | |
| 10-Oct | 675.2 | Increase | 5,369.2 | Increase | 125.0 | |
| 10-Nov | 615.3 | Decrease | 7,224.9 | Increase | 41.0 | |
| 10-Dec | 683.6 | Increase | 9,112.5 | Increase | 111.0 | |
| Sub Total | 7,741.4 | Increase | 4,413.8 | Increase | 667.0 | |

Table 5.10: Monthly GRD Consumption Levels, Average Daily GRD Storage Levels (MI), , Monthly Rainfall Levels (mm) and Major Management Strategies focused on the period 2008, 2009 and 2010.

5.6. Summary

This chapter presented the findings on the risk conditions that drove the acute urban water scarcity in the George Municipality.

The chapter reported that the drought was both meteorological and hydrological. It examined aspects of rainfall that included the increasing atmospheric variability, shifting seasonality and decreasing trends in recent rainfall record. GRD storage and consumption level data were also presented and analysed. These indicated that the downward trend in storage was attributed to both increasing urban water consumption and decreasing rainfall. The results indicated that prior to the drought, urban water consumption exceeded maximum water availability estimated for the GRD.

The chapter continued by illustrating the role played by heavy rainfall events in averting water scarcity emergencies in previous years. It concluded by presenting the sequence of management interventions that reversed the declining trend in available water storage and underlined the importance of managing urban water demand in this case study.

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CHAPTER SIX

DISCUSSION AND CONCLUSION

6.1. Introduction

This final chapter discusses the urban water scarcity findings in relation to prevailing literature on drought risk reduction and the management of urban risk in Africa. It places particular emphasis on management of urban water demand and urban water scarcity. It concludes by revisiting the study objectives and suggests areas for future study.

6.2. The 2009 – 2010 George Drought: Findings revisited

This research project sought to investigate the 2009 – 2010 George drought, an event popularly attributed to rainfall failure and associated with climate change (George Herald, 2009). With a specific focus on storage levels of the Garden Route Dam that supplies the municipality, the researcher examined rainfall prior to, and during, the drought event. She also determined daily, monthly and annual rainfall in the 30 years prior to the drought event. Recognising that urban water consumption constituted a central factor in GRD storage levels, the researcher also quantified monthly, then annual GRD consumption levels from 2000 – 2010. The findings reveal a complex urban risk profile associated with both climate variability and the management of urban water demand.

6.2.1 Confirming Meteorological Drought

Research findings indicate the occurrence of “back-to-back” meteorological droughts in 2008 and 2009. This was evidenced by less than 75% of the average annual rainfall for the P.W. Botha Lughawe and George P.W. Botha stations (702mm) for the 31 year study period. Application of the SAWS meteorological drought criterion also revealed a meteorological drought in 2005, where rainfall was at 457mm or 65.1% of the average annual rainfall (2011).

As described in Chapter 3 and 5, the reduction in rainfall reported for the George Municipality coincided with a global El Niño which extended from June 2009 – May 2010 (NOAA, 2009). Prevailing literature on ENSO suggests that this may have contributed to the diminished rainfall, in addition to the drying trend identified in climate change projections (Midgley *et al*, 2005)

6.2.2. Rainfall trends, Rainfall Variability and Seasonality

Given prevailing concerns about changing rainfall frequencies and magnitude associated with climate change (Midgley *et al*, 2005) the study also examined rainfall variability and seasonality.

Results demonstrated declining annual rainfall, falling from a maximum 1,214mm in 1981 to 371mm in 2009. Although this study predominantly used data derived from the P.W. Botha Lughawe and George P.W. Botha, rainfall data from four other stations located in the municipality showed decreasing rainfall. This declining rainfall however was punctuated by periodic heavy rainfall events, most of which occurred within the six years prior to the 2009 meteorological drought.

Moreover, closer examination of 'high' and 'low' rainfall reveals that the two driest years of the 31 year period occurred in 2005 and 2009 with 457mm and 371mm respectively. However, the second heaviest rainfall year over the 31 year period occurred in 2007, recording rainfall of 951mm. Such findings are consistent with prevailing climate change projections which anticipate increased variability and intensity rainfall events, along with increasing extremes and lengthening dry periods. (Midgley *et al* 2005, 2010:42).

In addition, findings suggest that there is a shift in seasonality with rainfall consolidating around the summer rainfall months at the end of the calendar year. This is evidenced by the shift in summer rain one month later to October – December. Similarly, it is indicated with autumn rains shifting one month earlier to February – April.

Such findings on declining annual rainfall, heavier rainfall events and seasonal consolidation of rainfall between October and April are all consistent with current climate projections for the Southern Cape (Midgley *et al*, 2005).

6.2.3. Hydrological Drought

Although meteorological drought may be determined by establishing rainfall deviation from the climate mean over a 30 year period, the occurrence of hydrological drought is more difficult to establish. This is because its occurrence is influenced by other factors in addition to rainfall (Wilhite, 2005). The criterion applied in this study adapted Moorsom *et al* (1995) definition of hydrological drought, "...occurs when water reserves fall below the average" and applied it to GRD storage levels. Study results confirmed that hydrological drought conditions indeed prevailed in 2009 and 2010, as the average GRD storage levels during these two years were 51.7% and 45.1% respectively. These values fell well below the GRD's average annual FCS of 80.2% from 2000 – 2010.

6.2.4. Urban Water Consumption

Prior to this study, limited attention had been applied to the role of urban water consumption in the George Municipality as a key co-risk driver of urban water scarcity along with adverse meteorological conditions. Specifically, there was no reference to changing consumption levels in

the years prior to the drought; although the municipality's considerable population growth had been acknowledged (George Local Municipality IDP, 2011/2012).

This study shows that the George Municipality's annual GRD consumption rose substantially from 8,003.1MI in 2000 to 11,606.0MI in 2007 long before the 2009 – 2010 drought. This represented an approximate 45% increase in annual water consumption. Significant and unexplained annual consumption increases were particularly evident between 2007 and 2009 when yearly demand rose to a maximum of 12,650.1MI in 2008, exceeding Historical Firm Yield projections of 12,100 MI. This was despite the relatively low annual rainfall in 2008 and therefore warning of possible meteorological drought in 2009. Monthly consumption only adjusted downwards towards the end of 2009, with monthly levels stabilizing at less than 800MI for the rest of 2010.

Such results underline the urgency for strengthened urban water demand as stressed by Mafuta *et al* (2011) and Iglesias *et al* (2007). The findings suggest that the severity of the 2009 – 2010 urban water scarcity in the George Municipality should more accurately be attributed to the combined impact of rainfall failure and poorly managed increasing urban water demand. This is evidenced by the achievement of 100% FCS in 2010, with vigilant controls on urban water demand despite lower than average rainfall of 665mm that year.

Such findings are consistent with disaster risk conceptualisations which argue that risk is the outcome of both hazard and vulnerability factors. In this instance, severe water scarcity risks were co-produced by hazardous meteorological drought conditions, amplified by the internal vulnerability of poor water demand management.

6.3. Managing drought events or reducing risk of urban water scarcity

6.3.1. Drought as a root cause of African disasters

Findings from this study also resonate with observations by Pelling and Wisner (2009) that African disasters are erroneously attributed to drought. In addition, the George Municipality case study shows that unregulated municipal water consumption constituted an important co-risk driver for the increasing urban water scarcity in addition to declining rainfall. This corroborates Applegren's (1998) arguments that water scarcity risks may be increased by development in the absence of robust water demand management. Moreover, the findings signal important differences between strengthened preparation for managing a "drought event" and ongoing development efforts to reduce the risks associated with urban water scarcity from 2000 onwards. In this case study, the "early warning signals" of escalating urban water scarcity risk were evident long before "trailing" indicators of low dam storage levels were recognised.

However, this unchecked and escalating rise in urban water consumption appeared to go undetected in George. As a result, it increased the municipality's vulnerability to serious meteorological drought shocks. Authors such as Mafuta *et al* (2011) and Iglesias *et al* (2007) again underline the need for integrated water management as essential for protecting scarce water supplies in growing African cities exposed to climate variability.

The results also raise questions about prevailing interpretation of hydrological drought in rapidly growing urban centres that depend on water storage and where unregulated consumption can "drive down" storage levels as significantly as rainfall failure. These observations are consistent with concerns raised by UNISDR (2011) and Iglesias *et al* (2007) that prevailing indicators for hydrological drought are inadequate and require further development.

6.3.2. The Protective Role of Severe Weather Events

With Africa being recognized as an increasingly urbanizing continent with much of its population residing in informal settlements, there has been growing attention on severe weather and flood exposure of major African cities. However, less attention has been directed to urban water scarcity as the continent's town and city populations grow.

The findings from this study also show that the 'disastrous' severe weather events that has caused serious damage to the George Municipality (Pers. Communication, Eden District Disaster Management, 2011) in the last decade actually could also be playing a coincidental 'protective' role in supplying the municipality with water in times of duress. This was most evident in 2006, when intense rainfall from a cut-off low pressure system successfully raised the GRD storage levels to FCS, reversing a downward trend. It is significant also, that the absence of heavy rainfall events in 2009 constituted a risk factor for the subsequent drought.

6.4. The necessity for IWRM in a highly complex and variable climate

6.4.1. Contributors to the increasing urban water demands in the George Municipality

Although not the focus of the study, interesting research questions were generated from the increase in GRD consumption levels from 2000 and then an even steeper incline from 2007 – 2009. Natural population growth as well as in migration have been noted (Thomas, 2005). However these, factors alone do not explain the rapid escalation in consumption from 2007 onwards which significantly decreased the GRD storage levels.

Possible explanations include "coping responses" to the reduced rainfall in 2008. This may have

resulted in increased use of reservoir water for watering gardens and filling of swimming pools (Pers. communication, Eden District Disaster Management). It could also be attributed in part to the significant growth of the local tourism industry during the study period. For instance, a recent study noted that in 2007, more than 3.5 million tourists visited the George Municipality (Urban-Economist Development Economists, 2009). Moreover, 20,663 bed nights were reported in 2006. It also noted that between 2004 and 2006, the number of tourist beds within the municipality increased by 4,750 (ibid, 2009).

There is growing interest in the role of tourism in promoting sustainable development (Iglesias *et al*, 2007: 779). However, recent studies also suggest that tourism brings additional demands on water supplies, especially in water scarce areas. For instance, Iglesias *et al* notes that the tourism industry demands about three times the amount of water than normal local water demands (ibid, 2007: 779).

6.4.2. Service Delivery and Sustainability

An important area of study, although not the focus of the study, is balancing requirements for service delivery and sustainability. The high levels of basic service provision in the George Municipality indicate commitment and due diligence by the Municipality. However, it also faces significant challenges, balancing its obligations for basic service provision for a growing population, while striving for sustainability in a highly variable climate.

This case study has illustrated the complexities facing the municipality, including increasing demands for basic services, lack of adequate management capacity and a highly variable and changing climate. For instance, section 3.2.2 described how the municipality successfully expanded access to water supplies from 1996-2007, increasing the number of households reached from 24,151 to 42,793. This represented a 77.3% increase in supply requirements. This growth in water demand resulted in escalating and unregulated consumption that undermined the sustainability of water supply under meteorological drought conditions.

6.4.3. Balancing Supply vs. Demand Strategies

The complexity of managing urban water supplies in Africa has been underlined (Mafuta *et al*, 2011). This prompts more understanding and organization of balancing supply and demand. Mafuta *et al* (2011) also argue that in the African context, the focus has, in the past, emphasised water supply interventions which are costly to construct and maintain, instead of attention to demand measures which require rigorous organisation and management. This requires institutional capacity, willingness of departments to integrate and communicate the data that are collected. Both supply and demand strategies are important to balance to achieve sustainability and to achieve integrated

water resource management goals set out for the African continent. The George case study illustrated how strengthened water demand management (in the absence of costly capital water projects) from late 2009-2010 effectively protected the city's water security.

6.4. Conceptualising urban water scarcity

This case study has illustrated numerous gaps, not only in the operational management of urban water emergencies, but also in the initial conceptualization of the risk itself. The conceptual framework described, applied both hazard and vulnerability components to this episode of urban water scarcity in the George Municipality that was initially framed as an "unforeseen drought" (Pers. Communication, Eden District Disaster Management, 2011). The case study illustrates the shortcomings already noted by the disaster risk literature (Wisner and Pelling, 2009) of responding to hazard occurrences reactively rather than rising vulnerability conditions that increase likelihood of a risk being realised in a disaster or emergency.

In this example from the George Municipality, accumulating vulnerability factors related to escalating urban water consumption went undetected, although these were evident well before the meteorological drought triggered an urban water emergency. Results also suggest that the magnitude of over-water consumption (i.e. greater demand than the projected HFY of 12.1MI) in 2008 and early 2009 generated its own lagged effects on water storage in advance of the meteorological drought. The study findings underline the value of prevailing disaster risk reduction alongside approaches that emphasises developmental vulnerability reduction, rather than preparedness for hazard events.

6.5. Conclusion

This study sought to recognize and document the atmospheric and human-induced risk drivers that contributed to the acute urban water scarcity in the George Municipality from 2009-2010. Such understanding is viewed as central to sustainable urban development in rapidly growing Africa cities already exposed to climate extremes.

The findings of this study suggest that the disaster event was in-part attributed to meteorological and hydrological drought. They also point to a downward rainfall trend, highly variable rainfall and its shifting seasonality in the George Municipality. GRD storage levels show an overall downward trend significantly due to rising GRD consumption levels, which markedly increased prior to the drought emergency.

The municipality's low dam storage levels were reversed due to the combined effect of heavy rainfall

and more vigilantly managed urban water demand. However, the results indicate the importance of integrated water resource management as a key element in the management of urban water scarcity risk, especially in areas exposed to highly variable rainfall.

6.6. Summary

This chapter related the study findings with prevailing literature on disaster risk reduction. It revisited the main findings from Chapter Five with regard to the rainfall, GRD storage levels and GRD consumption levels.

The chapter discussed the differences between managing a disaster event and reducing risk factors developmentally. It continues by considering the protective role played by the severe weather events and the necessity for integrated water resource management, especially the need for balancing water supply with local demand as illustrated in this study.

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