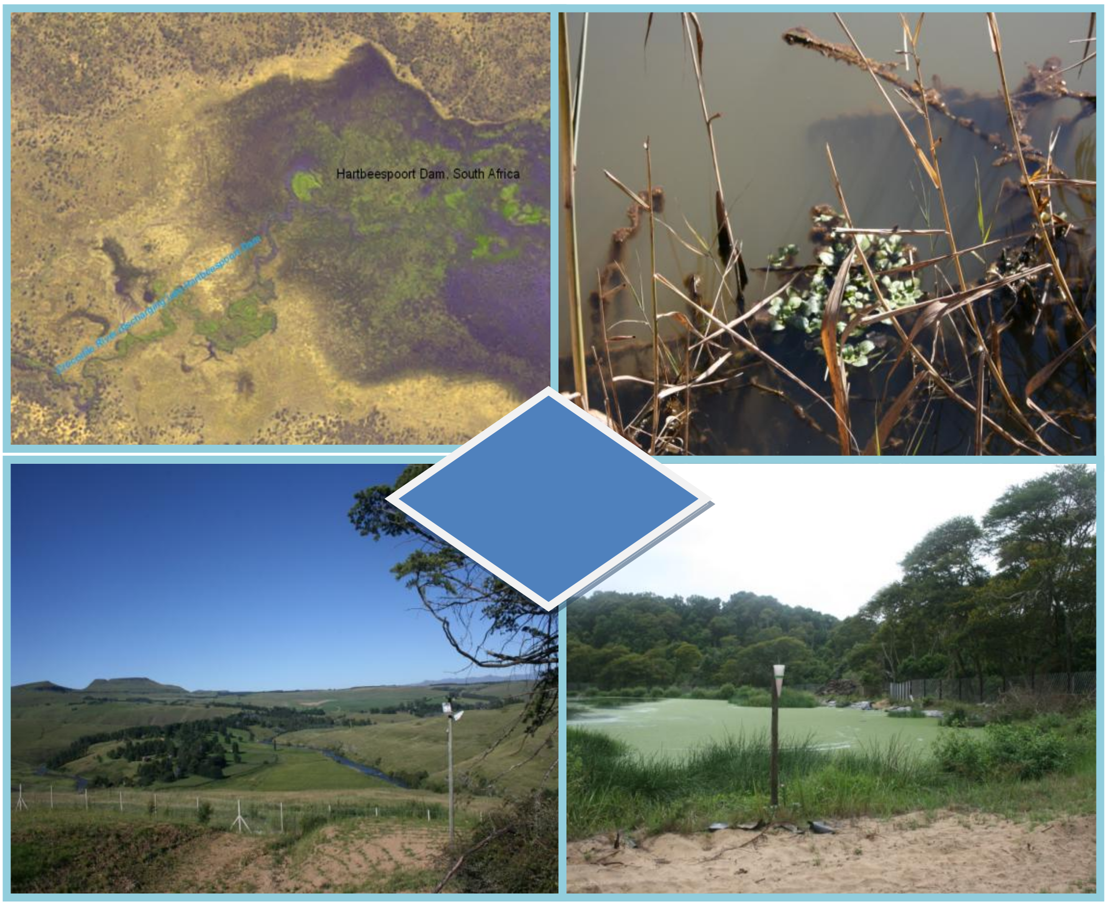
THE ANNUAL NATIONAL STATE OF WATER RESOURCES REPORT

OCTOBER 2011 TO SEPTEMBER 2012



PREPARED BY

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water affairs

Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

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DEPARTMENT OF WATER AFFAIRS

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The Directorate: Water Resource Information Programmes under the Chief Directorate: Water Resource Information Management of the Department of Water Affairs facilitates and leads the coordination and production of the national state of water resources report.

The report is a collaborative effort of all the Directorates: Resource Quality Services (RQS), Spatial and Land Information Management (SLIM) and Hydrological Services (HS), within the CD: WRIM. Directorates from the Chief Directorates: Integrated Water Resource Planning (IWRP), Resource Directed Measures (RDM), Water Resources Information Management (WRIM), Water Regulations and Water Services and the Gauteng Region also contributed to this report.

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EXECUTIVE SUMMARY

South Africa is facing freshwater scarcity, which is exacerbated by its increasing demand, pollution, unsustainable use, and climate change. Water is critical for sustainable economic and social development as well as for maintaining healthy ecosystems. Over-abstraction and pollution continue to threaten the integrity of natural ecosystems, undermining ecosystem services. It is therefore crucial that water be conserved, managed and developed in an environmentally sound manner to achieve socio-economic development. A multidisciplinary and holistic approach should be adapted which will address the intricate nexus between water scarcity, water use and development.

This report presents the status quo of the country's water resources for the 2011/12 hydrological year. During the reporting period, the country experienced somewhat dry conditions as a result of the less rain received. The central and north-eastern parts were the worst affected by dry conditions. The south eastern and western regions were fairly wet and this was attributed to the heavy rains and snow which fall in those areas during the months of March and July. The heavy rains were a result of tropical low pressure systems.

There has been a noticeable increase in temperatures across the country in the past 40 years. During the summer months of 2011/12, temperatures greater than 26℃ were observed in the Northern Cape, North West, Limpopo and northern parts of Kwa-Zulu Natal Provinces. The winter months saw temperatures soaring to below 10℃, resulting in some parts of the country experiencing cold conditions and snow fall.

The less rain received, accompanied by high temperatures and high evaporation rates, translated into less runoff resulting in low national water storage levels. The 2011/12 hydrological year recorded the lowest storage levels in the past 4 years (2007-2011). Also as a result of less rains, baseflow was low resulting in less groundwater recharge. This was most evident in the Limpopo, North West and Mpumalanga Provinces, where groundwater levels declined to as low as 2m. The decline in levels could also be attributed to over-abstractions, especially in the Limpopo Province. Water level declines were also observed at bulk water supply schemes such as Grootfontein and certain dolomitic aquifer compartments in Gauteng. In the winter rainfall region however; significant snowfalls and rainfall experienced in the past hydrological cycles enhanced recharge, raising the groundwater levels.

The quality of the country's water resources is severely compromised due to rapid development and urbanisation. Anthropogenic activities such as agriculture, industries, mining, and human settlements continue to introduce pollutants into water resources. The pollutants alter the biological, chemical and physical characteristics of water; often rending it unfit for use and/or consumption. Pollution also compromises on the health of riverine biota; indicators of the health of the river. It is therefore important that water resources are monitored for quantity, quality and use to ensure protection for sustainable use. The DWA has established monitoring networks and/or programmes which collect data on the quality of surface and groundwater resources.

Data from the monitoring programmes showed a continuous deterioration in water quality (surface and groundwater) over the reporting period. The major water quality problems were eutrophication, faecal pollution, salinisation and acid mine drainage. The majority of dams severely affected by eutrophication were in the Crocodile (West) Marico WMA. Other dams with serious eutrophication potential were in the Upper Vaal, Middle Vaal and Berg WMAs. The problem of faecal pollution continues to exasperate. It is important to note that faecal pollution is currently monitored at a few 'hotspot' areas and therefore does not provide a representation of the national status. Results from monitored sites showed unacceptable levels of *E. coli*, particularly in the Crocodile (West) Marico and the Berg WMAs. There is a high health risk associated with drinking untreated water directly from the rivers and wetlands in all monitored sites.

The problem of salinisation is wide-spread in the county and either occurs naturally as a result of leaching from geological features, groundwater discharges and/or salt water intrusion; or from land-based activities such as mining, industries and agriculture. The western and southern parts of the Western Cape are the most affected by natural salinisation with sodium and chloride being the dominant. The inland rivers, where mining activity is dominant, are rich in sulphates, total alkalinity, magnesium, etc. These rivers include the Olifants and Vaal, which are impacted by mine effluent. The acid mine drainage is a problem in the Gauteng, Witbank and Vryheid areas. Due to the localised nature of South Africa's aquifer systems, the groundwater quality was significantly influenced by local land-based activities causing a rise in the salinity levels. The increase in salinity in the Upper Orange and Lower Vaal was part of a long-term decreasing water quality trend in the order of about 15 mg/l per annum. Also the deterioration in the northern sub-catchment of the Lower Orange, i.e. the Nossob and Auob Rivers flowing from Namibia, is a concern that requires urgent attention. On the contrary, salinity levels declined (improved) in the Limpopo and Olifants catchments and at some localised aquifer systems in the Crocodile-West and Marico catchments, and in the northern parts of the Lower Vaal.

The Department has put in place measures to ensure the protection of water resources and sustainable use. These include Resource Directed Measures (RDM), Source Directed Controls (SDC) and river health programmes. RDM aims at achieving a balance between protection and use of water in order to achieve socio-economic development. SDC links the protection of water with its regulation, by ensuring compliance to set standards. Through the classification process, under RDM, DWA can relate water use to the value and benefits to the economy. At the end of the 2011/12 hydrological year, classification processes were completed for the Vaal, Olifants and Olifants-Doorn WMAs. The total number of surface and ground water reserves undertaken during this period were 1128 and 94 respectively. This included desktops, rapid, intermediate and comprehensive reserves. The reserves are currently undertaken in the catchments of priority. A total volume of 4 512 million m^3 was registered at the end of the hydrological year, with the agricultural sector accounting for the most volumes. The Letsema project managed to authorise 274 water use licences, 47 of which were from historically disadvantaged individuals.

The report only provides a synopsis of the status of water resources. This form of reporting is important as it provides an overview of the county's water situation thus enabling managers to make prompt and informed decisions with regards to the management of the resource. The report is also aimed at informing the stakeholders and the general public of the status of their water resources.

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LIST OF ACRONYMS

AMD	Acid Mine Drainage
CRR	Critical Risk Rating
DWA	Department of Water Affairs
EC	Ecological Class
EC	Electrical Conductivity
ECL	Environmental Critical Level
E. coli	Escherichia Coli
EDC	Endocrine Disrupting Compound
EI	Ecological Importance
ES	Ecological Sensitivity
FAO	Food and Agriculture Organization
FSC	Full Supply Capacity
GMP	Groundwater Management Project
HDIs	Historically Disadvantaged Individuals
IWRM	Integrated Water Resources Management
IWRP	Integrated Water Resources Planning
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
KZN	KwaZulu Natal
LMWL	Local Metric Water Line
MDG	Millennium Development Goals
NEMP	National Eutrophication Monitoring Programme
NESMP	National Estuarine Monitoring Programme
NGA	National Groundwater Archive
NMMP	National Microbial Monitoring Programme
NRMP	National Radioactivity Monitoring Programme
NTMP	National Toxicity Monitoring Programme
NWA	National Water Act
NWRS	National Water Resources Strategy
PES	Present Ecological State
POP	Persistent Organic Pollutants
RDM	Resource Directed Measures

RHP	River Health Programme
RSAP	Regional Strategic Action Plan
RQS	Resource Quality Services
SADC	South African Development Community
SAWS	South African Weather Service
SDC	Source Directed Controls
SLIM	Spatial and Land Information Management
STDDEV	Standard Deviation
TDS	Total Dissolved Solid
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNWWAP	United Nations World Water Assessment Programme
WARMS	Water Authorisation Registration Management System
WC/WDM	Water Conservation and Water Demand Management
WMA	Water Management Area
WMS	Water Management System
WRG	Water Resources Group
WRIM	Water Resource Information Management
WRIP	Water Resource Information Programmes
WSSD	World Summit on Sustainable Development
WWTW	Wastewater Treatment Works

1. Introduction

1.1 Purpose of the report

The Department of Water Affairs (DWA) collects information and reports on water resources at different areas, times and frequencies for different reasons. There are three distinct requirements for collecting information by DWA; assessing and comparing status and trends of both quality and quantity of water resources, checking for compliance to licence conditions and monitoring water use. This information is also used to assess the effectiveness of policies implemented and identify where additional measures may be required. DWA is also required to provide information to the general public. The information provided to the public ranges from raw data from databases through reports on the state of water recourses. The information must also be made accessible to the public.

The objectives of the report are:

- to produce a clear overview of the state of the country's water resources;
- to produce an integrated report (for various reporting requirements) on the various components of the water cycle;
- to provide information on the factors that impact on the status and sustainable use of the country's water resources;
- to promote better management and protection of our water resources by making information on the status of the country's water resources available to all stakeholders on an annual basis; and
- to highlight issues that need to be addressed, emerging water problems and important information gaps.

Overall, the report aims to give an overview of the state of water resources in the country during the hydrological year including trends. The information should be able to inform the decision-makers as to whether the policies being implemented are having an impact. It is important to note that this piecemeal reporting approach does not provide a comprehensive overview of the state of water resources.

1.2 Setting the scene

Water is the common thread that connects the three critical issues of food, energy and climate change. It is one of the key focus areas in enabling growth and development and plays an important role in the green economy. Water is essential for social and economic developments and for maintaining healthy ecosystems. Sustaining economic growth is only possible if we recognise the limited capacity of ecosystems to supply the water needed for agriculture, industry, energy generation and the production of the many goods and services required by society (www.unwater.org/rio2012). It is therefore critical that water management be improved in order to achieve food security, conserve ecosystems and reduce risks from water scarcity and the degradation of freshwater ecosystems. Improved governance is also needed which defines property rights, incorporates the full cost of water into decision making, and allocates water to the environment. The National Development Plan, Vision 2030 identifies water as a strategic resource that is critical for social and economic development (National Planning Commission, 2011).

The country is facing a challenge of freshwater scarcity that is exacerbated by its increasing demand, resource pollution, unsustainable use, wastage and climate change. Yet DWA is expected to make more water available for economic growth and development. As a water-scarce country, South Africa has to protect and conserve water to ensure availability for future generations. Increasing water abstraction has threatened the integrity of natural ecosystems, leading to the loss of significant biological diversity and undermining ecosystem productivity. Wetlands are disappearing, fish species are endangered, and rivers are drying up or are no longer reaching the sea.

Water scarcity affects all social and economic sectors and threatens the sustainability of the natural resource base. A multidisciplinary and inter-sectoral approach is required to address the scarcity and manage water resources. This helps to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. The integration needs to take into account development, supply, water use and requirements, and to place the emphasis on people, their livelihoods and the ecosystems that sustain them. Furthermore, protecting and restoring the ecosystems that naturally capture, filter, store and release water, such as rivers, wetlands, forests and soils is crucial in increasing the availability of water of good quality (UN Water, 2007). Access to water and sanitation are the priority targets of the Millennium Development Goals (MDGs) and the Johannesburg Plan of Action as decided at the World Summit on Sustainable Development (WSSD, 2002). The problem of water scarcity does not only affect South Africa but it is a global challenge.

Water security is one of the fast growing social, political and economic challenges of today. It underpins and connects food, climate change, economic growth, migration, urbanisation (World Economic Forum, 2011). As our economy grows, the demand for energy, industrial and water urban systems also increases. Water security is about i) improving drinking water and sanitation services, ii) balancing water supply and requirements, iii) mitigating water resources degradation and improving health of water resources, , and iv) adapting to extreme events (UNWWAP,2011) (Figure 1.1).

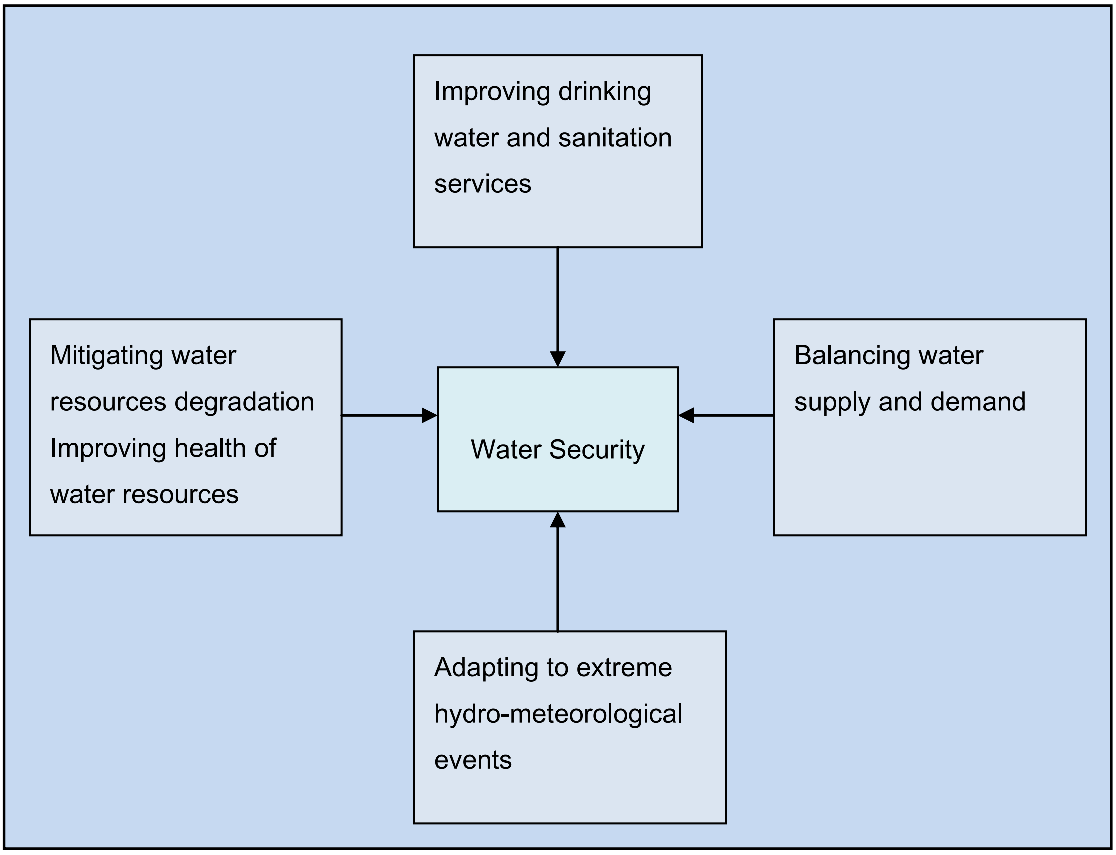


Figure 1.1: Objectives of water security (UNWWAP, 2011).

In South Africa water security depends on how the DWA can manage the equitable and effective use of its water resources. The impact of climate change poses challenges such as increased variability in stream flows and frequency of extreme conditions and increased temperatures, resulting in increased cost of providing water. It is therefore important that the DWA invests in effective monitoring systems and capabilities optimise the re-use of water and assist in ensuring our Wastewater Treatment Works (WWTW) function well to meet norms and standards. DWA should also see to it that programmes such as rainwater harvesting, Water Conservation and Water Demand Management (WC/WDM), desalination etc. are implemented effectively.

Water and energy are inextricably linked and as a country we are faced with the challenge of reducing energy consumption while at the same time improve water management to ensure sustainability. In South Africa growing water requirements/use are increasingly creating pressure on available water resources, resulting in higher energy consumption. Energy is important for economic and social development, for example energy is used to pump water through pipelines (e.g. water supply and wastewater sewers) and for groundwater utilisation. Water is essential for hydro-power and water cooling in thermal and nuclear power plants. Hydropower production can have far-reaching effects on aquatic habitat and river morphology as water temperature and pressure could increase. Also the timing of the release would more often not coincide with the in stream flow requirements. ..

Food security is dependent of adequate quantity and quality of water resources. Food production is also critical for sustainable development and provides employment to communities, alleviating poverty. However, agriculture uses significant amount of water thus impacting on water security. Also, if the wastewater from processing is not treated, recycled and is discharged into a water course, food production could change the quality of water in the stream. DWA need to promote maximum water use efficiency in the agricultural sector, which is the major user of water in the country. Furthermore, water loses from distribution pipes due to aging infrastructure, should be a priority as significant amount of water could be saved.

The preservation of freshwater ecosystems is fundamental to the concept of sustainable development as they provide services that are crucial for species survival, provide clean water for domestic use, industries irrigation, support fisheries, recycle nutrients, remove waste and replenish groundwater (ENEP, 2012).

Water plays a major part in strategies for achieving most of the MDGs, including eradication of extreme poverty and hunger, universal primary education, improved health and combating diseases, ensuring environmental sustainability, promoting gender equality and empowering women and promoting global partnerships. For example, water scarcity management is crucial for environmental sustainability; and fair and equitable access to water; and land is crucial to the eradication of poverty and hunger goals. Therefore, effective water management is essential to achieve optimal social and economic performance in a sustainable manner.

Legislation

The South African National Water Act, (NWA 36 of 1998) prescribes that water resources be protected, used effectively and efficiently, managed and controlled well. The Act also states that water allocation must be equitable for the benefit of all people and future generations. DWA must regulate water use and activities having detrimental impacts on water resources. The implementation plan is explained in the National Water Resources Strategy (NWRS), which is now in the process of review.

Governance

South Africa is divided into 19 Water Management Areas (WMA) (Figure 1.2). The establishment of Catchment Management Agencies (CMA) in each WMAs and the subsequent involvement of stakeholders are critical as it promotes engagement and buy-in resulting in effective management of water resources. The establishment plan for the CMAs will be in 3 phases: The Inkomati – Usuthu, Breede Gouritz and Pongola-Umzimkulu (phase 1); the Berg-Olifants-Doorn, Vaal-Olifants and Limpopo (phase 2) and the Orange and Mzimvubu-Keiskamma (phase 3). There are currently plans to reduce the number of WMAs from nineteen (19) to nine (9).

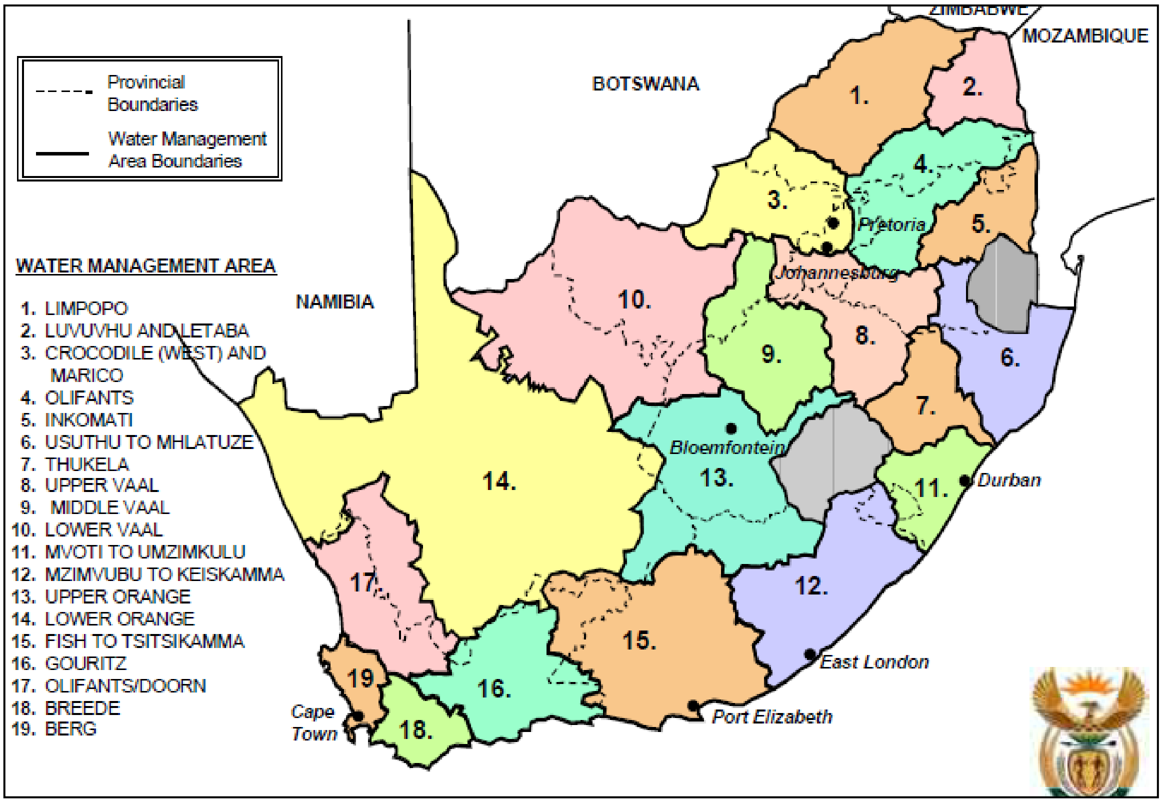


Figure 1.2: The 19 WMAs in South Africa.

1.3 Integrated Water Resources Management

Integrated Water Resources Management (IWRM) is defined as the sustainable development, allocation and monitoring of water resources use in the context of promoting social equity, economic efficiency and environmental sustainability. It aims to provide access to sufficient water resources, ensure water is available for productive use and secure the environmental function of aquatic ecosystems. In other words, IWRM strikes a balance between the resource use and conservation to sustain its functions for future generations. Sustainability means that the protection of water resources must be balanced by their development and use. The approach attempts to address competing demands from different sectors and the sustenance of ecosystem livelihoods and biodiversity by involving stakeholders. (Jägerskog & Jønch Clausen, 2012). IWRM can also assist communities to adapt to changing climatic conditions that limit water availability or may lead to excessive floods or droughts (UNDP- Cap-Net, 2012). IWRM requires cooperation between all tiers of government, institutions and various stakeholders that have an interest in water. Water resources management entails the maintenance and development of adequate quantities of good quality water. The key objective is to reconcile the supply of water with the requirements and the goals are economic efficiency, social equity and environmental sustainability. These goals are the pillars of IWRM (UNDP- Cap-Net, 2012). These could be achieved through effective stakeholder engagement, water allocation, pollution control, monitoring, flood & drought management, catchment planning, economic and information management (Figure 1.3).

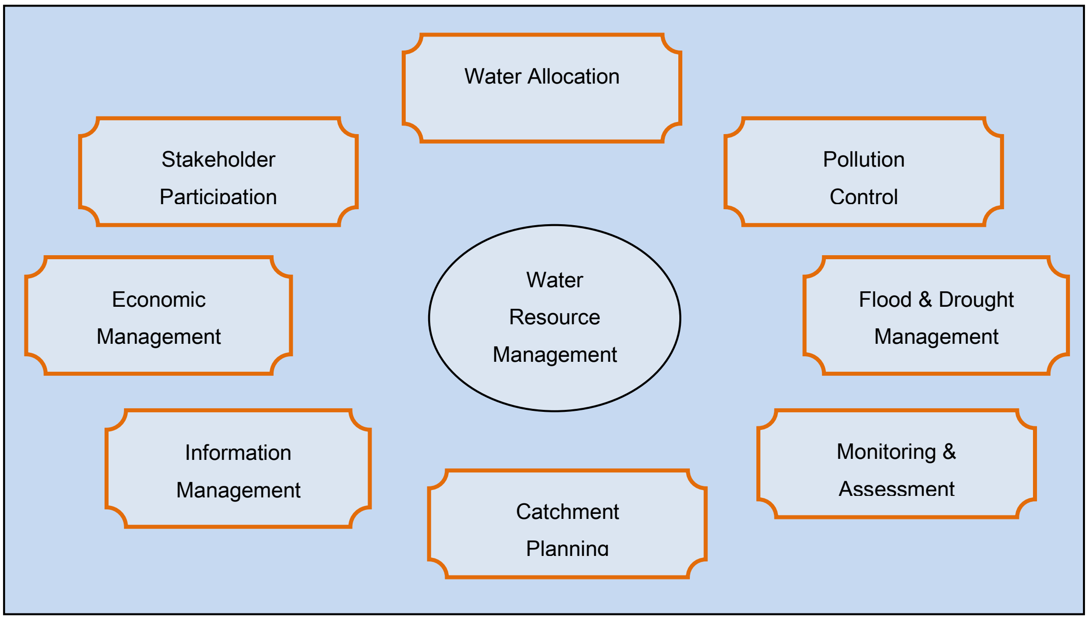


Figure 1.3: Different pillars of Water Resource Management in a catchment (modified from (UNDP- Cap-Net, 2012).

In 1992, Agenda 21 of the Earth Summit called for the application of integrated approaches to the development, management and use of water resources. South Africa is one of the countries that have adopted IWRM approach and this has resulted in changes in the water legislation and the NWA.

In an effort to improve water resources management and close the gap by 2030, DWA has formed partnership networks with South African Breweries, Nestle, Anglo American, Sasol, Eskom, Development Bank, Water Research Commission and BHP Billiton under the umbrella of Water Resources Group (WRG). The WRG works with SA helping with i) water use efficiency through reduction of water losses, ii) treatment and re-use of mine water and iii) improving water productivity in the agricultural sector. DWA, through this partnership, has produced an investment framework, for the refurbishment and building of new infrastructure.

1.4 Monitoring of water resources

The water resources are impacted by a wide range of human activities in a catchment. The land-based activities such as agricultural irrigation, industries, mining, settlements, urbanisation, etc degrade the quality of water in rivers, dams, estuaries and groundwater. They also affect the health of riverine biota, indicators of the health of the river ecosystems. Uncontrolled and excessive abstractions of surface water, increased water consumption and treated sewage effluents not returned to the river system affect the availability of water. Excessive abstraction of groundwater reduces the water levels it becomes difficult to recharge aquifers and sinkholes may develop in some areas. It is therefore important that water resources are monitored for quantity, quality and use to ensure protection for sustainable use. Water resources must be protected to provide clean drinking water and support ecosystems. To effectively protect water resources DWA must effectively implement strategies to prevent and reduce pollution.

Monitoring, assessments and information management are crucial in determining the state of water resources. Monitoring generates data which is processed into information to develop knowledge. An assessment of a catchment helps in understanding what is happening in the catchment as well as identifying the challenges. IWRM approach requires comparable information to form a common basis for decision-making, which requires harmonised and comparable assessment methods and data management systems as well as standardised reporting procedures.

The purpose of monitoring is to produce information on water availability, water quality, and rainfall variability. This information is used for different purposes such as proper planning; determining water use and quality, and enforcement of compliance by users. The planners use the information to establish water requirements and availability.

DWA is engaged in a number of national monitoring programmes which include hydrological (river flows, dam levels and evaporation), geohydrological (groundwater levels, chemistry and isotopes), surface water quality (microbial, eutrophication, radioactivity, toxicity and chemical) and biological (aquatic ecosystem health). DWA is currently working on expanding the networks to ensure wider coverage. A cost benefit analysis process to establish whether the monitoring conducted by the department is cost effective and efficient is currently underway.

The quantity of water available is monitored via gauging stations using river flows and water levels. The challenge is that the number of active stations has been declining due to various reasons. Evaporation is monitored using pan-evaporations (S and A pan). Water quality is monitored through sampling and analysis parameters to identify whether there is pollution taking place or establish if the user is complying with the set conditions of the issued licence. Parameters such as Electrical Conductivity (EC) or Total Dissolved Solids (TDS), pH, salts etc are used to assess the status of water. DWA also monitors the environmental status or the health of the river using biological indicators (fish, diatoms). The biological indicators show the effect of pollution over a period of time whereas other methods measure what is in the water at that given time. Monitoring of groundwater is mainly done to assess the changes in levels, and water quality.

Photo 1: A typical gauging station and the pan-evaporation

1.5 Data/Information Management

Information management is about providing essential data necessary to make informed decisions for planning, development and sustainable management of water resources in a catchment. Historical data is the foundation of good decision making and planning. It is therefore important that data collected is accurate and reliable. For data to be reliable there must be effective monitoring and data management systems in place. To ensure that it is always available and accessible, information must be stored and managed properly.

The first phase is collection data from an analysed water sample. The data must be quality assured and controlled to ensure accuracy. The data is then captured and stored in a database as raw data. When the need arises data are retrieved and processed into information for use by decision-makers. DWA has processes in place to ensure that information is secured for protection. The information can now be shared and disseminated to all stakeholders (e.g political, water sector and civil society) either as raw data, processed data, spatial data (maps) or reports. The process of information management is shown in Figure 1.4.

Data and information are collected by DWA through the monitoring networks and relevant institutions. Information is captured and stored in different systems such as Water Management Systems for water quality for both surface and ground water; HYDSTRA for stream flows; National Groundwater Archives (NGA) for groundwater levels and Water Authorisation

Registration Management System (WARMS) for registered water use. The problem is that these systems are not linked and therefore integrating the information becomes a challenge. However DWA has initiated a process of integrating the existing systems.

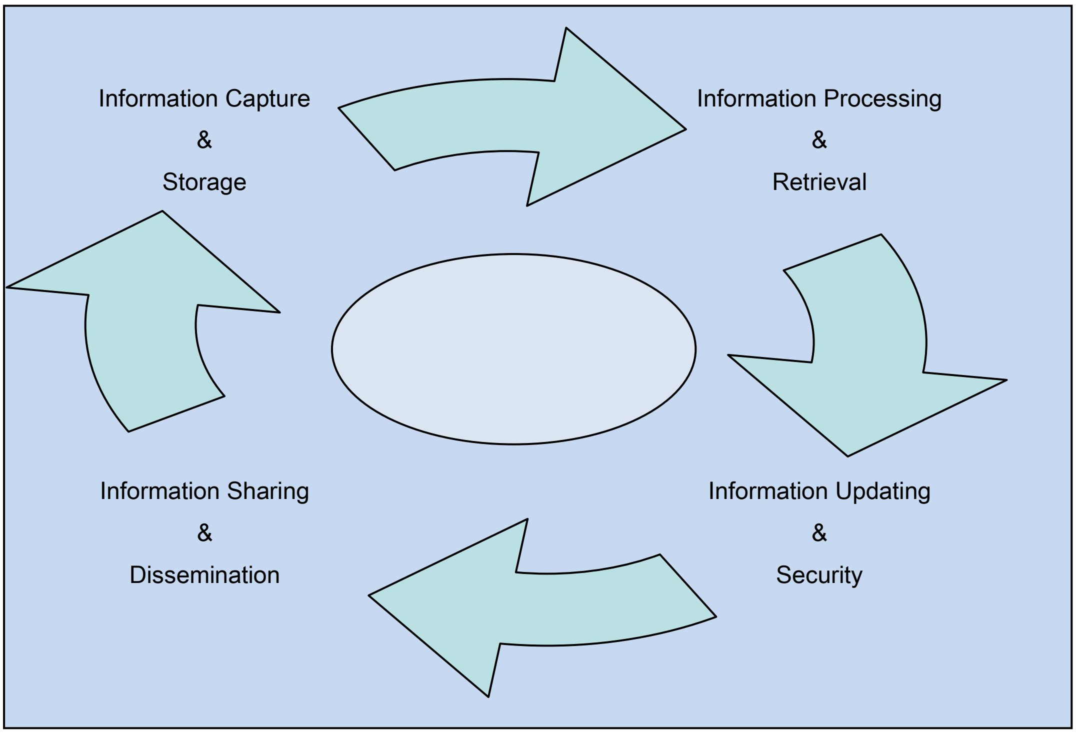


Figure 1.4: The information management process.

A challenge in data collection is the decline in monitoring stations for stream flows and rainfall, and water quality. The reasons for the decline are inadequate maintenance, vandalism and the reduction in budget allocation towards monitoring. Also, the lack of partnership between DWA and institutions that have interest in data is hampering any improvement in the availability of data. This has implications in that DWA will not be able to accurately assess the state of water resources in the country in future if the problem is not addressed

At the World Water Week 2012, it was mentioned that countries need to invest in data collection in order to improve r data quality. Integrated systems must be in place and well maintained. It was also acknowledged that the challenge is to maintain the systems.

1.6 Impacts of Climate Change on water resources

Climate change can potentially lead to changes in the frequency, intensity, length, timing and spatial coverage of extreme events (e.g. floods and drought). According to the Intergovernmental Panel on Climate Change (IPCC), there is a possibility of an increase in the frequency of precipitation/rainfall and high sea levels (IPCC, 2011). It is envisaged that there could be a high probability of frequency and magnitude increase in daily maximum temperatures and a decrease in cold weather during the 21st century. South Africa seems to be experiencing the impact as temperatures have become more variable. The falling of snow in places such as Gauteng, and heavy rains in the Eastern Cape could be taken as indications of climate variability or change.

Climate change has direct impact on five aspects of the environment namely; water security, ecosystems, air quality, oceans and weather changes (IPCC, 2007). These in turn affect some aspects of human health such as water-borne diseases, allergies, respiratory diseases etc. (www.niehs.nih.gov/climatereport, 2010).

Climate change can impact on water resource quality by increasing pollutants and water-borne diseases or reducing river flows and water levels in wetlands and lakes. Heavy rainfall could increase the volume of run-off into rivers washing down sediments, pollutants etc. Increases in temperatures may increase the level of toxins in water as substances in the water could react against each other. Climate change can impact on ecological processes affecting ecosystems, biodiversity, food security and the spread of diseases (Figure 1.5). It can also impact on ecosystems as different species are adapted to specific environmental conditions, depending on a combination of water availability and average temperature.

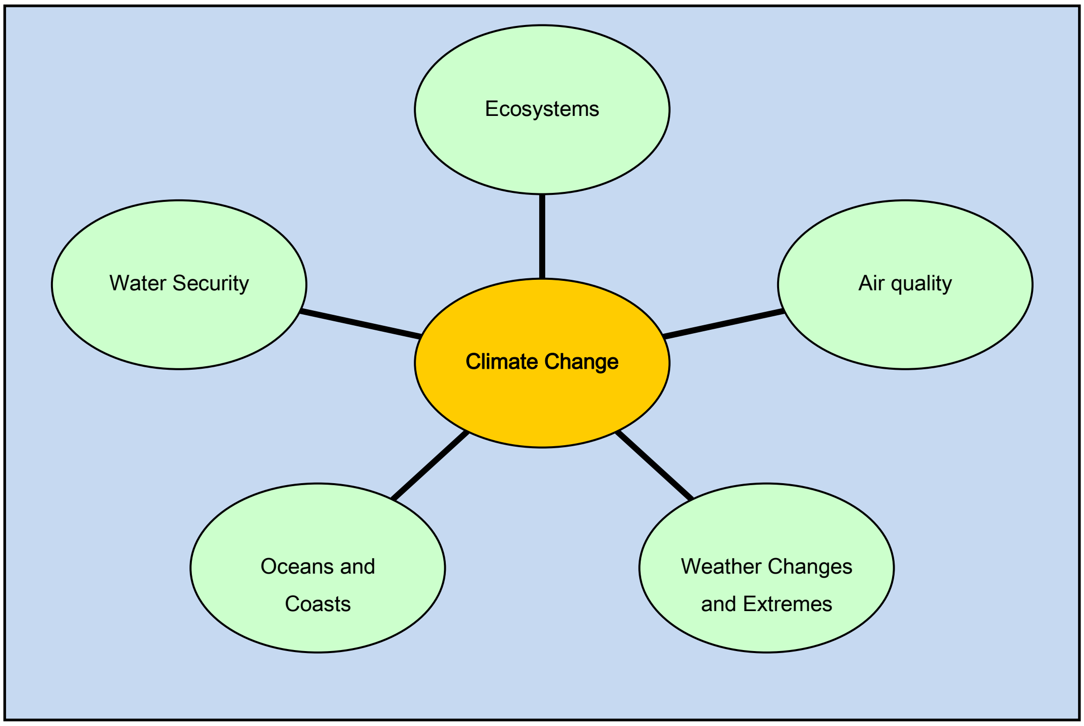


Figure 1.5: Aspects of the environment that are impacted by climate change (Modified from Portier *et al.*, 2010).

South Africa is a water scarce country and the influence of climate variability is exacerbating the situation. The growth in water requirements will soon surpass what is currently available in many areas. Population and economic growth, and urbanisation are the main drivers. The country is facing a major challenge of adapting to the potential climate change effects. This has resulted in DWA initiating a process of developing a climate change adaptation strategy.

Climate change is expected to exacerbate water scarcity due to changes in rainfall patterns. For example, if stream flows are reduced in areas producing hydropower, it will in turn reduce the quantity of energy produced. It is therefore important that the country improves catchment management and increase protection against drought. Climate change trends have shown negative impacts on wheat and maize yields in the past 30 years (Lobell *et al.,* 2011). The changes are also having an impact on the availability on natural resources and on food security (UNEP, 2011).

The use of biofuels instead of fossil fuels can help reduce greenhouse gas emissions. The country should therefore develop policies that will protect both the land and ecosystems to maintain food and water security. Integrated planning and management can reduce the risk associated with the use of biofuels and still contribute to the building of a green economy (UNEP, 2011, UNEP *et al*., 2011).

DWA has developed some adaptation measures or interventions to climate change for water stressed conditions. These are to reduce water waste through recycling of water; save water in domestic use; increase efficiency in agriculture; desalinisation of seawater; pollution prevention through the waste discharge system; rehabilitation of wetlands; development of new dams to ensure more storage and redirecting of water through building canals and pipelines. Other adaptation interventions are water pricing, rain harvesting, water restrictions and effective management of groundwater.

1.7 Transboundary water resources

The bulk of SA water resources are transboundary in nature and that has implications for quality, quantity and environmental and disaster management. South Africa shares four international river basins, namely Orange, Inkomati, Limpopo and Maputo with six neighbouring countries, i.e., Botswana, Lesotho, Namibia, Swaziland, Mozambique and Zimbabwe (Figure 1.6). To ensure good management of water resources, bilateral cooperation agreements were signed between South Africa and each o the countries involved. South Africa is signatory to the South African Development Community (SADC) Protocol on Shared Water Courses, making an obligation to cooperate with its neighbours in the management of water resources. Table 1.1 and Figure 1.7 list South African aquifers which are shared with SADC countries.

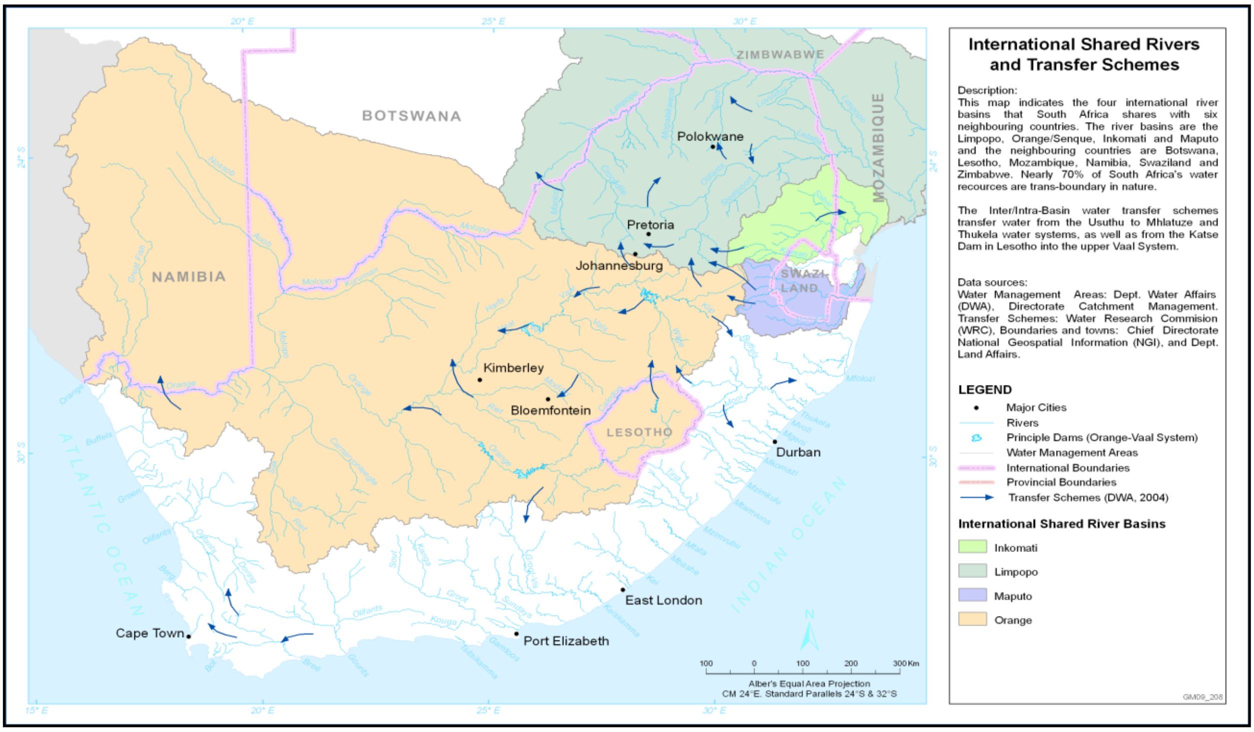


Figure 1.6: International Rivers shared by South Africa with neighbouring countries and transfer schemes (DWAF, 2004)

Table 1.1: Transboundary aquifers within SA and the neighbouring countries (Turton *et al.,* 2005).

Transoundary River Basin	Riparian States	Transboundary Aquifers within River Basin	Aquifer Riparian State within River Basin
Orange	Botswana Lesotho Namibia South Africa	Gariep Coastal Aquifer Karoo Sedimentary Aquifer Ramotswa Dolomite Aquifer Kalahari Aquifer Pomfret-Vergelegen Dolomitic Aquifer	Namibia, South Africa Lesotho, South Africa Botswana, South Africa Botswana, Namibia, SA Botswana, SA
Limpopo	Botswana Mozambique South Africa Zimbabwe	Pafuri Alluvial Aquifer Tuli-Shashe Aquifer Ramotswa Dolomite Aquifer Limpopo Granulite-Gneiss Belt	Mozambique, SA, Zimbabwe
Inkomati	Mozambique South Africa Swaziland	Incomati Coastal Aquifer	Mozambique, SA, Swaziland
Maputo	Mozambique South Africa Swaziland	Incomati Coastal Aquifer	Mozambique, SA, Swaziland

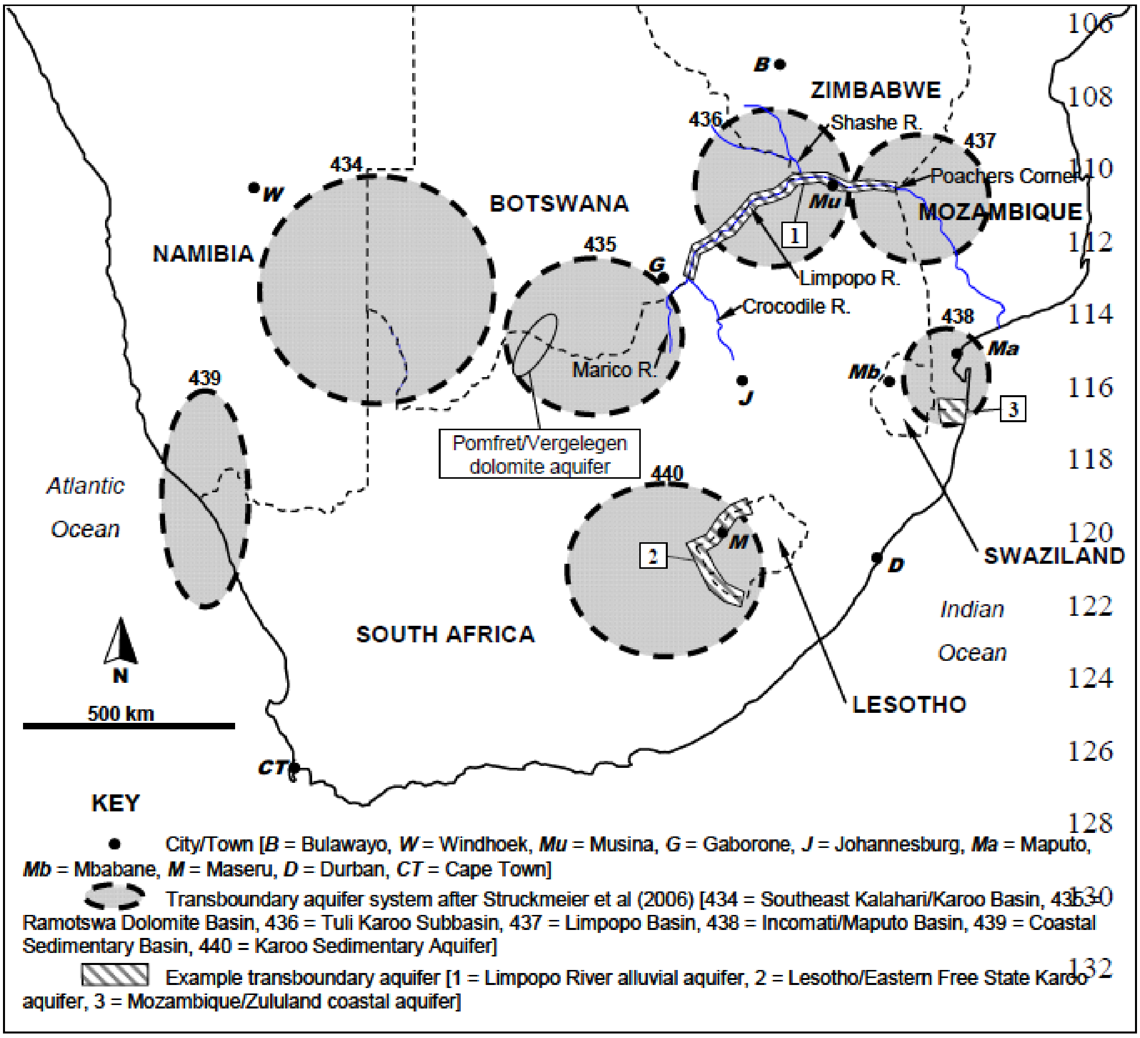


Figure 1.7: An overview of South Africa's transboundary aquifers (Struckmeier *et al.*, 2006).

2 Climatic Conditions

Climate includes processes such as precipitation or rainfall, evaporation and temperature that are variable, and can have important implications on runoff, dam storage levels, and supply of water for domestic purposes, rain-fed agriculture, groundwater recharge, forestry, and biodiversity, as well as for maintaining or changing sea levels. A reduction in rainfall or its variability and an increase in evaporation due to higher temperatures have impacts on the country's scarce water resources. The climate varies from desert to semi-desert in the west to sub-humid along the eastern coastal areas. The natural availability of water across the country is highly uneven due to the poor spatial distribution of rainfall. This is compounded by the strong seasonality of rainfall over virtually the entire country, and the high within-season variability of rainfall.

There are three major climatic zones in the country namely; the eastern parts, central and western parts and the area between the Cape Fold Mountains and the sea. Each zone has unique vegetation (biomes) such as succulent and nama karoo, savanna and grassland, which are influenced by climatic conditions.

The uneven distribution of water resources has resulted in water transfers within WMAs and internationally to augment the available water in a catchment. Water is stored in dams and used for abstraction for various uses such as for domestic use, irrigation, power generation, recreation etc.

2.1 Rainfall

Rainfall is essential to understanding climatic variability in a catchment and is influenced by temperature and evapotranspiration. The more rainfall experienced in an area, the more runoff is observed. However, not all rainfall translates into runoff as there are other factors that come into play.

In general, less rain was received during the 2011/12 hydrological year (Figure 2.1) as compared to the previous period of 2010/11 (Figure 2.2). The central part of the country receives rain its rain mainly in summer. However Figure 2.3 shows that the central interior experienced heavy rainfall rain in June; this could be a contribution of changes in climate. Figure 2.3 shows that approximately half of the country experienced dry to very dry conditions. Only parts of Western, Eastern and Northern Cape Provinces received fair rainfall. The month of May was the driest month as almost the whole country received very little or no rain (Figure 2.3).

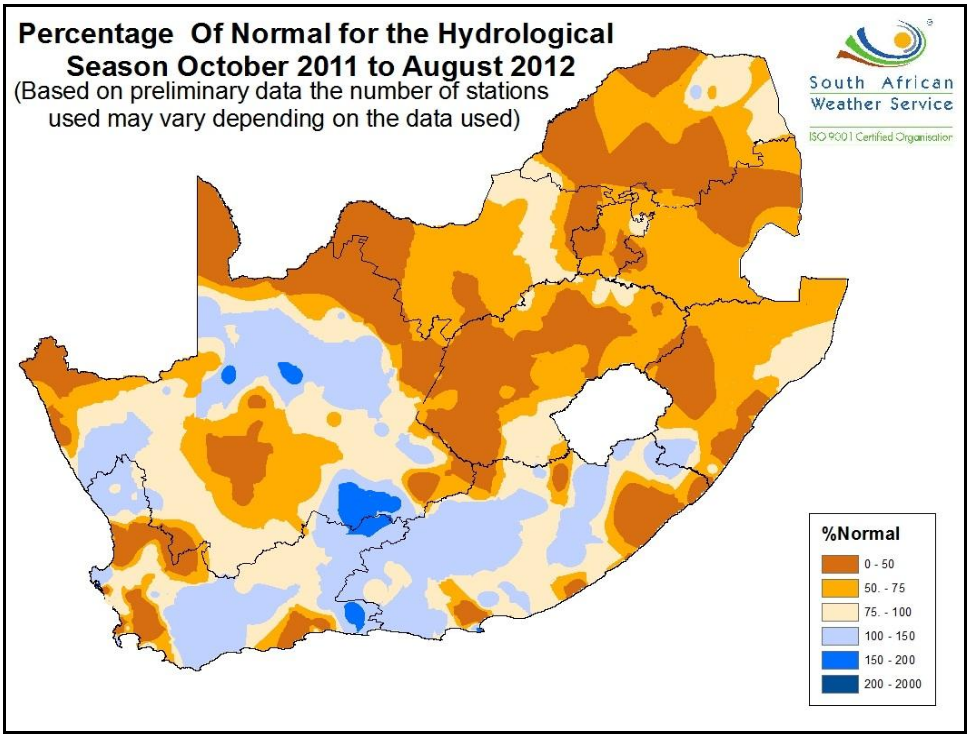


Figure 2.1 The Percentage of normal rainfall for the hydrological season 2011/2012 (Compiled by SAWS).

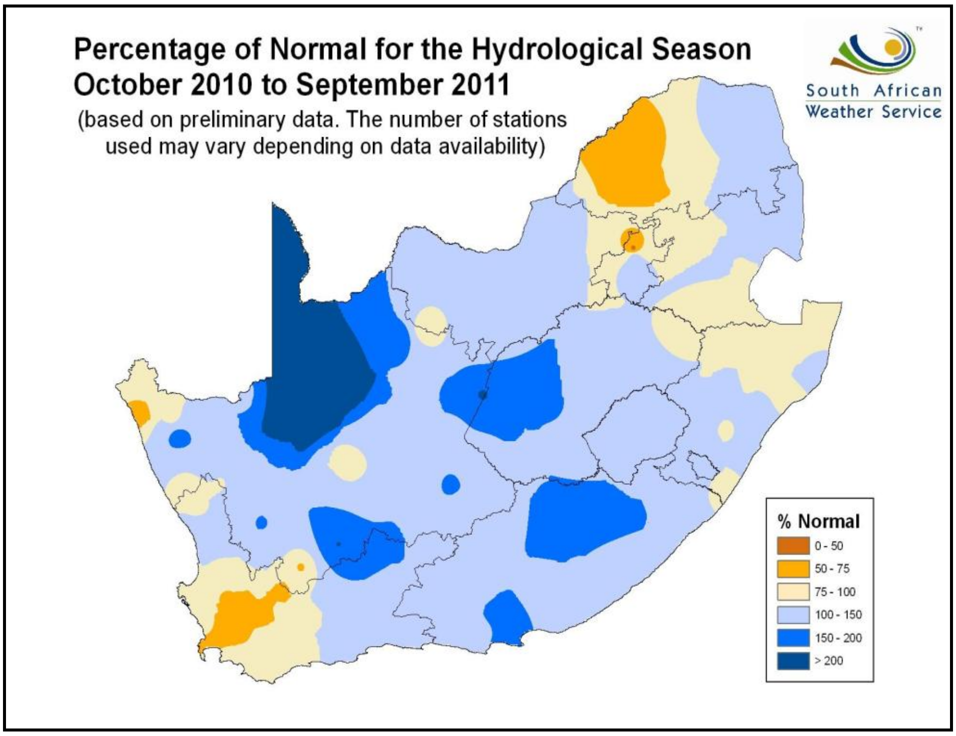


Figure 2.2: The Percentage of normal rainfall for the hydrological season 2010/2011 (Compiled by SAWS).

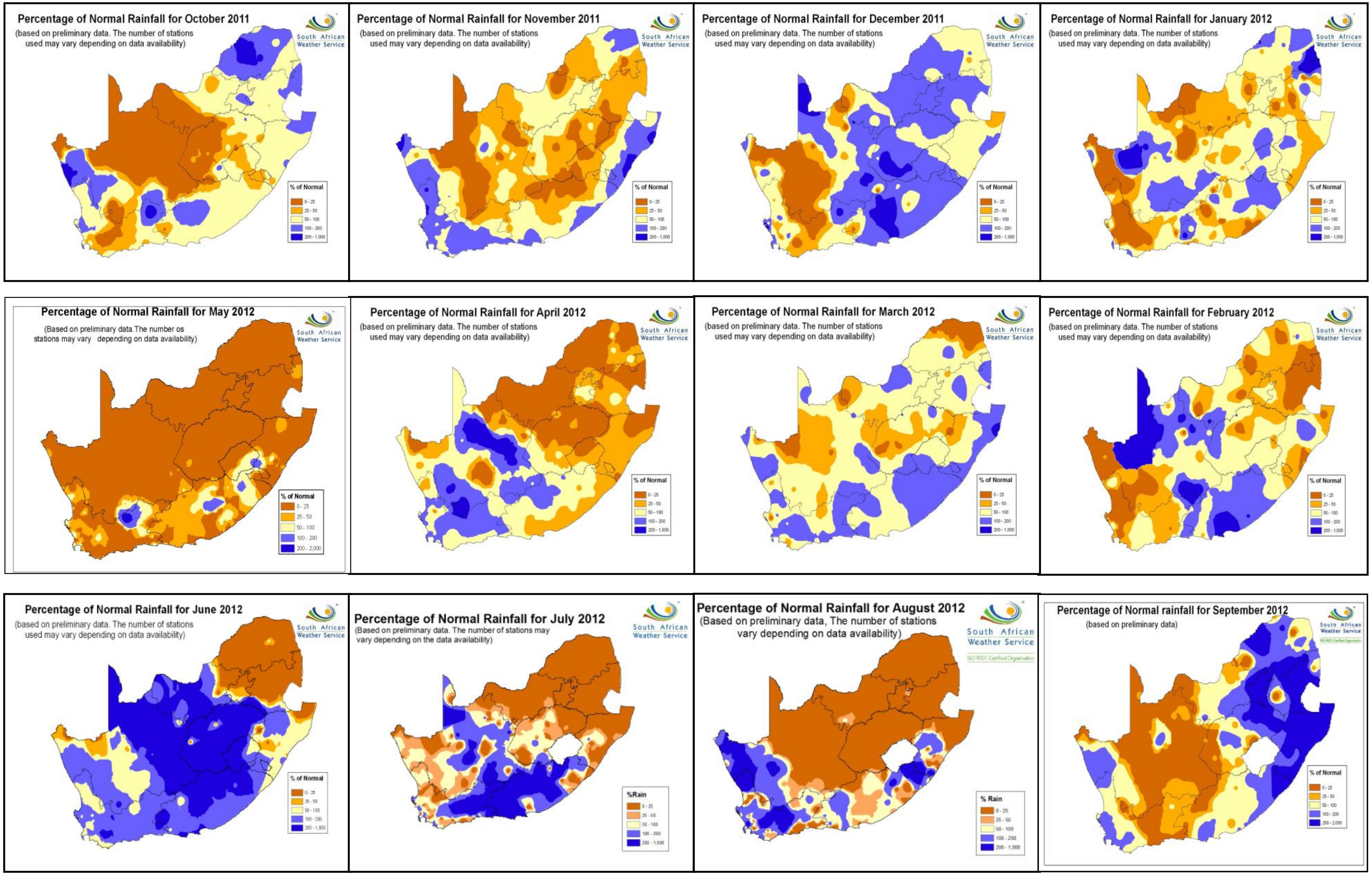


Figure 2.3: The monthly percentage of normal rainfall from October 2011 to September 2012 (Compiled by SAWS).

Figure 2.4 shows the average provincial rainfall for the reporting period. According to the figure, most Provinces experienced high rainfall during the months of December and January. Mpumalanga and Limpopo Provinces received the most rainfall in January; this was as a result of Tropical cyclone Dando which caused floods during that time. KwaZulu Natal was hit by Tropical cyclone Irina in March, resulting in high rainfall as depicted in the figure. The Western Cape received the highest rainfall during the winter months (Jun-Aug) and this was as expected as the south-western region of the country receives winter rainfall. Heavy rains and snowfall was experienced in Eastern Cape during the month of July

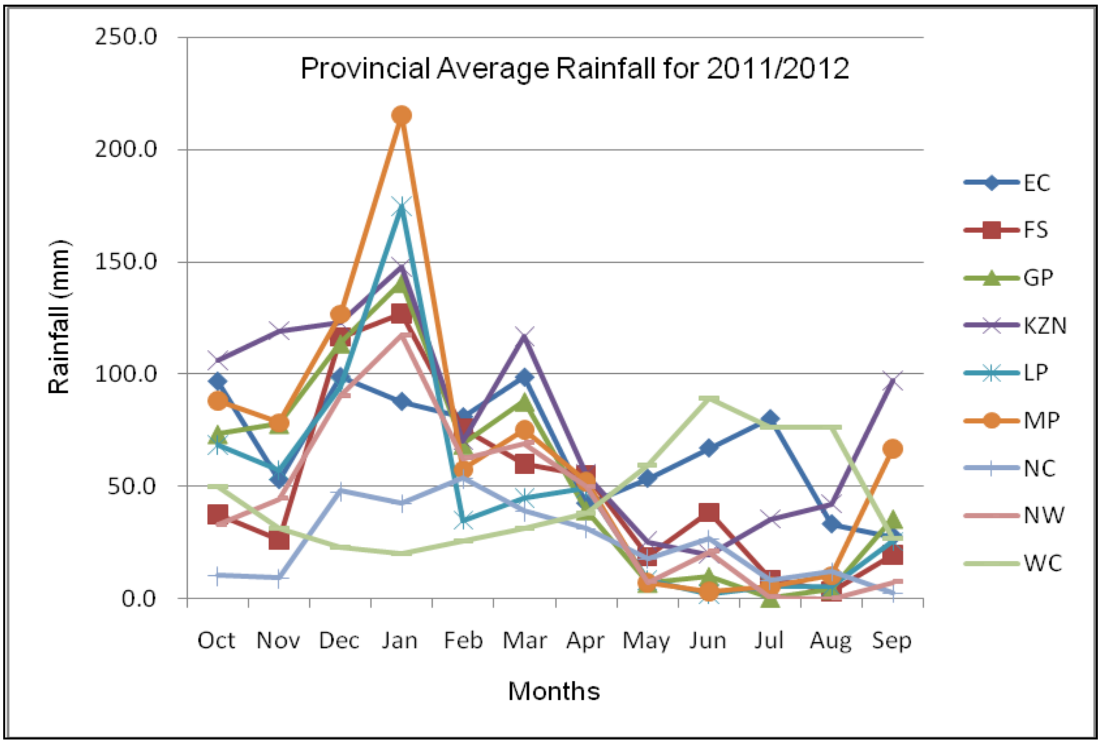


Figure 2.4: Provincial average rainfall (mm) for the period of October 2011 to September 2012.

The rainfall trend, per province, over an 11-year period is shown in Figure 2.5. The figure shows a downward trend in rainfall as of 2001 to 2009. The country received the least rain (≥40 mm/a) between 2005 and 2009, with the exception of Western Cape which received between 60 to 80 mm/a. Overall, it seems Mpumalanga experienced the most rain during the 11 year period and the Northern Cape the least.

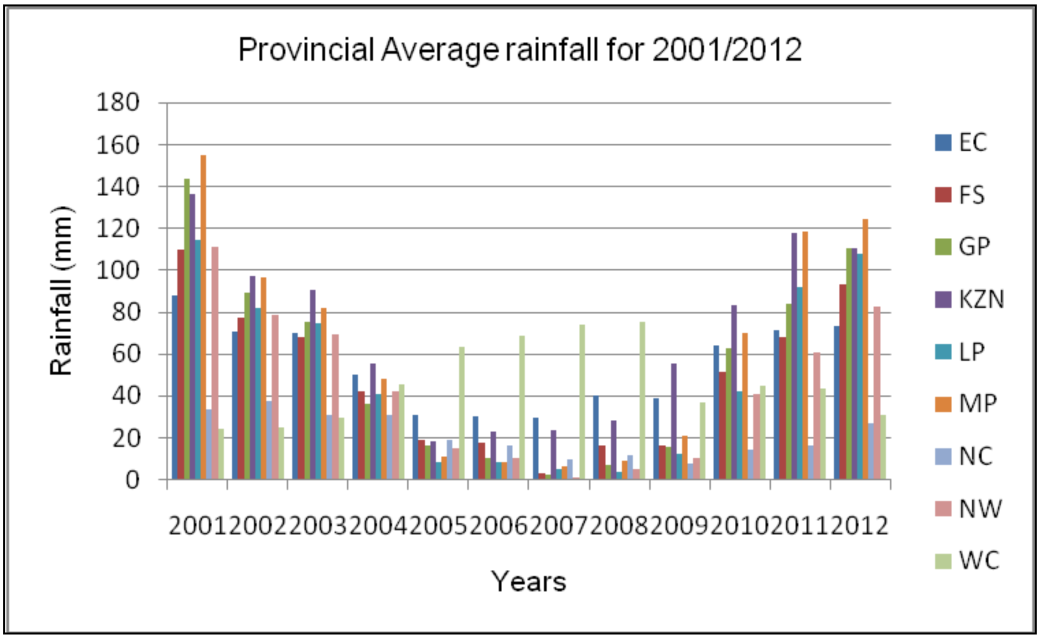


Figure 2.5: Provincial average rainfall (mm) from 2001 to 2012.

2.1.1 Surface runoff

Runoff is the total amount of water from precipitation flowing into a river or stream or the sum of direct runoff and base-flow. Direct runoff is the sum of surface runoff and interflow. Surface runoff is the sum of overland flow and saturation excess overland flow (i.e., precipitation that cannot be absorbed due to soil saturation) (Figure 2.6). Only about a third of the precipitation that falls over land runs off into streams and rivers and is returned to the oceans. The other two-thirds is evaporated, transpired, or infiltrates into groundwater (USGC, 2010).

The drainage area, vegetation, land-uses, soil types etc have an influence on the rate of runoff. Also human factors such urbanisation and development (roads, buildings) can reduce infiltration of water into the ground and accelerate runoff to ditches and streams, affecting the volume of runoff. The construction of drainage networks, removal of vegetation and soil, grading of the land surface, increase runoff volumes and shorten runoff time into streams (USGC, 2010).

Following a rainfall event, the runoff translates into surface runoff, interflow and baseflow. During this reporting period, surface run-off was generally lower except for the Southern and Western Cape as these areas experienced heavy winter rains which caused flooding in July 2012. However, nationally surface run-off was less than the previous period. This could explain why the levels of dams were generally lower than the previous year which experienced more rain with the exception of Western Cape.

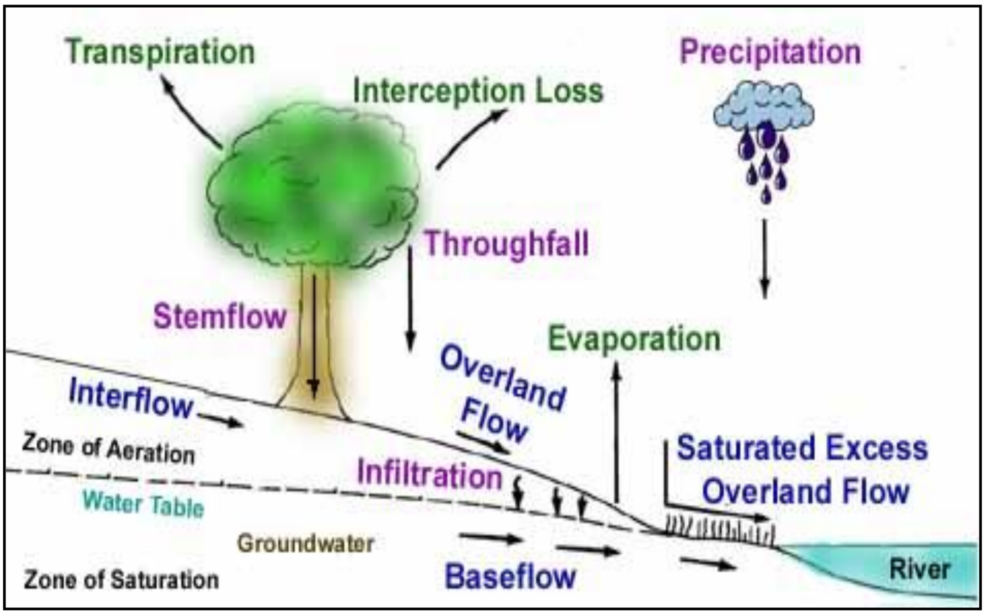


Figure 2.6: The hydrological cycle, showing the different types of runoff (www.co.portage.wi.us).

2.2 Temperature

Increased temperatures could increase the risk of extinction of sensitive species. It will also increase the decomposition rate of organic matter resulting in a decrease in oxygen levels. Higher temperatures can alter stratification and water mixing in reservoirs thus affecting the nutrient balance in the reservoir. This could increase plant biomass and the frequency of algal blooms (UNEP, 2008).

South Africa has been experiencing a warming trend in the past 40 years with the western, northern and the northern-eastern parts of the country showing an increase in temperatures (Kruger & Sekele, 2012). Figure 2.7 illustrates that the mean temperatures of the past 15 years were all above the 1961 to 1990 average (Kruger *et al.*, 2012).

Figure 2.8 shows the mean daily average temperatures during October 2011 to September 2012. It shows that places such as the Northern Cape, North West, Limpopo and northern parts of Kwa-Zulu Natal Provinces experienced very high temperatures

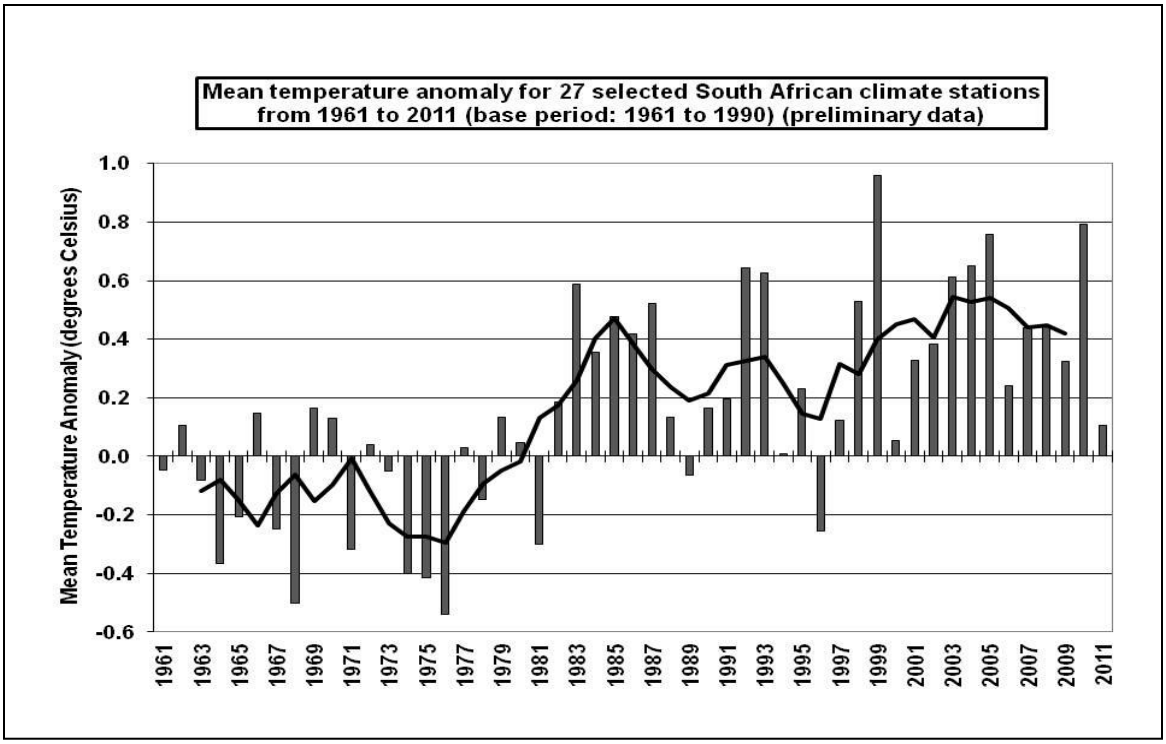


Figure 2.7: Annual mean temperature anomalies (base period 1961 - 90) of 27 climate stations in South Africa, 1961 - 2011 (Kruger *et al.*, 2012).

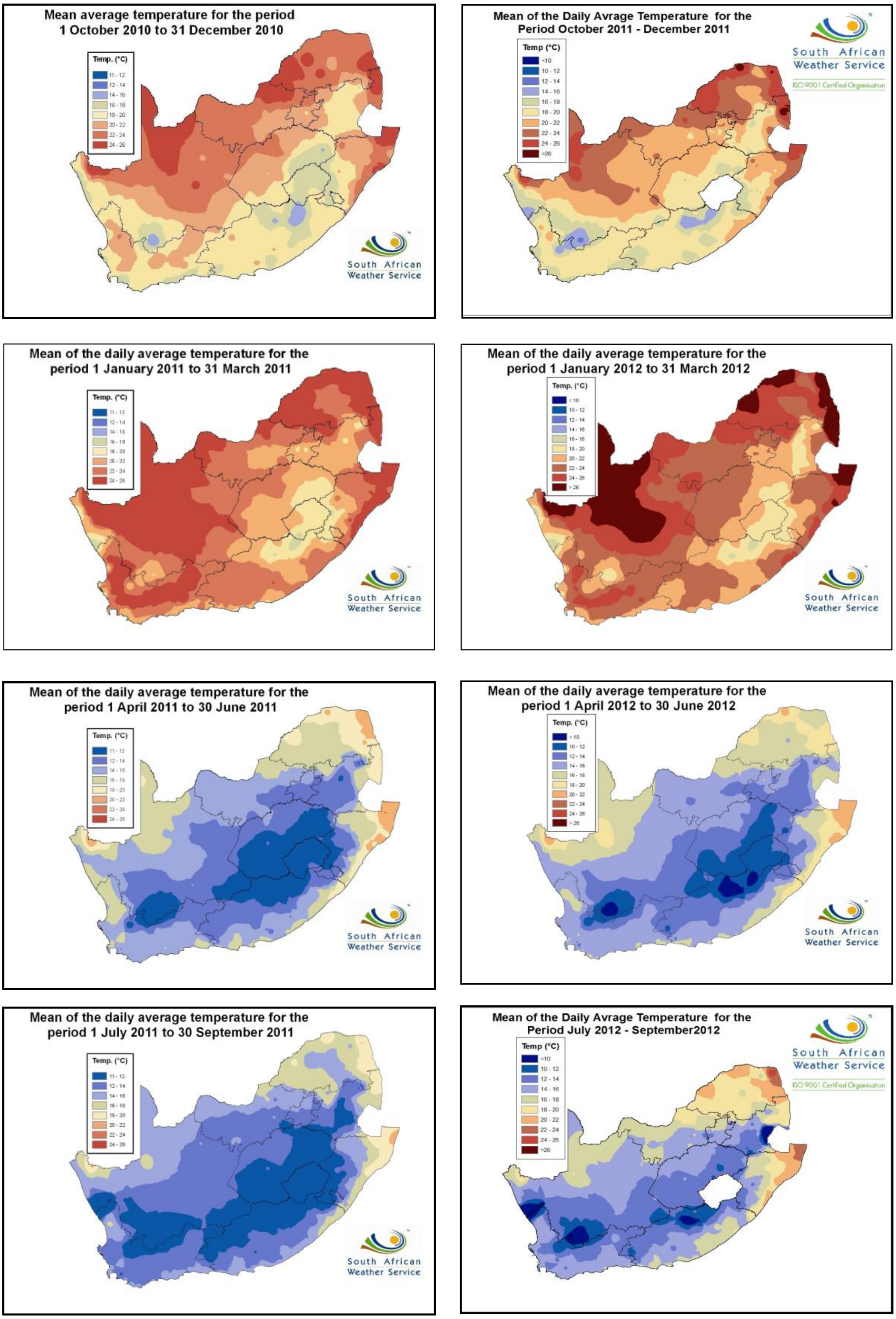


Figure 2.8: Mean daily average temperature for the period of October 2010 to September 2012 (Compiled by SAWS).

Although the average temperatures were high in summer, during winter months (July and August 2012) they plummeted, resulting in snow fall in certain parts of the country (Photo 2). Even areas such as Gauteng had their fair share of snow, a very rare occurrence.



Photo 2: Snowfall in Fraserburg in the Northern Cape (Mail & Guardian), Johannesburg (SABC News), Beaufort West (H. Bennewith, The Post) and Barkly East (News 24) in July 2012.

2.2.1 Evapotranspiration

Through evapotranspiration, forests reduce water yield. The types of vegetation and land cover/use significantly affect evapotranspiration, and therefore the volume of water leaving a catchment. Plants with long reaching roots tend to draw more water as they transpire constantly. Evapotranspiration influences the amount of rainfall. The process of evapotranspiration is shown in Figure 2.9.

Transpiration is the evaporation of water from the plant leaves. It is affected by temperature, relative humidity, type of plant, soil moisture and wind speed. The increase in temperature and wind tend to increase the rate of transpiration while the humidity and soil moisture reduce transpiration. Where the water table is near the surface, the plants can transpire directly from groundwater resulting in drawdown of the water table.

Evaporation from the oceans accounts for 80% of the water delivered as precipitation, with the balance occurring on land, inland waters and plant surfaces. The DWA is monitoring evaporation at 350 evaporation sites located mainly at state dams. The data from the stations was used to create Figures 2.10 & 2.11 below.

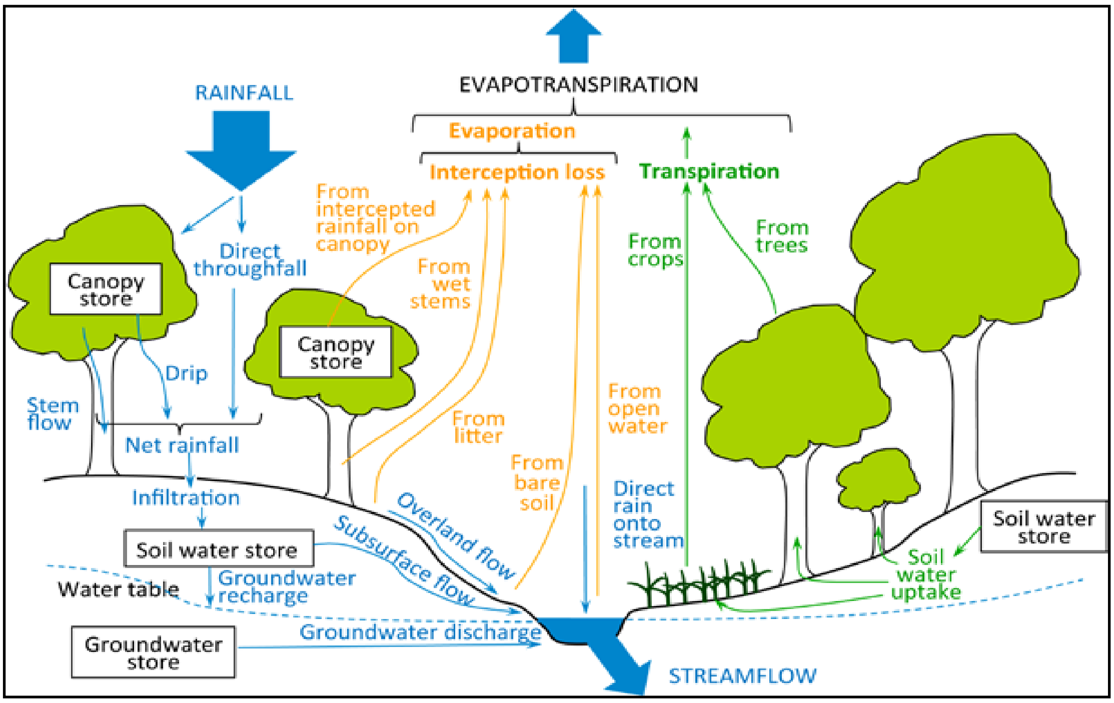


Figure 2.9: The process of evapotranspiration (UNEP, 2011).

According to the figures 2.10 and 2.11, evaporation appears to have increased over a wide area in 2011/12 with the Lower Orange and Lower Vaal WMAs being the most affected and Limpopo to some extent. In 2010/11, the most affected area was in the Lower Orange WMA. The high evaporation in these areas can be linked to very high temperatures between January and March 2012 (Figure 2.8). Interestingly, although the northern part in the Usutu to Mhlatuze WMA experienced high temperatures (Figure 2.8), there is no indication of high evaporation (Figure 2.11). This could probably be due to heavy rains experienced.

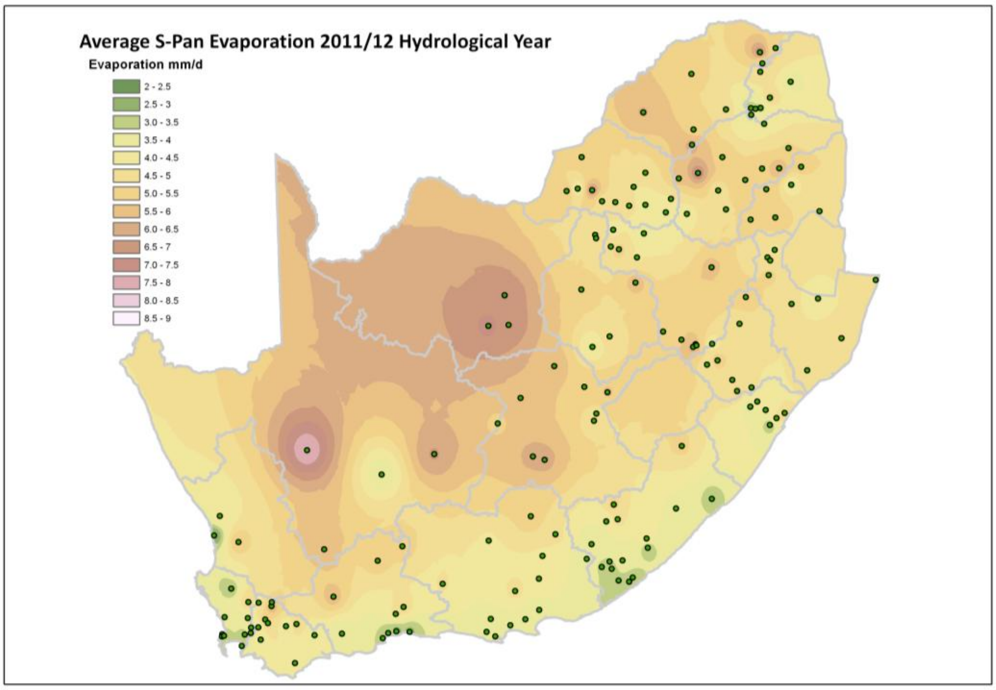


Figure 2.10: Average S-Pan Evaporation 2011/2012 hydrological year.

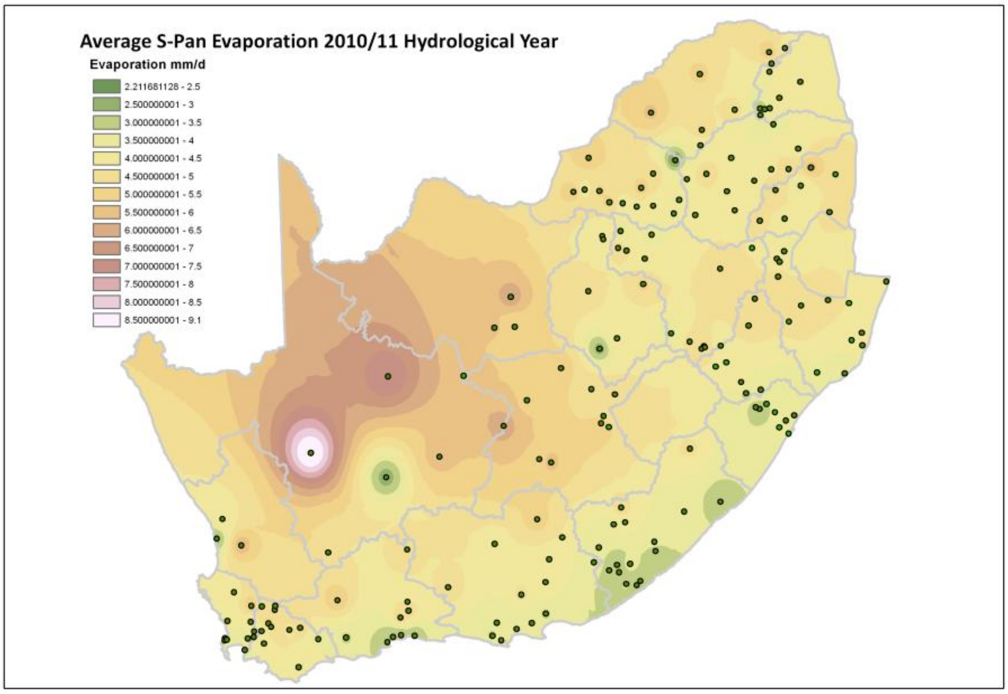


Figure 2.11: Average S-Pan Evaporation 2010/2011 hydrological year.

2.3 Surface water availability

South Africa is a water stressed country with uneven spatial distribution and seasonal rainfall. Some of the country's catchments are experiencing water stress. The uneven distribution of water resources, the rapid population growth and economic development are exacerbating the problem of adequate supply. Because major urban and industrial developments are located far from major water resources, water transfers have been put in place to augment the required supply.

2.3.1 Surface water storage

The frequency and quantity of rain received during the reporting period has contributed to the levels of storages in the country. Generally, the levels of storages were lower than the previous year both nationally and provincially.

2.3.1.1 National water storage levels

The national water storage levels in dams for the past six years are shown in Figure 2.12. The storage levels in 2011/12 showed a decrease in storage until June 2012, thereafter a gradual increase. Generally the 2011/12 storage was lower than the previous four years, with 2010/11 having the highest storage.

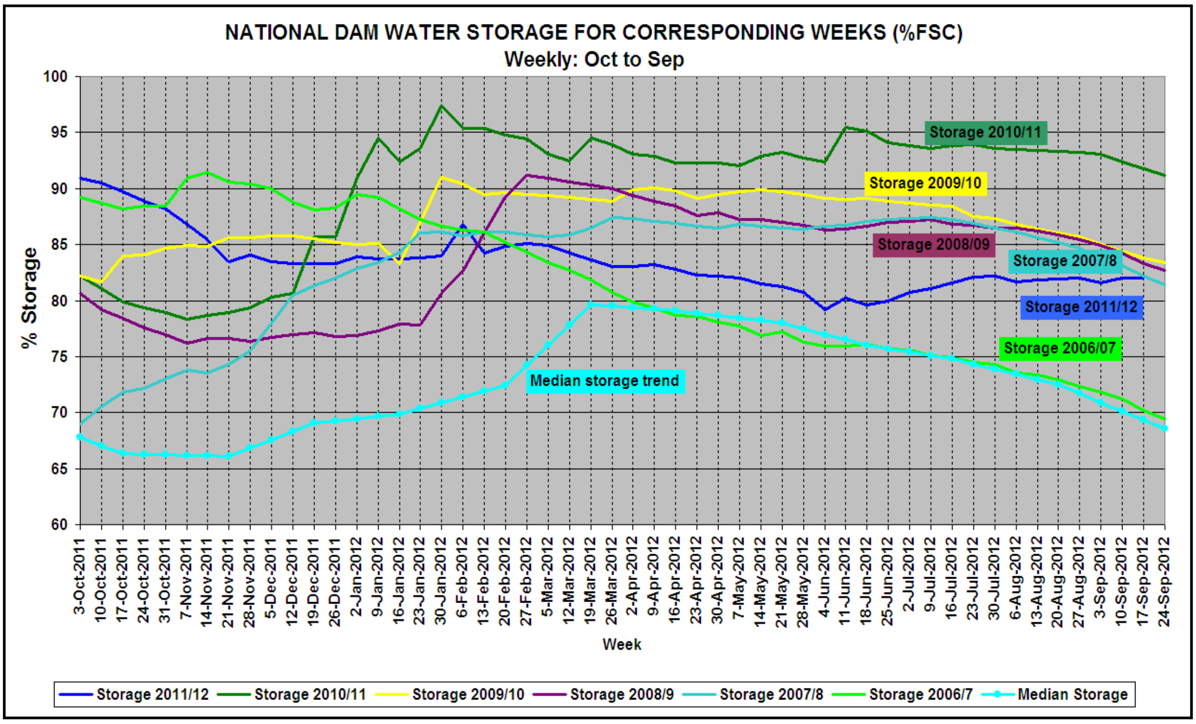


Figure 2.12: Annual national weekly water storage levels for the period of October to September (Compiled by E. Nel, DWA: IWRP).

There have been fluctuations in storage levels in the past 13 years with 2011/12 only being the 9th highest in total storage (Figure 2.13). This could be an indication of the lower rainfall and run-off received during the 2011/12 hydrological year.

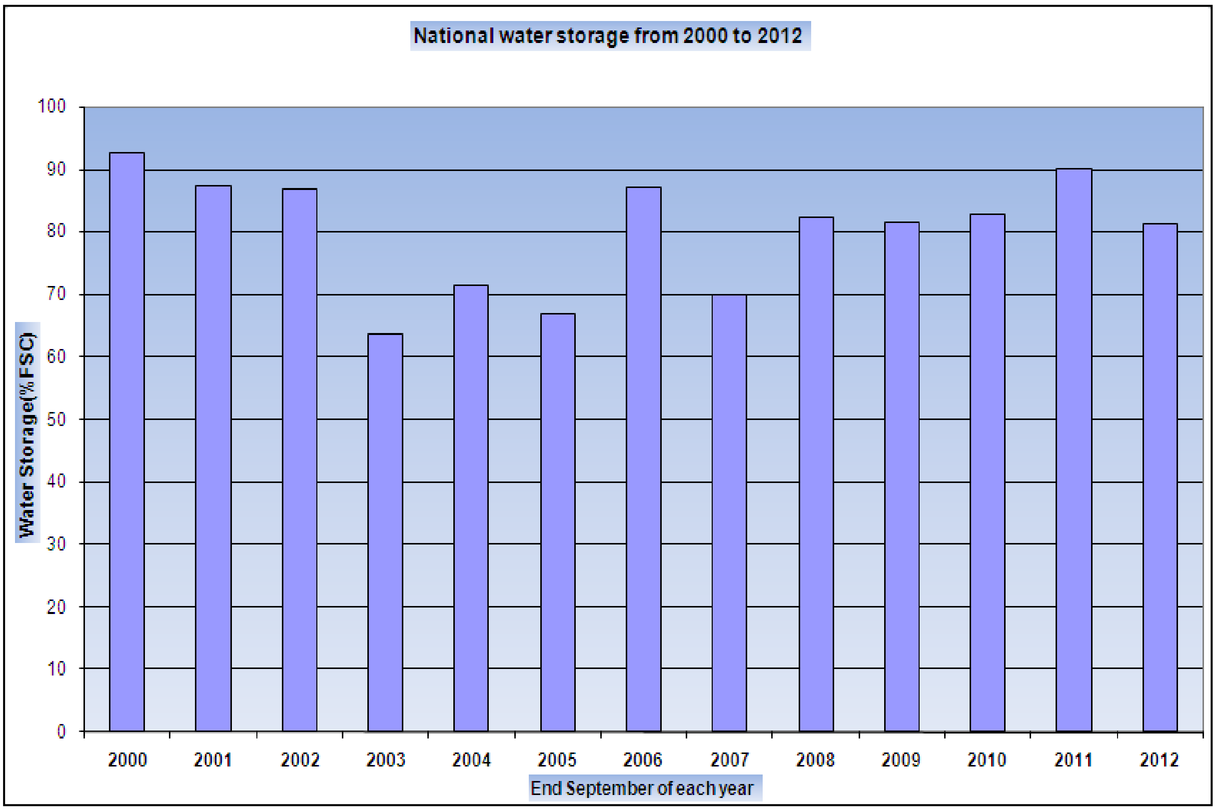


Figure 2.13: Total national water storages for the period of 2000 to 2012.

2.3.1.2 Provincial storages

It must be noted that some provinces have dams with large capacities while others have small capacity. Dams with the largest capacities per province are shown in Table 2.1. The Free State Province has 5 large dams with total full supply capacity (FSC) of greater than 1 000 million cubic meters namely; Gariep, Vanderkloof, Sterkfontein, Vaal and Bloemhof. Gauteng has only 5 very small dams with total FSC of 114.8 million cubic meters. Northern Cape has few small dams with total Full Supply Capacity (FSC) of 145.5 million cubic meters which is the lowest of all the provinces. The Western Cape has many very small dams with Tweewaterskloof Dam being the largest.

Table 2.1: Three (3) of the largest dams in each Province (volumes in $10^6 m^3$).

Province	Dam	FSC	Province	Dam	FSC
Eastern Cape	Umtata Lubisi Ncora	248 158. 147	Mpumalanga	Heyshope Loskop Grootdraai	445 362 350
Free State	Gariep Vanderkloof Sterkfontein	5 196 3 117 2 617	North West	Molatedi Hartbeespoort Roodekopjes	201 187 102
Kwa-Zulu-Natal	Pongolapoort Woodstock Goedertrouw	2 267 373 301	Western Cape	Theewaterskloof Brandvlei Kwaggakloof	480 284 174
Limpopo	Flag Boshielo Middel-Letaba Nandoni	185 172 166			

The storage situations of reservoirs within the Provinces for 2011/12 were lower compared to the previous hydrological year with the exception of the Western Cape, which showed higher storage than the previous period (Figure 2.14). This could be attributed to less rainfall experienced during the reporting period. The high rainfall in the Western Cape caused flooding in some areas. Table 2.2 shows a list of dams that experienced very low storage with the majority situated in the Limpopo Province. These are very small dams except for the Albasini Dam. The fact that there was low rainfall or no rain in the better part of the period has contributed and affected dam storage in the Limpopo Province.

2.3.1.3 Water Management Area storages

The Upper Orange had the highest FSC followed by the Upper Vaal and Usutu to Mhlathuze. Because of the volumes of water in the Upper Orange, there are a number of transfers to other catchments. The Upper Vaal receives a transfer from the Lesotho Highlands to ensure it meets the water demand. The Lower Vaal, Lower Orange and Olifants/Doorn have the least number of dams with very low capacities. Although Usutu to Mhlathuze has eight dams, their total capacity is low at 115.3 million m^3 (Table 2.2)

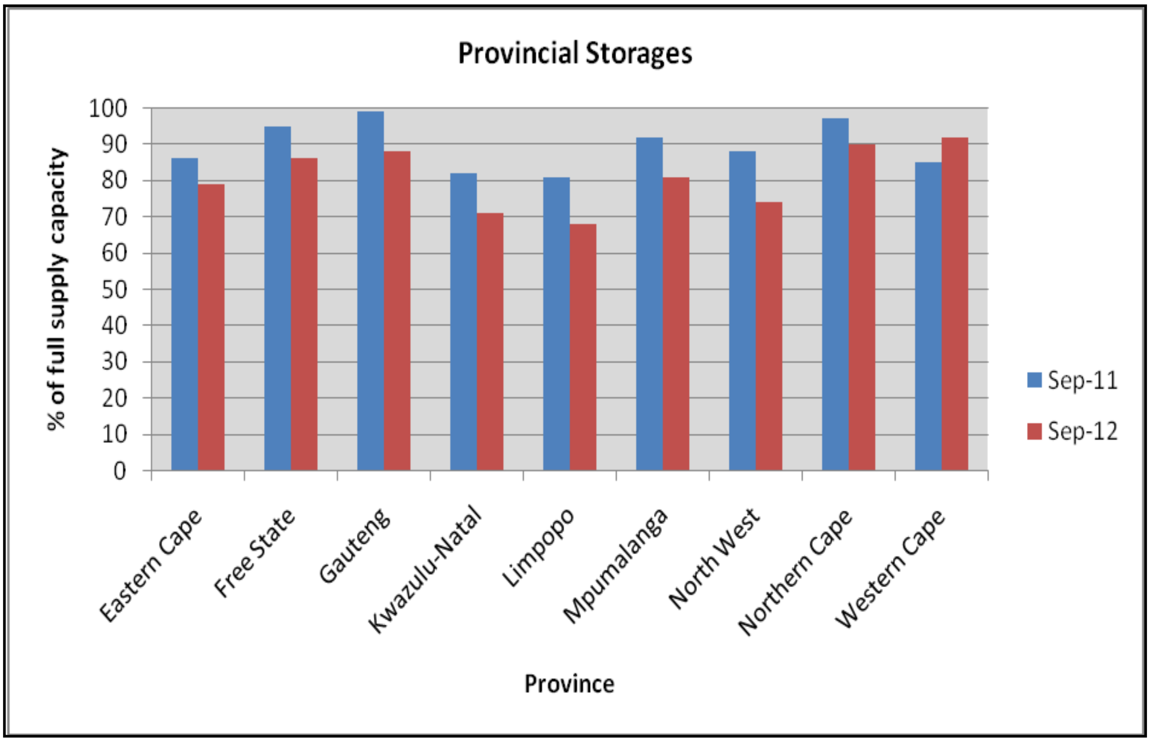


Figure 2.14: Comparison of provincial storages for 2011 and 2012.

Table 2.2: The number of Dams per WMA

WMA	No of dams	FSC (10^6m^3)	WMA	No of dams	FSC (10^6m^3)
Limpopo	7	280.4	Mvoti to Umzimkulu	5	801.9
Luvuvu & Letaba	11	652.5	Mzimvubu to Keiskama	27	1083.1
Crocodile (West) & Marico	22	812.4	Upper Orange	14	11428.3
Olifants	14	1073.9	Lower Orange	2	36.1
Inkomati	8	1049.5	Fish to Tsitsikama	13	725.2
Usutu to Mhalthuze	8	3276.2	Gouritz	20	268.8
Thukela	8	115.3	Olifants/Doorn	3	128.2
Upper Vaal	9	5659.2	Breede	13	1038.9
Middle Vaal	6	1671.6	Berg	6	416.5
Lower Vaal	2	108.5			

In terms of water storage, the majority of WMAs had storage levels above 80% of FSC, while the Middle Vaal and Luvuvhu and Letaba WMAs were either at or below 60% (Figure 2.15). However, the water storages per WMA were lower than the previous year except in the Breede, Berg and Gouritz WMAs while the Olifants/Doorn and Fish to Tsitsikamma WMAs were approximately the same. The storage was high in these four WMAs possibly due to the heavy rains experienced in the western parts of the country in June and August 2012 (Figure 2.3).

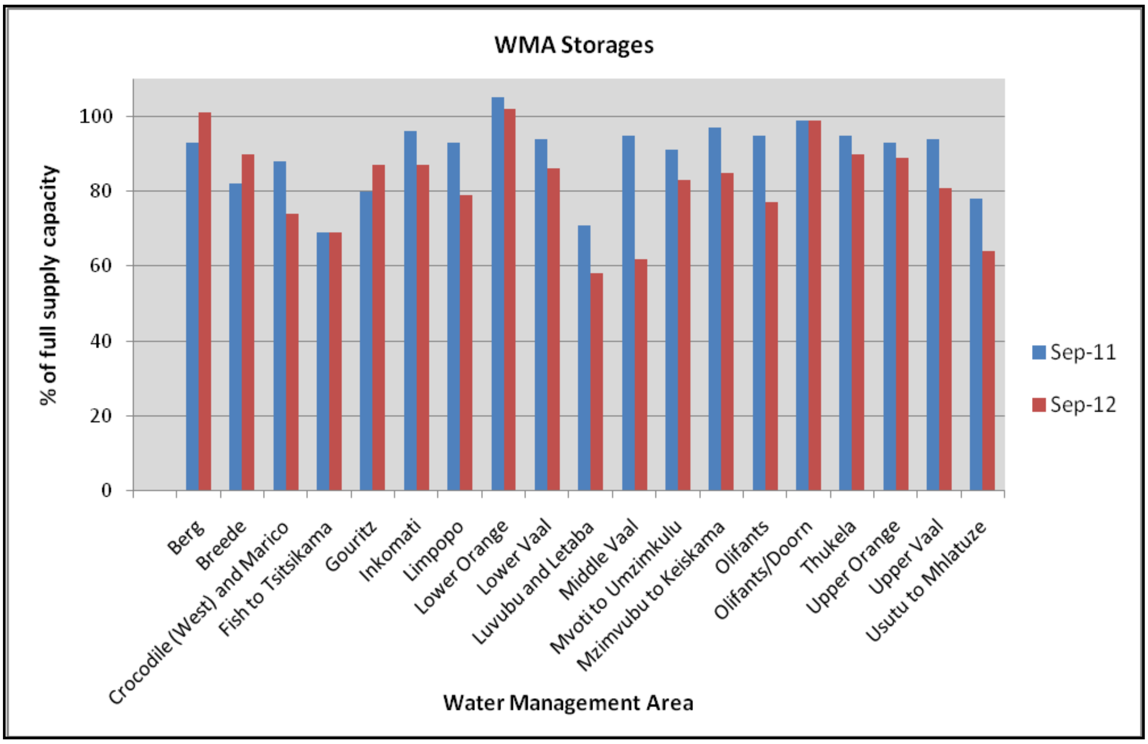


Figure 2.15: Comparison of water storages per Water Management Area for 2011 and 2012.

2.4 Status of major dams

Figure 2.16 below shows the storage status of dams across the country on 24 September 2012. According to the figure, the storage was generally high with the exception of a few dams in the Crocodile (West) Marico, Fish to Tsitsikamma, Limpopo, Levuvhu-Letaba and Usuthu to Mhlathuze WMAs that have very low storage. Table 2.3 lists those dams which experienced low to extremely low storage conditions. These are dams in the Limpopo Province and the low storages could be attributed to the less rains received in the Province (Figure 2.1).

Table 2.3: Dams which experienced low to extremely low storages as at end September 2012.

Dam	River	End Sept 2011	End Sept 2012	Province
Albasini Dam	Luvuvhu River	47.1	34.2	Limpopo
Luphephe Dam	Luphephe River	82.5	33.4	
Middel-Letaba	Middel-Letaba	10.1	0.7	
Nsami Dam	Nsama River	45.9	18.1	
Nwanedzi Dam	Nwanedzi River	80.5	44.9	
Nzhelele Dam	Nzhelele River	89.0	50.4	

The storage status of the 25 major dams in the country is given in Table 2.4. The majority of the dams had high storage levels; except for the Molatedi Dam in the Crocodile (West) Marico and Kalkfontein Dam in Upper Orange.

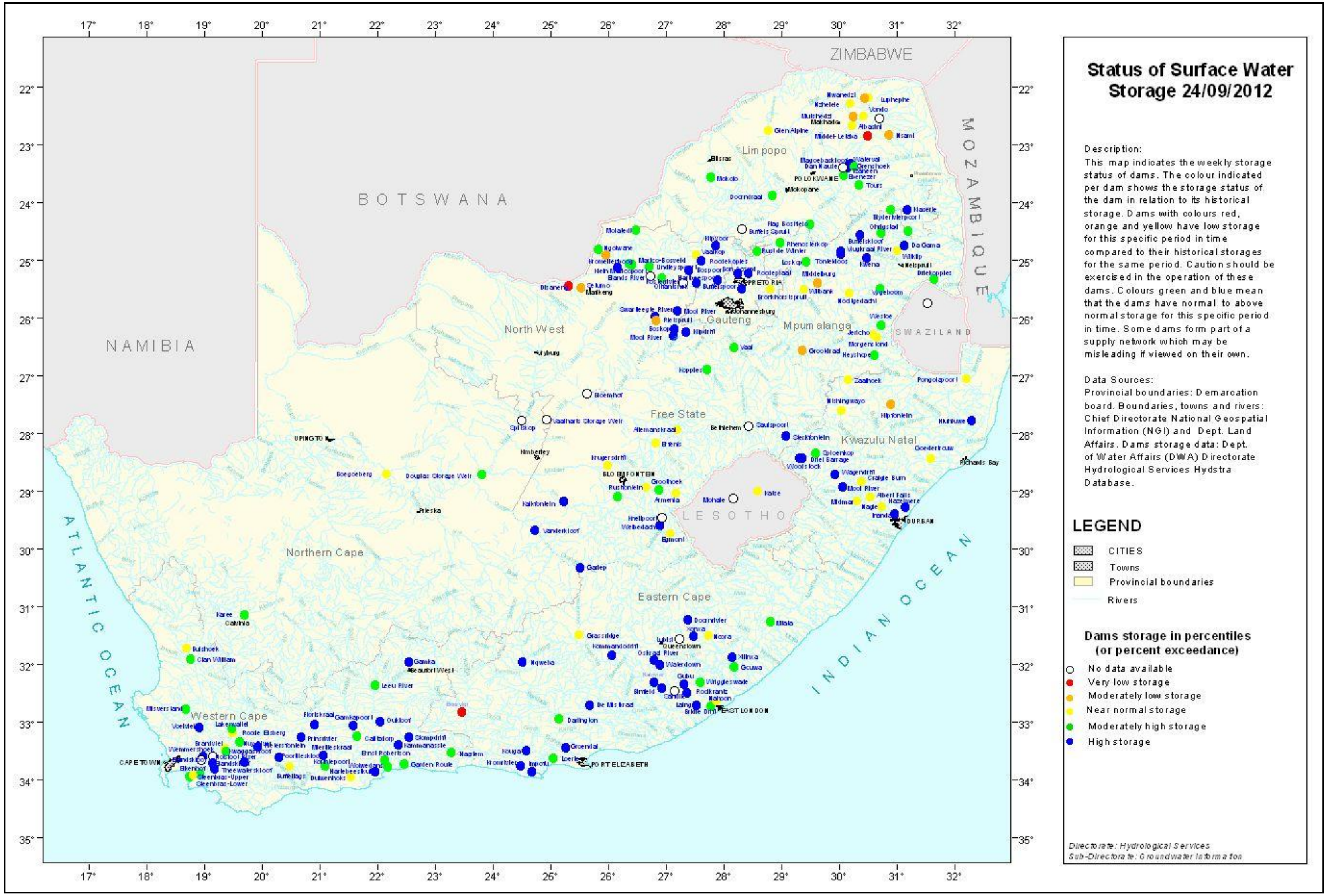


Figure 2.16: Status of surface water storage levels at September 2012.

Table 2.4. Status of the 25 major dams in South Africa.

Dam	River	WMA	FSC ($10^6 m^3$)	Actual capacity ($10^6 m^3$)		%	Purpose
				Sep 2011	Sep2012		
Rhenosterkop	Elands		204	181	200	98.1	Domestic, Irrigation and Industrial supply
Molatedi	Groot Marico		200	78	67	33.8	Domestic and Irrigation
Midmar	Mgeni		235	203	186	79.2	Irrigation, and primary use
Rhenosterkop	Elands	3	204	181	200	98.1	Domestic, Irrigation and Industrial supply
Hartebeespoort	Crocodile		186	184	184	99.0	Irrigation, domestic and Industrial
Loskop	Olifants		362	343	353	97.7	Irrigation, primary and industrial use
Erfenis	Groot Vet	4	207	86	152	73.7	Industrial and domestic use
Driekoppies	Komati	5	250	180	245	97.8	Irrigation, industrial and water transfer
Pongolapoort	Pongolo		2 267	1732	1742	76.8	Irrigation, industrial and for primary use
Goedertrouw	Mhlatuze	6	301	188	197	65.6	Irrigation, primary and industrial use
Woodstock	Tugela		380	366	326	87.5	Transfer to vaal System
Spioenkop	Tugela		270	193	228	84.6	Irrigation, domestic, industrial,
Ntshingwayo	Ngagane	7	194	169	152	78.2	Primary use, industry and irrigation
Grootdraai	Vaal		354	267	301	86.3	Hydropower and industrial use
Vaal	Vaal		2 603	2326	2420	93	Domestic and industrial supply
Sterkfontein	Nuwejaarspruit	8	2 616	2563	2557	97.7	Back up for the Vaal dam in cases of drought
Bloemhof	Vaal	9	1 240	1108	1134	91.5	Primary use, industry and irrigation
Albert Falls	Mgeni		288	261	236	82.2	Irrigation, industrial and domestic use
Inanda	Mgeni		241	221	215	90.6	irrigation and domestic use
Zaaihoek	Slang	11	185	174	167	90.8	Transfer and & Industrial supply
Mthatha	Mthatha	12	248	136	195	78.5	Domestic, industrial and primary use
Kalkfontein	Riet		318	64	107	33.2	Irrigation, primary and industrial use
Vanderkloof	Orange		3 171	3093	3086	97.53	Irrigation , Domestic use and Hydropower
Gariep	Orange	13	5 341	4458	4224	81.3	Irrigation, Domestic use and Hydropower
Brandvlei	Brandvlei		284	2 2 7	2 1 5	75.9	Irrigation
Theewaterskloof	Sonderend	18	480	487	450	93.9	Water supply

2.5 Hydrological extreme conditions

The most common extreme events in South Africa are drought and floods. These can be destructive resulting I loss of life and damage to infrastructure. Floods can also have positive effects such as recharging natural ecosystems. The impact of drought is usually shown by reduction in flows as there is less or no rain at all. Reduced flow could translate into low dam storage.

2.5.1 Drought

Drought is driven by natural climate variability which affects the availability of water. The percentage of normal rainfall has been fluctuating in terms of space and time over the past few years. Very dry conditions are putting severe pressure on South Africa's scarce resources, and are therefore a threat to food security. Drought conditions are also a threat to livestock farming as it diminishes food and water supply. It contributes to poverty, poor health, malnutrition as communities cannot plant or crops become damaged. In the coastal areas, when freshwater runs low, seawaters move in rendering water saline. The levels of groundwater, dams and flows in rivers are affected during drought conditions resulting in limited resources. Water restrictions are usually implemented in some areas as a way of managing resources.


Photo 3: Drought conditions (www.bloomberg.com) and Drought hit maize fields in North West Province (Timeslive)

Drought conditions are a result of low rainfall and very high temperatures, resulting in less runoff, low storage levels and loss of soil moisture. The standardised precipitation index (SPI) has been used to indicate dry conditions. The 12- and 24-month SPI maps give an indication of areas where prolonged droughts existed because of below-normal rainfall recorded over a period of one year or longer. Figure 2.17 illustrates the extent of dry conditions experienced in the country during the reporting period. There is clear indication that parts of North West, Lompopo, Free State, Mpumalanga and Northern Cape Provinces were affected by moderate to extremely dry conditions.

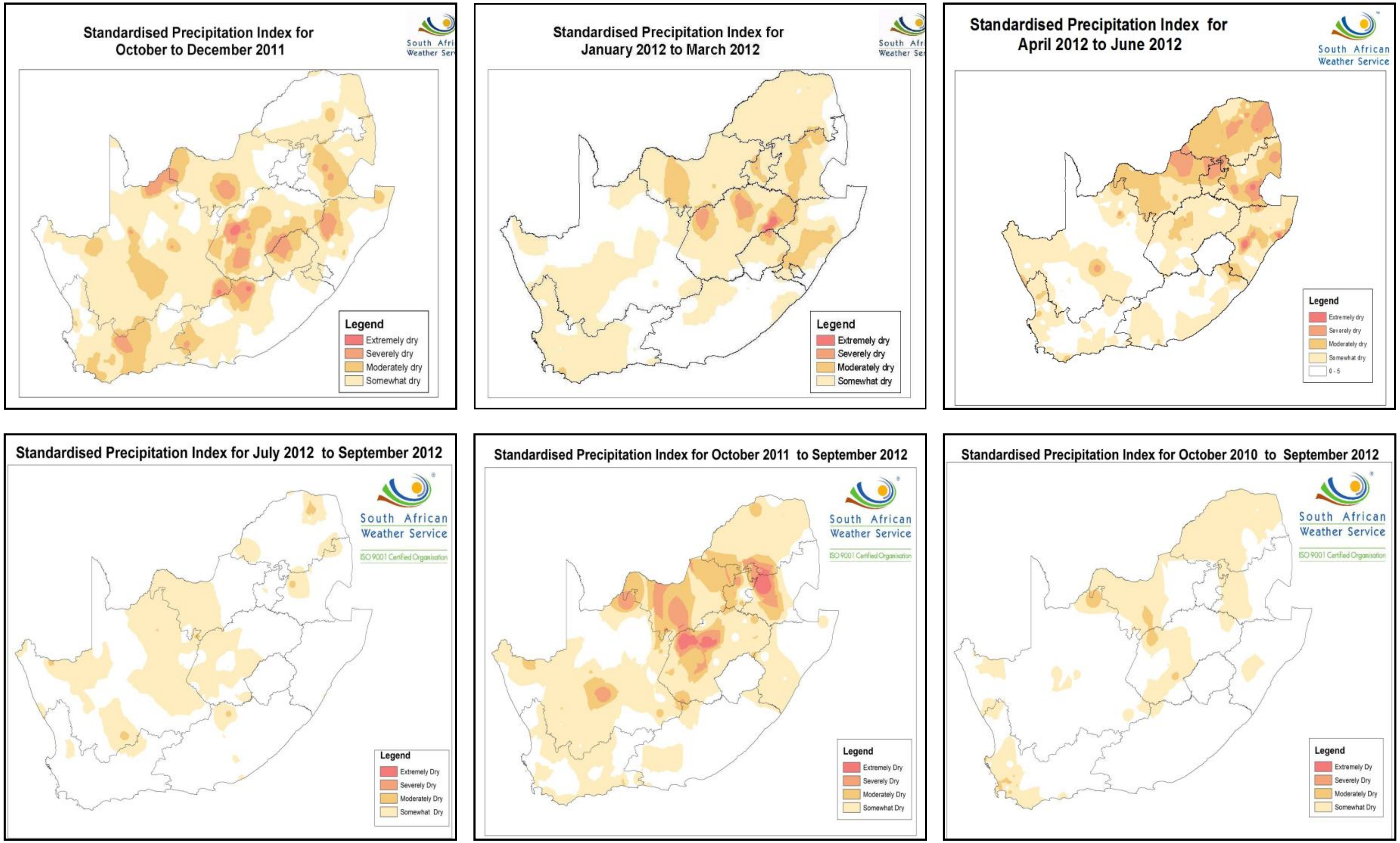


Figure 2.17: An indication of dry conditions in the country using SPI (SAWS, 2012).

2.5.2 Floods

Flow gauging stations that are used for early flood warning both in the country and to neighbouring states. Unfortunately, some of the stations are longer working well because some of the instruments and telemetry systems were damaged during heavy rains and were never repaired. A majority of the big dams have free overflow spillways; which means that, when they are full, the quantity of water that flows in flows out at the same time. This gives a challenge as these dams have limited options to be operated for flood management.

In January 2012, heavy rains fell in Southeast Africa (including Mozambique) affecting the Limpopo and Mpumalanga Provinces of South Africa. Road were damaged and bridges washed away and lives were lost. The Hoedspruit area was the most affected with people having to be lifted to safety from trees and rooftops (Photo 4). The flooding was as a result of a severe tropical low pressure system Tropical Cyclone Dando, a fourth storm to hit the country during the season. The January floods were influenced by La Nina.


Photo 4: Effects of floods at the Hoedspruit area, Limpopo and Kruger National Park.

In March 2012 flooding also hit St. Lucia, Richards Bay and Durban in the Kwa-Zulu Natal Province due to Tropical Storm Irina causing severe damage to houses and infrastructure. The storm also affected Mozambique and Swaziland. The Liesbeek River burst its banks. The Western Cape experienced floods in the third quarter of the hydrological year which were accompanied by very cold weather. Port Elizabeth and surrounding areas in Eastern Cape had its share of flooding and snow in July 2012 (Photo 5).

Photo 5: Effects of floods in Port Elizabeth (www.showme.co.za) and Cape Town (www.homesecuritysite.wordpress.com).

2.6 Sedimentation of Dams

Sedimentation is the process in which eroded soil is transported through water and deposited in a river as sediment. Although soil erosion is a natural process, it is exuberated by human activities such as over grazing, afforestation, etc. Sedimentation affects the flow regime of rivers and reduces the storage capacity of reservoirs as the sediment settles at the bottom of reservoirs.

DWA conducts routine surveys of selected dams and weirs to determine the extent of sedimentation. Based on the outcomes of the survey, a decision will then be taken as to whether to dreg a weir or a dam. Results from the 2012 survey indicated that Welbedacht Dam, on the Caledon River, and Gilbert Eyles Dam, on the Mzimkhulwana River, were the worst affected by sedimentation (Figure 2.18).

2.7 Water restrictions

Water restrictions are imposed in areas where there are water shortages and the decision is based on water levels in the dams and population size. The purpose of water restrictions is to encourage communities to conserve water thus ensuring consistent availability. Water restrictions were imposed mainly in the Free State. Irrigation from the Allemanskraal dam was restricted by 10%, meaning only 90% of the quota could be abstracted. From Erfenis dam irrigation was restricted by 5%, meaning that irrigators could only abstract 95% of their quota. Some form of water restrictions were also applied in uThungulu district in the KwaZulu-Natal Province.

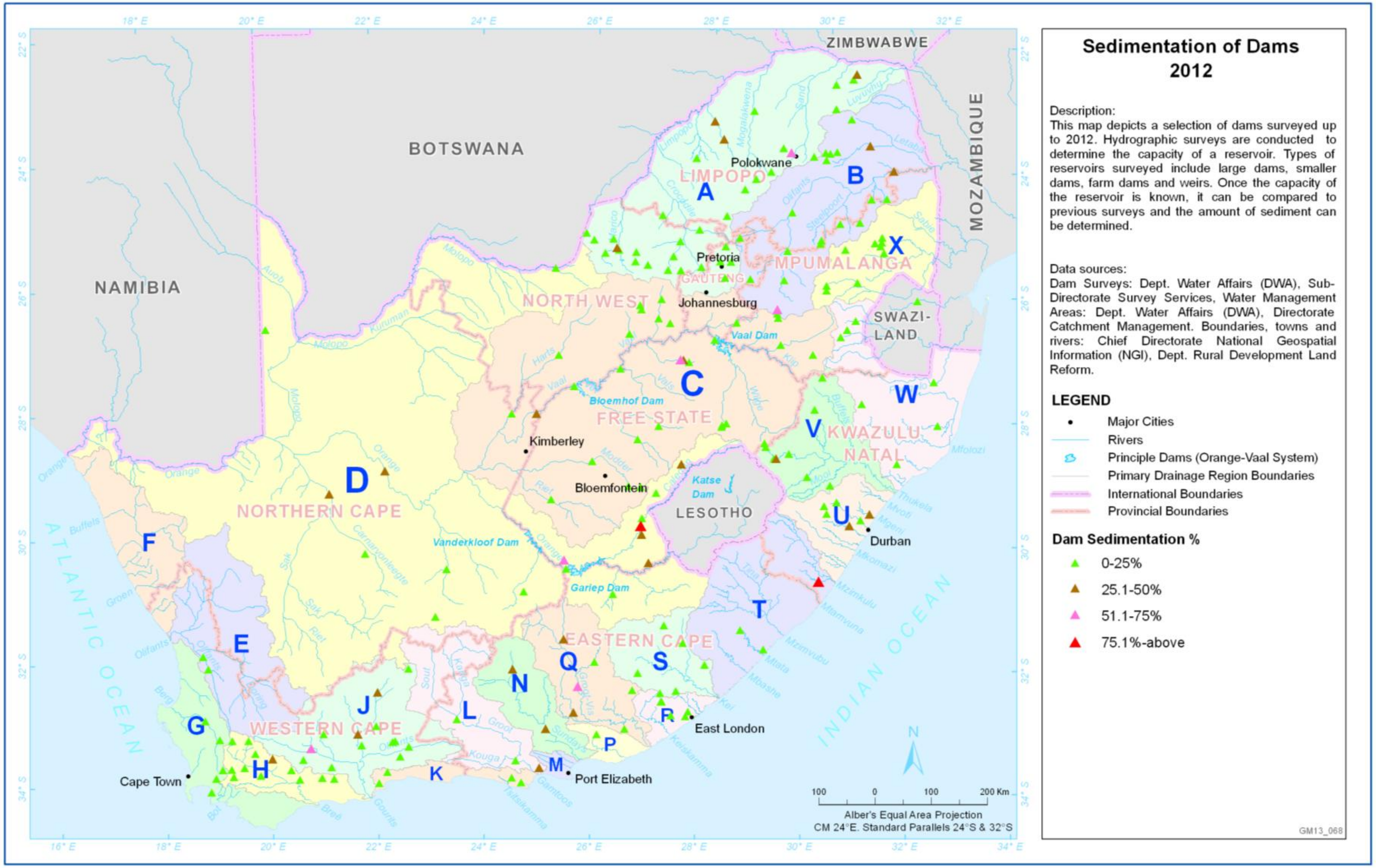


Figure 2.18: Sedimentation levels at selected dams as at end 2012 (Compiled by DWA: SLIM).

3. Surface Water Resource Quality

Water from natural sources contains dissolved substances and non-dissolved particulate matter. It can contain substances that are harmful to life such as metals and living organisms, and these are usually introduced to the water body through a variety of activities. Anthropogenic activities have modified the quality of both surface and ground water resources. The physical, chemical and biological water characteristics influence the ability of aquatic ecosystems to sustain their health. Generally, freshwater bodies have a limited capacity to process the pollutants in effluents from land-based activities. A severe impact on the quality of water affects the aquatic ecosystems and may affect humans depending on the level of contamination. Some aquatic ecosystems are sensitive to small changes in water quality whereas others are resistant to large changes with no detectable effects in composition and function.

South Africa is faced with water quality challenges which are mainly induced by human activity. The problems emanate from industries which produce chemical waste; acidic and metal-rich water from mining; WWTW discharging untreated or poorly treated effluents rich in nutrients, and coliforms (Photo 6); and agricultural run-off rich in pesticides, herbicides and fertilisers. These activities introduce chemicals, microorganisms and other toxic substances into the water.


Photo 6: Sewage effluent from treatment works and overflowing manhole discharging into streams (Picture by WRIP).

The major water quality problems facing the country are eutrophication, faecal pollution, salinisation and acid mine drainage. DWA collects, collates and disseminates information about the chemical, biological and physical attributes of surface water resources at representative sites across South Africa. Currently monitoring is done at 1 741 surface water sites- including dams, rivers, canals and estuaries—for general chemistry, eutrophication, faecal pollution, ecosystem health and, to a limited extent, toxicity.

Water quality is determined by comparing the physical, chemical and biological characteristics of water against the set guidelines or standards. The key attributes of concern for domestic use are: Electrical Conductivity (EC) or Total Dissolved Solids (TDS), nitrate and nitrite as nitrogen

(NO_3 + NO_2 as N), ammonium (NH_4 as N), pH, fluoride (F), calcium (Ca), magnesium (Mg), sulphate (SO_4), chloride (Cl), sodium (Na), potassium (K) and coliforms. The key attributes of concern for irrigated agricultural use are: the Sodium Adsorption Ratio, EC, pH, and salts (Cl, Na, Mg, etc).

3.1 Eutrophication

The problem of nutrient enrichment (phosphorus and nitrogen) associated with excessive plant growth in rivers and reservoirs is known as eutrophication. Although eutrophication is a natural process, the process is accelerated by human activity; a process referred to as 'cultural eutrophication'. Human sources of nutrients include agricultural and urban run-off, settlements without sanitation facilities, raw sewage from overflowing man-holes and poorly treated effluent. Excessive nutrient enrichment can result in the abundance of cyanobacteria or blue-green algae which produce cyanotoxins. The process and causes of eutrophication are shown in Figure 3.1.

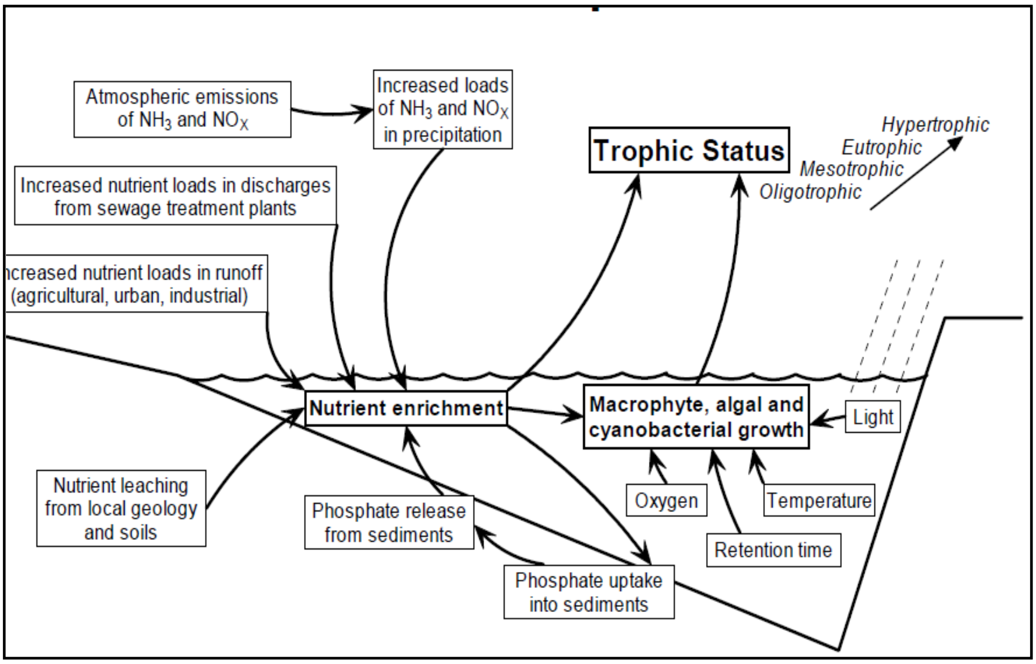


Figure 3.1: Nutrient cycle, indicating causes of eutrophication (Data Source: DWA, 2002).

Eutrophication is a serious problem with many negative impacts on both humans and the environment. The use of water containing cyanotoxins for human and livestock consumption poses a health risk or even death. The presence of weeds and/or algal blooms on the surface of the water prevents light penetration and oxygen adsorption necessary for aquatic life. Eutrophication can also have detrimental effects on the recreational, aesthetic and economical potential of a water resource. The impacts of eutrophication are summarised in Figure 3.2. These include loss of recreation, increased cost of water treatment, clogging of drainage systems, noxious odours and taste, etc.

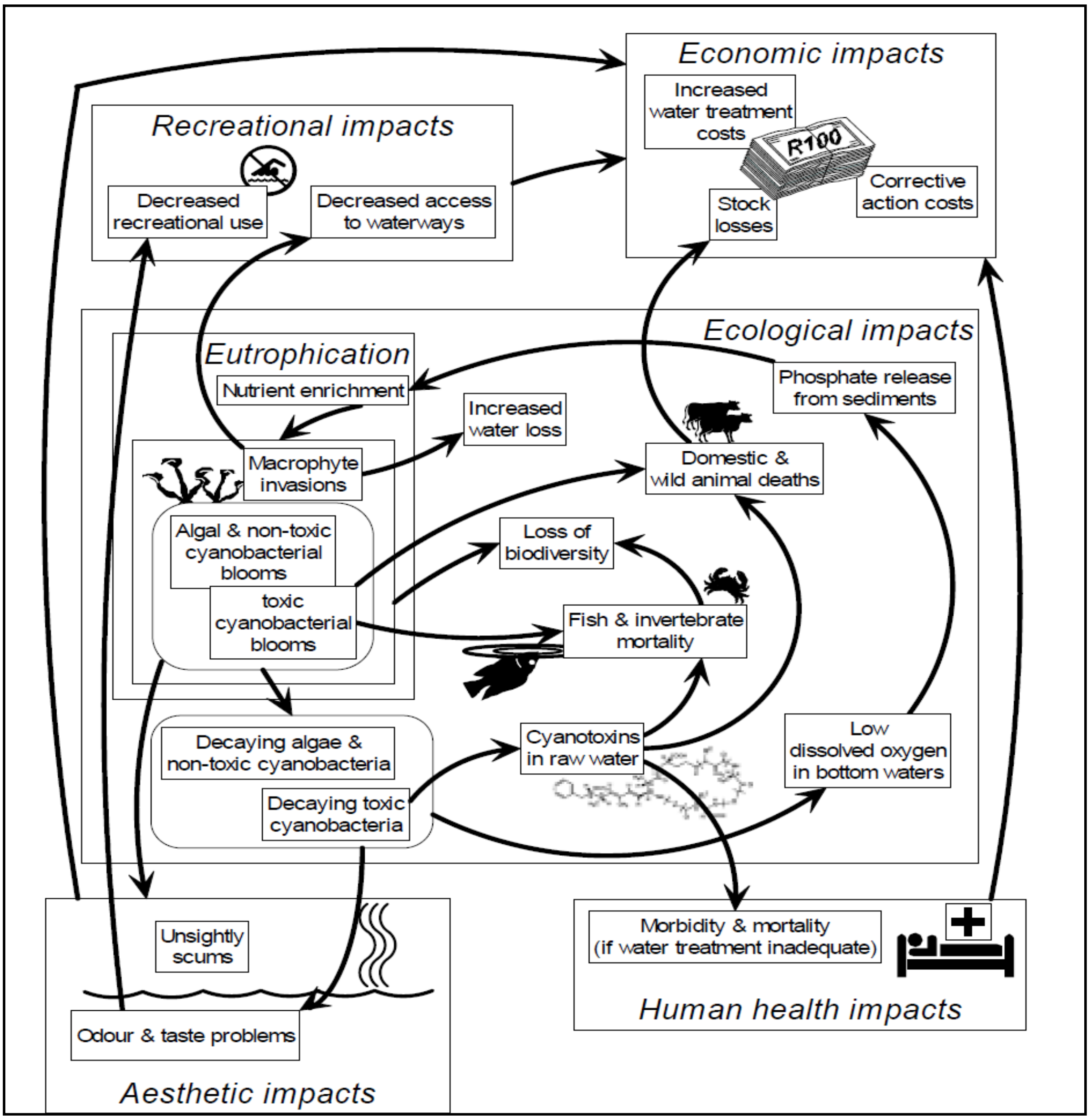


Figure 3.2: Diagram showing impacts of eutropication (Data Source: Du Preez *et al.*, 2002).

3.1.1 The trophic status of dams

A water body can be classified as either oligotrophic, mesotrophic, eutrophic or hypertrophic. The trophic status and eutrophication potential of dams are determined by the levels of chlorophyll *a* and total phosphorus in the water and are presented in Table 3.1. Chlorophyll *a* is a photosynthetic pigment which gives a good estimate of the seriousness of algal growth in a water body. Photo 8 shows Hammesrsdale Dam, in Umgeni, infested with water hyacinth.

Table 3.1: The classification of the trophic status of dams of a water body (Modified from: van Ginkel, 2002).

Table 3.1				
	Current trophic status			
	0<X ≤10	10 < X ≤ 20	20 < X ≤ 30	>30
Mean annual chlorophyll a (µg/l)	Oligotrophic (Low)	Mesotrophic (moderate)	Eutrophic (significant)	Hypertrophic (serious)
% of time chlorophyll a > 30 µg/l	Current nuisance value of algal bloom productivity			
	0	0 ≤ X ≤ 8	8 < X ≤ 50	> 50
	negligible	moderate	significant	serious
Mean annual total phosphorus	Potential for algal and plant productivity			
	X ≤ 0.015	0.015 < X ≤ 0.047	0.047 < X ≤ 0.130	>0.130
	negligible	moderate	significant	serious

Photo 8: Hammersdale Dam in Umgeni catchment partially covered with water hyacinth (Picture by: WRIP).

Table 3.2 List of the dams affected by eutrophication in South Africa.

WMA	Dams	Status
Crocodile (West) Marico	Hartbeespoort	Hypertrophic
	Roodeplaat	Eutrophic
	Roodekopjes	Hypertrophic
	Bon Accord	Hypertrophic
	Bospoort	Eutrophic
	Rietvlei	Eutrophic
	Klipvoor	Hypertrophic
	Vaalkop	Eutrophic
	Bruma Lake	Hypertrophic
	Cooke"s Lake	Eutrophic
Olifants	Bronkhorstspruit	Eutrophic
	Loskop	Serious eutrophication potential
Usutu to Mhlatuze	Klipfontein	Serious eutrophication potential
	Goedertrouw	Serious eutrophication potential
Upper Vaal	Grootdraai	Serious eutrophication potential
	Vaal	Serious eutrophication potential
Middle Vaal	Erfenis	Serious eutrophication potential
	Allemanskraal	Serious eutrophication potential
	Koppies	Serious eutrophication potential
Lower Vaal	Spitskop	Eutrophic
Mvoti to Mzimkhulu	Shongweni	Eutrophic
	Nagle	Serious eutrophication potential
	Inanda	Serious eutrophication potential
	Hammersdale	Eutrophic
Mzimkhulu to Keiskamma	Laing	Eutrophic
	Kariver	Serious eutrophication potential
	Nahoon	Serious eutrophication potential
	Bridledrift	Serious eutrophication potential
Upper Orange	Kalfontein	Eutrophic
	Krugersdrift	Serious eutrophication potential

Table 3.2 above lists some of the dams which are known to be eutrophic as well as those that are at the risk of becoming eutrophic. The Crocodile (West) Marico WMA has the most number of eutrophic to hypertrophic dams. The main sources of pollution in the WMA are sewage effluent and diffuse sources of pollution from urbanised and informal settlements as well as runoff from agriculture and industries. There are more than 30 waste water treatment plants in the WMA with total capacity of <800 Ml/d (DWAF, 2008). According to the Green Drop progress report (DWA, 2012*a*), the City of Tshwane, was the lowest performer in the Gauteng Province, with the most number of treatment plants in high risk positions. Plants such as Sunderland, Rooiwal, Babelegi and Raton scored less than 50% for chemical compliance. These plants contribute towards the high nutrient loads in dams.

During the reporting period, DWA monitored chlorophyll *a* and total phosphorus at about 80 dams and rivers across the country, under the eutrophication monitoring programme. The concentration of total phosphorus is a measure of the potential for eutrophication. The monitoring is not country-wide but only focuses on specific areas. Data showed that the majority of dams in the Crocodile (West) Marico WMA (3) were hypertrophic, with serious eutrophication potential (Figure 3.3). These included dams in the Gauteng and North West Provinces; areas known for their burgeoning economic development and population growth. Other dams with serious eutrophication potential were in the Upper Vaal, Middle Vaal and Berg WMAs.

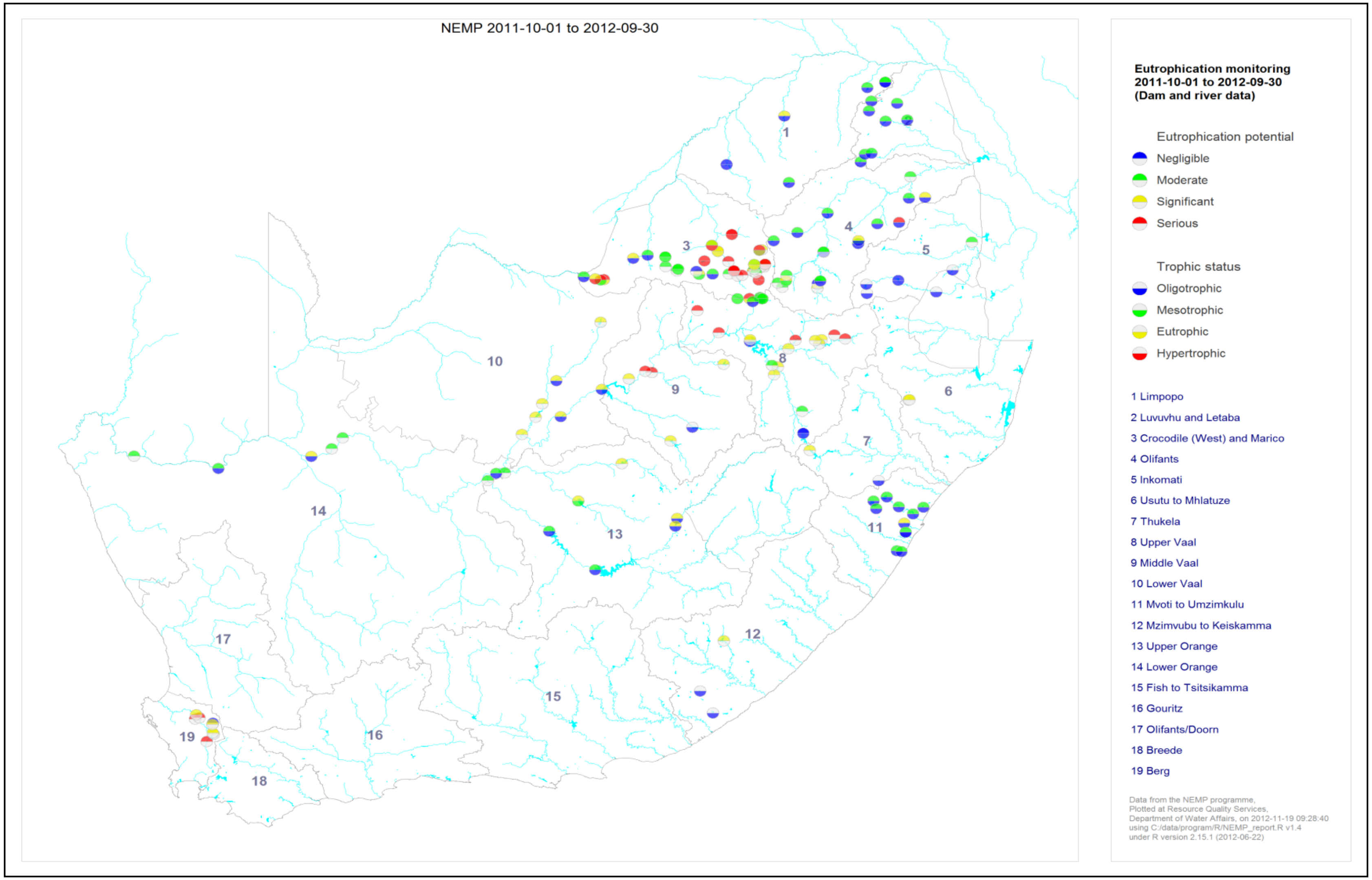


Figure 3.3: Summary of the trophic status and eutrophication potential in South Africa (Compiled by DWA: NEMP).

The effect of temperature on eutrophication was determined on some of the dams by comparing their trophic status during summer and winter seasons. Warm water temperatures and sufficient sunlight are known to be some of the factors favouring eutrophication (Water Wheel, 2008 & van Ginkel, 2011). It was therefore anticipated that eutrophication would proliferate during the warm summer months of the year. As expected, most dams (Hartbeespoort, Rietvlei, Bon Accord, Kalfontein) experienced worse trophic conditions during summer, than in winter. The trophic status of other dams (Vaalkop, Klipvoor) remained the same, irrespective of the season (Table 3.3). Detailed seasonal assessment of dams is available on: (http://www.dwa.gov.za/iwqs/eutrophication/NEMP/report?NEMPyears.htm).

Table 3.3: Trophic status of the dams during the summer and winter months of 211/2012. (Data modified from: DWA: NEMP).

Dam	River	Trophic Status	
		Summer (Oct '11-Mar '12)	Winter (Apr '12-Sep '12)
Hartbeespoort	Crocodile	Hypertrophic	Eutrophic
Rietvlei	Hennops	Hypertrophic	Eutrophic
Bon Accord	Apies	Hypertrophic	Mesotrophic
Roodekoppies	Crocodile	Hypertrophic	Oligotrophic
Kalfontein	Riet	Eutrophic	Mesotrophic
Bruma Lake	Juskei	Hypertrophic	Mesotrophic
Vaalkop	Elands	Hypertrophic	Hypertrophic
Klipvoor	Pienaars	Hypertrophic	Hypertrophic
Bospoort	Hex	Hypertrophic	Hypertrophic
Bronkhorstspruit	Bronkospruit	Mesotrophic	Mesotrophic
Roodeplaat	Pienaars	Eutrophic	Hypertrophic

Eutrophication management options currently in place

In order to effectively manage eutrophication, the problem must be treated at the source (i.e., the source of pollution). However based on limiting nutrient concept, most control measures are aimed at reducing the external loads of a nutrient entering into a water body. Unfortunately it is not always feasible to reduce the nutrient load and in such cases, control programmes which target the symptoms of eutrophication, are employed. It is important to note that these control programmes only treat the symptoms and not the problem (Rossouw *et al.,* 2008).

DWA is currently in the process of determining charge rates for implementation of Waste Discharge Charge System. The purpose is to encourage the water users to ensure their effluents meet set standards before being discharged into water resources. There is also a process of developing guidelines for the prevention, management and control of eutrophication in water reservoirs. Other interventions and/or management plans have been initiated to rehabilitate the algae infested dams.

The '*Harties Metsi A Me*' biological rehabilitation programme is an example of a holistic eutrophication management plan. The programme consists of a number of projects which include in-lake management techniques targeting the dam basin area; controlling of the external nutrient loads from upstream catchments as well as measures to control the symptoms at the dam. An example of one of these projects is the construction of artificial wetlands to re-stabilise the degraded shoreline vegetation and restore the shoreline buffer zone functionality. The destruction of the shoreline has impacted negatively on the aquatic food-web as habitat for zooplankton and other aquatic life was lost in the process. This also affected the bio-filtering function of the riparian vegetation to help trap nutrients and prevent erosion. The objective of rehabilitating the shoreline and implementing floating wetlands is to improve the habitat conditions for the breeding and maintenance of zooplankton, invertebrate, insect, fish and bird populations. Figure 3.4 showed illustration of the wetland and supported communities of macro-invertebrates, plants, birds etc. In august 2012, a total of 235 wetlands were built and in operation and 8 530 m² of shoreline rehabilitated (www.harties.org.za/wetshore.aspx).

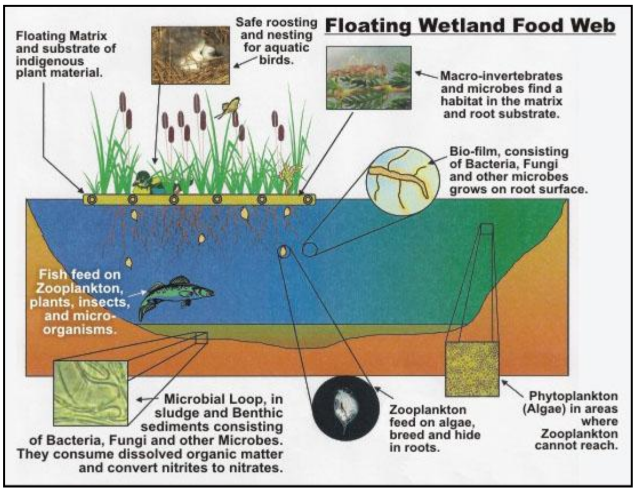


Figure 3.4: Schematic illustration of floating wetland and food web (Data source: www.harties.org.za/wetshore.aspx).

Box 1: Rehabilitation of Rietvlei Dam

Rietvlei Dam has been utilised by the City of Tshwane for drinking water, since 1934. The Dam supplies around 41 million litres of water daily, which is about 3% of the metro's drinking water requirements. The Dam is situated downstream of some of Gauteng's urbanised areas (Centurion, Kempton Park). This has resulted in the Dam becoming hypertrophic with cyanobacterial blooms, causing bad odours and taste.

As a means to solve the problem, six (6) SolarBees™ were installed in the Dam. SolarBees™ are solar-powered machines which circulate water thus disturbing the habitat for cyanobacteria by making the conditions unfavourable. Although the machines only treat the symptoms and not the actual problem, they have been found to be effective in improving the quality of the water by improving aeration thus increasing the dissolved oxygen levels. However, SolarBees™ cannot take all the credit for the recovery of Rietvlei Dam. Studies have shown that the Rietvlei's wetland, just upstream of the Dam, has played a key role in purifying the water before it flows into the Dam. The wetland has been one of the subjects of an intensive restoration project run by Working for Wetlands.

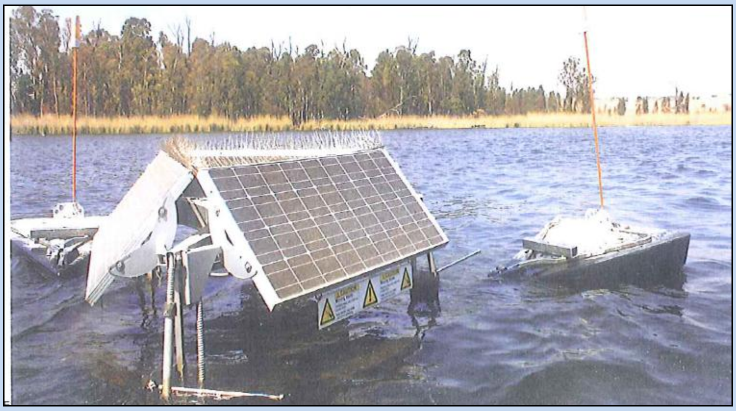


Photo 8: One of the six solarBees™ installed in Rietvlei Dam (Data source: Water Wheel, 2012).

There's a possibility of SolarBees™ being rolled out in other eutrophic and hypertrophic dams across the country including Loskop and Roodeplaat Dams. However the high cost of the technology is likely to become a challenge. The technology is being used to rehabilitate Bruma Lake, an initiative by the City of Johannesburg.

3.2 Microbial pollution/contamination

The DWA National Microbial Monitoring Programme (NMMP) monitors and provides information on the status and trends of faecal pollution in surface water resources in selected high health risk areas, referred to as 'hotspots', across the country. A high health risk area is defined as 'an area that has (at the time that the assessment was done) been exposed to factors that might have contributed to a potential health risk, due to faecal pollution of surface water resources' (van Niekerk, 2000). The programme uses bacteria *Escherichia coli (E. coli)* as an indicator organism for faecal contamination. According to water quality guidelines, drinking water should contain no indicator organism and high counts of *E. coli* in rover water suggest that the water is faecally contaminated and poses a health risk (water-borne diseases).

DWA analysed 2 210 *E. coli* samples collected from 134 hotspot sites during the reporting period. Figure 3.5 shows the extent of faecal contamination (*E. coli*) at the various hotspot sites across the country. Most of the monitored sites had unacceptable levels of *E. coli*, particularly the Crocodile (West) Marico and the Berg WMAs. Users in these catchments must take precaution when using the water, especially for drinking purposes.

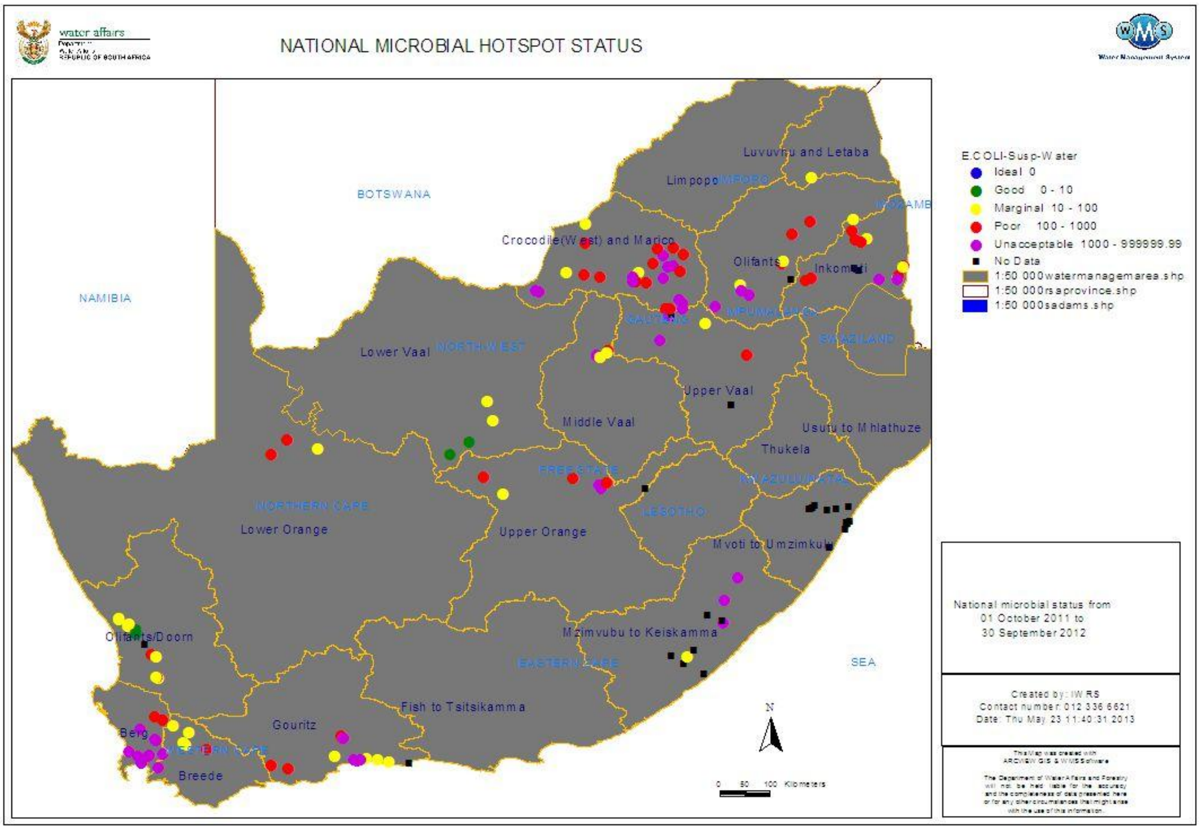


Figure 3.5: The microbial status at hotspot sites as of end September 2012.

Four water uses are considered in the NMMP to assess microbial contamination. These are: drinking untreated water, drinking water with limited treatment, irrigation of crops eaten raw and full or partial contact (recreational activities. The analysis of data indicated that most of the rivers were faecally contaminated and posed health risk to users, especially when using the water without any treatment (Table 3.4).

According to Figure 3.6, many of the hotspots sites posed a high health risk associated with the use of untreated river water for drinking purposes. This was with the exception of a few sites in the Olifants/Doorn, Mzimvubu to Keiskamma and Olifants WMAs, which showed low to moderate risks. A number of WMAs also indicated a high risk associated with the use of water for recreational purposes. There are areas in the Crocodile-West and Marico, Mvoti to Mzimkulu, Mzimvubu to Keiskamma and Berg WMAs that pose a high health risk for irrigating crops that are eaten raw (Figure 3.6). A site-level interrogation of the data is important for detailed analysis and complete results on NMMP are available from the DWA website: http://www.dwa.gov.za/iwqs/microbio.reprt/index.asp.

Table 3.4: Rivers most affected by microbial contamination (Data modified from: DWA: NMMP).

WMA	Affected Rivers	Risks associated with use
Crocodile (West) Marico	Jukskei, Kareespruit, Moretele, Tolwane, Apies, Sand, Elands, Hex	Drinking without treatment, drinking with partial treatment, full or partial contact irrigation of crops
Olifants	Steelpoort, Spekboom, Witpoort	Drinking without treatment
Inkomati	Sabie, Crocodile, Komati, Elands, Leeuspruit	Drinking without treatment, full or partial contact
Upper Vaal	Rietspruit, Klipspruit	Drinking without treatment, drinking with partial treatment, full or partial contact
Middle Vaal	Koekemoerspruit, Jagspruit, Skoonspruit	Drinking without treatment, irrigation of crops
Lower Vaal	Vaal, Harts	Drinking without treatment
Mvoti to Umzimkhulu	Mgeni, Msunduze, Mdloti	Drinking without treatment, full or partial contact, irrigation of crops
Mzimvubu/Keiskamma	Umtata, Mzimvubu, Gcuwa	Drinking without treatment, full or partial contact, irrigation of crops, drinking with partial treatment
Upper Orange	Caledon, Riet	Drinking without treatment, full or partial contact
Gouritz	Gwaing, Sout, Meul, Skaapkop	Drinking without treatment, full or partial contact
Olifants/Doorn	Olifants, Boontjies, Dissel	Drinking without treatment
Breede	Klipdrif, Bree	Drinking without treatment, full or partial contact, irrigation of crops, drinking with partial treatment
Berg	Berg, Dipe, Eerste	Drinking without treatment, full or partial contact, irrigation of crops, drinking with partial treatment

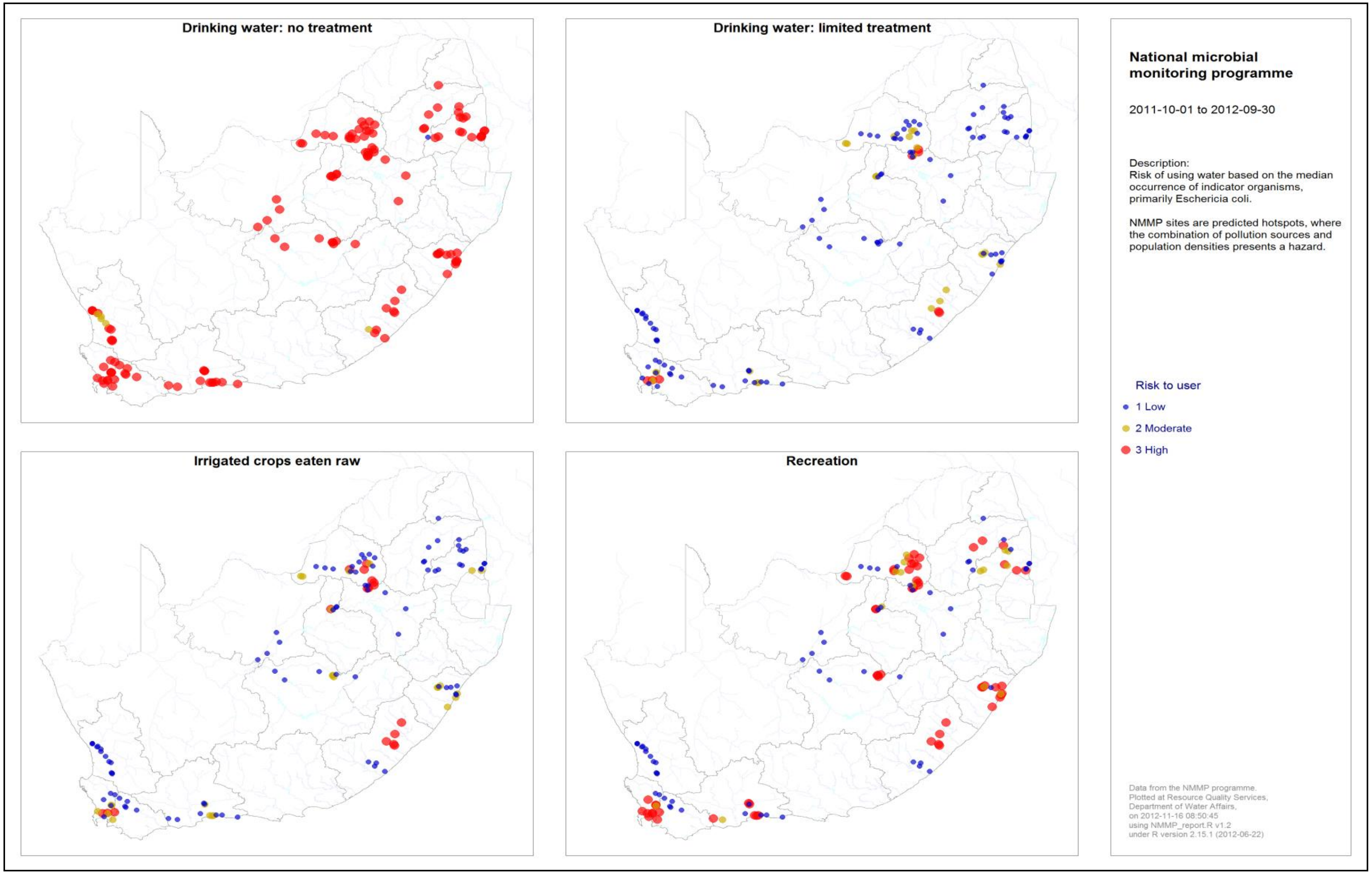


Figure 3.6: Levels of risks associated with the use of water contaminated with *E.coli.* (Compiled by DWA: NMMP).

3.3 Salinisation

Salinisation or mineral salts can arise from a number of sources, either naturally as a result of leaching from geological features, groundwater discharges and/or salt water intrusion; or from land-based activities such as mining, industries and agriculture. Activities such as coal mining can introduce elevated levels of salts such as sulphates and magnesium into water resources. Some industries, e.g. textile, tanneries and pulp and paper can contribute to high concentrations of sodium, chloride, sulphate and heavy metals. High levels of salinity may affect crop yields as some crops are sensitive to salts.

In South Africa there are areas with natural salinisation due to geological formations. The western and southern parts of the Western Cape are the most affected. Marine geology and possibly the intrusion of salt water from the sea have been contributed to high saline water in coastal regions. Table 3.4 shows the dominant water types found in natural surface water in South Africa. Deviation from these common compositions suggests potential contamination of water.

Table 3.5: The four dominant water chemistry types found in natural surface water in South Africa (Day & King, 1995; Allanso, 2004; Huizenga, 2011).

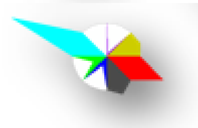
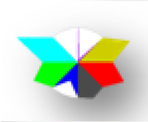
Category	Chemical composition	Maucha diagram	Geology
1	Calcium and magnesium carbonate, low salinity		High basaltic cap, dolomites
2	Calcium and magnesium carbonate, high salinity		Karoo and Waterberg sedimentary rocks; igneous rocks of the Bushveld complex
3	Ions co-dominant		Intermediate types
4	Sodium chloride		Table mountain sandstones, western arid Karoo sediments, coastal plain of KwaZulu-Natal

Figure 3.7 shows the different water chemistry types found in some of South Africa's river systems. The rivers in the south-western regions (Breede and Berg) are rich in Sodium and Chloride. The inland rivers, where mining activity is dominant, are rich in sulphates, total alkalinity, magnesium etc. These rivers include the Olifants and Vaal, which are impacted by mine effluent.

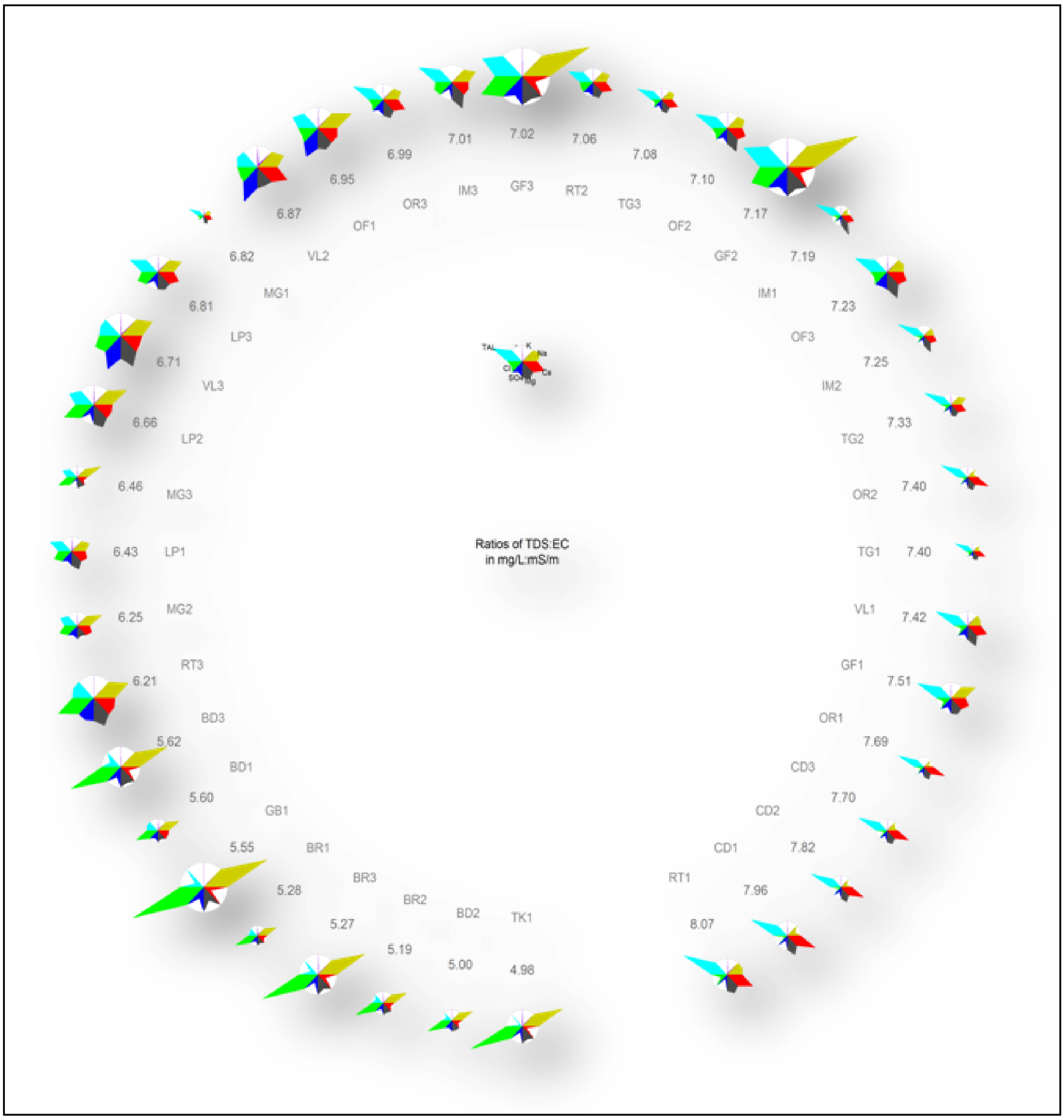


Figure 3.7: Range of water chemistry types and TDS:EC ratios observed in South African River systems.. (Data source: Silberbauer, 2012). *BD=Breede, BR=Berg, CD=Caledon, GB=Groot Brak, GF=Great Fish, IM=Inkomati, LP=Limpopo, MG=Mngeni, OF=Olifants, OR=Orange, RT=Riet, TK=Tsitsikamma, TG=Thukela, VL=Vaal.

DWA monitors the inorganic chemical quality at priority sites across the country. The distribution of the priority sites is such that there is one sampling site close to the downstream end of each tertiary drainage region as a descriptor of the water quality situation of the entire tertiary catchment.

Analysis of inorganic chemical data for the reporting period indicated that the Western and Southern Cape coastal areas were mainly dominated by sodium (Na^{+}) and chloride (Cl^{-}) ions

(Figure 3.8). This could be attributed to several factors including the geology, intrusion of sea water and/or impacts of land-based activities (agriculture). The inland areas on the other hand, were dominated by bicarbonate (HCO_3^-), magnesium (Mg^{2+}) and calcium (Ca^{2+}) ions. The presence of these chemicals on inland waters levels could be due to several reasons, such as the chemical weathering of rocks (Huizenga, 2011). In areas dominated by mining activity, the presence of calcium and magnesium carbonate could emanate from alkaline mine waters (pH>5) and/or from conventional treatment of acidic water by liming (Novhe, 2012). The affected areas included the Olifants, Upper and Middle Vaal WMAs; areas known for mining activity. Also illustrated in Figure 3.8 are the slightly elevated levels of sulphate levels at some sites in the Olifants WMA; an indication of acid mine drainage.

The risks associated with using saline water for domestic and agricultural uses are presented in Figure 3.9. For domestic use, poor to unacceptable levels of TDS or EC, Na, Cl, SO_4 and Mg were found in some parts of the coastal regions (parts of the Western and Southern Cape). Once again, marine geology and salt water intrusion could be contributing factors to the salinity of surface water along the Western and Southern Cape. Fair conditions were present in the Middle and Lower Vaal WMAs. The situation could be attributed to urban, mining and agricultural return flows. Fluoride levels were in the fair range at sites in the Olifants WMA.

Figure 3.10 shows mean salinity (EC) trends for the past 5 years. Over the years, there seems to be general fluctuation in EC levels, particularly in the south-western parts of the country. However, during 2010/11 hydrological year salinity levels were particularly higher in the Gouritz and Fish to Tsitsikamma WMAs. Stable and low salinity levels were present in the central and eastern regions (Upper Orange, Mzimvubu to Keiskamma and Thukela WMAS. This was with the exception of those areas where mining is predominant such as the Vaal and Olifants catchments.

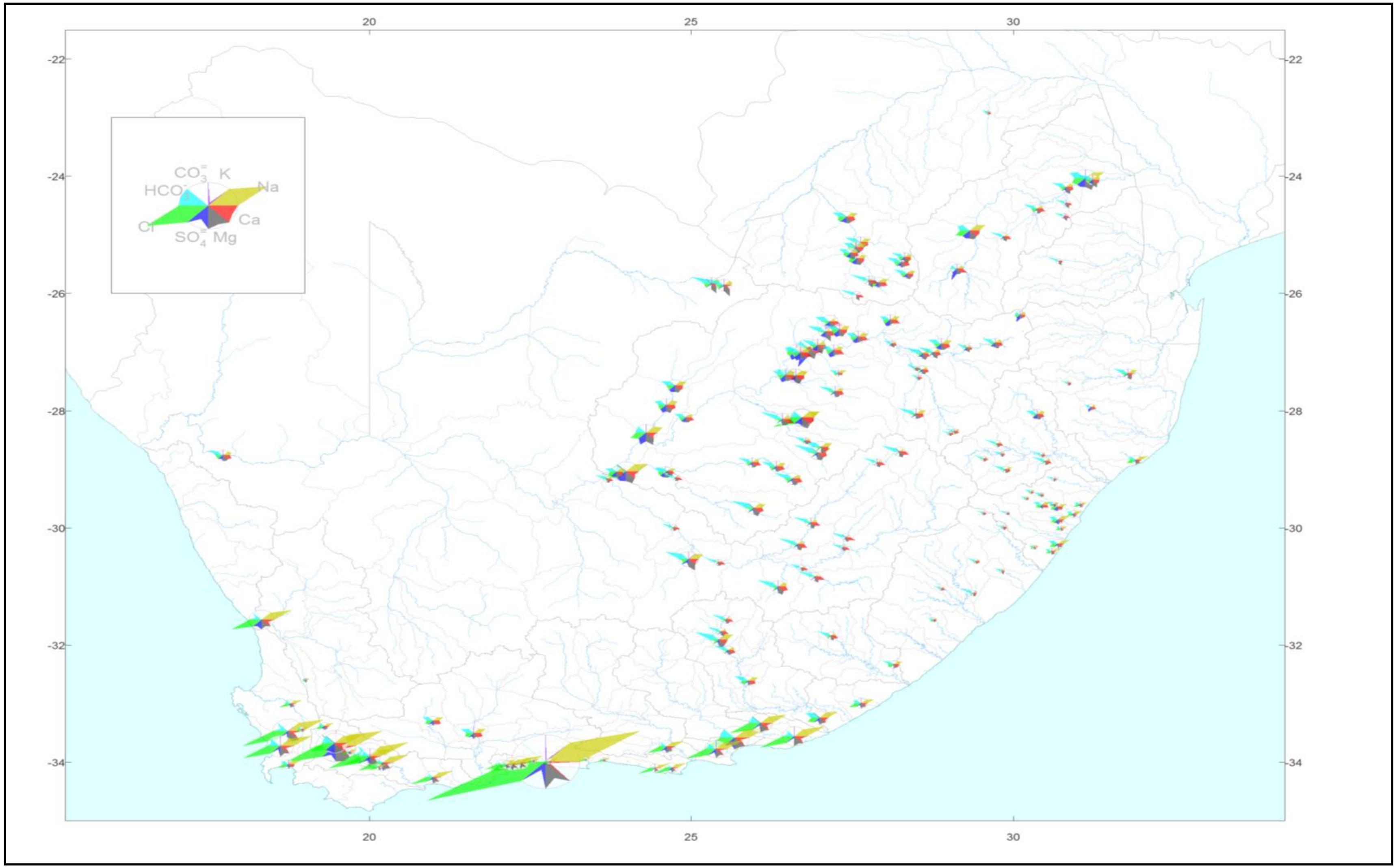


Figure 3.8: National inorganic water quality status as at end September 2012 (Compiled by M. Silberbauer, DWA: RQS).

Figure 3.9: The chemical analysis for salinity and its risk to various users (Compiled by M. Silberbauer, DWA: RQS).

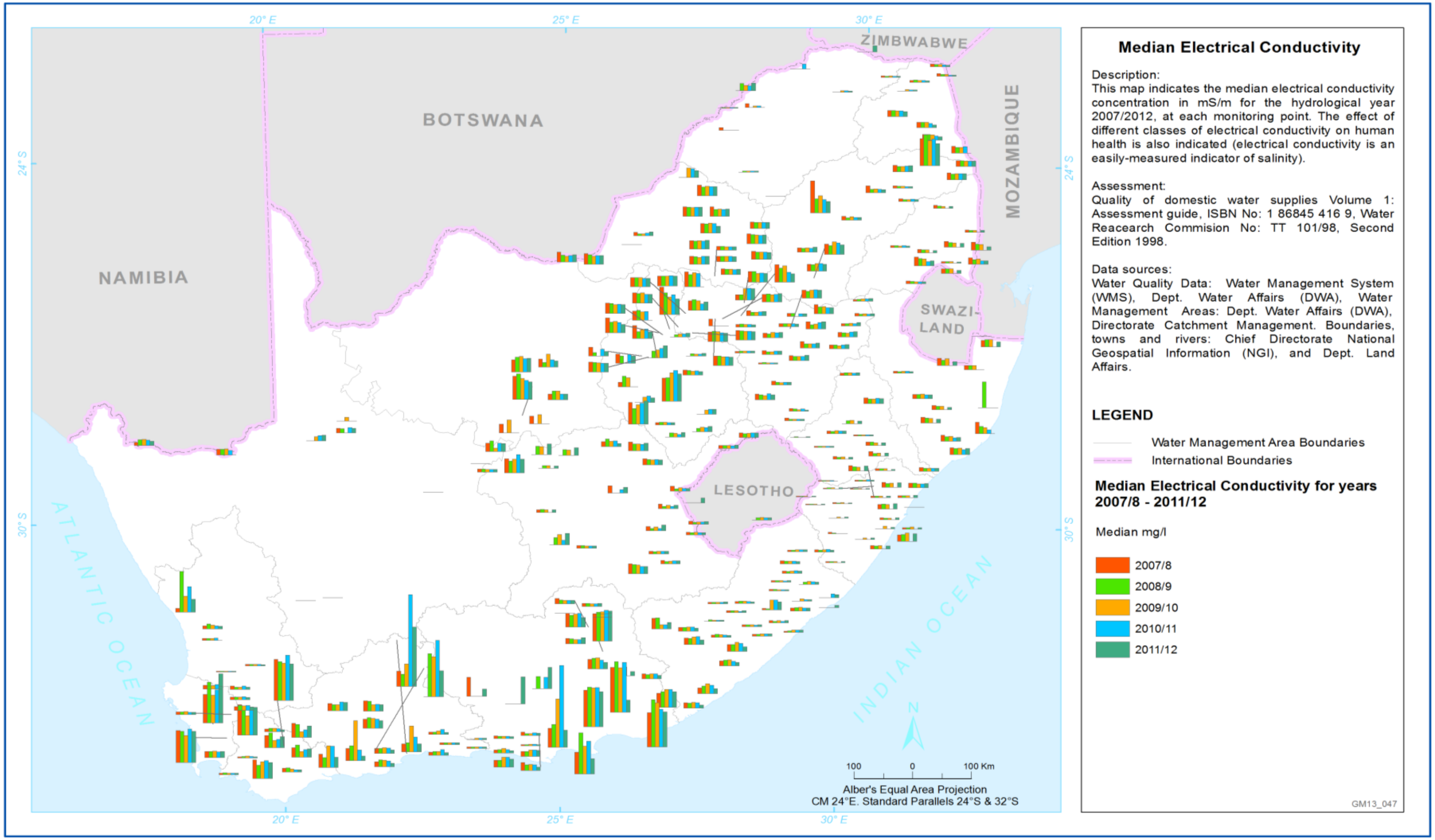


Figure 3.10: Salinity (electrical conductivity) trends covering period of 2007 to 2012 (Compiled by M. Smidt, DWA: WRIP).

3.4 Radioactivity and Toxicity monitoring

Radioactivity assessment is conducted as a pilot study in the Vaal area (Figure 3.11). Sampling was done four times at intervals of 2 months from October 2011 to April 2012. In general, the analysis showed the radiological status to be within acceptable limits. However, two sites (MV1 and MV2) in the Middle Vaal show elevated uranium content (241 and 233 µg/L respectively) which is three times the target value and may pose toxicity risk to humans and high TDS (4 675 and 5 680 mg/l respectively). The elevated uranium and TDS could be linked to the mining activities in the Middle Vaal area.

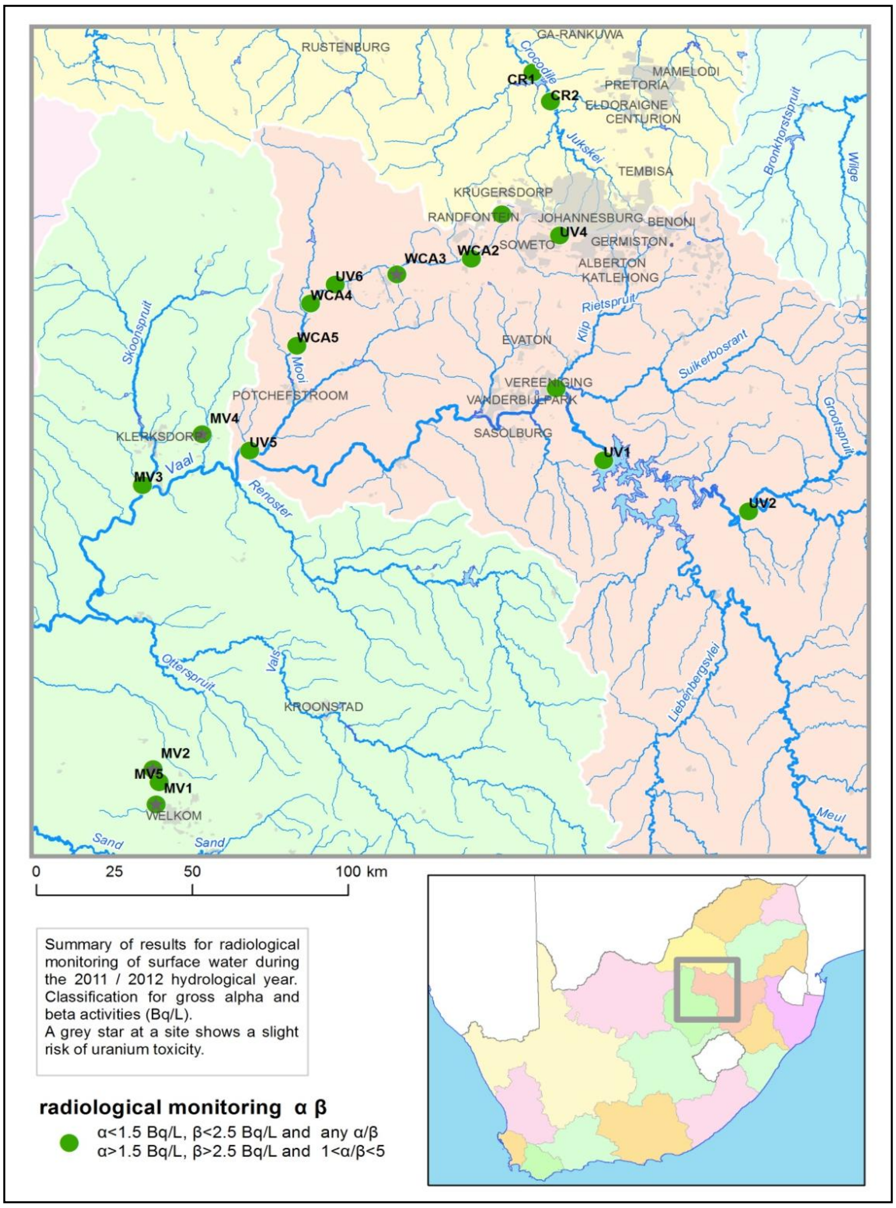


Figure 3.11: Radioactivity monitoring sites in the Vaal catchment (Compiled by DWA: NRMP).

Toxicity monitoring focuses on contaminants such as Endocrine Disrupting Compounds (EDCs), Persistent Organic pollutants (POPs) and organochloride pesticides; organic pollutants which were not originally accommodated in the water quality guidelines. The monitoring is undertaken at three (3) sites along the Jukskei River. These are sites expected to be contaminated with toxicants, due to surrounding land-based activities. Some of the land based activities in the Juskei catchment are industrial, residential, sand mining, wastewater treatment works and urban runoff.

During the reporting period, 48 samples were collected and analysed. The zooplankton (Daphnia pulex) and fish (Danio rerio) were used for acute toxicity testing and algal (Selenastrum capricornutum) growth stimulation and bacterial rapid test (Vibrio fischeri) luminescence stimulation, were used for chronic tests. The chronic tests were positive for water from all the sites. The testing is focusing on Polycyclic Aromatic Hydrocarbons, Polychlorinated Biphenyls, Organochlorine Pesticides, Organophosphorus Pesticides, Phthalates and Triazine Herbicides. Only three sites are used for this. Phthalates come from plastics and Triazine Herbicides is used for agricultural food production. All three sites presented with high Polychlorinated Biphenyls (Arochlor 1254). The Marlboro site also presented with high levels of Polycyclic Aromatic Hydrocarbons (Phenanthrene) and Phthalates (Di-n-butyl phthalate) while the Midrand and N14 sites showed high levels of Organochlorine Pesticides (BHC-beta) and Triazine Herbicides (Atrazine) respectively.

Table 3.6: Number of samples and mean response and percentage samples showing effect for 2012 hydrological year.

Toxicity test	***Marlboro***		***Midrand***		***N14***	
	Mean response	% samples With effect	Mean response	% samples With effect	Mean response	% samples With effect
DR % E&LM	60.3	97.92	26.1	95.83	22.6	100
DP % mortality	26.0	100	<17.0	97.92	20.3	100
DP % RI_{21DAYS}	<10.0	2.08	N/A	N/A	<18.5	4.17
DP % RS_{21DAYS}	137.0	68.75	139.3	70.83	109.7	70.83
DP % RM_{21DAYS}	47.0	85.42	27.6	85.42	22.1	87.5
SC % GS_{96Hr}	108.0	87.5	84.3	85.42	73.1	70.83
SC % GI_{96Hr}	N/A	0	N/A	0	78.3	18.75
VF % GI_{Rapid}	<10.0	2.08	26.0	2.08	35.7	39.58
F % GS_{Rapid}	41.7	97.92	45.1	95.83	30.0	30.0

DR = *Danio rerio*, E&LM = Embryos and Larvae Mortality, DP = *Daphnia pulex*, RI_{21DAYS} = 21 days Reproduction inhibition, RS_{21DAYS} = 21 days Reproduction Stimulation, RM_{21DAYS} = 21 days Reproduction Mortality, SC = *Selenastrum capricornutum*, GS_{96H} = 96 hrs Growth Stimulation, GI_{96H} = 96hrs Growth inhibition, VF = *Vibrio fischeri*, GI_{Rapid} = Rapid Growth inhibition and GS_{Rapid} = Rapid Growth Stimulation

3.5 Acid Mine Drainage

The pH of water can be influenced by the geological formations and soil in the area. For example, river water in the Western Cape tends to be naturally acidic. There are also human-induced acidifications which are usually caused by land-based activities such as mining and industries. Mining activities are contributing to environmental damage and threaten the health of communities in the area. The seepage water from abandoned open pits, mine waste dumps, tailings, stockpiles and mine shafts is highly acidic. The acid mine drainage (AMD) is one of the water quality challenges emanating from mining activities. The most affected areas by AMD are the gold mines in the Western Basin (Krugersdorp area), the Central Basin (Roodepoort to Boksburg) and the Eastern Basin (Brakpan, Springs and Nigel area) of the Witwatersrand as shown in Figure 3.12. Mining in these areas ceased in 2010, and since then the underground voids have been filling up with AMD. Other areas affected by mining activities include Mpumalanga, Limpopo and Kwa-Zulu Natal.

In order to address the AMD problem in the eastern, central and western basins, a technical task team was appointed. The task team came up with the following short and long-term recommendations which were approved by cabinet:

- Water must be pumped from the Western, Central and Eastern Basins to maintain water levels at least below the relevant environmental critical levels or, by agreement with stakeholders, the lowest level of underground activity within the basin.
- Steps must be implemented to reduce the ingress of water into the underground workings, as far as is possible. This will reduce the volumes of water which need to be pumped and treated to more acceptable levels and consequently reduce the operational costs of AMD management.
- The water which will be pumped will not be of a suitable quality for productive use or discharge to river systems and will therefore need to be treated. In the short-term, it is proposed that water be neutralised in a process which will address the low pH, high acidity and high iron and other metal content. In the medium- to long-term, consideration should be given to steps which will reduce the mine water contribution to the salinity of major river systems.
- Improved monitoring of mine water, groundwater, surface water, seismicity, subsidence and other geotechnical impacts of mine flooding and related targeted research is required. It is recommended that a multi-institution monitoring committee be established to facilitate the implementation of the required monitoring and the necessary assessment programmes. Monitoring will show if there are significant changes in the quality of mine water which may have an impact on future

management strategies. Monitoring results may also identify additional remedial measures required in the future.

- The feasibility of implementing an environmental levy to be paid by operating mines to cover the costs of the legacies of past mining needs to be investigated.

To date, the following has been done:

i. <u>Western Basin IMMEDIATE SOLUTION</u>: Refurbished AMD neutralisation plant is operational and presently treating ~22 ML AMD daily. Uncontrolled decant of AMD is currently zero. Further upgrade in process and projected for commissioning by end-May 2013. Short-term solution in this basin provisionally deferred pending assessment on the viability of installing clarifiers and/ or implementation of a proposal on using mine tailing to neutralise AMD. Recent evidence confirms that the immediate solution has allowed for an improvement in surface and groundwater qualities.

ii. <u>Central Basin SHORT-TERM solution</u>: Construction commenced in January 2013. Project is currently at the level of advanced civil works and test commission will commence by November 2013. Full commissioning projected for January 2014.

iii. <u>Eastern Basin SHORT-TERM solution</u>: Construction is planned to commence in January 2014, subject to budget availability.

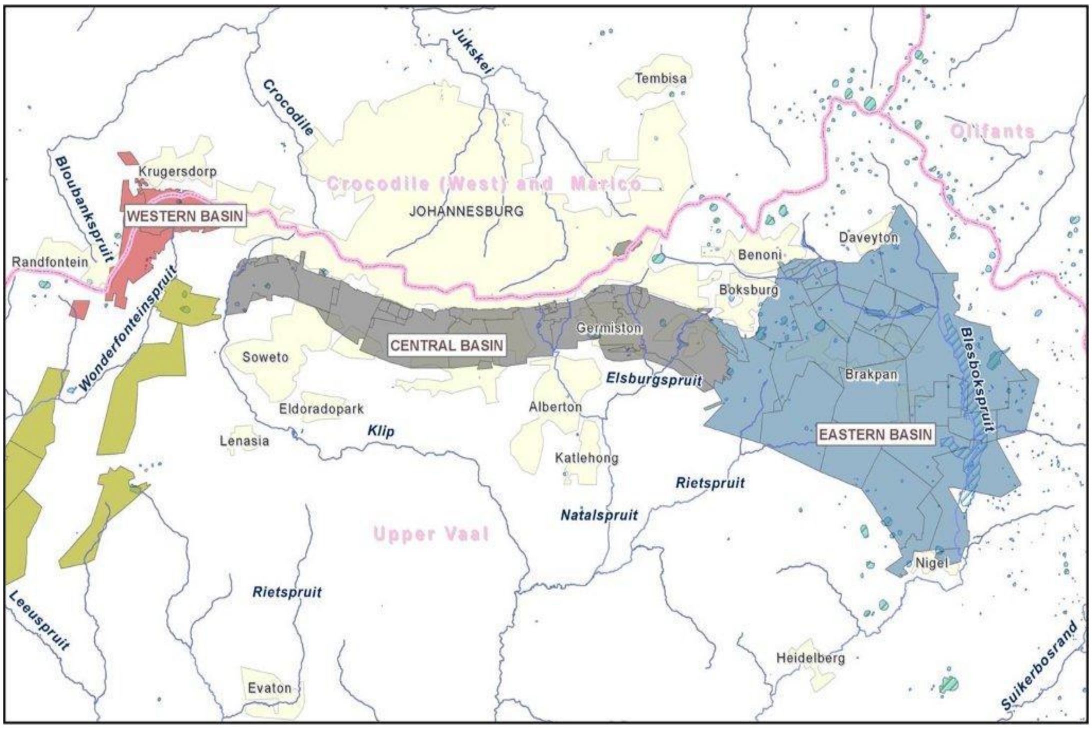


Figure 3.12: Witwatersrand Basin areas impacted by AMD (AMD Newsletter, 2012).

Box 2: Carolina's water crisis due to mine seepage

The town of Carolina, Mpumalanga Province, experienced water shortages as the town's water was polluted by AMD. This problem started in January 2012, following heavy rains (82mm) during a short period of time. This resulted in seepage from surrounding mines polluting the Boesmanspuit Dam, the town's main water supplier. The water from the dam was found to have high levels of metals associated with AMD; following fish kills. Residents were advised not to use the water (drinking, washing and even cooking) as the municipality promised to provide water tankers; whilst investigations ensued. However, the water supply from the municipality was not reliable and residents were forced to look for alternatives. The problem ensued for months and an emergency task team was appointed to solve the problem. The solutions are both short-term (liming) and long-term (construction of treatment plant) (www.mg.co.za & www.rainwaterharvesting.co.za).

Photo 9: Communities queuing to collect water from water tankers (www.mg.co.za).

4 Groundwater

The amount of water that an aquifer may yield is dependent upon the porosity and permeability of the material found in the earth layer. Responses of groundwater quantity and quality are different from surface waters' in that groundwater depends on geological structures, soil conditions, rainfall patterns and anthropogenic activities in the recharge zones of the aquifer systems. Aquifer media in South Africa is classified as shown in Figure 4.1. The Department of Water Affairs has produced Hydrogeological Maps at a scale of 1:500 000 covering most of the country, indicating aquifer types and related aquifer properties. Some of these maps are accompanied by Explanation brochures, giving more hydrogeological characteristics regarding groundwater quality and quantity. The Department also developed a National Groundwater Strategy in 2010, which one of its aims is that the knowledge and use of groundwater is increased along with the capacity to ensure sustainable management. Some aquifers extend across international borders (transboundary aquifers), resulting in a joint responsibility for their management and development.

4.1 Groundwater availability

It takes at least three months for any changes in the status of the water table, depending on the geological characteristics of the aquifer, to manifest itself to such an extent that it can be technically observed. Hence, the Department collects data from various Geosites, monthly, every 3 months or 6 months depending on the region and the objective of the monitoring programme(s). Quantity data is captured and stored on the National Groundwater Archive (NGA) and time-series data on HYDSTRA. Quarterly reports on the status of groundwater levels in the country are produced based on that information, and at the end of the hydrological cycle, an annual report.

The Utilizable Groundwater Exploitation Potential in South Africa is estimated at 10 300 million m^3 per year (7 500 million m^3 in a drought year), allowing for factors such as physical constraints on extraction, potability, and a maximum allowable drawdown (Middleton and Bailey, 2009). The country only uses between 2 000 million m^3 and 4 000 million m^3 per year of this groundwater currently. This is approximately 16.1% of the country's total water use (both surface and groundwater) based on the information registered in WARMS. The actual percentage is perceived to be higher considering that Schedule 1 use is not registered in the system.

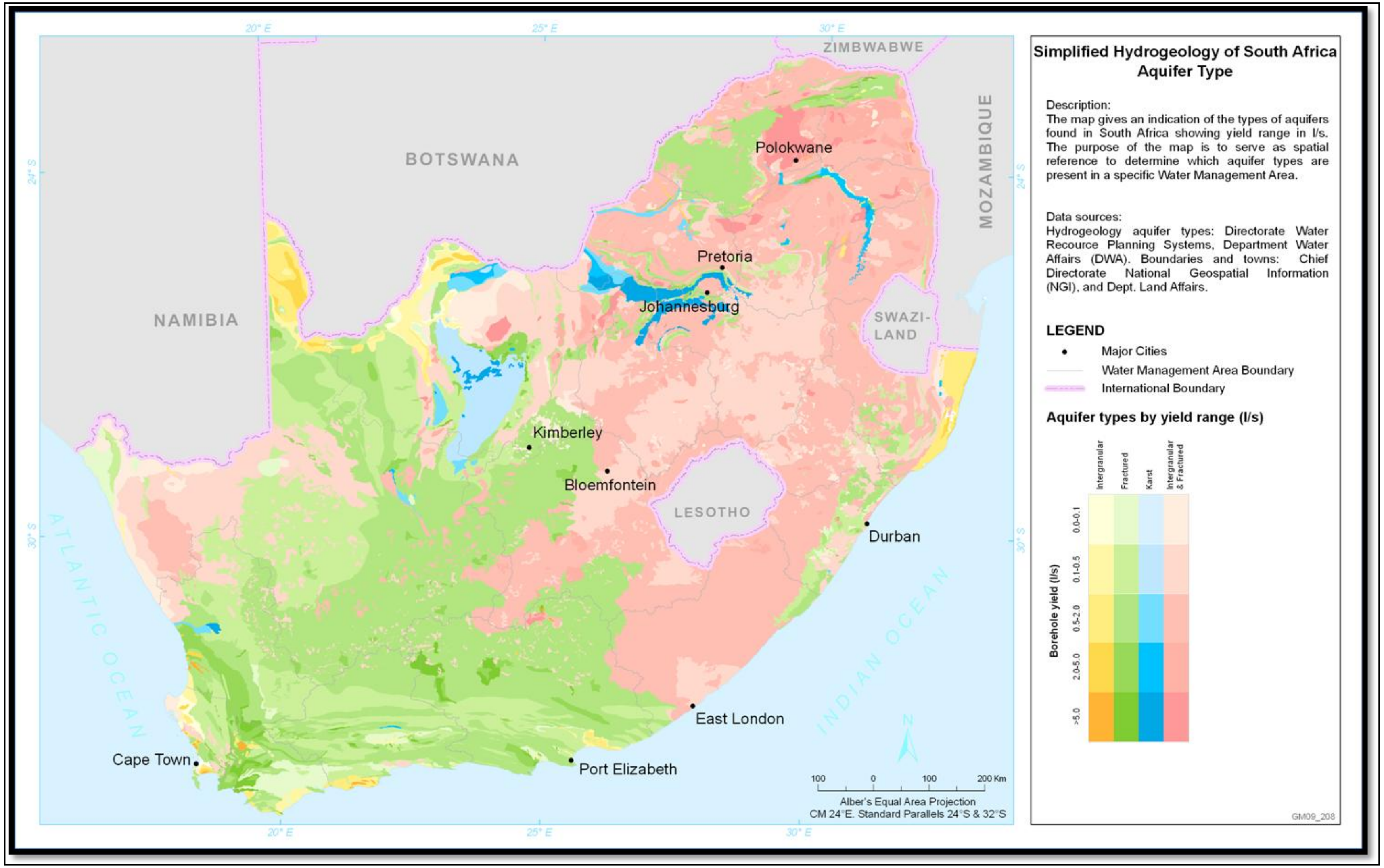


Figure 4.1: Aquifer media map of South Africa

The challenge however, is that groundwater is not evenly distributed, but spread variably, often thinly, over the whole country. This can be an advantage in providing water for small-scale local use but to utilise most or all of the available groundwater, distributing it to centres of need, will require a large number of boreholes and connecting pipelines.

4.1.1 Groundwater level status

The groundwater level trends for the 2011/12 hydrological year are illustrated in Figure 4.2. The north-eastern parts of the country received “below normal” rainfall during the reporting period. This affected groundwater recharge, resulting in the decline in groundwater levels. Due to continuation of local abstraction rates, a general decline in the aquifer saturation levels has been observed in some areas specifically the Limpopo Region (Limpopo, Luvuvhu & Letaba and the Olifants catchments). These are the catchments that experience a long-term declining condition (water table recession rates in the order of 0.3 to 1m per annum). Towards the west, water level trends are also declining; although varying between 0.2 and 5 m per annum. High water level declines were observed at bulk water supply schemes such as Grootfontein (5m since June 2012) and certain dolomitic aquifer compartments in Gauteng (2m since October 2011 in the Far West Rand). The annual rainfall for this region was significantly lower during 2011/12, with only 490 mm measured in Pretoria East, unlike the previous year where prolonged and heavy rainfall events were experienced from mid-December 2010 and led to significant recharges. Water levels in KwaZulu-Natal reported similar declining trends which was part of a long-term aquifer saturation-level recession (since the reference monitoring has started in 2004).

The south-western regions of the country experienced significant groundwater recharges. High winter rainfall/snowfall in some regions initiated a replenishment of aquifer systems thus the rising water levels. Aquifer saturation levels of the Brandwag Aquifer Unit (east of Beaufort West) increased by almost 38 m due to the good rains received during that time. This particular recharge event was enhanced by significant snowfalls and associated winter rainfall in the Western Cape during the past two hydrological years (2010/11 and 2011/12).

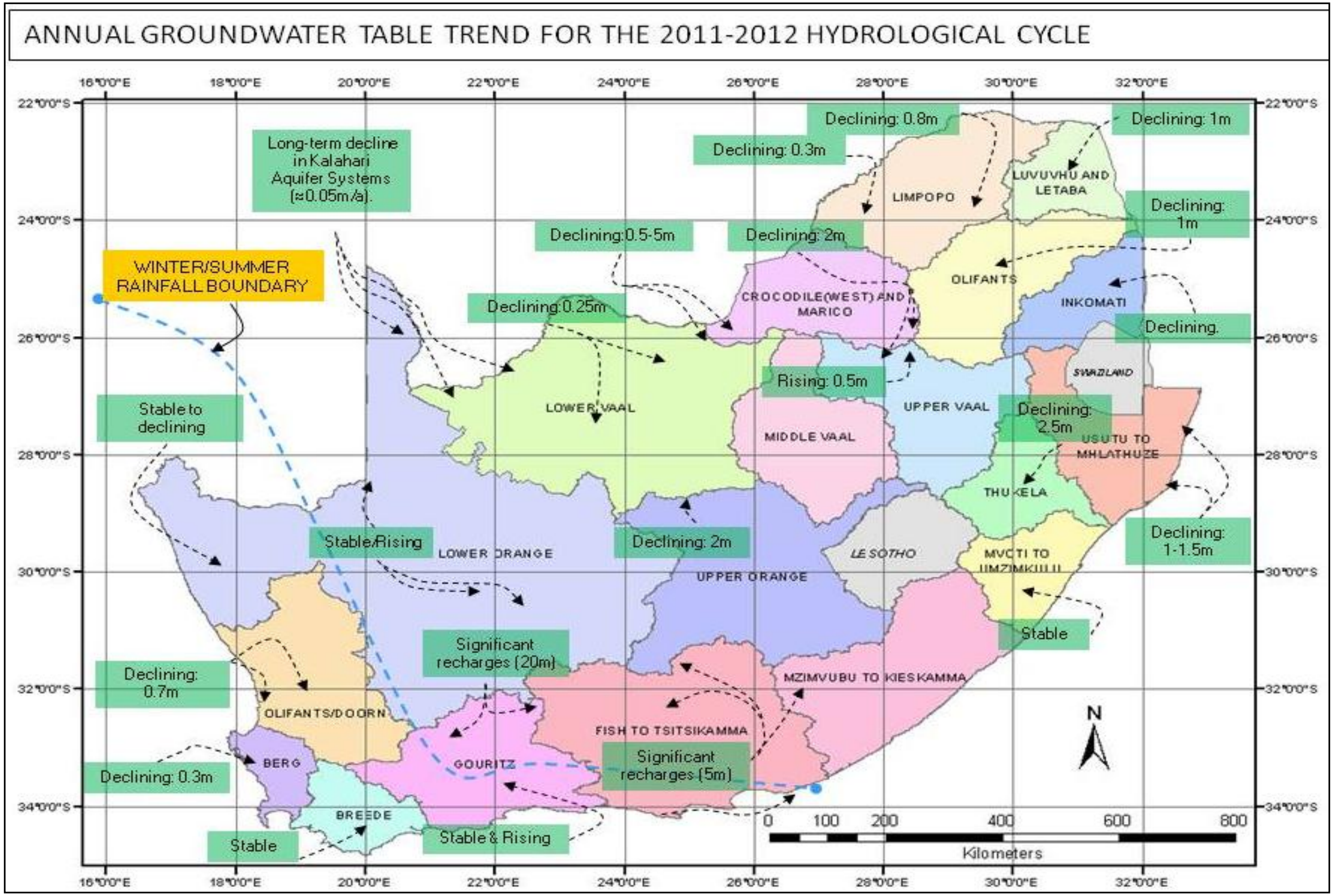


Figure 4.2: Groundwater level trends for 2011/2012 hydrological year.

There was however, a decline in water levels in the Western Coast regions (Berg and Olifants/Doorn WMAs) which was probably as a result of bulk groundwater abstractions (Langebaan Road, Lamberts Bay and the Sandveld Aquifer Systems). Water level trends in the northwest region (Lower Orange catchment) varied from stable (±0.25m) to a rising trend. Several municipalities in the Kenhardt and Riemvasmaak aquifer systems are supplied by piped surface water; thus the dependency on local groundwater resources is minimal.

Generally, aquifer saturation levels are dependent on good annual rainfall. Whilst the southern Karoo areas received good summer rainfall, groundwater recharge was enhanced by a good winter rainfall/snowfall event during the 2010/11 and 2011/12 hydrological years. Summer rainfall for the reporting period, particularly in the northern and eastern parts, has been categorized as "below normal" over several regions; thus the probability for an effective groundwater recharge is low. Aquifer saturation levels are reporting declining conditions which go back to 2004/05 in some cases (Luvuvhu & Letaba, Limpopo, Thukela, Usutu to Mhlathuze, and Mvoti to Umzimkhulu).

4.1.2 Transboundary groundwater studies in South Africa

Groundwater is the main the source of water for 70% of the rural population in the SADC region. Regional Strategic Action Plan (RSAP) III was produced in 2011, placing greater emphasis on emerging issues such as climate change adaptation; ecosystem approach; and human rights base approach to water. Programme 11 of RSAP III covers groundwater management and development for which the main objective is to improve coordination over the management of groundwater resources.

SADC has developed a Groundwater Management Project (GMP) with the overall objective of promoting the sustainable development of groundwater resources at a regional level, incorporating research, assessment, exploitation and protection, particularly related to groundwater drought management. Groundwater occurrence information in South Africa is indicated on Table 4.1.

Table 4.1: Groundwater occurrence statistics for South Africa in different aquifer types.

Groundwater occurrence	Coverage (km^2)	Mean blow yield (l/s)	Mean EC (µS/cm)
Porous – Intergranular	189 477	1.7	3 529
Fissured	451 465	2.5	1 327
Karst	37 667	5.3	894
Low permeability	598 790	2.6	1 485

UNESCO is assisting SADC in projects such as 'SADC-Internationally Shared Aquifer Resources Management and Sustainable Development and Management of Transboundary Aquifers' in SADC in an effort to improving management of transboundary aquifers.

According to Ramoeli & Vogel (2012), Japan International Cooperation Agency (JICA) plans to conduct a survey to assess the feasibility and scope of work for a project on "Sustainable Development and Management of Transboundary Aquifers" in the Orange-Senqu river basin with ORASECOM.

4.2 Groundwater quality

The data was collated from the National Groundwater Quality Monitoring Program on a bi-annual interval, based on a "before/after" rainfall season sampling program for the summer and winter rainfall regions of South Africa. The analyses include three bi-annual groundwater sampling runs; although each monitoring station's long-term trend (since 1993) was considered as well. Salinity trends are obtained from field measurements of the groundwater's electrical conductivity taken during the bi-annual sampling exercises.

4.2.1 Groundwater quality status

Figure 4.3 shows the general groundwater quality in the country based on electrical conductivity. The north-western parts of the country indicate concerning quality conditions with EC recording above 520 mS/m. Groundwater quality deterioration in the northern sub-catchment of the Lower Orange, i.e. the Nossob and Auob Rivers flowing from Namibia, is a concern, and the cause for that is not clear yet.

The groundwater salinity trends for the 2011/12 hydrological year are illustrated in Figure 4.4. For the larger part of the country, salinity trends were quite stable and varied (standard deviation) between <5mg/l (almost stable) and 50mg/l. These are representing small water quality oscillations due to internal aquifer quality modulation and annual recharge events replenishing the aquifer systems with good quality rainwater. Aquifer systems where groundwater quality changed (positive and negative trends) are illustrated in Figure 4.4

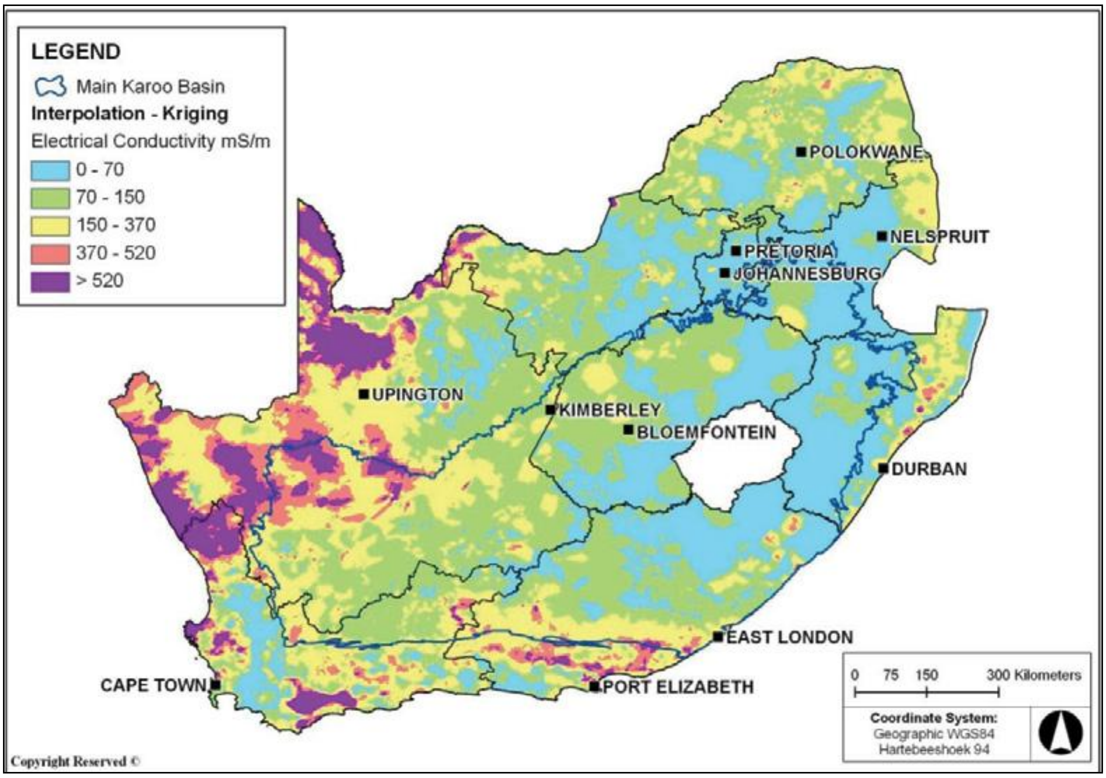


Figure 4.3: General groundwater quality map for South Africa (Murray *et al.*, 2012).

Groundwater salinity improved in the Limpopo and Olifants catchments and some localised aquifer systems in the Crocodile-West and Marico catchments. Similarly, salinity improved in the northern parts of the Lower Vaal. Areas where the groundwater quality deteriorated are also indicated on Figure 4.4; showing elevated salinity values. Although these increasing salinity values were significant (in the order of 205 ± 160 mg/l), they have manifested after April-May 2012 and could be an indication of sporadic local pollution due to local recharge events after a long dry period; especially those in the Gouritz, Fish to Tsitsikamma and the Mzimvubu to Keiskamma catchments. The salinity increase in the Upper Orange and Lower Vaal is part of a long-term decreasing water quality trend in the order of about 15 mg/l per annum.

To illustrate the alarmingly rapid deterioration of groundwater quality in the Lower Orange, Figure 4.5 was plotted showing salinity trends from 1996 till 2012. Since then, electrical conductivity increased from 220 mS/m to about 435 mS/m in this borehole.

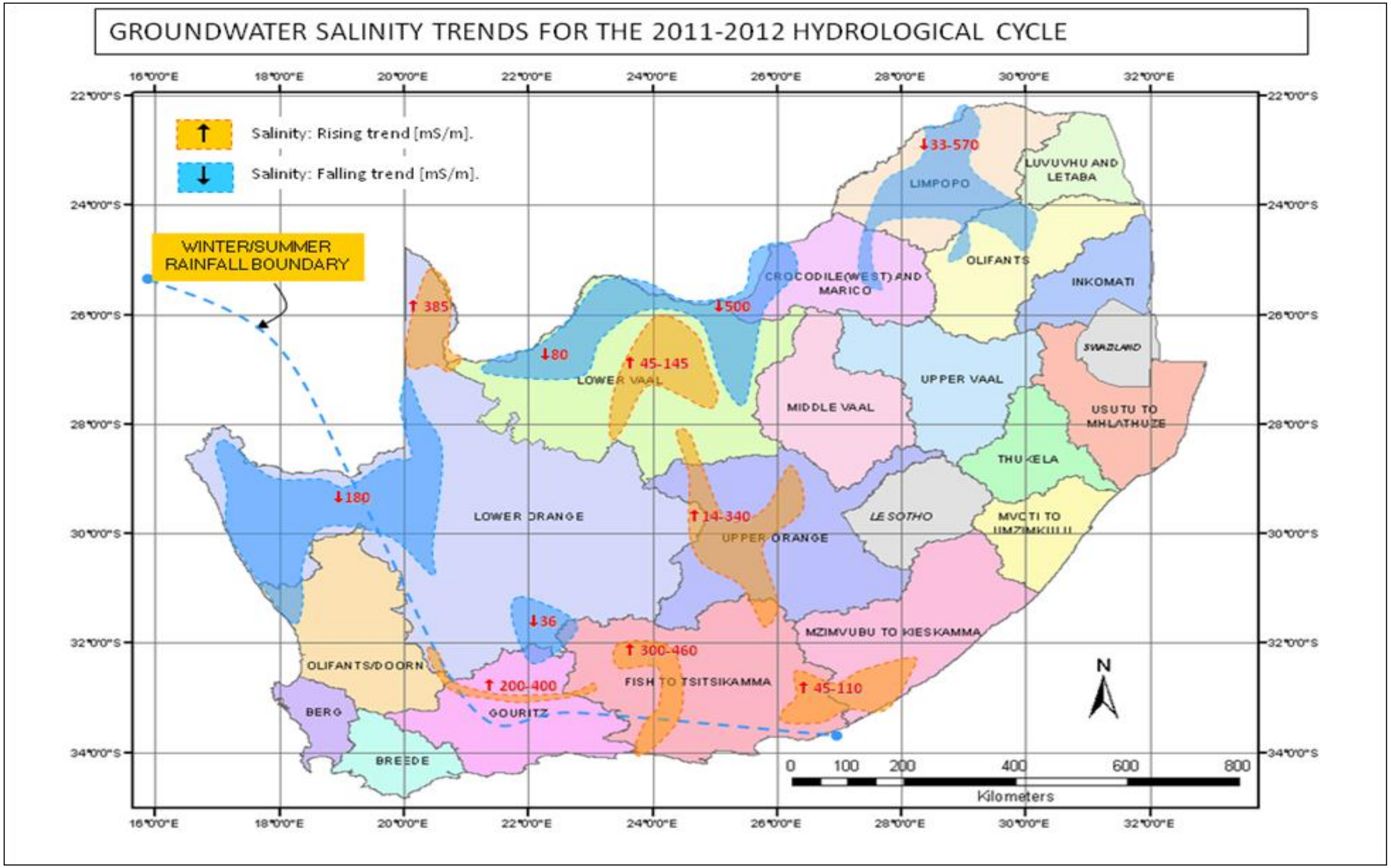


Figure 4.4: Groundwater salinity (electrical conductivity) trend for 2011/2012 hydrological period.

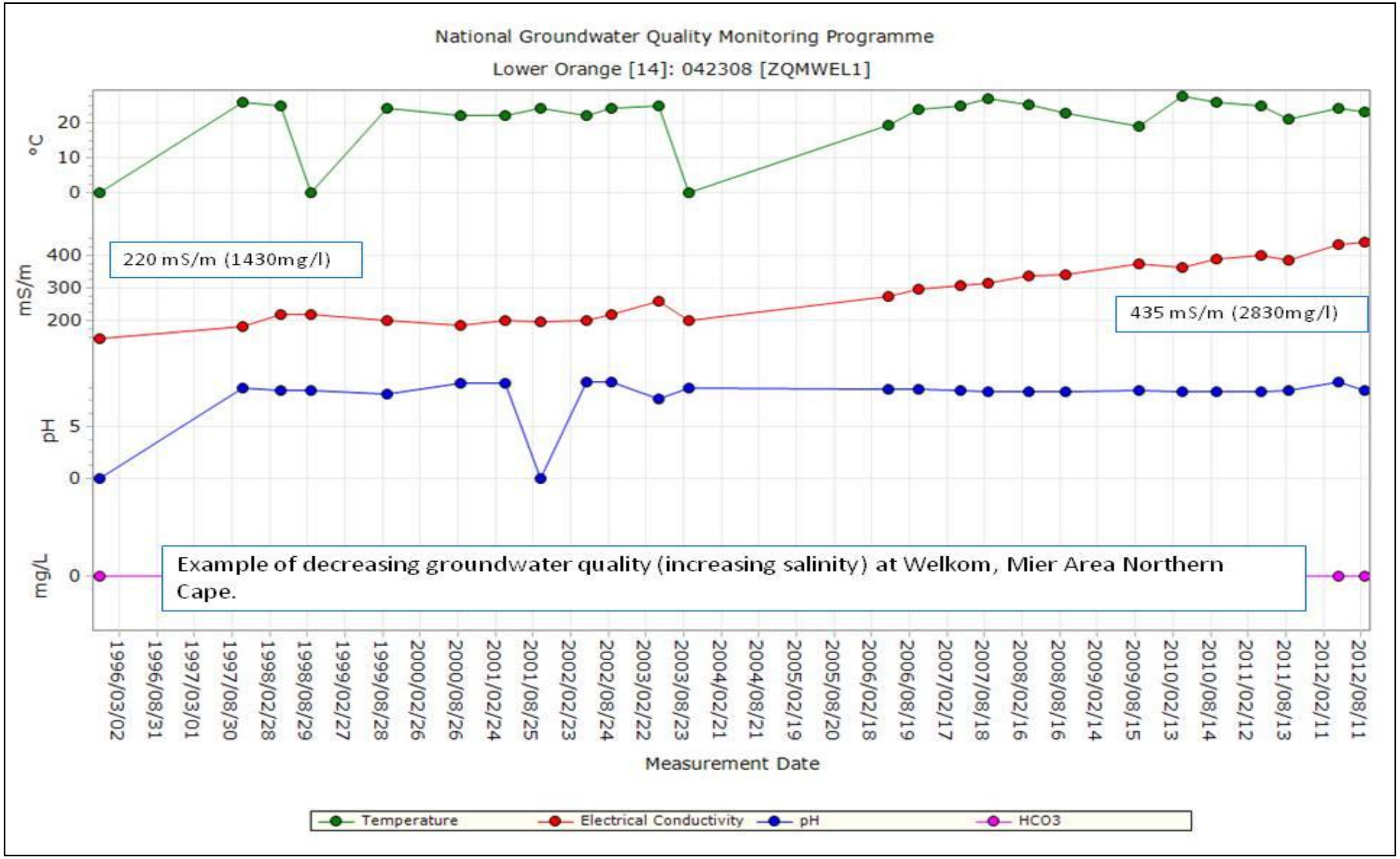


Figure 4.5: Increasing salinity trend in one of the monitoring boreholes of the Lower Orange catchment (Compiled by E van Wyk, HS).

BOX 3: Hydraulic fracturing – ‘fracking’

Hydraulic fracturing is the fracturing of various using a pressurized liquid, in short, in order to release the required gas. The South Africa’s Department of Mineral Resources has lifted the moratorium on fracking in the country which was imposed temporarily to allow further investigations. The lifting enables the commencement of shale gas exploration by the companies that have applied. They are only allowed to proceed with the initial stages of exploration, including geological field mapping and other data gathering activities, until such time when an appropriate regulatory framework has been put in place. Meanwhile, research is going on with regards to water consumption and water resource protection related to fracking. This stems from concerns as to where the required water will come from, considering that South Africa’s water resources requirements are projected to reach the peak around 2025, excluding water required during fracking. Possible pollution of water, especially groundwater, is another concern. Government has vowed to apply stringent conditions in order to protect water resources and the environment from possible impacts that could result from fracking.

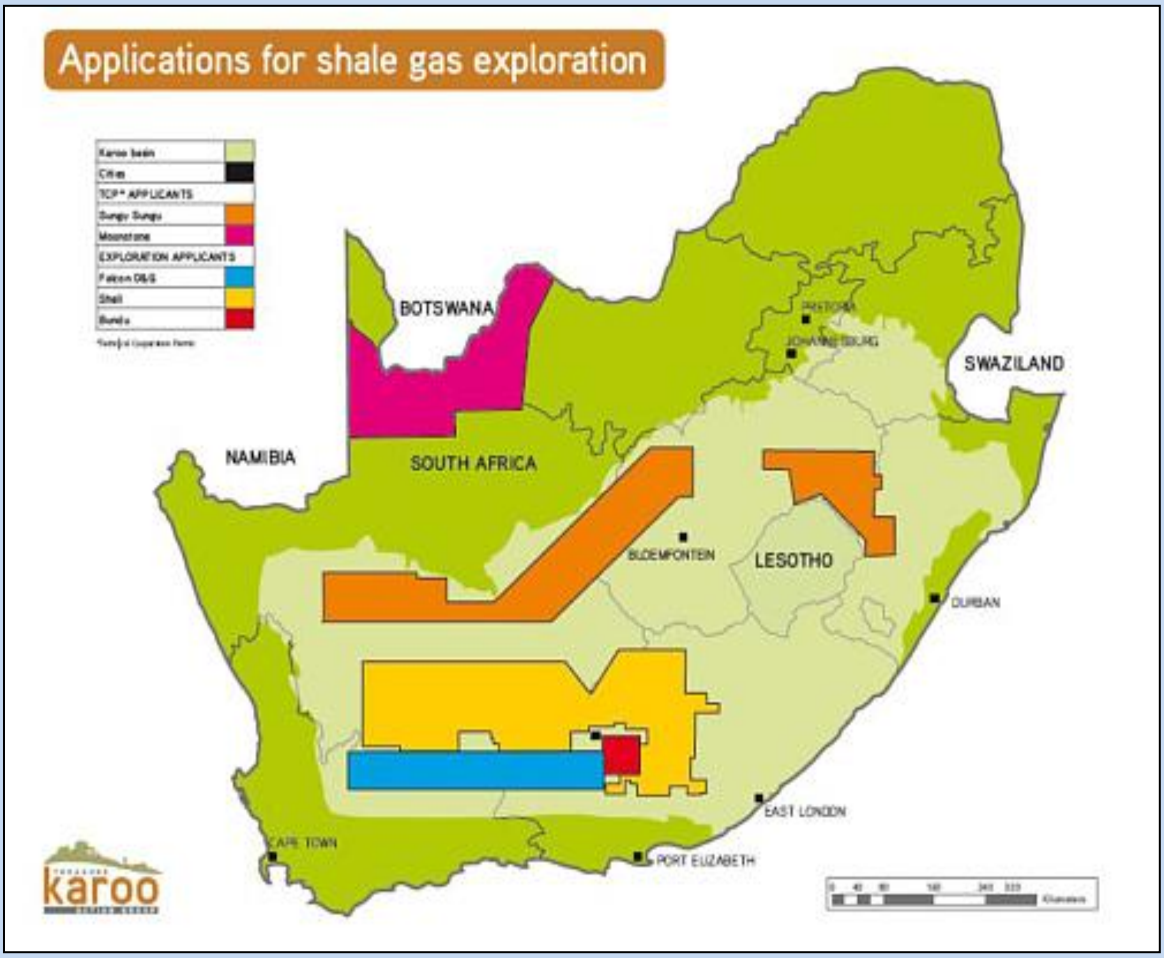


Figure 4.6: Possible fracking areas in South Africa as applied for by different companies (www.wecanchange.co.za).

4.3 Groundwater-surface water interaction

There are no clear guidelines for quantifying groundwater-surface water interaction and related impacts in South Africa currently. The overall contribution of groundwater to surface water yields per aquifer unit at a regional scale is not yet fully understood. DWA is currently using WRSM2000, a surface water model, which includes a Surface-Ground water interaction model although its applicability on a large scale is questionable (DWAF, 2010).

Groundwater abstracted from river beds, close to streams, and from shallow alluvial aquifers has a very direct influence on river flow, and should be not be viewed as an additional water resource. Such groundwater plays an important role in sustaining wetlands (South African types of wetlands are shown in Figure 4.7), river flows ("base flows"), and supporting refuge pools during dry season (Driver *et al.*, 2011). One of the human benefits from groundwater-surface water interaction is the maintenance of river flows during dry seasons. Moreover, refuge pools in seasonal rivers support water-dependent animals that would otherwise not survive when the rivers dry up. Healthy riparian areas, which filter pollutants that drain from the land, are also often maintained by groundwater. According to Driver *et al.* (2011), it is only when groundwater has very weak links to surface water (such as in deep, confined aquifers) that it may be possible to abstract it without significantly impacting on river flow; however, long-term impacts are not well understood.

There are various other relevant research studies conducted elsewhere in the country, and in this section we look at three that were conducted by different individual teams. They cover the mountain catchments rainfall-runoff-discharge relationship, sea water intrusion, and an AMD impacted site.

The first study, conducted by Bredenkamp (2012), simulated the more rapid runoff responses and extended groundwater flows of three experimental catchments in Jonkershoek near Stellenbosch, Western Cape and two in Magaliesberg, Gauteng from monthly rainfall. The two regions displayed a similar quadratic/exponential rainfall-runoff relationship despite their differences in climate and catchment size. The total discharge of the upper Zachariashoek terrain in Jonkershoek showed an exponential response in relation to the groundwater levels in its catchment (Figure 4.8)

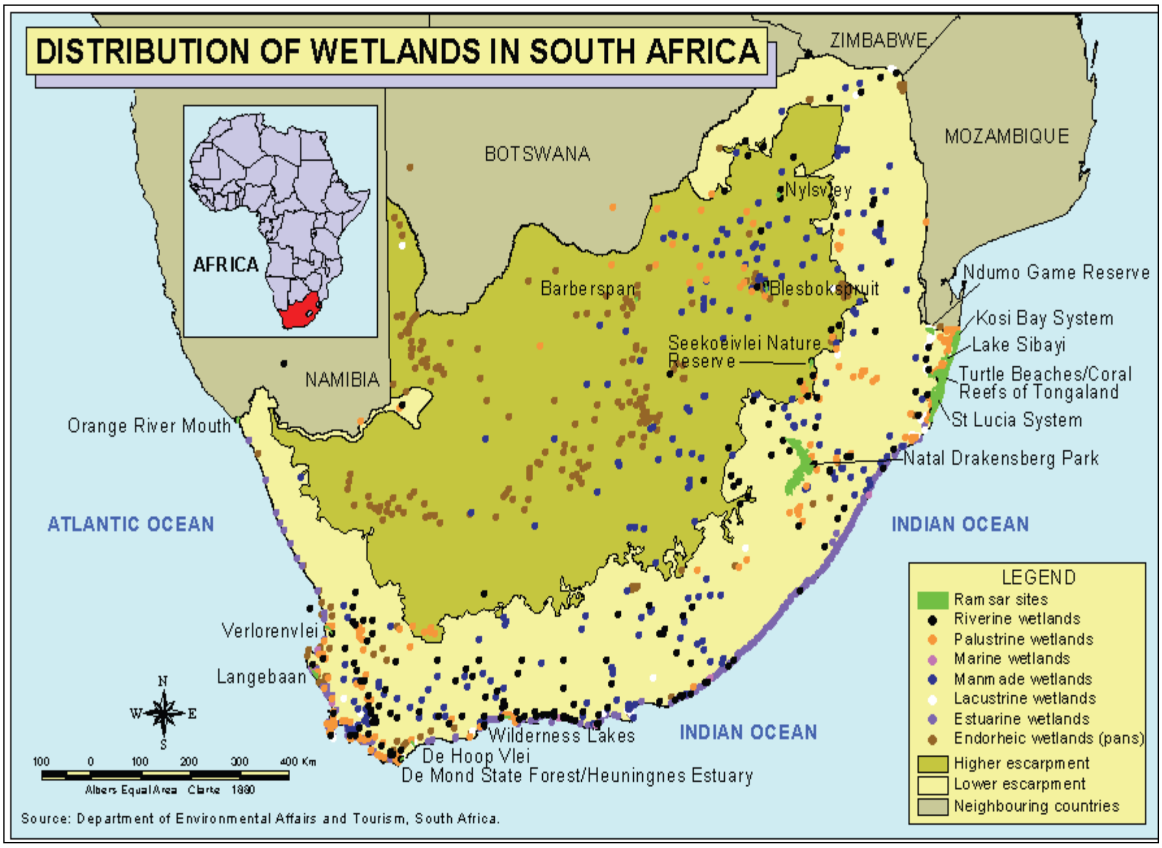


Figure 4.7: Distribution of different types of wetlands in South Africa (Data source: WRC, 2010).

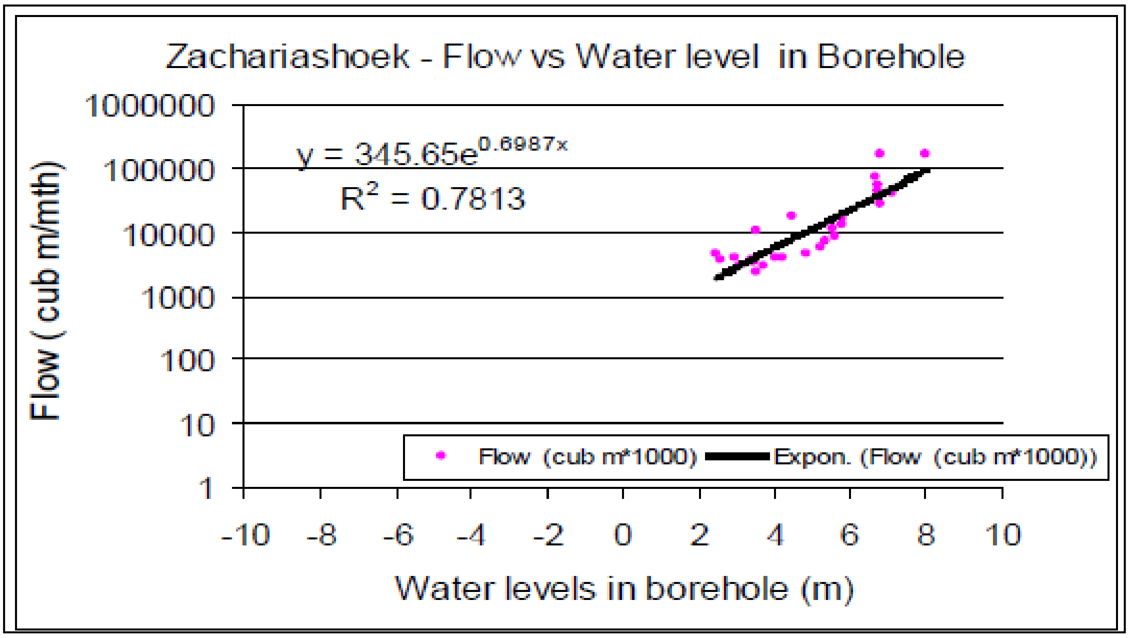


Figure 4.8: The total discharge from the upper Zachariashoek catchment showing an exponential response in relation to the monthly water levels in the observation boreholes (Bredenkamp, 2012).

The study concluded that both the fast flow and groundwater related components of the runoff conform to a similar relationship, thus providing a method (i) to obtain a regional relationship by which the average flood runoff and base flow could be derived with a high degree of reliability; and (ii) to derive a preliminary reliable estimate of the average total responses of an unknown mountain catchment area.

The second selected study in the southern Cape by Parsons (2012) revealed that the Ghyben-Herzberg relationship fails to take account of hydraulic properties of the subsurface and flow vectors. This study recommended that future application of the relationship when drilling boreholes at or near the saltwater–freshwater interface must take cognisance of the three-dimensional nature of groundwater and the landward and seaward contributions if the quality of groundwater is to be predicted. Moreover, it is critical that the quality of groundwater abstracted from each borehole used to obtain feed water is monitored individually to see how the relative contributions of the upper (and/or landward) good quality groundwater and deeper saline groundwater change with time.

The third selected study was carried out in the West Rand region in Johannesburg in order to determine the nature of interactions of surface and ground water based on the hydrogeochemistry and environmental isotopes (Bamuza & Abiye, 2012). The dolomitic aquifers in the West Rand are under increasing stress due to expanding urban, mining and industrial developments (Witthüser & Holland, 2008). Hydrochemical and isotope variables are important components indicating sources of water in a water reservoir, directions of water flow, travel times of water, and local geology. These variables can also assist in groundwater and surface water interaction investigations.

The winter and summer isotope values collected were plotted for δ18O against δ2H against the Local Meteoric Water Line (LMWL) as shown in Figure 4.9. Most of the values plot below the LMWL and only two points plotted above the meteoric water line. The relative positioning of the relatively enriched winter samples with respect to summer samples demonstrate that summer rain and discharge is responsible for the winter base-flow, which instead supports the presence of interaction in the area within the highly fractured quartzites and dolomites. The winter samples also show evaporation before infiltration but are enriched in heavy isotopes unlike the summer samples. This means the aquifer was recharged after evaporation of the lighter isotopes in the surface water had occurred.

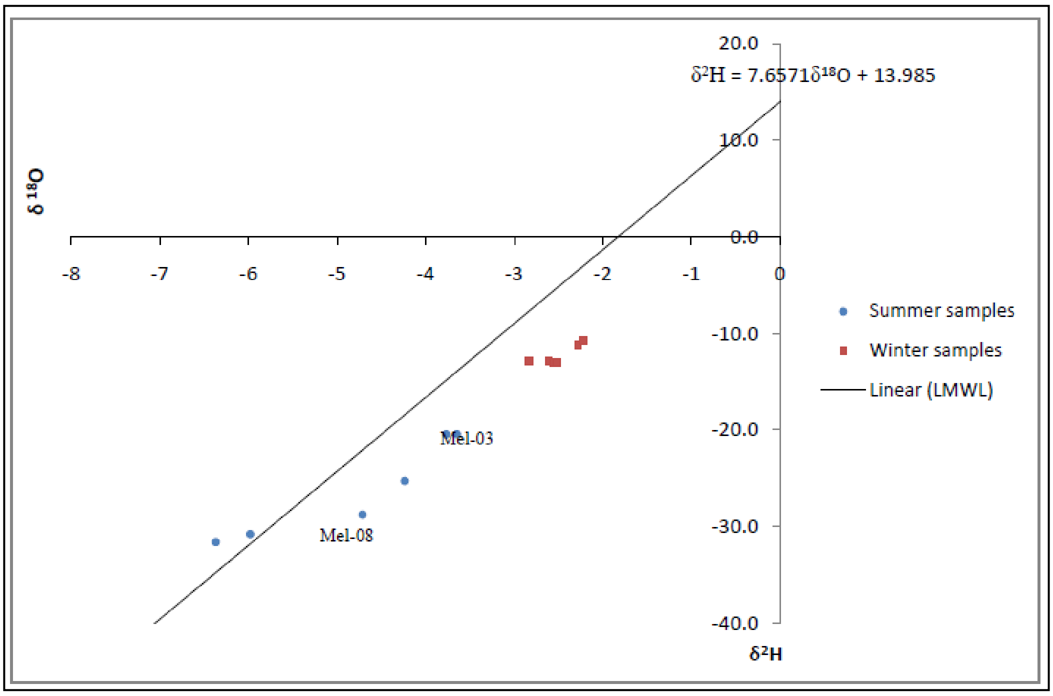


Figure 4.9: Distribution of environmental isotopes in the study area, West Rand.

The study concluded that acid mine decant deteriorates surface water quality in the area which could indicate that acidic groundwater is the main cause for surface water quality change which instead infiltrates into pristine dolomitic water.

4.4 Groundwater development

The assessment phase of a groundwater development project started during this reporting period in the Baviaans Local Municipality and it is entitled “Feasibility study for augmentation of water supply to Karoo towns by means of groundwater development: Phase 2A – Baviaans Municipality”. The development phase still needs to be done depending on the availability of funds. The project will include the following towns: Rietbron, Vondeling, Miler, Willowmore, Mount Stewart and Steytlerville (DWA, 2012*b*).

Not much work was done during this reporting period regarding development of artificial groundwater recharge, however, Terms of Reference have been developed for proposed feasibility studies and they are due for approval. Further progress is anticipated in the following year.

5 Water Use and Protection

South Africa's scarce water resources are under increasing pressure and need to be managed efficiently and effectively in order to build a sustainable future. In order to achieve this, we need to know how much water is used, by whom, and where. This information will provide an indication of how much water is required against what is available. Some parts of the country will have water surplus (availability exceeds demand) whilst other will experience deficiency (availability exceed requirements). In such cases, water can be transferred from areas with surplus to those experiencing shortages. Effective implementation of strategies such as Water Conservation and Water Demand Management (WC/WDM) is crucial in ensuring the available water conserved.

The DWA is responsible for ensuring that water resources are protected. Strategies have been developed and are being implemented to ensure comprehensive protection of the country's water resources and prevention of pollution.

5.1 Water Use

Water use is regulated in terms of a system of permissions and authorisations (NWA, 1998) namely: permissible use, General Authorisation, Existing lawful use, licensed water use. Water uses for all sectors are registered and captured in the Water Authorization Registration Management System (WARMS).

5.1.1 Registered Water Use

The agricultural sector accounted for the highest water use with a total of 2664.7 million m^3, followed by the domestic/industry sector with 1498.5 million m^3, forestry sector accounted for 248.4 $10^6 m^3$ and non-billable sector recorded registered volume of 100.8 million m^3 as displayed in Figure 5.1 and Table 5.1. A comparison of water use in 2012 and 2011 is also shown in Table 5.1. The use and proper implementation of conservation and demand strategies could significantly reduce the high usage of water in the agricultural sector. The registered non-billable activities over this reporting period seemed to account for the least volume usage. The non-billable sector comprises of registered schedule water uses, water storage, recreational water use, and waste related water uses etc.

The agriculture sector, as in previous years, accounts for the highest registered water use volume in most WMAs, except for the Middle and Upper Vaal, Mvoti-Mzimkhulu, Mzimvubu-Keiskamma, and Berg WMAs.

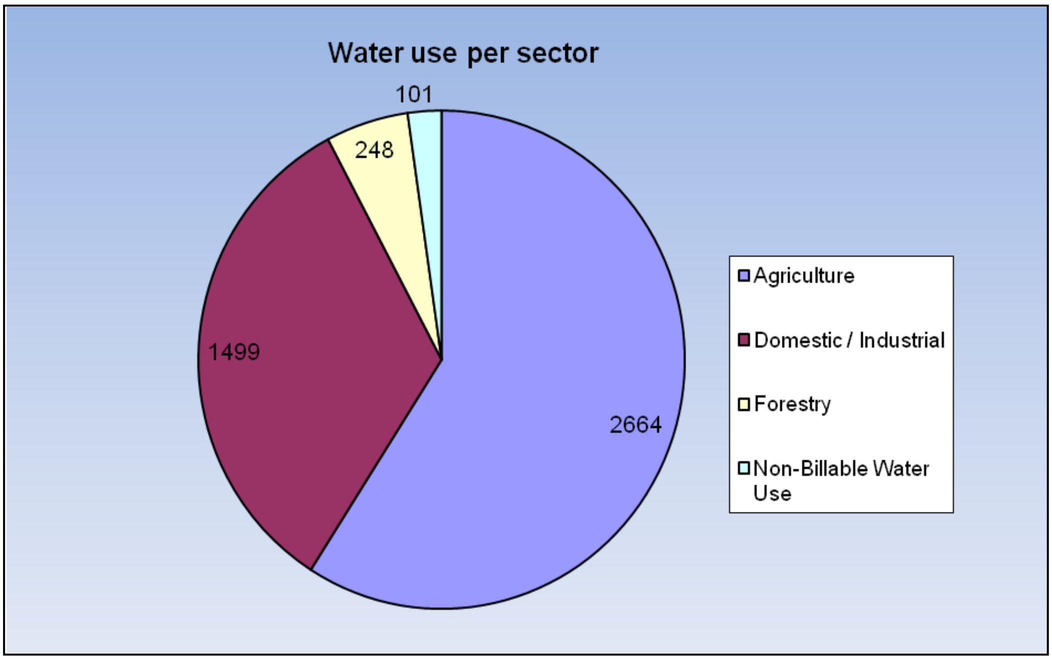


Figure 5.1: Registered water use volumes (10^6m^3) per sector.

Table 5.1: Total registered water use volumes (10^6m^3) per WMA during 2011/12.

WMA	Agriculture	Domestic / Industrial	Forestry	Non-Billable Water Use	Grand Total (per WMA) Sep 2012	Grand Total (per WMA) Sep 2011
Limpopo	136.7	18.5	0.4	0.16	**155.8**	**150.8**
Luvuvhu Letaba	102.5	23.9	8.7	3.9	**138.9**	**130.4**
Crocodile (W), Marico	168.4	76.2	0.01	12.1	**256.7**	**256.4**
Olifants	152.4	90.1	6.5	10.5	**259.5**	**275.7**
Inkomati	261.7	85.9	63.2	65.2	**476.1**	**412.7**
Usutu-MhlatuzE	158.2	89.2	87.8	0.9	**336.2**	**337.7**
Thukela	68.8	30.5	7.6	0.2	**107.1**	**104.1**
Upper Vaal	98.2	530.3	0.001	0.2	**628.6**	**632.9**
Middle Vaal	68.1	80.5	0	0.001	**148.6**	**148.6**
Lower Vaal	153.0	40.3	0	0.05	**193.4**	**183.9**
Mvoti-Umzimkulu	60.2	155.3	52.5	0.3	**268.5**	**265.3**
Mzimvubu-Keiskamma	40.7	57.8	12.8	1.9	**113.3**	**109.5**
Upper Orange	203.1	24.8	0	0	**227.9**	**226.1**
Lower Orange	233.1	20.6	0	0	**253.7**	**252.1**
Fsh-Tsitsikamma	256.1	45.5	3.8	3.6	**309.0**	**295.2**
Gouritz	98.5	18.8	2.7	0.11	**120.1**	**119.0**
Olifants/Doorn	104.4	3.9	0.03	0.16	**108.6**	**108.5**
Breede	214.5	12.3	1.3	0.8	**228.9**	**228.2**
Berg	85.6	94.0	1.04	0.7	**181.4**	**182.085**
Total	**2664.6**	**1498.5**	**248.4**	**100.749**	**4512.3**	**4418.93**

The total registered water use volume across the country was 4,512 million m³ as at the end of September 2012 an increase of 93 million m³ from September 2011. The Upper Vaal WMA with the total registered volume of 628 million m³ has the most registered water usage. On contrary, uThukela WMA has the least registered water usage over the same period with total registered volume of 107 million m³ (Figure 5.2).

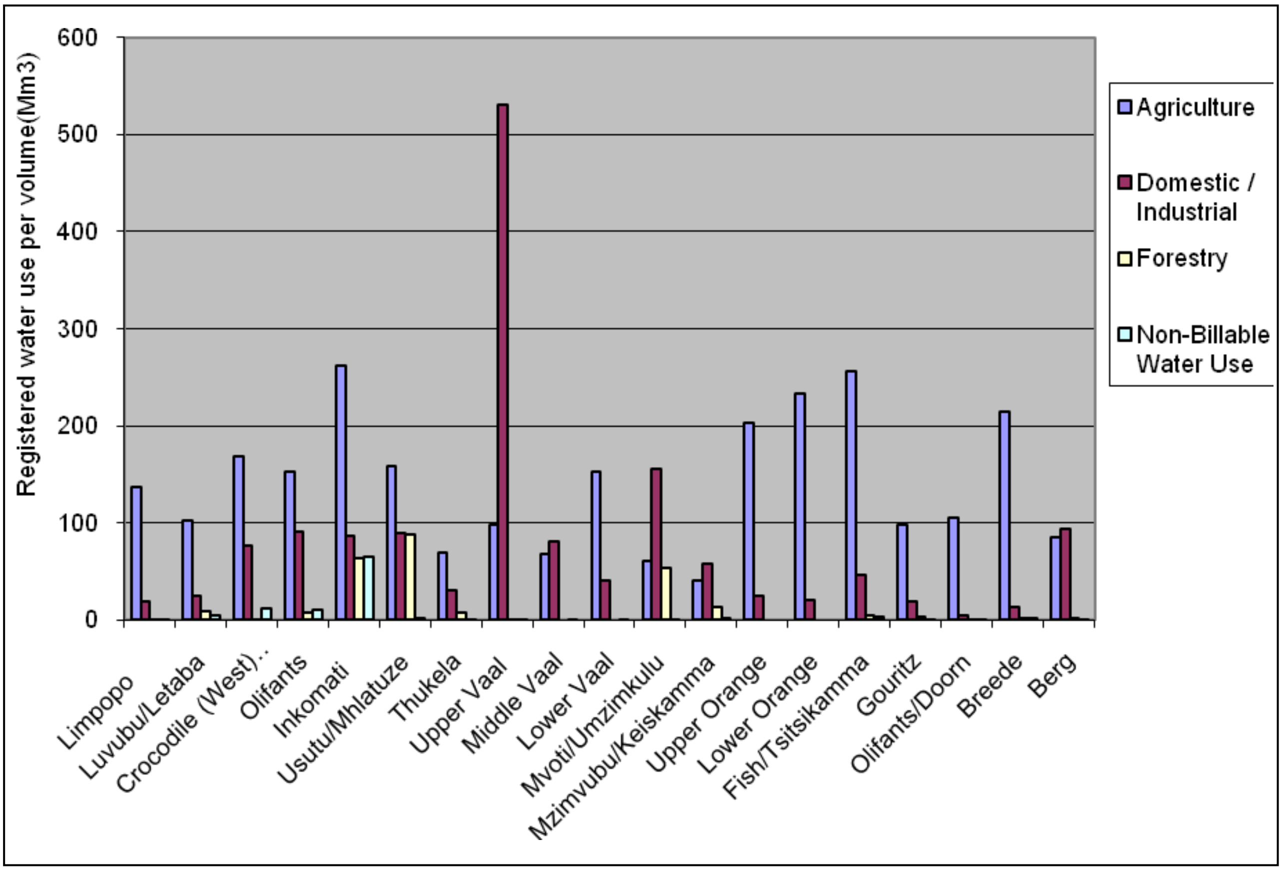


Figure 5.2: Registered water use volumes (10⁶m³) per WMA as of end September 2012.

5.1.2 Water allocation

Due to water scarcity, there is a need to regulate the water usage to ensure sustainable, equitable and efficient utilisation of the resource. The regulation is normally through General Authorisation or licensing process. Equitable access to water, or the benefits derived from its use is critical to the eradication of poverty and promoting economic growth. Equity means that everyone has fair opportunities to access, use and control of the water resources. The system of water allocations use water pricing, limited term allocations and other administrative mechanisms to bring supply and requirements into balance in a manner which is beneficial in the public interest. (NWA, 1998). One of the fundamentals of water allocation is that any form of abstraction, transfer, storage or other influence on a natural stream gives effects in the entire downstream river system.

The DWA is running a Water Allocation Reform Programme. Its objectives are to ensure meaningful transformation in water use; support poverty eradication and economic development. It helps balance resource protection, equity and growth. Where water is not available, Compulsory licensing process is undertaken and. Where water is available, the water use licensing process is implemented taking into account the redress requirements.

5.1.1.1 Compulsory Licensing

Compulsory licensing has been initiated in 3 catchments namely Tosca in the Northern Cape; Jan Dissel in the Western Cape and Mhlathuze in KwaZulu Natal. Table 5.2 illustrates the summary of water allocations in Tosca, Jan Dissel and Mhlathuze.

Table 5.2: Summary of Water Allocations in Tosca, Jan Dissel and Mhlathuze.

TOSCA ALLOCATION				
Water use sector	**Non HD Cubic metres**	**DHI Cubic Metres**	**Total water allocation Cubic Metres**	**% HDI per Sector**
Irrigation	6983827	2616581	9600408	28%
Municipal		340870	340870	100%
JAN DISSEL ALLOCATION				
Irrigation	1763185	2422238	4185422	58%
Municipal	71155	373565	444720	84%
Storage	608850	590590	1199440	49%
MHLATHUZE ALLOCATION				
Irrigation	73609635	29433843	103043478	29%
Municipal	19448	34052	53500	63%

5.1.1.2 Licensing

The management of water use authorisations and licences has been a challenge for the DWA because of the backlog of applications accumulated over the past few years. However, there has been a great improvement in the processing of water use license applications with the backlog applications reduced significantly. The current backlog is at 1 142 and most backlogs are due to lack of verifiable information in the application. The total number of licences issued during 2011/2012 period is 274 including the 47 licences issued to HDIs (Table 5.3). The number of licences issued to previously disadvantaged individuals has increased as they have been prioritised. Mining has a greater number of licences that have been issued.

Table 5.3: Number of licences issued per sector during 2011/12 period.

Regions	Agriculture	Industry	SFRA	Local Gov and Development	Mining	Total	%Per Region	HDI
Eastern Cape	9	0	2	5	1	17	6%	2
Free State	4	0	0	1	0	5	2%	0
Gauteng	2	5	0	13	2	22	8%	1
KwaZulu - Natal	4	0	28	7	2	41	15%	4
Limpopo	20	2	2	9	3	36	13%	21
Mpumalanga	1	5	0	8	34	48	18%	2
North West	0	5	0	20	8	33	12%	0
Northern Cape	10	2	0	3	35	50	18%	17
Western Cape	8	3	0	9	2	22	8%	0
TOTAL	**58**	**22**	**32**	**75**	**87**	**274**	**100%**	**47**
% Per Sector	21%	8%	12%	27%	32%	100%		

5.1.3 Water Conservation and Water Demand Management

The country's rapid population and economic growth necessitates the expansion of the available water resources but the country's skewed water distribution and indifferent rainfall are proving to be the limiting factors. Water conservation and water demand management (WC/WDM) has been elevated as a high priority intervention in addressing the water challenges in the country. It is aimed at reducing the need for additional new sources of water through the optimal use of the existing water and the reduction of water losses and wastages in the different water uses (domestic, mining, agriculture). The National Development Plan has indicated the importance of WC/WDM programme with clear national and local targets.

DWA has initiated Water Use Efficiency plans, as agreed during the JWW Summit. Water use efficiency is meant to reduce water losses from the system. Water loses are mainly caused by leakages from water distribution systems and lack of proper maintenance and operation of water systems. For the programme to be effective, stakeholder and community involvement is crucial. The DWA is running a War-on-leaks campaign as part of the programme.

During the 2011/12 financial year, DWA assisted 17 municipalities in implementing mechanisms to curb water loss. Table 5.4 below summarises the amount of water saved during 2012/12 financial year through interventions.

A range of measures were implemented to achieve these results. These included imposing water restrictions, repairing leaks as well as installing/repairing pressure control valves.

Table 5.4: Total water savings achieved during 2011/12 hydrological year.

Quarters	Target (10^6m^3)	Water Savings (10^6m3)
Q1: October - December	3	62.9
Q2: January - March	2	10.098
Q3: April - June	4	12, 95
Q4: July - September	3	485.5
TOTAL	**12**	**571. 45**

5.2 Protection of water resources

The DWA's objective is to improve the protection of water resources and ensure their sustainability. The protection of water resources is related to their use, development, conservation, management and control. Resource Directed Measures (RDM), classification of water resources, setting of resource quality objectives and reserve determination have been put in place to ensure comprehensive protection of water resources. Also, Source Directed Controls (SDC) is a link between protection of water resource and regulation of water use. Monitoring of water users for compliance to set conditions in issued licences is critical with the aim of minimizing the impacts of waste from point and non-point sources. The DWA has also developed a Waste Discharge Charge System to deter pollution and to encourage water re-use. The DWA is currently piloting the system.

5.2.1 Resource Directed Measures

Resource Directed Measures (RDM) ensures a balance between protection and water use for social and economic development. It focuses on the overall health or conditions of water resource measured by its ecological status.

In keeping with the mandate for protecting our water resources, the DWA established a water resources classification system, prescribed through Regulations which were gazetted in September 2010. The DWA is now in a better position to relate the use of a particular water resource to the value and benefits to the economy as well as to the social well-being of those who rely on the water resources.

5.2.1.1 Classification

Since the promulgation of the classification system, DWA has subsequently initiated studies in highly stressed catchments to classify significant water resources. The Department is in the process of completing the process of classification of water resources in the Vaal, Olifants and

Olifants-Doorn WMAs, where recommended management classes for each significant water resource, have been drafted and will be gazette for public comment before final approval by the Minister of Water and Environmental Affairs. Other areas, in which the Department has progressively started to implement the water resources classification system, are the Crocodile (West) Marico, Mokolo and Matlabas and Letaba catchments and the Mvoti to Umzimkulu.

5.2.1.2 Reserve Determination

The Reserve Determinations for both surface and ground water are done per quaternary. There are four types of reserves namely; Desktop, Rapid, Intermediate and Comprehensive. Approximately 1128 surface water reserves and 94 groundwater reserves have been completed during the reporting period. The total number of surface and ground water reserves undertaken during the reporting period is shown in Tables 5.5 and 5.6 respectively. The current status of reserve determination for surface and ground water is shown in Figures 5.3 and 5.4 respectively.

Table 5.5: The total number of surface water reserves determined during 2011/12 period (Compiled by DWA: RDM).

Drainage Region	Desktop	Rapid	Intermediate	Comprehensive	Total
A	51	8	8	-	67
B	85	4	1	25	115
C	86	30	-	11	127
D	67	19	-	-	86
E	2	-	-	70	72
F	1	1	-	-	2
G	11	24	1	1	37
H	17	4	8	-	29
J	8	5	0	-	13
K	12	32	15	-	59
L	7	-	-	-	7
M	4	-	-	-	4
N	9	-	-	-	9
P	2	-	-	-	2
Q	28	1	3	-	32
R	14	2	3	-	19
S	30	1	6	-	37
T	70	38	6	-	114
U	46	6	-	-	52
V	41	16	-	15	72
W	88	11	1	8	108
X	32	9	1	23	65
TOTAL	**711**	**211**	**53**	**153**	**1128**

Table 5.6: The groundwater reserves determined during 2011/12 period (Compiled by DWA: RDM).

WMA	Desktop	Rapid	Interm	Comprehensive	Tot Quats done	Tot Quats
Limpopo	2		All		2	85
Luvubu & Ietaba	3				3	62
Crocodile West Marico	9	A21, A22, A23, A24,A31,A32			9	84
Olifants	24				18	158
Inkomati	2				2	120
Usuthu to Mhlathuze	2				2	142
Thukela	4				4	122
Upper Vaal	6				6	131
Middle Vaal	0				0	74
Lower Vaal	13				13	53
Mvoti to Mzimkulu	4				4	110
Mzimvubu to Keiskamma	1				1	230
Upper Orange	7				5	186
Lower Orange	9				9	186
Fish to Tsitsikamma	5				5	247
Gouritz	0				0	165
Olifants/Doorn	0				0	118
Breede	2				2	108
Berg	2				2	46
Total	**88**	**6**	**0**	**0**	**87**	**2 427**

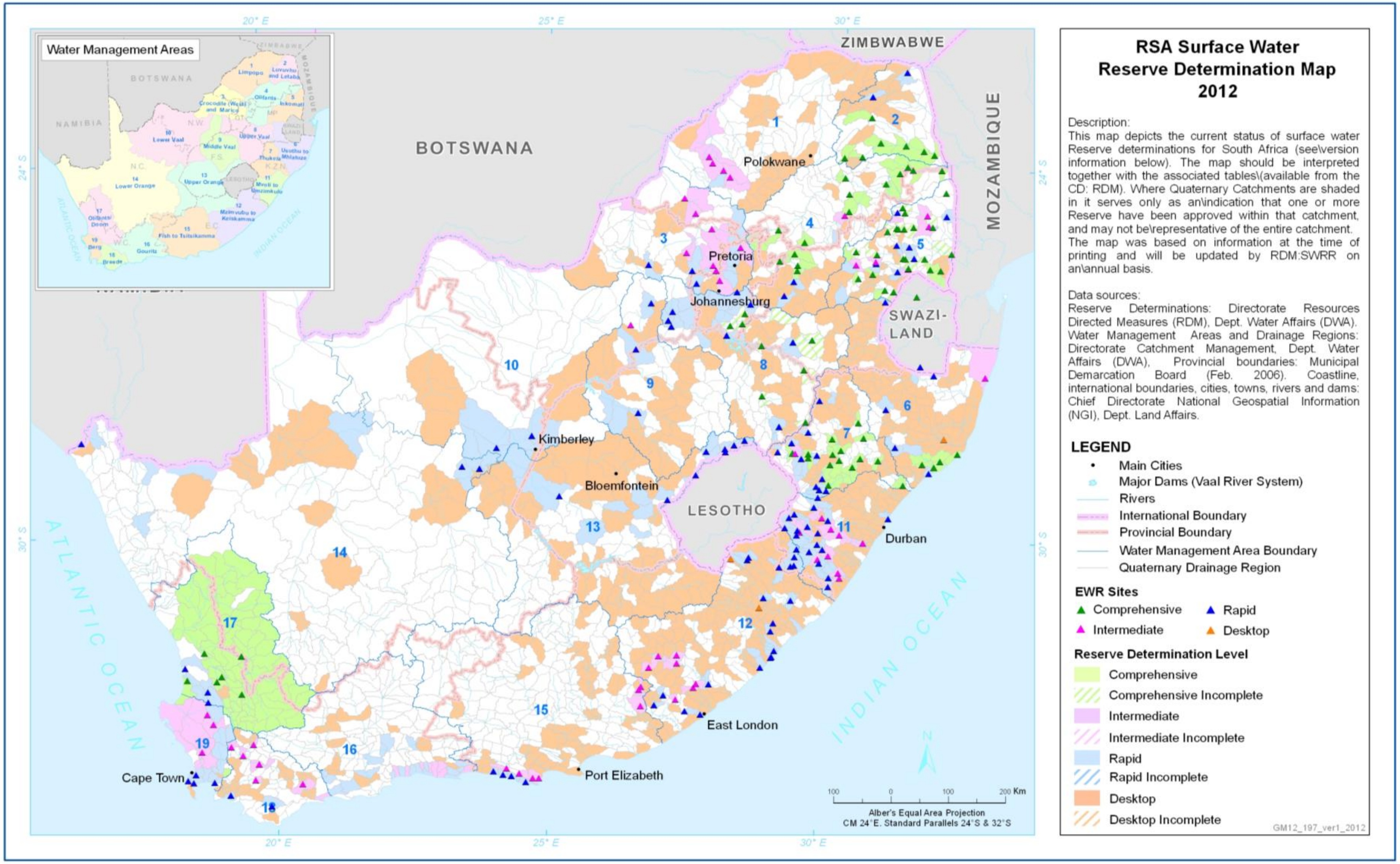


Figure 5.3: Map showing different types of surface water reserve determinations completed as at September 2012 (Compiled by DWA: RDM).

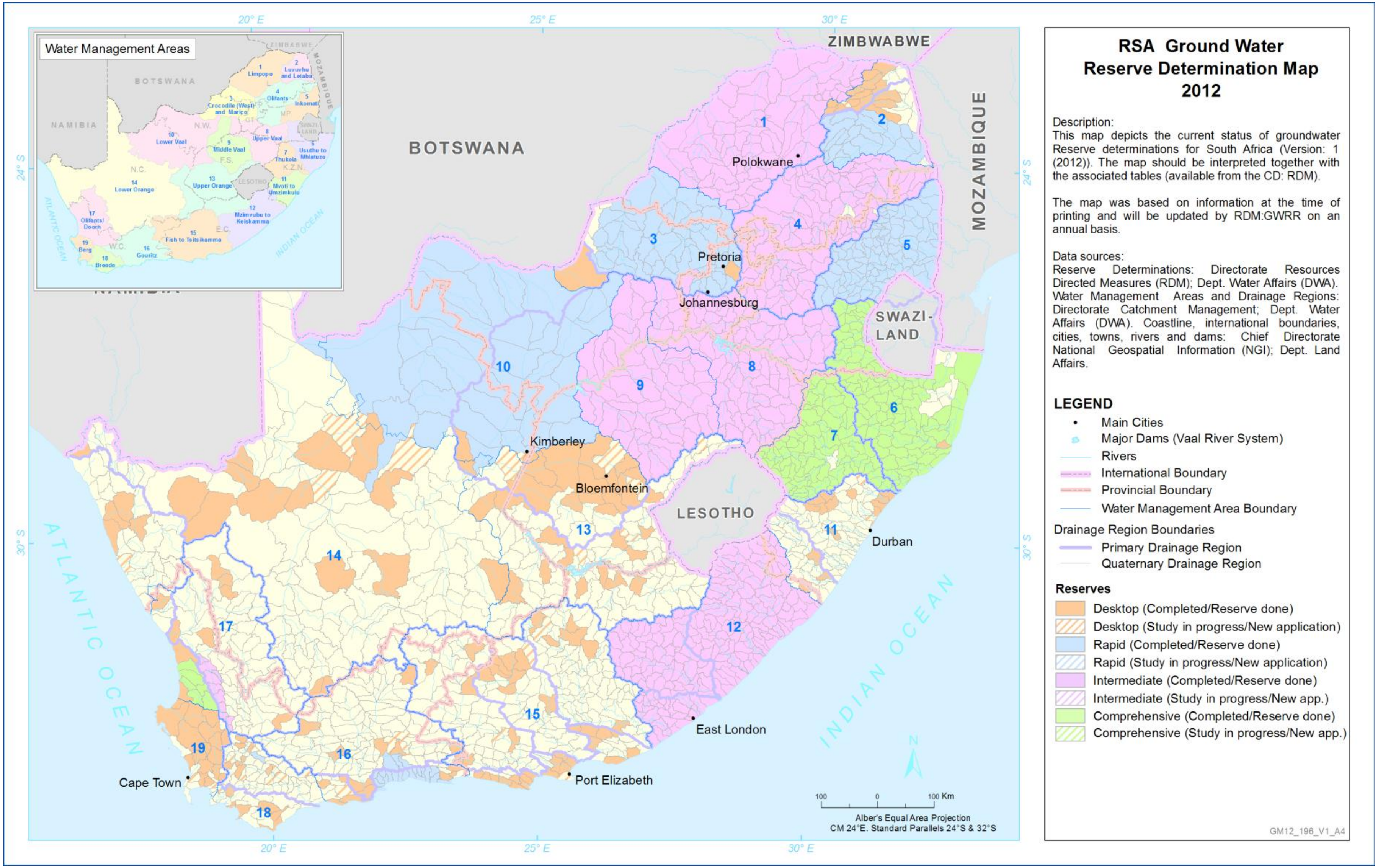


Figure 5.4: Map showing different types of groundwater reserve determinations completed as at end September 2012 (Compiled by DWA: RDM).

5.2.2 Aquatic ecosystem health

While the main ecosystem health activities have taken place under the River Health Programme, estuarine studies are also becoming important and a great deal of progress is being made in ecological status determination.

5.2.2.1 River health

In spite of difficulties in operating the rivers database, which is not compatible with the current Windows operating system and is in need of an update, River Health Programme (RHP) members persisted and were able to log 288 site visits for the current reporting period (Figure 5.5).

The RHP surveys generally run independently from hydrological years. During the period of the 2011-2012 hydrological year a number of RHP surveys were done in Kwa-Zulu Natal, Eastern Cape, Western Cape, Mpumalanga and the Free State. However the results for surveys were not available for reporting except for the Free State Province.

The study area consists of the upper to middle reaches of the Orange River System that fall within the Upper Vaal, Middle Vaal and Upper Orange WMSs and lie primarily within the Free State Province (Figure 5.5).

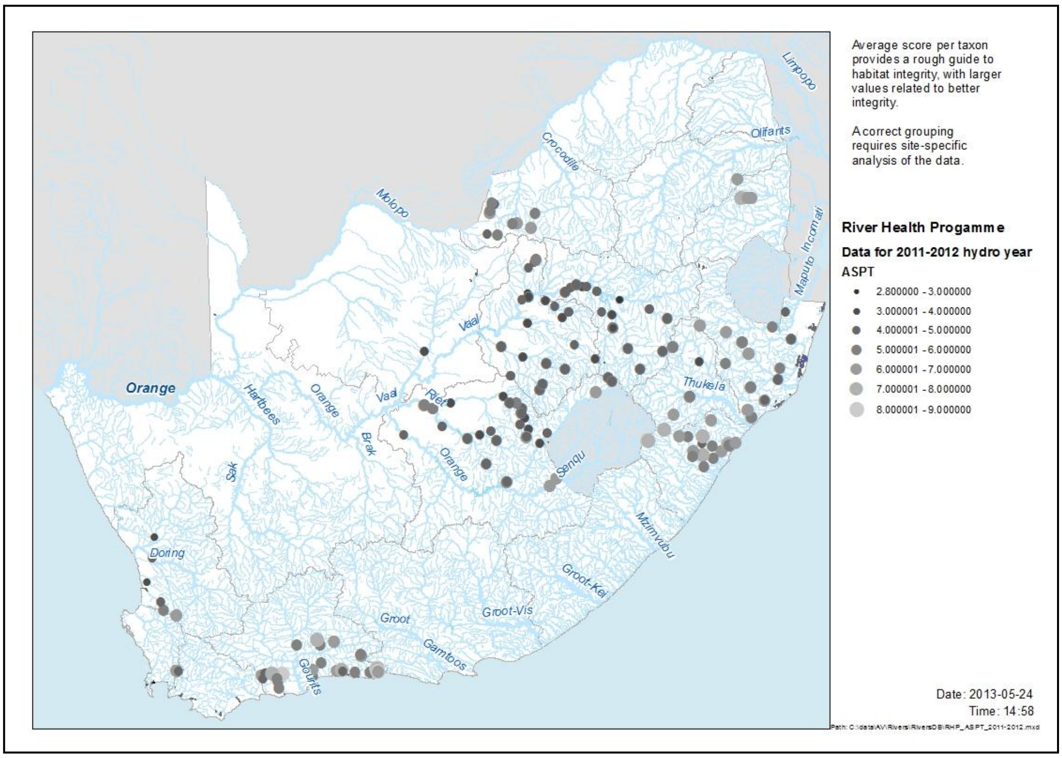


Figure 5.5: An overview of River Health Programme monitoring (Compiled by DWA:RHP).

Although a broad suite of indicators were used for this study only Fish, Macroinvertebrates, In-stream Ecostatus, Diatoms and Habitat Integrity are presented at this stage. The results should be regarded as preliminary since limited data was collected and used for analysis. The preliminary results showed that the Upper and Middle Vaal and the Upper Orange Rivers are not in good healthy conditions (Figure 5.6). The information is specific to sites and reaches and should not be extrapolated to regions.

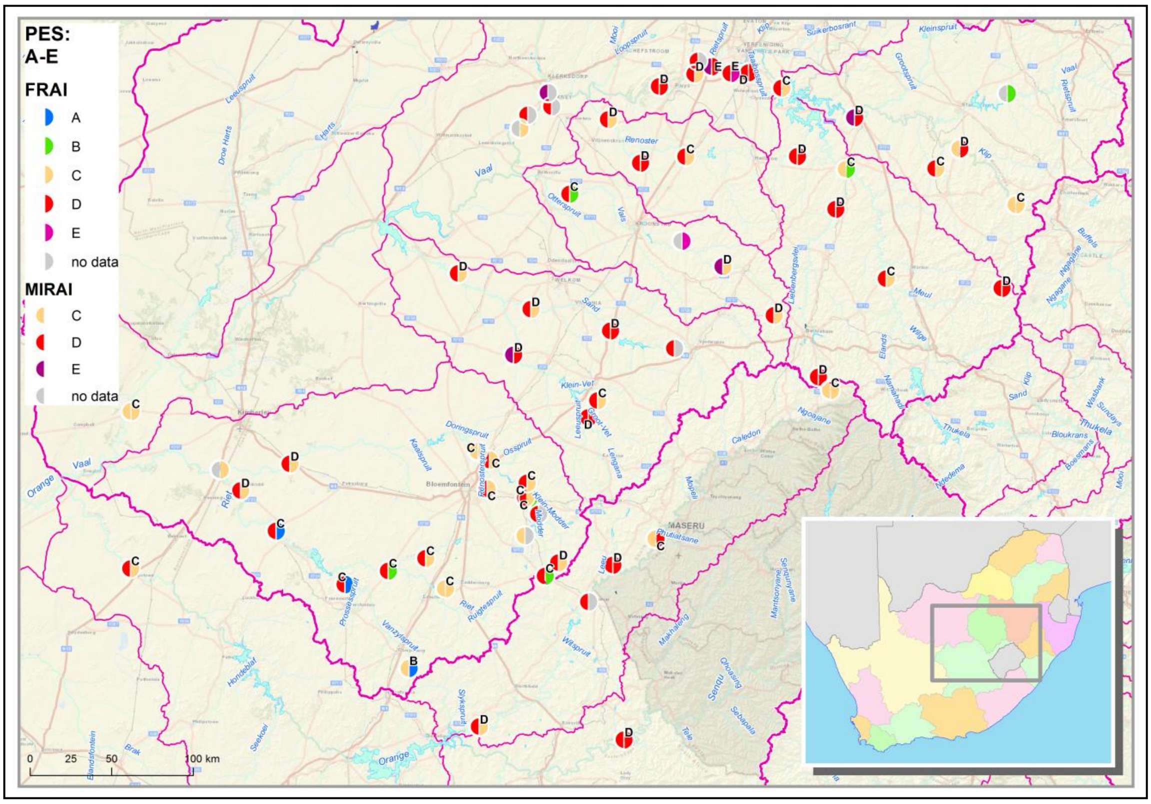


Figure 5.6: Preliminary River Health Programme results for the upper to middle reaches of the Orange River system (Compiled by DWA:RHP).

5.2.2.2 Ecological characteristics indices

The Present Ecological State (PES), Ecological Importance (EI) and Ecological Sensitivity (ES) project is in the process of assessing ecological characteristics for all rivers of South Africa, at a desktop level using scale of 1:500 000. The PES, EI and ES is more detailed and is an improvement of the 1999 version. The products of this project will provide essential information for licensing, ecological reserve determination, ecological monitoring and classification of aquatic resources.

The DWA is using data and information provided by local experts to assess the 148 secondary drainage areas of South Africa. Approximately 9400 river reaches will be assessed during this process. Local experts populated templates with available ecological data for 86 secondary catchments—in primary catchments A, C, D, K, L, M, N, P, Q, S, T, U, V and W—during the period September 2011 to October 2012 (Figure 5.7). The templates have been submitted for independent evaluation and assessment.

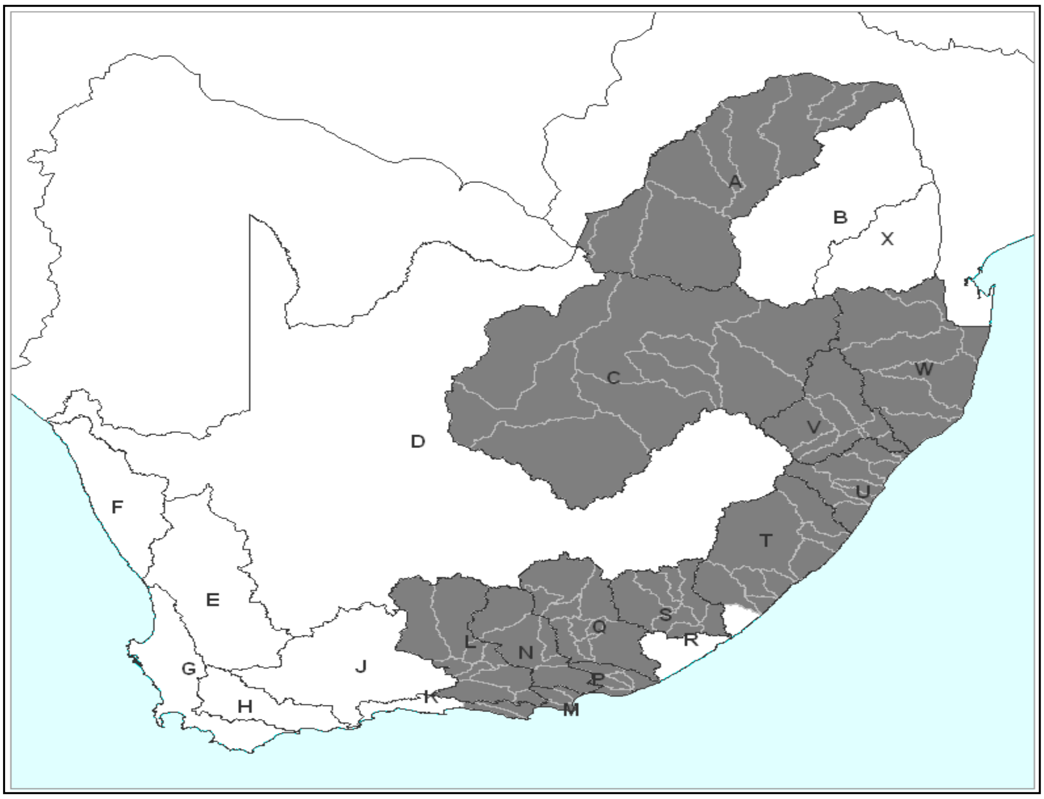


Figure 5.7: The secondary catchments for which 86 PES, EI, ES project templates are complete.

5.2.3 Estuaries

Estuarine ecosystems function through a complex relationship between fresh and marine water. Various ecological drivers influence estuaries spatially, in the longitudinally, vertically and transverse direction, and temporally. The most important drivers are salinity, temperature, turbidity; dissolved oxygen; river flow; tidal exchange; and sediment characteristics (Whitfield & Elliot, 2002).

Observing environmental and ecological change resulting from human activities is difficult in estuaries, primarily as a result of high natural background variability in estuary ecosystems (Whitfield & Elliot 2002). Variability between and even within ecological drivers and processes is large, which in turn affects the biological composition and thus the response indicators. Estuaries are under increasing pressure from land based activities in catchments and climate change as flow is modified, sea level rise and water quality deterioration.

South Africa has about 300 estuaries covering approximately 70 000 ha, which comprise one of the country's most productive habitats but also the most threatened habitats (Turpie *et al.,* 2002, van Niekerk & Turpie, 2012). South Africa's coastline comprises three distinct biogeographical regions (Day 1981, Whitfield 1998).

Subtropical	Kosi Bay to Mbashe Estuary
Warm Temperate	Mbashe Estuary to Cape Point
Cold Temperate	Cape Point to the Orange River Estuary

The distribution of the estuary types within the three biogeographical areas is shown in Table 5.7. The South African estuarine functional zone is the entire area associated with an estuary that ensures its functionality. It therefore is not only limited to the open water area, but also includes floodplains and salt marshes. The extents of the estuarine functional zone in each biogeographical zone are summarised in Table 5.7.

Table 5.7: The distribution of estuary types and the extent of the SA Estuarine Functional Zone in the three biogeographical regions (Whitfield, 1992; van Niekerk & Turpie, 2012).

ESTUARY TYPE	BIOGEOGRAPHICAL REGION		
	SUBTROPICAL	WARM TEMPERATE	COOL TEMPERATE
Estuarine Bay	3	1	0
Permanently open estuary	16	29	2
Estuarine lake	4	4	0
Temporarily open closed estuary	94	86	5
Modified or canalised estuary	0	2	1
River mouth	4	6	2
FUNCTIONAL ZONE			
Proportional Estuarine Functional Zone (Ha)	102 746	41 785	26 516
% of total functional zone	60	24	16

Human activities influence different estuaries to different degrees, and important ecological effects on the estuarine environment include:

1. Decreased water flow in estuaries as a result of catchment related abstraction and impoundments;
2. Pollution from catchment related activities including agriculture, industry and human settlements;
3. Habitat change as a result of urban development in the form of housing, roads and transport infrastructure expansion next to estuaries; and

4. Over-exploitation of natural resources including invertebrates, fish and vegetation for recreational, subsistence and industrial use.

5.2.3.1 Status quo of South African estuaries

The study conducted by South African National Biodiversity Institute found that very small system were still in an excellent to good condition while the larger systems were predominately in a fair to poor quality. This is indicating a decline in the health of these systems (SANBI 2011). Based on the number of estuaries 17% percent of the total number of estuaries was in excellent condition, 41% in good condition, 35% were in a fair state and 7% were in a poor state (Figure 5.8a). Analyzing hectares of total habitat changes the picture substantially, with 1% being in an excellent condition, 14% in good condition and 85% in a poor to fair state (Figure 5.8b). The Fresh Water Ecosystems Priority Areas project identified 122 priority estuaries for biodiversity conservation (Nel *et al.,* 2011).

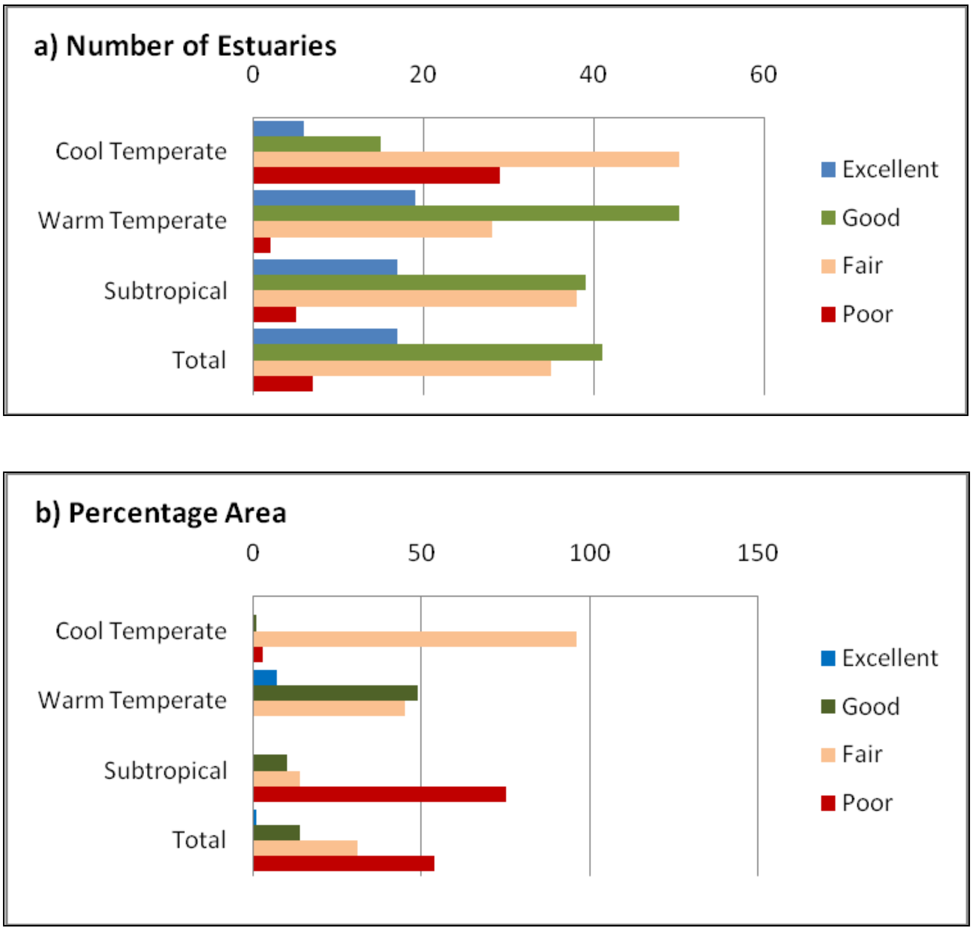


Figure 5.8 a&b. A comparison of estuary health based on a) the number of estuaries and b) total estuarine area for the National Biodiversity Assessment (van Niekerk & Turpie 2012).

The key findings of the National Biodiversity Assessment with reference to South African estuaries suggest that estuaries are generally in a poor state and require attention (van Niekerk & Turpie 2012):

1. The Lake St Lucia system represents more than 55% of the total estuarine area of South Africa and is in a very poor condition;
2. 43% of estuary ecosystem types (20 of 46 types) are threatened, representing 79% of South African estuarine area; and 59% (27 of 46 types) not protected, making up 83% of South African estuarine area;
3. The total freshwater inflow of the 20 largest catchments in South Africa has been reduced by approximately 40 % from the pristine condition and freshwater flow requirements have only been determined for 12% of all estuaries;
4. Flow reduction, habitat modification, fishing and pollution are cumulative pressures, while invasive alien species, mariculture and desalination plants are emerging pressures that could pose a significant risk to biodiversity;
5. Freshwater flow into estuaries and the marine environment is not wasted and is vital to the productivity of the near-shore coastal environment;

The Government of South Africa has prioritised the protection of the country's estuaries. This resulted in the DWA establishing a National Estuarine Monitoring Programme (NESMP) to improve the general ecosystem health while ensuring their protection. The National Estuarine Monitoring Programme of DWA is currently in pilot testing phase and is targeting estuaries listed in Table 5.8.

Table 5.8: The types and ecological categories of the estuaries in the first phase of the National Estuarine Monitoring Programme (van Niekerk & Turpie 2012).

Permanently open	Ecological category	Temporary open / closed	Ecological category	Estuarine lake	Ecological category
Mlalazi	B	Nonoti*	B	Wilderness	B
Breede	B	Mpenjati	B	Klein	C
Swartkops	C	Mtamvuna	B	Bot	C
Olifants	C	Zinkwazi	C	Verlorenvlei	D
Kromme	D	Mhlanga	D		
Berg	D	Mgeni	D		
		Groot Brak	D		

5.2.4 Source Directed Controls

Water abstractions, waste discharges are monitored for compliance to standards as the aquatic ecosystems health depends on good management of water use. The DWA is monitoring and in some cases auditing agriculture, industries, mines and WWTWs operations to check for possible impacts on water resources.

The DWA is also running the Blue and the Green Drop programmes, which are aimed at ensuring that municipalities produce good quality drinking water and final effluents from sewage works that comply to set standards and situation specific conditions.

5.2.4.1 Blue Drop status

The Blue Drop strategy is aimed at motivating Water Service Authorities to improve the functioning of their water treatment works so that they can supply good quality water to communities. A total of 931 Water Treatment Works in 153 municipalities were assessed in 2012. The assessment results show an improvement in performance across the provinces (Table 5.9).

Table 5.9: Performance of municipal wastewater treatment systems per province over time (DWA 2012*a*).

Province	2009	2010	2011	2012	Performance trend
Gauteng	74.4	85.54	95.1	98.1	↑
Western Cape	95	94.45	94.09	94.2	→
KwaZulu-Natal	73	65.91	80.49	92.9	↑
Eastern Cape	54.33	79.4	77.33	82.1	↑
Free State	40.03	48.5	64.01	73.6	↑
Limpopo	40.82	54.95	64	79.4	↑
North West	39.97	66.01	62.25	78.7	↑
Northern Cape	28.3	46.87	62.07	68.2	↑
Mpumalanga	51	65.42	56.5	60.9	↑

Key ↑ = improved →= no change ↓ = deteriorating

5.2.4.2 Green Drop status

The Green Drop process is used to assess the performance of wastewater treatment works run by Water Service Authorities. The process uses a ‘risk-based’ regulation criterion to identify and prioritise the critical risk areas within wastewater treatment process and to take corrective measures to abate these (DWA 2012*a*).

A total of 952 WWTWs, 831 municipal plants; 117 Department of Public Works plants and 4 privately owned, were assessed. Table 5.10 below lists the CRR %deviation values, risk trends and the status of risk for each province from 2009 to 2012. For the 2011/12 assessment, five (5) out of the nine (9) municipalities managed to abate the CRR values. The Western Cape Province was the best performer by managing to lower its CRR from 62.5% in 2009/10 to 51.5% in 2011/12. Although other Provinces such as Limpopo, NW, NC and Mpumalanga also managed to lower their risk levels, their CRR still fall within the medium-high risk categories. Gauteng, Kwa-Zulu Natal, Eastern Cape and Free State Provinces failed to abate the CRR, with the FS (83.5%) being in the critical risk category. These provinces need to be more stringent in terms of the management and operations of their wastewater treatment facilities.

Table 5.10. The comparative analysis of the provincial CRR (DWA 2012*a*).

Provinces	CRR and % deviation from CRR_{max}			Risk Trend	# of Plants in Critical Risk	# of Plants in High Risk
	2009/10	2010/11	2011/12			
Western Cape	63	61	52	↓	3	19
Limpopo	77	85	78	↓	14	32
North West	78	79	60	↓	2	13
Northern Cape	78	76	66	↓	12	24
Mpumalanga	63	73	69	↓	15	29
KwaZulu-Natal	54	58	58	↑	17	15
Gauteng	58	59	62	↑	1	16
Eastern Cape	77	75	76	↑	41	38
Free State	75	81	83	↑	49	27

Key: ↓ = improvement, ↑ = digress

6. References

Allanson, B. R. 2004. Limnology in South Africa: Past and Present Status and Future Needs, pages 1-116.

AMD Newsletter. 2012. Feasibility Study for a Long-Term Solution to address the Acid Mine Drainage associated with the East, Central and West Rand Underground Mining Basins, Gauteng Province. Newsletter, Edition 1, July 2012.

Bamuza, M. L. and Abiye, T. A. 2012. Nature of surface and groundwater interaction in the crystalline aquifers. . In: 16th SANCIAHS National Hydrology Symposium, October 2012. University of Pretoria, South Africa.

Bredenkamp, D. B. 2012. Characteristics of runoff and recharge from small mountain catchments in experimental catchments of the Jonkershoek and Magaliesberg Mountains of South Africa. In: 16th SANCHIAS National Hydrology Symposium, October 2012. University of Pretoria, South Africa.

Day, J. H. 1981. Summaries of current knowledge of 43 estuaries in southern Africa (In: Day JH (Ed) Estuarine Ecology with Particular Reference to Southern Africa. Cape Town, A.A. Balkema pp 251 – 329.

Day, J. A. and King, J. M. 1995. Geographical patterns, and their origins, in the dominance of major ions in South African rivers. South African Journal of Science, 91:299-306.

Department of Water Affairs and Forestry (DWAF). 1996a. South African water quality guidelines, Volume 1, Domestic Water Use. 2nd Edition. Pretoria, South Africa.

Department of Water Affairs and Forestry (DWAF). 1998. National Water Act. Pretoria, South Africa.

Department of Water Affairs and Forestry (DWAF). 2004. National Water Resource Strategy, First Edition. Pretoria, South Africa.

Department of Water Affairs and Forestry (DWAF). 2010. National Groundwater Strategy. Pretoria, South Africa.

Department of Water Affairs and Forestry (DWAF). 2008. Development of reconciliation strategy for the Crocodile (West) water supply system: Summary of previous and current studies. DWAF Report No P WMA3/03/000/003408. Pretoria, South Africa.

Department of Water Affairs (DWA). 2012*a.* Green Drop Report. Department of Water Affairs. Pretoria, South Africa.

Department of Water Affairs (DWA). 2012*b.* Feasibility Study for a Long-Term Solution to address the Acid Mine Drainage associated with the East, Central and West Rand Underground Mining Basins Assessment of the Water Quantity and Quality of the Witwatersrand Mine Voids. Study

Report No. 5.2 P RSA 000/00/16512/2 August 2012 SECOND DRAFT V2.0. Water Resource Planning Systems Series, Water Quality Planning. Pretoria, South Africa.

Driver, A., Nel, J.L., Snaddon, K., Murray, K., Roux, D.J., Hill, L., Swartz, E.R., Manuel, J., Funke, N., (2011). Implementation Manual for Freshwater Ecosystem Priority Areas. Water Research Commission. WRC Report No.1801/1/11.

Du Preez, M., Murray, K., and van Ginkel, C.E. 2002. National Eutrophication Monitoring, Programme Research Report. Water Research Commission. WRC Report No. K5/1147/0/1.

ENEP. 2012. The UN-Water Status Report on the application of integrated approaches to water resources management.

Intergovernmental Panel on Climate Change (IPCC) 2007. Working Group II. Cambridge University Press. IX, 976 p, Karl, T, et al. 2009, New York: Cambridge University Press.

Intergovernmental Panel on Climate Change (IPPC). 2011. Summary of Policymakers. Field, C.b., Barros V. In Intergovernmental Panel on Climate Change Special Report on Managing the Risks of Extreme Events and Disaster to advance Climate Change adaptation. Stocker TF., Qin, D., Dokken, D., Ebi, KL., Mastrandrea MD, mach KJ., Plattner, G-K Allen SK., Tignor M., and Midgely PM. (eds).

Huizenga, J. M. 2011. Characterisation of the inorganic chemistry of surface waters in South Africa. Water SA, 37(3):401-410.

Jägerskog A. and Jønch Clausen T. 2012. Feeding a Thirsty World – Challenges and Opportunities for a Water and Food Secure Future. Report Nr 31. SIWI, Stockholm.

Kruger, A.C. and Sekele, S. S. 2012. Trends in extreme temperature indices in South Africa: 1962 – 2009. International Journal of Climatology, in press.

Lobel, I.D., Schlenker, Costa-Roberts J. 2011. Climate Trends and Global Crop Production since 1980. Science, 333(6042), 616-620.

Middleton, B.J. and Bailey A.K. 2009. Water Resources of South Africa, 2005 Study (WR2005). Water Research Commission. WRC Report No TT380/08. Pretoria, South Africa.

Murray, R., Baker, K., Ravenscroft. P., Musekiwa, C. and Dennis, R. 2012. A Groundwater Planning Toolkit for the Main Karoo Basin: Identifying and quantifying groundwater development options incorporating the concept of wellfield yields and aquifer firm yields'. Water Research Commission, WRC Report No: 1763/1/11. Pretoria, South Africa.

Nel, J.L., Strydom W.F., Maherry A., Petersen C., Hill J., Roux D.J., Nienaber, S., van Deventer, H., Swartz, E. and Smith-Adao, L.B. 2011. Atlas of Freshwater Ecosystem priority areas in South Africa: Maps to support sustainable development of water resources. Water Research Commission. WRC Report No TT500/11. Pretoria, South Africa.

News 24. Snow closes Western Cape pass [online]. Available from: http://www.news24.com/SouthAfrica/News/Snow-closes-Western-cape-pass-20120116. [Accessed 13 December 2012].

Novhe, N. O. 2012. Evaluation of the applicability of the passive treatment for the management of polluted mine water in the Witwatersrand goldfields, South Africa. International Mine Water Association, September 2012. South Africa: Council for Geoscience.

Parsons, R. 2012. Observations From The Other Side of The Saltwater – Freshwater Interface. In: 16th SANCHIAS National Hydrology Symposium, October 2012. University of Pretoria, South Africa.

Portier, C.J., K.T. Thigpen, S.R. Carter, C.H. Dilworth and Grambsch, A.E. 2010. A human health perspective on climate change: A report outlining the research needs on the human health effects of climate change. The Interagency Working Group on Climate Change and Health. Available from: http://ehp03.niehs.nih.gov/static/climatechange.action. [Accessed 12 December 2012].

Ramoeli P, and H. M., Vogel, 2012. Southern African Development Community Water Sector Technical Report. April 2012.

Regional Strategic Action Plan (RSAP) III. 2011. Regional Strategic Action Plan on Integrated Water Resources Development and Management (2011-2015) RSAP III, December 2011.

Rossouw, J.N., Harding, W.R and Fokoti, O.S. 2008. A guide to catchment-scale assessment for rivers, reservoirs and wetlands. Water Research Commission. WRC Report No K5/1343. Pretoria, South Africa.

SABC News. Jo'burg snow fulfils couple's white wedding dream [online]. Available from: http://www.sabc.co.za-SABCnews-Snow. [Accessed 07 December 2012].

Silberbauer, M. 2012. Spatial variation in the TDS to EC ratio in South African rivers. Poster presented at 2012 conference of the Southern African Society of Aquatic Scientists.

Struckmeier W. F., Gilbrich W. H., Gun Jvd, Maurer T., Puri S., Richts A., Winter P., Zaepke M. 2006. HWYMAP and the World Map of Transboundary Aquifer Systems at the Scale of 1:50 000 000 Special Edition for the 4th World Water Forum. Mexico City. March 2006. BGR, Hannover and UNESCO, Paris.

Timeslive. Dry Weather wilts hopes of a better maize crop [online]. Available from: http://www.timeslive.co.za/local/2012/08/12/dryweather-wilts-hopes-of-a-better-maize-crop. [Accessed 21 December 2012].

Turpie J. K., Adams, J. B., Joubert A., Harrison, T. D., Colloty, B. M., Maree, R. C., Whitfield, A. K., Wooldridge, T. H., Lamberth, S. J., Taljaard, S. and van Niekerk, L. 2002. Assessment of the conservation priority status of South African estuaries for use in management and water allocation. Water SA 28(2) 191 – 206.

Turton, A. R., Earle, A., Malzbender, D. and Ashton, P. J. 2005. Hydropolitical vulnerability and resilience along Africa's international waters. Chapter 2. In Wolf, A.T. (Ed.) Hydropolitical Vulnerability and Resilience along International Waters: Africa. United Nations Environment Programme Report no. DEW/0672/NA. Nairobi.

UNWWAP. 2011. Water Policies Monitoring Framework: Draft Text for the UNSD-WWAP "Glossy" Publication. Sixth Meeting of the UN Committee of Experts on Environmental-Economic Accounting, New York, 15-17 June 2011.

UNDP Cap-Net. 2012. International Network for Capacity Development in Sustainable Water Management. Accessed from: http://www.cap-net.org/ [Accessed:Date]

UNEP. 2008. Water quality for ecosystem and human health 2nd edition.

UNEP. 2011. Working towards a Balanced and Inclusive Green Economy: United Nations System-wide perspective. Prepared by the Environment Management Group.

UNEP, IEA and Oeko-Institut. 2011. The bioenergy and water Nexus

Availbale from: http://www.unep.org/pdf/Water_Nexus.

UN Water. 2007. Coping with water scarcity: challenge of the twenty-first century.

van Niekerk, 2000. A first report on the identification and prioritisation of areas in South Africa with a potentially high risk due to faecally contaminated surface water. The National Microbial Monitoring Programme. Department of Water Affairs. Available from: http://www.dwa.gov.za/iwqs/microbio/Document/prioritisefin2.htm. [Accessed 13 May 2013].

van Niekerk, L. and Turpie, J. K. (eds). 2012. South African National Biodiversity Assessment 2011: Technical Report. Volume 3: Estuary Component. CSIR Report Number CSIR/NRE/ECOS/ER/2011/0045/B. Council for Scientific and Industrial Research, Stellenbosch.

van Ginkel, C. 2002. Trophic status assessment: Executive Summary. Institute of Water Quality Studies. Department of Water Affairs and Forestry. Available from: http://www.dwaf.gov.za/iwqs/eutrophication/NEMP/default/htm. [Accessed 15 April 2013].

van Ginkel, C. 2011. Eutrophication: present reality and future challenges for South Africa. Water S.A, 37 (5): 693-701.

Water Wheel. 2008. Eutrophication: microscope refocused on S.A water quality threat. Water Research Commission. Available from: http://www.wrc.org.za/knowledge/reports. [Accessed 20 May 2013].

Water Wheel. 2012. The changing face of Rietvlei Dam. Water Research Commission. Available from: http://www.wrc.org.za/knowledge/reports. [Accessed 20 May 2013].

Water Research Commission (WRC). 2010. Wetland Valuation Volume I *Wetland ecosystem services and their valuation: a review of current understanding and practice.* Water Research Commission, WRC Report No. TT 440/09. Pretoria, South Africa.

Whitfield, A. K. 1992. A characterisation of southern African estuarine systems. Southern African Journal of Aquatic Sciences 18: 89-103.

Whitfield, A. K. 1998. Biology and Ecology of Fishes in South African Estuaries. Ichthyological Monographs of the JLB Smith Institute of Ichtyology No 2, 223pp.

Whitfield, A. K. and Elliot, M. 2002. Fish as indicators of environmental and ecological changes within estuaries: a review of progress and some suggestions for the future. Journal of Fish Biology (61)229-259.

Witthüsser, K. T. and Holland, M. 2008. Hydrogeology of the Cradle of Humankind World Heritage Site, South Africa. The 12th International Conference of International Association for Computer Methods and Advances in Geomechanics (IACMAG).

World Economic Forum. 2011. Water Security: the water-food-energy-climate nexus: the World Economic Forum initiative. Edited by Dominic Waughray.

www.bloomberg.com. Midwest weather expected to be dry through July [online]. Available from: http://www.bloomberg.com/news/2012-07-19/midwest-weather-expected-to-be-hot-through-July.html. [Accessed 15 January 2013].

www.co.portage.wi.us. Different types of runoff. [Accessed 11 March 2013].

www.mg.co.za. Another cold snap headed for South Africa [online]. Available from:http://www.mg.co.za/article/2012-07-17-snow. [Accessed 18 December 2012].

www.niehs.nih.gov/climatereport. A human health perspective on climate change: A Report outlining the Research Needs on the Human Health Effects of Climate Change 2010 [online]. Available from: www.niehs.nih.gov/climatereport. [Accessed 15 January 2013].

www.showme.co.za. Flooding in Port Elizabeth [online]. 2012. Available from: http://www.showme.co.za/port-elizabeth/news/flooding-in-port-elizabeth-October-2012 [Accessed 06 December 2012].