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Water Reconciliation Strategy Study for the Large Bulk Water Supply Systems: Greater Bloemfontein Area

Final
Water Quality Assessment Report

June 2012

aurecon

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water affairs

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Water Reconciliation Strategy Study for the Large Bulk Water Supply Systems: Greater Bloemfontein Area

WATER QUALITY ASSESSMENT REPORT

FINAL

June 2012

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Directorate National Water Resource Planning

Water Reconciliation Strategy Study for the Large Bulk Water Supply Systems: Greater Bloemfontein Area

APPROVAL

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Water Reconciliation Strategy Study for the Large Bulk Water Supply Systems: Greater Bloemfontein Area

Study Reports

Report Name	DWA Report Number	Aurecon Report Number
Inception	P WMA 14/C520/00/0910/01	402992/6231
Preliminary Reconciliation Strategy	P WMA 14/C520/00/0910/02	402992/6232
Interventions Report	P WMA 14/C520/00/0910/03	402992/6233
Water Quality Assessment	**P WMA 14/C520/00/0910/04**	**402992/6234**
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EXECUTIVE SUMMARY

The purpose of this report is to document the outcomes of the Water Quality Assessment Task (Task 8). This report is an assessment of the water quality situation, focusing mainly on river salinity in the Greater Bloemfontein Area. In aquatic ecosystems, salinity represents the total concentration of dissolved ions present and the most common measurement of salinity is Electrical Conductivity (EC). In addition to EC, nitrate/nitrite, phosphates, ammonium, and pH, sulphates, and chlorides were also assessed.

Water quality is determined by the activities on the catchment, the landuse and the geology. The Domestic, Agriculture, and Aquatic Ecosystem water quality guidelines published by the Department of Water Affairs were used to develop combined criteria for the assessment of the identified variables for this study.

The primary study area is located within the Karoo Super Group geology. Dewetsdorp and Thaba Nchu sedimentary geology is characterised by purple and green shale and thick sandstone beds of the upper stage of the Beaufort Group. Reddersburg is also located in the Beaufort Group of the Karoo Super Group and the sedimentary geology is characterised by sandstone, shale and mudstone beds of the middle stage of the Beaufort Group. Ikgomotseng and Edenburg are located in the Beaufort Group and more specifically in the Adelaide Formation of the Karoo Super Group. The sedimentary geology of Ikgomotseng is characterised by mudstone and sandstone beds. The geology of Edenburg is characterised by blue-grey and purple mudstones, interbedded with yellow sandstone and siltstone. The sedimentary geology specifically shale and mudstone are often associated with saline groundwater (GHT, 2009).

The municipalities in the study area include Masilonyana Local Municipality in the Lejweleputswa District Municipality located in the north, the Motheo District Municipality which is in the south and includes the Manguang and Naledi Local Municipalities, and the Xhariep District Municipality which includes the Kaponang and Mahokare Local Municipality areas. The main urban centre is Bloemfontein (now in Mangaung Local Municipality). To the east of Bloemfontein lies Botshabelo (second largest township in South Africa) and Thaba Nchu (FS PGDS May 2005).

The surface water resources, both within the Upper Orange WMA and in Lesotho are well developed and have a high degree of utilisation (Interim Strategy Report, 2010). The two largest dams in the Upper Orange WMA are the Gariep and Vanderkloof dams. Other major dams are the Welbedacht and Knellpoort dams in the Caledon catchment and the Krugersdrift, Rustfontein, and Kalkfontein dams in the Modder-Riet River catchment. The Welbedacht Dam is situated on the Caledon River and supplies water to urban users in Bloemfontein, Botshabelo, Dewetsdorp, and various other smaller users, as well as irrigators downstream of Welbedacht Dam along the Caledon River. Krugersdrift Dam is located on the Modder River and supplies water for irrigation purposes to the Modder River Government Water Scheme. Mockes Dam on the Modder River supplies water to Bloemfontein via the Maselspoort WTW. The Groothoek Dam is located on the Kgabanyane River, a tributary of the Modder River, and supplies water to Thaba Nchu. Rustfontein Dam is located on the Modder River and forms the major storage reservoir in the Modder River catchment. Water is released from Rustfontein Dam to supplement the abstraction from Mockes Dam and currently provides the major portion of water supplied to Bloemfontein at Maselspoort. Tierpoort Dam is situated on a tributary of the Riet River upstream of Kalkfontein Dam and supplies water to the Tierpoort Irrigation Board through a network of unlined canals (Interim Strategy Report, 2010). Kalkfontein Dam is on the Riet River and supplies water for irrigation through a network of canals and syphons to the Riet River Government Water Scheme. Urban water is also supplied to the towns Koffiefontein and Jacobsdal, through the aforementioned canal system (Interim Strategy Report, 2010). The Gariep Dam and the Vanderkloof Dam are the two largest reservoirs in South Africa and are both situated in the Upper Orange River. These two reservoirs form the main component of the Orange River Project and are utilised to supply water to urban and irrigation users. They are also used for hydro-power generation and flood control (Interim Strategy Report, 2010).

The main land use in the Caledon catchment is crop production (maize and wheat), while in the Orange River catchment the main land is stock grazing. Much of the area in the Riet and Modder River catchments is used for cattle and game farming in the west and sheep farming towards the east (up to 75% of the land-use is natural grassland and bossieveld). About 60% of the 22 000 square kilometres of the Caledon catchment is grassland and bossieveld. Dryland crop production, mainly wheat and maize, comprises almost 33% of the Caledon River catchment. Stock grazing is the main land-use for the Orange and Kraai River catchments. The Gariep Dam is one of the major tourist attractions, as it offers a variety of accommodation and leisure facilities, which are mainly centred on water sports

The water quality assessment results show that generally the surface water quality in the study area is of good quality. The EC is within the ideal to acceptable ranges. The assessment shows that the EC for the Caledon River (as measured at the Welbedacht Dam), the Orange River (as measured at the Gariep Dam) and the Modder River are within the ideal and acceptable ranges. The Lower Riet River has higher EC which is in the tolerable range. This may be due to irrigation return flows which have a major impact on salinity in the Lower Riet River.

An assessment of groundwater EC levels was also conducted for some of the towns in the study area (Bloemfontein, Thaba Nchu, Dewetsdorp, Edenburg, Ikgomotseng and Reddersburg). The results show that the EC in all the towns are within acceptable ranges except for Ikgomotseng where the EC is within unacceptable ranges. Industrial, chemical and mining activities as well as irrigation are often the factors responsible for elevated salts. Furthermore, various sub-factors, such as geology, soil, land use and flow of water (i.e. conductivity increases as water flow decreases) also affect the salinity of water, thus influencing EC. The high levels of EC in groundwater at Ikgomotseng, which is also known as Soutpan may be due to high levels of Na^+ and Cl^- ions which may be leaching into the groundwater from salt mining. There are a number of salt lakes that are found in and around Ikgomotseng.

The Reconciliation Strategy has identified a number of potential interventions identified to augment the future water requirements as summarised in the table below to provide additional water to the study area.

Ref	***Intervention***
A1 & 2	*Urban WC/WDM – Efficient use of water and loss management*
B1	*Agricultural WC/WDM*
C1	*Utilising surplus capacity in the Orange River by pumping to Knellpoort Dam from Gariep Dam*
C2	*Utilising surplus capacity in the Orange River by pumping to Knellpoort Dam from Vanderkloof Dam*
C3	*Utilising surplus capacity in the Orange River by pumping to Knellpoort Dam from Bosberg/Boskraai Dam*
C4	*Modifications to Welbedacht Dam: Extend scour*
C5	*Modifications to the Caledon-Modder System*
C6	*Polihali Dam – Lesotho Highlands Phase 2*
D1	*Planned direct re-use: New North Eastern WWTW*
D2	*Planned indirect re-use: Transfer to upstream of Mockes Dam*
D3	*Planned indirect re-use: Krugersdrift Dam*
D4	*Planned direct re-use: Bloemspruit WWTW*
D5	*Re-use of treated effluent: Direct use for irrigation*
E1	*Groundwater abstraction at Ikgomotseng*

Ref	***Intervention***
E2	*Groundwater abstraction at Bloemfontein*
E3	*Groundwater abstraction at Thaba Nchu*
E4	*Groundwater abstraction at Reddersburg*
E5	*Groundwater abstraction at Edenburg*
E6	*Groundwater abstraction at Dewetsdorp*
E7	*Groundwater abstraction at Wepener*
E8 & 9	*Well field developments along the route of the existing pipelines*
F1	*Water trading*
G1	*Tunnel from the Caledon River*
G2	*New dam on the Caledon River*
G3	*Transfer of mine water*
G4	*Canal option (to be still developed)*

A full description of each intervention is provided in the main Interim Report. Based on the assessment of river salinity, the identified potential interventions identified to augment the future water requirements will generally have no impact on river salinity. However, disposal of brine from reverse osmosis may present a problem.

An assessment of the nutrients showed that the water quality in the study area is of good quality. The levels of nitrite/nitrates in the study area are within ideal ranges. Ammonium and phosphate levels in the four rivers are mostly within tolerable ranges. The only cause for concern is the high levels of phosphates in the Upper Riet River as high nutrient levels lead to eutrophication. High phosphorous loads in water may result from domestic and industrial effluents or surface and subsurface drainage, nutrients in the irrigation return flows, wash-off and return flows from settlements. Drainage from agricultural land on which fertilizers have been applied is believed to represent the biggest contributor of phosphorous loading in this catchment. Although the detailed analysis of WWTWs falls outside the scope of this study, it is common knowledge that municipalities with their limited budgets and other resources are not managing WWTWs as they should be and therefore have a serious water quality impact on the receiving surface water resources. An assessment of the status of the WWTWs in the catchment showed phosphate levels for all the WWTWs were below the standard (10 mg/ℓ). Although the nutrient levels are below the standard, loads from treated wastewater in the catchment will in future have a negative impact in the Krugersdrift Dam, unless the discharge standard for orthophosphate is changed from the current 10mg/ℓ (general standard) to 1mg/ℓ (special standard).

Urban Pollution comprises of storm water pollution and pollution from litter (plastics, paper, metals, glass, vegetation, animals and construction material). However since storm water runoff from streets and urban litter does not contain high nutrient concentrations, they are not expected to have an impact on the potential schemes.

Analysis of other variables (pH, sulphates, and chlorides) was also conducted. The results showed that generally the pH and sulphate levels are in the ideal and acceptable ranges. The chloride levels range between ideal and acceptable, with the Lower Riet River having slightly higher levels of chloride, within tolerable ranges.

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ABBREVIATIONS

ACRONYMS

AIDS	Acquired Immune Deficiency Syndrome
BW	Bloem Water
DEAT	Former Department of Environmental Affairs and Tourism (Rep. of South Africa)
DWA	Department of Water Affairs
DWAF	Former Department of Water Affairs and Forestry, now the Department of Water Affairs, Republic of South Africa
EC	Electrical Condictivity
EWR	Ecological Water Requirements
FS PGDS	Free State Provincial Growth and Development Strategy
GGP	Free State Geographic Product
GWS	Government Water Scheme
HIV	Human immunodeficiency virus
ILISO	ILISO Consulting (Pty) Ltd
ISP	Internal Strategic Perspective
MLM	Mangaung Local Municipality
TDS	Total Dissolved Substances
WMA	Water Management Area
WC	Water Conservation
WDM	Water Demand Management
WRC	Water Research Commission
WTW	Water Treatment Works
WWTW	Wastewater Treatment Works

1. INTRODUCTION

1.1 BACKGROUND TO THE RECONCILIATION STRATEGY

Water resource reconciliation studies involve an assessment of the availability, use, and future demands for water and how these can be 'reconciled' through various strategies. The objectives of the Reconciliation Strategy Studies are to:

- Develop future water requirement scenarios for the metropolitan and bulk water supply areas;
- Investigate all possible water resources and interventions, which can be implemented to provide additional water;
- Investigate all possible methods for reconciling the requirements for water with the available resources;
- Provide recommendations for development and implementation of interventions and actions required; and
- Offer a system for continuous updating into the future.

1.2 PURPOSE OF THE STUDY

The objective of this study is to develop a strategy that will set out a course of action to ensure adequate and sustainable reconciliation of future water requirements in the Greater Bloemfontein Area for at least 25 years. This study will:

- Investigate future water requirements scenarios for the Greater Bloemfontein Area;
- Investigate possible water conservation and water demand management (WC/WDM) interventions, groundwater interventions, re-use of treated effluent, and possible future surface water resource development options;
- Investigate possible scenarios for reconciling the requirements for water with the available resources; and
- Provide recommendations for development and implementation of interventions and actions required.

1.3 PURPOSE OF THIS REPORT

The quality of the water that is supplied to the Bloemfontein Area for domestic use is generally very good and ideally suited for human consumption. According to the Interim Strategy Report for the reconciliation strategy, the available supply and current water requirement of the Greater Bloemfontein system are currently in balance. However over the next couple of years it is anticipated that the water requirements will exceed the available supply. Future developments are planned for the Caledon Catchment – which could influence the availability of water.

It is expected that the water quality should not change significantly over the period (time horizon) that will be considered for this study. However, previous studies have shown that the discharge of poorly treated effluent does have a negative effect on water quality in the rivers and streams downstream of the major urban areas and larger towns. This can be expected to increase over time as the water uses, and the generation of waste water increases. This aspect is expected to overshadow any effects that increased water abstraction may bring about.

The purpose of this report is to document the outcomes of the ***Water Quality Assessment Task*** for the Development of Reconciliation Strategies for Large Bulk Scheme Water Supply Systems: Greater Bloemfontein Area. The task will include:

- Conducting a water quality assessment of the surface and groundwater resources in the study area;
- Conducting a qualitative investigation of the impacts of future potential schemes on river salinity; and

- Conducting a qualitative investigation of the effects of wastewater effluent return flows and urban pollution on potential schemes.

1.4 STRUCTURE OF THE REPORT

The following information is included in this Supporting Information Report:

- A description of the study area (**Chapter 2**);
- Data Collection (**Chapter 3**);
- Fitness for use classification (**Chapter 4**);
- Description of the results of the groundwater statistical analysis (**Chapter 5**);
- Discussion of the results (**Chapter 6**);
- Qualitative assessment of the impacts of potential schemes on river salinity and of potential impacts of nutrients and urban pollution on the potential schemes (**Chapter 7**); and
- Conclusion and recommendations (**Chapter 8**).

2. DESCRIPTION OF THE PRIMARY STUDY AREA

2.1 LOCALITY

The Greater Bloemfontein study area **(Figure** 2.1 and **Table 2.2)** is located in the Free State Province and falls predominantly in the Modder and Riet Rivers catchment, which is in the Upper Orange Water Management Area (WMA). A small section of the study area is located in the south east in the Caledon River Catchment in the Lower Orange WMA **(Figure 2.3).**

2.2 GEOLOGY

The primary study area is located within the Karoo Super Group geology. Dewetsdorp and Thaba Nchu sedimentary geology is characterised by purple and green shale and thick sandstone beds of the upper stage of the Beaufort Group. Reddersburg is also located in the Beaufort Group of the Karoo Super Group and the sedimentary geology is characterised by sandstone, shale and mudstone beds of the middle stage of the Beaufort Group (GHT, 2009).

Ikgomotseng and Edenburg are located in the Beaufort Group and more specifically in the Adelaide Formation of the Karoo Super Group. The sedimentary geology of Ikgomotseng is characterised by mudstone and sandstone beds. The geology of Edenburg is characterised by blue-grey and purple mudstones, which is interbedded with yellow sandstone and siltstone. The sedimentary geology of Wepener consists of feldspatic sandstone and grit as well as green shales of the Molteno stage of the Stormberg Group. The Bloemfontein geology consists of sandstone, shale and mudstone of the lower stage of the Beaufort Group. The north western side of Bloemfontein sedimentary geology has been intensively intruded by magmatic dolerite intrusives such as sills and dykes (GHT, 2009).

The sedimentary geology of Ikgomotseng, Thaba Nchu, Reddersburg, Edenburg, Dewetsdorp and Wepener has also been intruded by magmatic dolerite intrusive structures, which include sills and dykes. The baked contact zones between the dolerite intrusion and the sedimentary host rock has led to the formation of fracture zones, which are the main source of abstractable groundwater. The contact between dolerite dykes and the host rock, within the weathered zone, remains therefore the most important target for groundwater exploration (GHT, 2009).

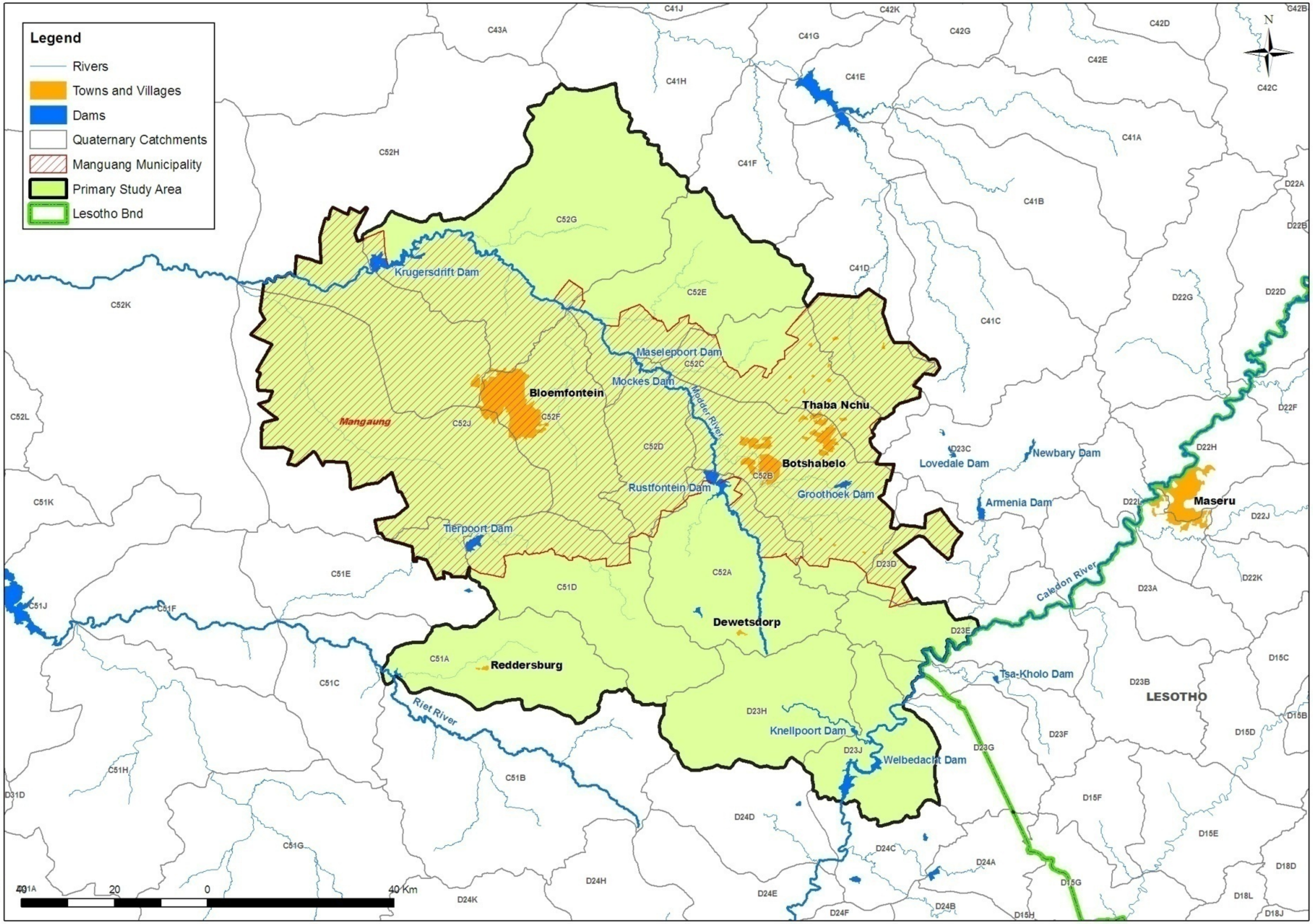

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Figure 2.1: **Study Area**

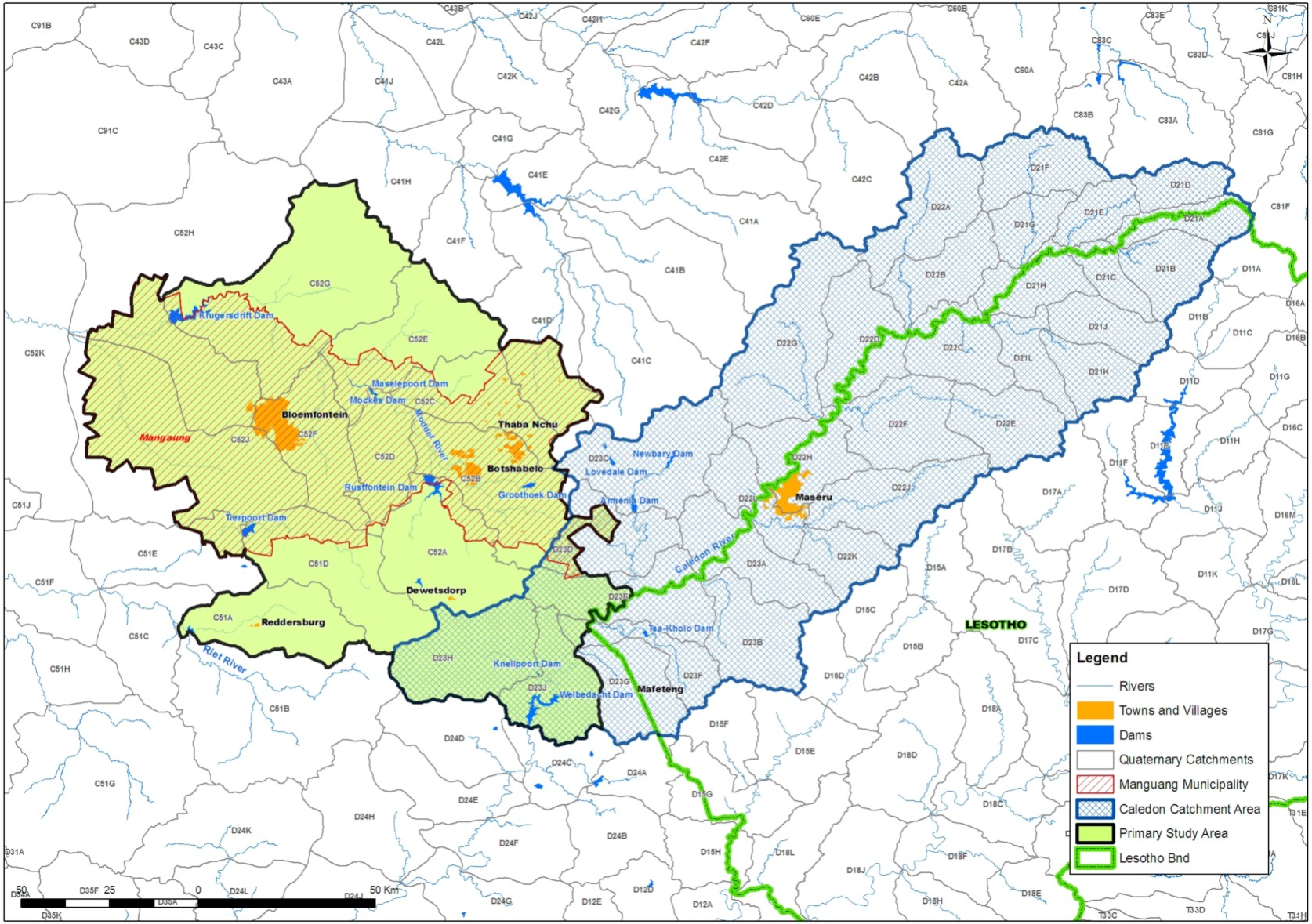


Figure 2.2: Study Area Catchments

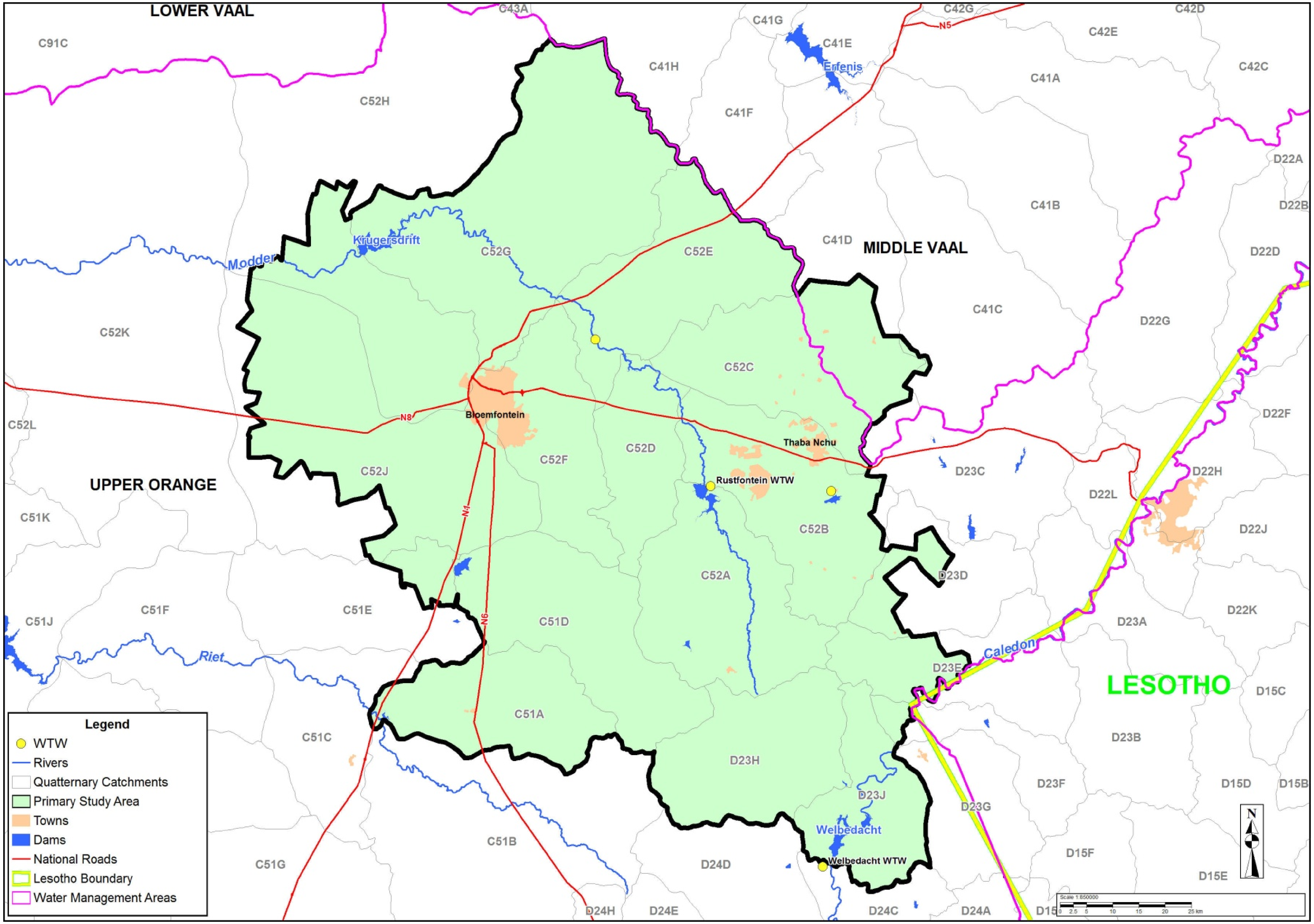


Figure 2.3: **Water Management Areas**

2.3 LANDSCAPE, CLIMATE AND RAINFALL

The Free State is situated on the flat boundless plains in the heart of South Africa between 1 000 m and 1 500 m elevation, with a mean annual rainfall is 532 mm. The western part of the province consists of plains, with pans as an important hydrological feature. There are a significant number of wetlands in the study area (GHT, 2009).

The eastern part is mountainous. The Maluti range along the border is connected to the Drakensberg on the border with Kwa-Zulu–Natal. The Free State is almost treeless, consisting mainly of grasslands with some Karoo vegetation in the south. The soil is rich and climate good, allowing a thriving agricultural industry. The Free State is a summer-rainfall region and is extremely cold during the winter months, especially towards the eastern mountainous regions where temperatures can drop as low as -9.5°C. The western and southern areas are semi-desert (GHT, 2009).

2.4 AQUATIC ECOLOGY

The aquatic ecology is mainly affected by the elevated levels in nutrients, specifically phosphorous. This can lead to eutrophic conditions in standing water, although in clear, shallow, moving water it can lead to excessive growth of rooted water plants and/or anchored algae that can choke waterways. The situation is seen as serious. The Middle Modder River is also subject to elevated ammonia levels that are cause for concern (GHT, 2009).

2.5 THE RESERVE

A rapid 3 Reserve determination with medium-high confidence was undertaken as part of the development of the Modder and Riet Rivers Reserve assessment (BKS, 2005). The results of the study are that all the sites have a Present Ecological State of D and the recommended Ecological Category for all the Ecological Water Requirements (EWR) sites is a Category D, with an alternative Category of C (GHT, 2009).

2.6 MUNICIPAL AREAS AND TOWNS

The municipalities in the study area include Masilonyana Local Municipality in the Lejweleputswa District Municipality in the north, the Motheo District Municipality in the south, which includes the Manguang and Naledi Local Municipalities, and the Xhariep District Municipality which includes the Kaponang and Mahokare Local Municipality areas **(Figure** 2.4**).**

Botshabelo and Thaba Nchu are both serviced by the Motheo District, which mainly comprises open grass field, with mountains in the eastern most parts. The main urban centre is Bloemfontein (now in Mangaung Local Municipality). Bloemfontein is the trade and administrative hub of the province, and boasts a university, the provincial government, large military facilities and the High Court of South Africa. To the east of Bloemfontein lies Botshabelo and Thaba Nchu. Botshabelo is the second largest township in South Africa. (FS PGDS, May 2005)

The Xhariep District is dry with extensive farming, mainly sheep and small platteland towns. The district comprises open grasslands. The Gariep Dam is one of the major tourist attractions, as it offers a variety of accommodation and leisure facilities, which are mainly centred on water sports (FS PGDS, May 2005).

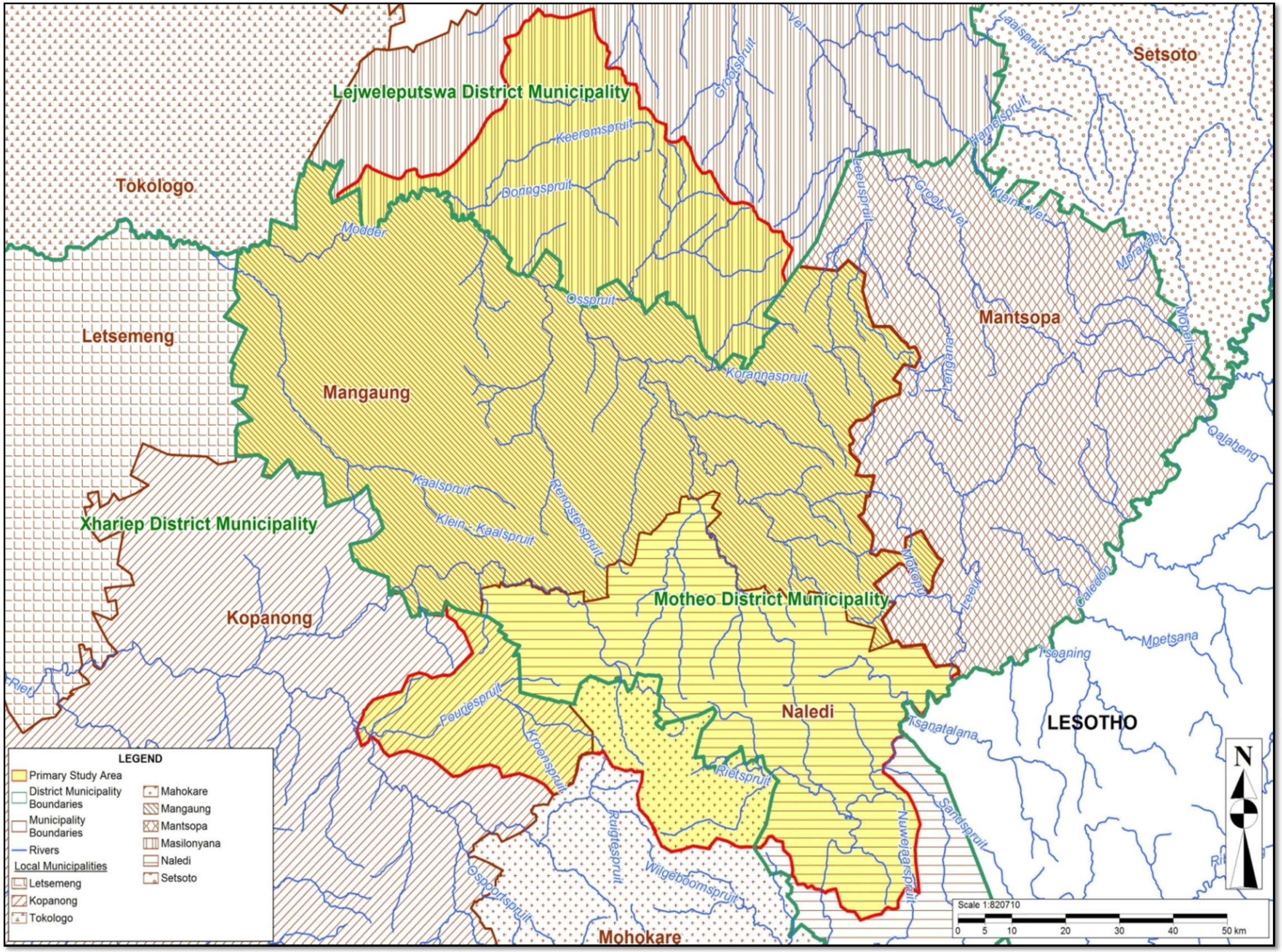


Figure 2.4: **Municipalities in the Study Area**

2.7 SOCIO-ECONOMICS

Seventy one percent of the population, about 2 million people, live in urban settlements. The Free State inherited two ex-Bantustans, i.e. Qwaqwa, a densely populated semi-rural area in the foothills of the Drakensberg mountains and Thaba Nchu (formerly part of Bophutatswana), with the apartheid-created settlement of Botshabelo as a dormitory town for Bloemfontein. Qwaqwa and Botshabelo have major problems in that they have artificially high populations in areas of low employment (FS PGDS May 2005).

2.8 LANDUSE

The main land use in the Caledon catchment is crop production (maize and wheat), while in the Orange River catchment the main land is stock grazing. Much of the area in the Riet and Modder River catchments is used for cattle and game farming in the west and sheep farming towards the east (up to 75% of the land-use is natural grassland and bossieveld). About 60% of the 22 000 square kilometres of the Caledon catchment is grassland and bossieveld. Dryland crop production, mainly wheat and maize, comprises almost 33% of the Caledon River catchment. Stock grazing is the main land-use for the Orange and Kraai River catchments. The Gariep Dam is one of the major tourist attractions, as it offers a variety of accommodation and leisure facilities, which are mainly centred on water sports (River Health Programme, 2003: 32).

2.9 BULK WATER SUPPLY SYSTEM SERVING THE GREATER BLOEMFONTEIN AREA

Bloem Water is the main supplier of bulk potable water to urban centres in the Modder / Riet sub-catchment. The Modder River is fully utilised and this has necessitated transferring water from the Orange and Caledon Rivers. The main transfer water supply schemes are: (1) the Caledon – Bloemfontein transfer which supplies Bloemfontein, Dewetsdorp, and small users from Welbedacht Dam, (2) the Maselspoort Scheme, and (3) the Caledon – Modder (also known as the Novo Transfer Scheme) which supplies water via the Rustfontein Treatment Works to Bloemfontein, Botshabelo, and Thaba Nchu (DWAF, 2002) (Please refer to the main Reconciliation Strategy Report for a full description of the Bulk Water Systems servicing the Greater Bloemfontein Area). The bulk water supply systems serving the Greater Bloemfontein Area is shown in **Figure 2.5.**

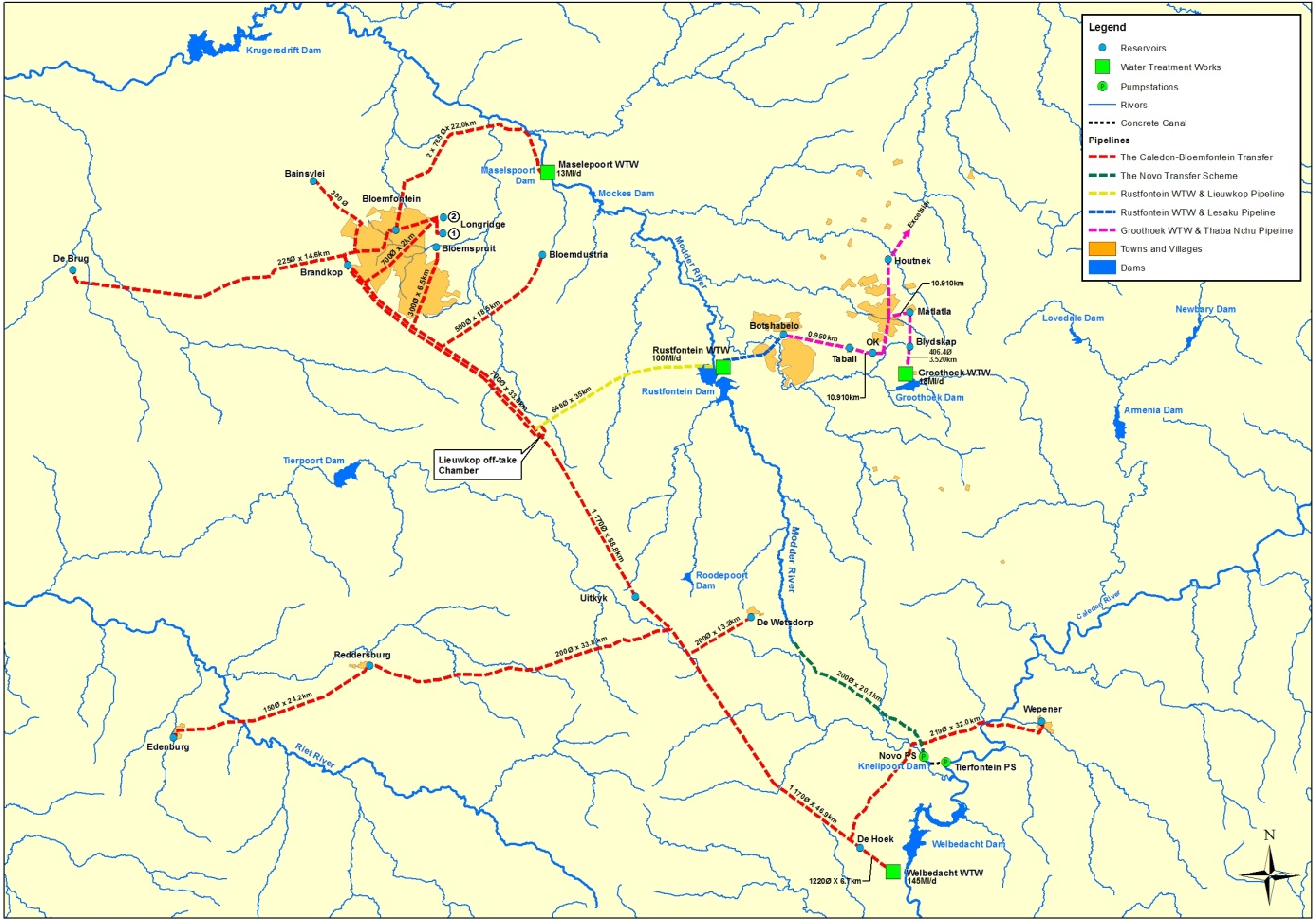


Figure 2.5: Bulk Infrastructure Supplying the Greater Bloemfontein Area

2.10 POTABLE WATER BULK INFRASTRUCTURE

Bloem Water supplies about 100 million m^3/a to about 580 000 people and is the main supplier of bulk potable water to the urban centres in the Modder / Riet River sub-catchment. The total current capacity of reservoirs serving the Greater Bloemfontein is 0.425 million m^3 (this includes MLM's reservoirs). The capacity of Bloem Water's bulk reservoirs is 0.278 million m^3. The Thaba Nchu and Botshabelo reservoirs have capacities of 0.156 million m^3 and 0.052 million m^3respectively (Interim Strategy Report, 2010).

Bloem Water together with MLM own and operate four WTWs with associated infrastructure **(Figure 2.6).** Details of these WTW are provided in **Table 2.1.**

Table 2.1: Maximum Capacity of Bulk Water Supply Infrastructure (Bloem Water, 2008)

Infrastructure	Annual Capacity (million m^3/a)	Capacity (Ml/d)	Owner	Area of Supply
Welbedacht WTW	51.465	145	BW	Bloemfontein / Mangaung
Rustfontein WTW	12.045	100	BW	Bloemfontein / Mangaung
Maselspoort WTW	40.150	110	MLM	Bloemfontein / Mangaung
Groothoek WTW	1.460	18	BW	Botshabelo / Thaba Nchu

2.11 MAJOR WASTEWATER TREATMENT WORKS

The re-use of treated effluent from wastewater treatment works (WWTW) could provide an alternative source to supply water to the Greater Bloemfontein Area in the future. **Table 2.2** lists the current WWTWs which serve Bloemfontein/Mangaung and Botshabelo/Thaba Nchu areas (Interim Strategy Report, 2010).

Table 2.2: Current Capacity of WWTWs which Serve MLM

Area	WWTWs	Capacity (Ml/d)
Bloemfontein/Mangaung	Bloemspruit	56
	Sterkwater	10
	Welvaart	6
	Bainsvlei	5
	Northern Works	1
	Bloemdustria	< 1
Botshabelo/Thaba Nchu	Botshabelo	20
	Selosesha	6

The geographic location of the WWTWs is provided in **Figure 2.6**.

The MLM is in the design phase to construct the new WWTW (referred to as the North Eastern WWTW), to allow further development in the northern, eastern, and western parts of the city (Interim Strategy Report, 2010).

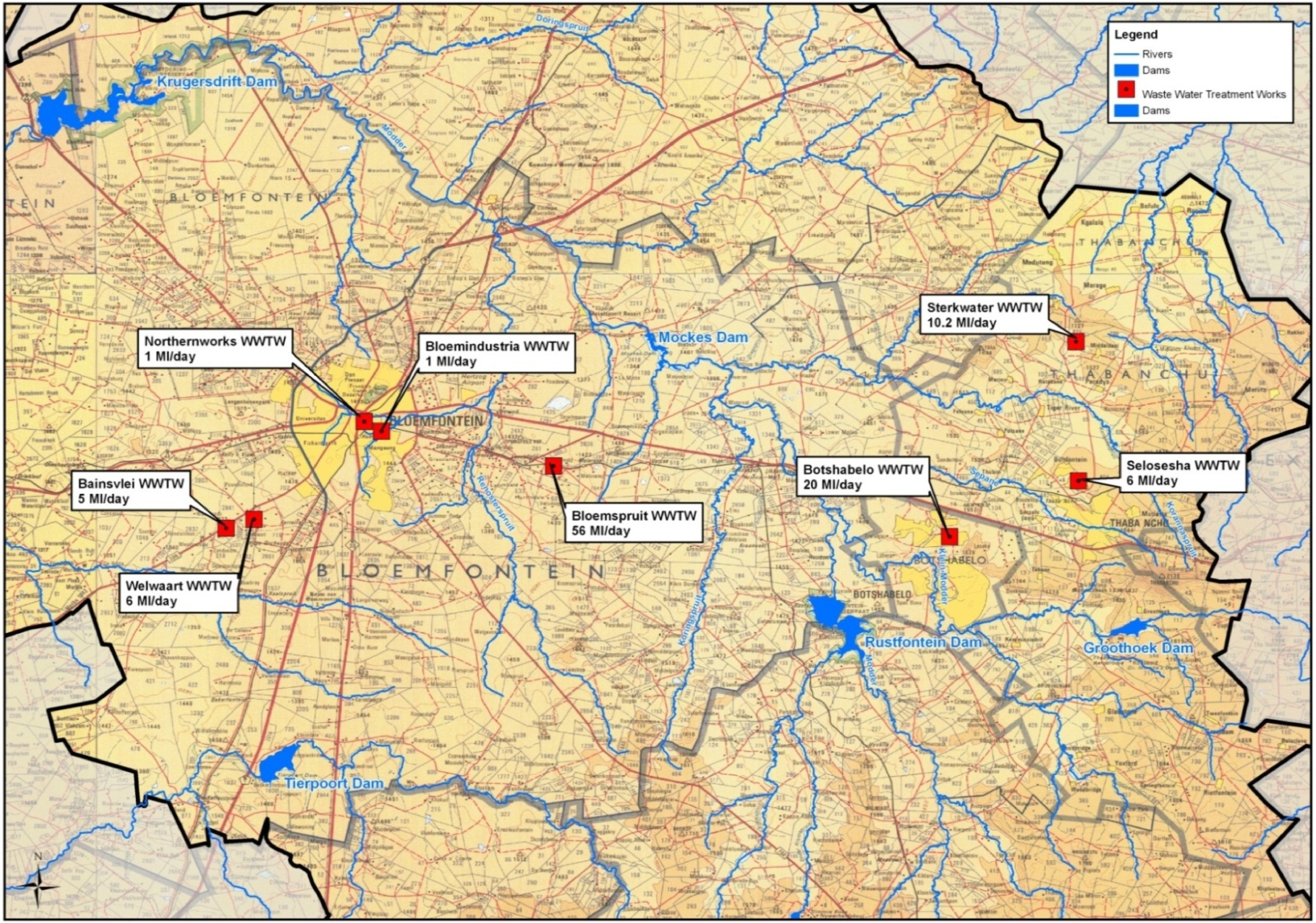


Figure 2.6: **WWTWs Located within the Primary Study Area**

2.12 WATER SOURCES

Nearly 70% of the total surface runoff, which would flow through the Upper Orange Water Management Area (WMA) under natural conditions, originates from Lesotho and just more than 30% from within the WMA. The surface water resources, both within the Upper Orange WMA and in Lesotho, are well developed and have a high degree of utilisation (Interim Strategy Report, 2010).

The two largest dams in this WMA are the Gariep and Vanderkloof dams, which reduce the incidence of floods in the Lower Orange WMA by about 50%. Other major dams are the Welbedacht and Knellpoort dams in the Caledon catchment and the Krugersdrift, Rustfontein, and Kalkfontein dams in the Modder-Riet River catchment. A description of the major dams per sub-catchment is provided in the following sections and is shown in **Figure 2.7.**

2.12.1 Caledon River Sub-catchment

The Welbedacht Dam is situated on the Caledon River and supplies water to urban users in Bloemfontein, Botshabelo, Dewetsdorp, and various other smaller users, as well as irrigators downstream of the Welbedacht Dam along the Caledon River. The irrigators downstream of the Welbedacht Dam have no claim to any water in Welbedacht Dam and only the inflow is released for irrigation purposes. The Welbedacht WTW at the Welbedacht Dam supplies water via the Caledon-Bloemfontein pipeline to Bloemfontein, Botshabelo, and other minor consumers (Interim Strategy Report, 2010).

2.12.2 Modder River Sub-catchment

The Krugersdrift Dam is located on the Modder River and supplies water for irrigation purposes to the Modder River Government Water Scheme. More than 50 weirs were constructed in the Modder River between the dam wall and the confluence with the Riet River (Interim Strategy Report, 2010).

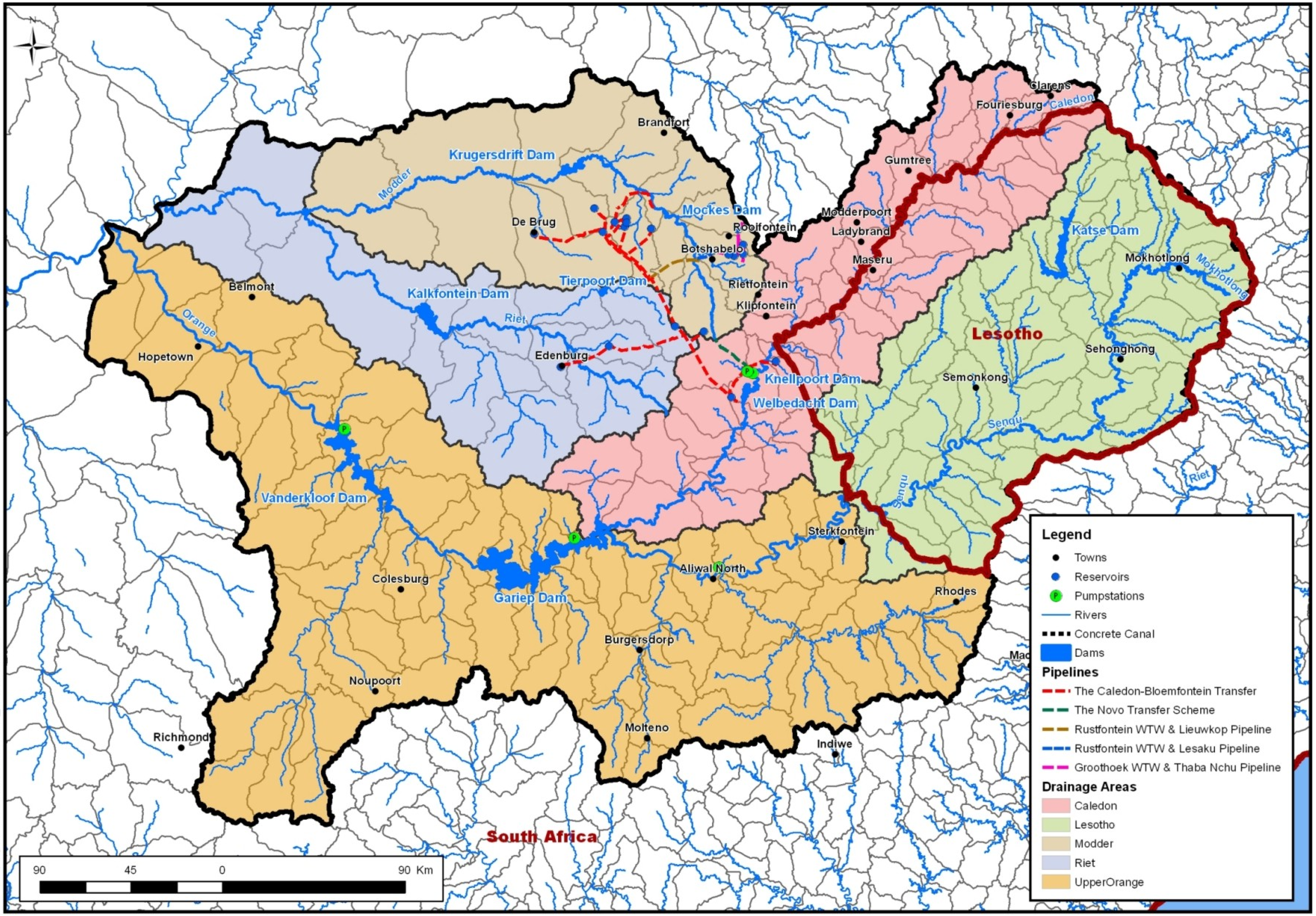
The Mockes Dam on the Modder River supplies water to Bloemfontein via the Maselspoort WTW. The Groothoek Dam is located on the Kgabanyane River, a tributary of the Modder River, and supplies water to Thaba Nchu (Interim Strategy Report, 2010).

The Rustfontein Dam is located on the Modder River and forms the major storage reservoir in the Modder River. Water is released from the Rustfontein Dam to supplement the abstraction from the Mockes Dam and currently provides the major portion of water supplied to Bloemfontein at Maselspoort (Interim Strategy Report, 2010).

2.12.3 Riet River Sub-catchment

The Tierpoort Dam is situated on a tributary of the Riet River upstream of the Kalkfontein Dam and supplies water to the Tierpoort Irrigation Board through a network of unlined canals (Interim Strategy Report, 2010).

The Kalkfontein Dam is on the Riet River and supplies water for irrigation through a network of canals and syphons to the Riet River Government Water Scheme. Urban water is also supplied to the Koffiefontein and Jacobsdal towns through the aforementioned canal system (Interim Strategy Report, 2010).



s:/projects/H402992/mxd/main_catchments.mxd

Figure 2.7: **Major Dams per Sub-catchment**

2.12.4 Upper Orange River

The *Gariep Dam* and the Vanderkloof Dam are the two largest reservoirs in South Africa and are both situated in the Upper Orange River. These two reservoirs form the main component of the Orange River Project and are utilised to supply water to urban and irrigation users. They are also used for hydro-power generation and flood control (Interim Strategy Report, 2010).

2.12.5 Lesotho

The Katse Dam in the Senqu sub-area is used for transfer of water to the Upper Vaal WMA. The Mohale Dam, in the same sub-area, is also used to transfer water to the Upper Vaal WMA (Interim Strategy Report, 2010).

2.13 SUMMARY OF WATER RESOURCES SERVING THE GREATER BLOEMFONTEIN AREA

The Greater Bloemfontein area currently utilises surface water from three primary sources (Interim Strategy Report, 2010). The “yield” of these water resources (excluding river losses) and registered water use is given in the **Table 2.3.**

Table 2.3: Summary of Primary Surface Water Resources

Source	Registered Water Use (million m^3)	Historical Firm Yield (million m^3)
Rustfontein Dam	9.74	8
Mockes Dam	14.8	
Groothoek Dam	0.74	
Welbedacht and Knellpoort Dams	37	85
Total of individual yield (excluding losses)	**62.28**	**93**

2.14 GROUNDWATER

Groundwater is currently not utilised as a water resource for the supply of potable water to Bloemfontein. However, groundwater is used by individuals for irrigation of gardens in residential areas. Groundwater is used extensively for agricultural purposes in the Bainsvlei / Kalkveld area and the area to the south-west of Bloemfontein. Groundwater is also utilised by small industry for bottling of water as well as micro irrigation of vegetables and nurseries (garden centres), which are in close proximity to the city limits (Interim Strategy Report, 2010).

Small towns and communities in the vicinity of Bloemfontein, such as Dewetsdorp, Reddersburg, and Edenburg, are solely or partially depended on groundwater for drinking and domestic purposes. Groundwater is therefore considered as an essential resource, specifically for the smaller towns (Interim Strategy Report, 2010). An estimate of the groundwater yields for the small towns in the vicinity of Bloemfontein is provided in **Table 2.4**.

Table 2.4: Estimated Groundwater Yields for Small Towns

Town	Estimated Average Yield of Existing Boreholes (Million m^3/a)	Number of Boreholes
Wepener	0.071	4
Dewetsdorp	0.080	4
Reddersburg	0.160	9
Edenburg	0.213	12

2.15 WATER USE

The Orange River, along with the Modder and Riet rivers, is a major contributor to supplying water to agriculture, domestic, and industrial users in the Upper Orange WMA. Agriculture is one of the key users of water in the Upper Orange WMA and there are several Government Water Scheme (GWS) and irrigation boards in this WMA. There are two major hydro-electric powerstations at Gariep and Vanderkloof Dams. There are also seven major dams in the Upper Orange River WMA, namely the Gariep, Vanderskloof, Welbedacht, Knellpoort, Rustfontein, Krugersdrift and Kalkfontein (DWAF, 2002; DWAF, 2004a; & DWAF, 2004b).

2.16 INTER-CATCHMENT TRANSFER SCHEMES

Extensive inter-catchment transfer schemes have been developed for the transfer of water within the Upper Orange WMA as well as to other WMAs. The most significant transfers are from the Katse Dam via the Lesotho Highlands Water Project to the Upper Vaal WMA and from the Gariep Dam via the Orange-Fish tunnel to the Fish and Tsitsikamma WMA.

2.17 WATER QUALITY

In the natural state the quality of surface water in the Upper Orange WMA is good, particularly water which flows from the Highlands of Lesotho in the Senqu River. Water in the Caledon River is naturally of high turbidity and carries a high sediment load. The irrigation return flows have a major impact on salinity in the lower Riet River (BKS, 2006).

3. AVAILABILITY OF DATA/DATA COLLECTION

3.1 INTRODUCTION

The water quality of a natural stream is determined by the concentration of the different chemical variables of the water body. The change in the concentration of these different variables is the result of a number of random processes, including rainfall, runoff, anthropogenic activities, geology etc. Water quality is therefore rarely static, but changes over time and location. The measurement of the concentration of these different chemical variables is the data required to complete a water quality assessment.

The water quality assessment, however, does not focus on the instantaneous concentration as it is seldom that the instantaneous concentration has an impact on the water user. Rather the overall difference in the magnitude of the concentration and range of concentration over a period of time must be used as a measurement of the water quality status. For this reason individual water quality measurements (or data) are of little use to water quality managers, and regular measurements over a number of years are required.

The source, number and frequency of measurements are important in the overall evaluation of the water quality and decision making.

3.2 SOURCE OF DATA

3.2.1 Surface Water

The surface water quality data used for the evaluation of water quality was obtained from the monitoring stations managed by the DWA.

3.2.1.1 Surface Water Quality Data Used

The main rivers that pass through the study area include the Modder River, the Riet River, the Caledon River, as well as the Orange River. The water quality data reviewed for the Caledon River was from the DWA stations on the Welbedacht Dam, and for the Orange River, the data was from the Gariep Dam. **Table 3.1** presents a list of the monitoring stations which were reviewed and **Figure 3.1** shows the location of these monitoring stations.

Table 3.1: List of DWA Surface Water Quality Monitoring Stations

Water Source	Description	Monitoring Station	Date of First Sample	Date of Last Sample	Number of Samples
Welbedacht	Welbedacht Dam	D2R004	2000/01/04	2009/01/07	225
Gariep	Gariep Dam	D3R002	2000/01/05	2009/01/08	527
Riet	Upper Riet (Tierpoort Dam)	C5R001	1991/04/02	2001/07/18	125
	Middle Riet (Kalkfontein Dam)	C5R002	1990/01/25	2000/12/07	111
	Lower Riet (Aucampshoop)	C5H016	1990/01/28	2000/10/01	131
Modder	Upper Modder (Rustfontein Dam)	C5R003	1992/04/01	2001/07/02	111
	Middle Modder (Krugersdrift Dam)	C5R004	1990/02/01	2001/04/09	116

Water Source	Description	Monitoring Station	Date of First Sample	Date of Last Sample	Number of Samples
	Lower Modder (Tweerivier)	C5H018	1994/01/03	2000/07/12	78

3.2.2 Groundwater

Groundwater data is obtained through the measurement of borehole water levels, borehole locations, groundwater quality, and other parameters. The DWA currently keeps groundwater data in a database called the National Groundwater Database (NGDB), which contains data on boreholes.

A lack of reliable groundwater data makes it difficult to make accurate assessments of the quality and quantity.

Since groundwater quality is not expected to change significantly over time, data used in the assessment span the period 1971 to 2008.

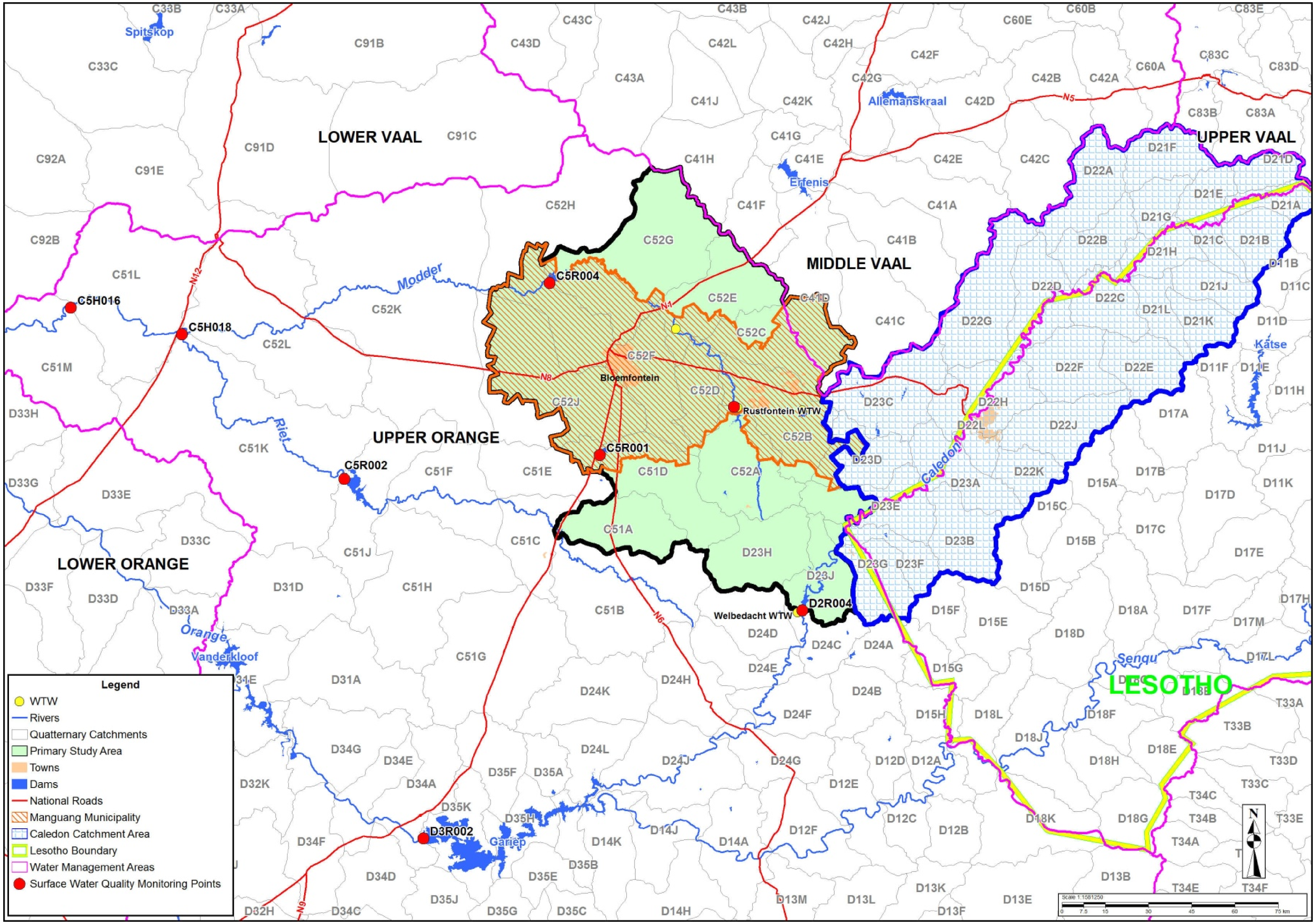


Figure 3.1: Surface Water Monitoring Stations

3.2.2.1 Groundwater Quality Data Used

Only stations which are located within the Bloemfontein, Ikgomotseng, Dewetsdorp, Reddersburg, Edenburg, Thaba Nchu and Wepener areas were reviewed. The groundwater data received from the DWA for most of the stations was old. **Table 3.1** presents a list of the monitoring stations which were reviewed. **Figure 3.2** shows the location of the groundwater monitoring stations which were reviewed.

Table 3.2: List of DWA Groundwater Quality Monitoring Stations

Area	Monitoring Point ID	Monitoring Point Name	Date of First Sample	Date of Last Sample	Number of Samples
Ikgomotseng	89733	ZQMSPN1 SOUTPAN	1995/05/24	1998/08/31	11
	162115	MIDDELBURG (DUP NAME 21116)	1982/06/22	1982/06/22	2
	162116	MIDDELBURG (DUP NAME 21117)	1982/06/22	1982/06/22	1
	166083	LEMOENKLOOF (DUP NAME 24241)	1986/11/06	1986/11/06	3
	166084	GOEDE HOOP (DUP NAME 24242)	1986/11/06	1986/11/06	1
	166085	WINTERSDAM (DUP NAME 24243)	1986/11/06	1986/11/06	1
	166086	WINTERSDAM (DUP NAME 24244)	1986/11/06	1986/11/06	1
	166087	THABA NCHU (DUP NAME 24245)	1986/11/10	1986/11/10	1
	166088	THABA NCHU (DUP NAME 24246)	1986/11/10	1986/11/10	1
	166089	THABA NCHU (DUP NAME 24247)	1986/11/10	1986/11/10	1
	166090	HAAGENS STAD	1986/11/11	1986/11/11	1
	166091	MULBERRY GROVE	1986/11/11	1986/11/11	1
	166094	VEELGELUK	1986/11/11	1986/11/11	1
	166096	SPIOENKOP (DUP NAME 24251)	1986/11/12	1986/11/12	1
	166098	QUAGGA DAM	1986/11/12	1986/11/12	1
	166099	KRISTAL	1986/11/13	1986/11/13	1
	166100	GELUK (DUP NAME 24252)	1986/11/13	1986/11/13	1
	166101	KLEINVERDEEL	1986/11/14	1986/11/14	1
	166102	VAALBANK (DUP NAME 24253)	1986/11/14	1986/11/14	1
	166103	GLENDOWER	1986/11/17	1986/11/17	1
	171921	FLORISBAD (DUP NAME 27687)	1994/01/11	1994/01/11	2
	183712	ZQMFBD1 2826CC00026 FLORISBAD WARM BATH	2000/11/10	2008/09/01	19
Bloemfontein	148191	FERREIRA (DUP NAME 9083)	1971/01/05	1971/01/05	1
	149030	SHANNON	1973/05/15	1973/05/15	1
	162711	ORANJE HOSPITAAL	1982/03/15	1982/03/15	1
	177405	ZQMBLM1 2926AA00111 BLOEMFONTEIN - KAMPUS U015	1999/04/28	2010/04/13	25
Reddersburg	89697	ZQMRDG1 2926CA00002 REDDERSBURG	1995/05/26	2008/04/17	31

Area	Monitoring Point ID	Monitoring Point Name	Date of First Sample	Date of Last Sample	Number of Samples
	90822	C5H021Q01 MOSTERS HOEK EYE AT MOSTERS HOEK	1975/10/29	1999/08/06	152
	91163	REDDERSBURG DORP	1972/09/05	1972/09/05	1
	91724	REDDERSBURG DORPSGRONDE (DUP NAME 1417)	1977/03/25	1977/03/25	1
	91725	REDDERSBURG DORPSGRONDE (DUP NAME 1418)	1977/03/26	1977/03/26	1
	156370	DORPSGROND (DUP NAME 16267)	1977/03/10	1977/03/17	7
	156371	DORPSGROND (DUP NAME 16268)	1977/03/21	1977/03/28	6
	156372	DORPSGROND (DUP NAME 16269)	1977/03/29	1977/04/05	8
	156370	DORPSGROND (DUP NAME 16267)	1977/03/10	1977/04/05	21
Edenburg	148188	EDENBURG	1971/01/06	1971/01/06	1
	155536	MUNGROND (DUP NAME 15507)	1977/02/23	1977/03/03	7
	155537	MUNGROND (DUP NAME 15508)	1977/02/28	1977/02/28	1
	155538	PAOGROND	1977/02/24	1977/03/02	7
Thaba Nchu	145899	POTSANE (DUP NAME 7579)	1997/12/19	1997/12/19	1
	145902	THUBISE	1997/12/13	1997/12/13	1
	145903	BULTFONTEIN 1	1997/12/13	1997/12/13	1
	145913	ROOIFONTEIN (DUP NAME 7584)	1997/12/23	1997/12/23	1
	145914	ROOIFONTEIN (DUP NAME 7585)	1997/12/23	1997/12/23	1
	145915	SERWALO	1997/12/23	1997/12/23	1
	148943	THABANCHU DORP	1972/08/28	1972/08/28	1
	173013	THABA'NCHU DORP	1970/11/02	1972/11/17	2
Wepener	148053	JAMMERSDRIFT	1970/11/12	1970/11/12	1
	148683	JAMMERSDRIF	1972/06/05	1972/06/05	1
	177413	ZQMWEP1 2927CA00019 WEPENER MEENT	1999/04/28	2008/09/22	22
Dewetsdorp	89983	ZQMDWP1 DEWETSDORP	1995/05/26	1997/11/18	6
	91187	2926DA00253 KAREEFONTEIN	1976/06/14	1976/06/14	1
	91188	2926DA00097 DEWETSDORP	1976/06/14	1976/06/14	1
	91189	2926DA00106 KAREEFONTEIN	1976/06/14	1976/06/14	1
	91190	2926DA00121 DEWETSDORP	1976/06/14	1976/06/14	1
	91191	2926DA00125 DEWETSDORP ERF NO 462	1976/06/14	1976/06/14	1
	91192	2926DA00156 KAREEFONTEIN	1976/06/15	1976/06/15	1
	91193	2926DA00276 KAREEFONTEIN	1976/06/16	1976/06/16	1
	91194	2926DA00271 KAREEFONTEIN	1976/06/24	1976/06/24	1
	91195	2926DA00275 KAREEFONTEIN	1976/06/24	1976/06/24	1

Area	Monitoring Point ID	Monitoring Point Name	Date of First Sample	Date of Last Sample	Number of Samples
	91196	2626DA00269 KAREEFONTEIN	1976/06/24	1976/06/24	1
	91197	2926DA00272 KAREEFONTEIN	1976/06/24	1976/06/24	1
	91198	2926DA00239 DEWETSDORP	1976/06/24	1976/06/24	1
	91199	2926DA00267 KAREEFONTEIN	1976/06/24	1976/06/24	1
	91200	2926DA00268 KAREEFONTEIN	1976/06/24	1976/06/24	1
	91201	2926DA00209 KAREEFONTEIN	1976/06/24	1976/06/24	1
	93923	2926DA00001 KAREEFONTEIN	1985/01/22	1985/01/22	2
	93924	2926DA00002 KAREEFONTEIN	1985/01/23	1985/01/23	2
	93925	2926DA00003 KAREEFONTEIN	1985/01/23	1985/01/23	1
	93926	2926DA00005 KAREEFONTEIN	1985/01/24	1985/01/24	1
	93927	2926DA00006 KAREEFONTEIN	1985/01/25	1985/01/25	1
	93928	2926DA00007 KAREEFONTEIN	1985/01/25	1985/01/25	1
	93929	2629DA00008 KAREEFONTEIN	1985/01/25	1985/01/25	1
	93930	2926DA00009 KAREEFONTEIN	1985/01/28	1985/01/28	1
	93931	2926DA00011 KAREEFONTEIN	1985/01/29	1985/01/29	1
	93932	2926DA00013 KAREEFONTEIN	1985/01/28	1985/01/28	1
	93933	2926DA00015 KAREEFONTEIN	1985/01/30	1985/01/30	1
	93934	2627DA00091 FRANKFURT	1985/01/31	1985/01/31	2
	93935	2926DA00237 ELIM	1985/01/31	1985/01/31	1
	93936	2926DA00254 FRANKFURT	1985/02/01	1985/02/01	1
	93937	2926DA00248 FRANKFURT	1985/02/04	1985/02/04	1
	93938	2926DA00259 KAREEFONTEIN	1985/02/05	1985/02/05	1
	93939	2926DA00263 KAREEFONTEIN	1985/02/07	1985/02/07	1
	148189	DUP NAME 9082	1971/04/05	1971/04/05	1
	148190	DEWETSDORP S	1971/03/03	1971/03/03	11
	150900	DUP NAME 11325	1971/03/03	1971/03/03	1
	160772	JOHANNA STROOM	1976/06/15	1976/06/15	1
	165072	2926DA00039	1980/12/08	1985/02/04	1
	165073	2926DA00028	1985/02/08	1985/02/08	1

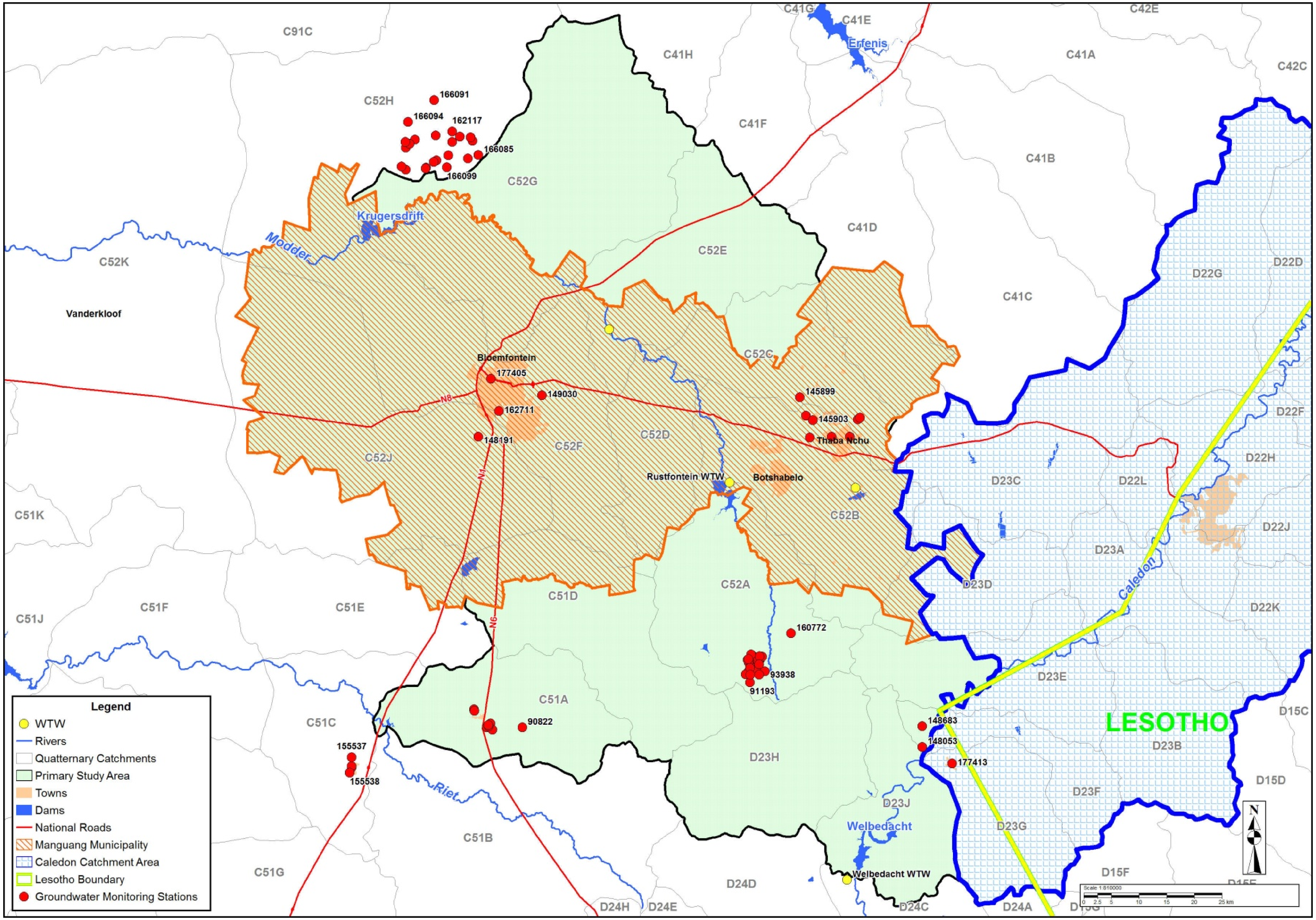


Figure 3.2: Groundwater Monitoring Stations

3.3 PREPARATION OF THE DATA

To determine the status of the water quality, the data was assessed in an unbiased manner for all the purposes for which the water is being used, following a basic systematic approach of:

1. Filtering of data to remove bias, a process of selecting a single measurement of the water quality for each month over the period of review; and
2. Checking of the completeness of data (sufficient data to present a statistically sound view of the water quality status of the water body).

3.4 CALCULATIONS

3.4.1 Statistics

The statistical parameters (50^{th} 75^{th} and 95^{th} percentiles) for the data sets were calculated by making use of the relevant functions in Excel. The results are shown in **Chapter 5**.

4. FITNESS FOR USE CLASSIFICATION

4.1 INTRODUCTION

Water quality measurements seldom follow a normal distribution, making it necessary to use non-parametric statistics to describe the central tendency of the measurements.

Non-parametric statistics were thus used to evaluate both the groundwater and surface water electrical conductivities. The 75th percentile value refers to a value that was not exceeded for 75 percent of the data points. The interquartile range (the values between the 25th percentile and the 75th percentile) indicate the central tendency, as the values fall between these two values for 50 percent of the time. The 95th percentile is an indication of the variability.

The water quality guidelines as developed by the DWA, South Africa (DWAF, 1996 - South African Water Quality Guidelines Volumes 1 to 7 (second edition)) were used as the main set of criterion for the evaluation process.

Water quality guidelines have been set for each of the major categories of water use, making it possible to have more than one guideline for each of the water quality variables (depending on how many water uses are affected or for how many variables a water use has had water quality guidelines set for it).

The guidelines provide a "description" of the impact that the water quality will have on the "usability" of that water. This "description" is a set of cut-off values, for each of the different fitness-for-use categories.

The process to determine the water quality status followed the following steps:
1. Selection of the variables of concern;
2. Determining a set of water user specific guidelines unique to the catchment and study;
3. The evaluation of the data against this set of guidelines; and
4. The interpretation of the evaluated data against a set of criteria to determine overall status of the water quality.

4.2 VARIABLES OF CONCERN

The objective of the study is to conduct a qualitative analysis of the effects of the future potential schemes on river salinity. Although the main focus was on salinity, an assessment of other variables including nutrients was also conducted.

Electrical Conductivity (EC)

The total amount of dissolved solids in water (total dissolved solids or TDS) can be estimated by measuring the electrical conductivity (EC) of the water. TDS is a measure of the quantity of various inorganic salts dissolved in water, normally at a ratio of TDS: EC of 6.5:1. Since EC is much easier to measure than TDS, it is routinely used as an estimate of the TDS concentration (DWAF: Domestic, 1996). Electrical conductivity is a measurement of the ease with which water conducts electricity and is used as an indicator of the salinity of the water. Health effects from EC occur only at levels above 370 mS/m and these include:

- Adverse effects on infants i.e. disturbance of salt and water balance;
- Adverse effects on certain heart patients and individuals with high blood pressure;
- Adverse effects on individuals with renal disease; and
- Laxative effects where there are elevated sulphate concentrations present (WRC, 1999).)

Conductivities above 150 m^{S}/m impart a salty taste to water and water with conductivity above 300 m^{S}/m does not quench thirst.

4.3 OTHER VARIABLES OF CONCERN

The other variables of concern that were assessed included:

4.3.1 Nutrients

Inorganic nutrients are elements essential to life and provide the chemical constituents on which the entire food web is based. The major nutrients (macronutrients), required for metabolism and growth of organisms include carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, sulphur, magnesium, and calcium (DWA, 2009). Catchment nutrient loads are the principal drivers of ecological processes in receiving waters. In aquatic systems, nitrogen (N) and phosphorus (P) are the two nutrients that most commonly limit maximum biomass of algae and aquatic plants (primary producers), which occurs when concentrations in the surrounding environment are below requirements for optimal growth of algae, plants and bacteria (UNEP-GEMS, 2006).

Nitrite/Nitrate (NO_2/NO_3)

Nitrogen refers to all inorganic nitrogen forms present in water, that is, ammonia, ammonium, nitrite and nitrate. Ammonia (NH_3) and Ammonium (NH_4^+) are the reduced forms of inorganic nitrogen and their relative portions in water are governed by water temperature and pH. Nitrite (NO_2) is the inorganic intermediate and nitrate (NO_3) the end product of the oxidation of organic nitrogen and ammonia. Nitrate is the more stable of the two forms, and usually, by far, the more abundant in the soil and water environment. In view of their co-occurrence and rapid interconversion, nitrite and nitrate are usually measured and considered together (DWAF: Irrigation, 1996). Nitrate/Nitrite (NO_3/NO_2): has a health effect on humans, and is also an indication of contamination from human activities in the catchment, notably the discharge of treated waste water. Nitrite has a toxic effect on aquatic organisms, particularly those organisms that breathe under water.

Ammonium (NH_4^+)

Ammonium (NH_4^+) occurs naturally in water bodies arising from the breakdown of nitrogenous organic and inorganic matter in soil and water, excretion by biota, reduction of the nitrogen gas in water by micro-organisms and from gas exchange with the atmosphere. Unpolluted waters contain small amounts of ammonium, usually <0.1 mg/ℓ as nitrogen. The NH_4^+ concentrations in major unpolluted rivers usually vary between 0.007 and 0.040mg/ℓ (DWAF, 2009).

Phosphate (PO_4)

Phosphorus can occur in numerous organic and inorganic forms, and may be present in waters as dissolved and particulate species. Elemental phosphorus does not occur in the natural environment. In unimpacted waters Phosphorus is readily utilized by plants and converted into cell structures by photosynthetic action. Phosphorus is considered to be the principle nutrient controlling the degree of eutrophication in aquatic ecosystems. Natural sources of phosphorus include the weathering of rocks and the subsequent leaching of phosphate salts into surface waters, in addition to the decomposition of organic matter. In South Africa, phosphorus is seldom present in high concentrations in unimpacted surface waters because it is actively taken up by plants. Elevated levels of phosphorus may result from point-source discharges, such as domestic and industrial effluents, and from diffuse sources (non-point sources) in which the phosphorus load is generated by surface and subsurface drainage. Non-point sources include atmospheric precipitation, urban runoff, and drainage from agricultural land, in particular from land on which fertilizers have been applied.

Phosphorus concentrations are usually determined as orthophosphates, total inorganic phosphate or total dissolved phosphorus (which includes organically bound phosphorus and all phosphates). The dissolved forms are measured after filtering the sample through a prewashed 0.45 µm filter. Concentrations of particulate phosphorus can be calculated from the difference between the concentrations of the total and dissolved fractions (DWAF: Ecosystems, 1996). Phosphate (PO_4): has no direct effect on the use of water, but is an indicator of contamination from activities in the catchment such as waste water discharge and fertilisers from agricultural activities.

4.3.2 Other Variables

pH

The pH of natural waters is a measure of the acid-base equilibrium of various dissolved compounds, and is a result of the carbon dioxide-bicarbonate-carbonate equilibrium which involves various constituent equilibriums, all of which are affected by temperature. Conditions which favour production of hydrogen ions result in a lowering of pH, referred to as an acidification process. Alternatively, conditions which favour neutralisation of hydrogen ions result in an increase in pH, referred to as an alkalinisation process. The pH of water does not have direct consequences on the use except at extremes. The adverse effects of pH result from the solubilisation of toxic heavy metals and the protonation or deprotonation of other ions (DWAF: Ecosystems, 1996). pH: is used as an indicator of characteristics such as the acidity or alkalinity of the water, which in turn is an indication of possible aggressive or corrosive properties. Health impacts are normally limited to irritation of mucous membranes or the eyes when swimming. The aquatic ecosystem is only affected by significant deviations from the natural background value.

Chloride (Cl)

Chloride (Cl): is an indicator of the nature of the salinity. It is an indicator of salty taste, and also corrosivity with respect to household appliances and irrigation equipment. In some water bodies sulphate has the same effect as chloride and the two should be assessed in conjunction with each other (DWAF, 2009).

Effects on the aquatic ecosystem as a result of salinity will be detected long before chloride in itself becomes problematic, and chloride can therefore be ignored when assessing water quality in this respect. Some crops, specifically deciduous trees such as citrus, are sensitive to chloride as it builds up in the leaves and causes leave sclerosis. This is probably the most sensitive use with respect to chloride (DWAF, 2006).

Sulphates

Sulphate concentrations in unpolluted water are typically less than 10mg/ℓ. Sulphates are particularly common in mining areas. The health effects include diarrhoea, particularly in users not accustomed to drinking water with high concentrations of sulphates. At elevated concentrations sulphates impart a distinctive taste to water (a slight bitter stringent flavour) and a rotten egg smell which may occur due to hydrogen sulphide which may occur with sulphate (DWAF, 2006).

4.4 FITNESS-FOR-USE CATEGORIES

Water quality does not suddenly change from “good” to “bad”. Instead there is a gradual change between categories and this is reflected by the fitness-for-use range which is graded to indicate the increasing risk of using the water.

Water quality criteria are discrete values that describe a specific effect as a result of a particular set of conditions. These criteria are then used to develop guidelines, which describe the effect on a user who is exposed to an ever increasing concentration or changing value.

Water quality criteria are used to describe the fitness-for-use. The fitness-for-use range can be divided into four sections which are classified as four categories, ranging from “ideal” to “unacceptable”. These categories are described as:

Ideal	:	the user of the water is not affected in any way;
Acceptable	:	slight to moderate problems are encountered;

Tolerable	:	moderate to severe problems are encountered; and
Unacceptable	:	the water cannot be used under normal circumstances.

The fitness-for-use range is colour coded for ease of interpretation of information during the assessment of the water quality. Refer to **Table 4.1.**

Table 4.1: Colour Codes Assigned to Fitness for use Ranges

Fitness For Use Range	Colour Code
Ideal	Blue
Acceptable	Green
Tolerable	Yellow
Unacceptable	Red

4.5 IDENTIFICATION OF FITNESS-FOR-USE

Water quality guidelines describe the fitness-for-use of the water. The biological, chemical or physical data is analysed and the results are compared against the guidelines to assess the water quality of a resource.

It is therefore necessary that water quality guidelines be identified for each water use and for each variable of concern. The basis of these guidelines can be found in the South African Water Quality Guidelines, Volumes 1 to 7 (DWAF: Domestic, 1996), (DWAF: Ecosystems, 1996), (DWAF: Irrigation, 1996) and (DWAF: Livestock, 1996).

The DWA water quality guidelines make provision for five water use categories, namely domestic, recreation, industrial, agricultural (irrigation, livestock watering, and aquaculture) and the aquatic ecosystem.

For the purposes of this study only three out of the five water use categories have been taken into account, namely domestic use, agricultural use (irrigation and livestock watering) and the aquatic ecology.

The guidelines provide a description of the effect that changes in water quality will have on the use and not an interpretation of whether this is acceptable or not. From these guidelines the cut-off values for the different fitness-for-use categories have been set.

The water quality guidelines identified for the abovementioned water uses for the variables of concern are summarised in **Table 4.2** and **Table 4.3**.

4.6 COMBINED FITNESS-FOR-USE CLASSIFICATION

The cut-off values for the fitness for use categories are per user and per variable and can be used to assess the fitness for use of the water in the Greater Bloemfontein area for individual uses or user categories such as domestic, agriculture, industry, recreation and the aquatic ecosystem.

In order to determine the fitness for use of the water resource in the study area, the different fitness for use categories for different users affected by the same variable were reconciled.

This was done by selecting the most stringent value, in other words the value for the most sensitive use to water quality deterioration, for each cut-off value in order to arrive at the management levels or combined fitness-for-use.

The summary of the combined fitness-for-use values are given in **Table 4.2.**

Table 4.2: User Specific Guidelines: Domestic

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
DOMESTIC					
Electrical Cond.	mS/m	< 70.00	70.00 to 150.0	150.0 to 370.0	> 370.0
pH (lower range) **(upper range)**	pH units	> 5.00 < 9.50	5.00 to 4.50 9.50 to 10.00	4.50 to 4.00 10.00 to 10.50	< 4.00 > 10.50
Nitrate / Nitrite	mg/l N	< 6.00	6.00 to 10.00	10.00 to 20.00	> 20.00
Ammonia	mg/l	< 1.00	1.00 to 2.00	2.00 to 10.00	> 10.00
Chloride	mg/l	< 100.0	100.0 to 200.0	200.0 to 600.0	> 600.0
Phosphate	mg/l P				
Sulphate	mg/l	< 200.0	200.0 to 400.0	400.0 to 600.0	> 600.0

Table 4.3: User Specific Guidelines: Agriculture & Ecology

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
AGRICULTURE: Irrigation					
Electrical Cond.	mS/m	< 40.00	40.00 to 270.0	270.0 to 540.0	> 540.0
pH (lower range) **(upper range)**	pH units	> 6.50 < 8.40			< 6.50 > 8.40
Nitrate / Nitrite	mg/l N				
Ammonia	mg/l				
Chloride	mg/l	< 100.0	100.0 to 175.0	175.0 to 700.0	> 700.0
Phosphate	mg/l P				
Sulphate	mg/l				
AGRICULTURE: Livestock Watering					
Electrical Cond.	mS/m	< 154.0	153.0 to 308.0	308.0 to 462.0	> 462.0
pH	pH units				
Nitrate / Nitrite	mg/l N	< 100.0	100.0 to 250.0	250.0 to 400.0	> 400.0
Ammonia	mg/l				
Chloride	mg/l	< 1000.	1000. to 1750.	1750. to 2000.	> 2000.
Phosphate	mg/l P				
Sulphate	mg/l	< 1000.	1000. to 1250.	1250. to 1500.	> 1500.
ECOLOGICAL					
Electrical Cond.	mS/m				
pH	pH units				
Nitrate / Nitrite	mg/l N				
Ammonia	mg/l	< 0.27	0.27 to 0.58	0.58 to 3.85	> 3.85
Chloride	mg/l				
Phosphate	mg/l P	< 0.01	0.01 to 0.03	0.03 to 0.25	> 0.25

Table 4.4: Combined Fitness-for-Use Categories

Variable	Units	Colour Ranges									
		Ideal		**Acceptable**			**Tolerable**			**Unacceptable**	
Electrical conductivity	m^S/m	<	40.00	40.00	to	150.00	150.00	to	310.00	>	310.00
pH (lower range)	pH units at 25°C	<	5.00	5.00	to	4.50	4.50	to	4.00	<	4.00
(upper range)		>	8.50	8.50	to	9.50	9.50	to	10.00	>	10.00
Ammonia	mg/l	<	0.20	0.20	to	1.00	1.00	to	2.00	>	2.00
Chloride	mg/l	<	100.00	100.00	to	175.00	175.00	to	600.00	>	600.00
Sulphate	mg/l	<	200.00	200.00	to	250.00	250.00	to	400.00	>	400.00
Nitrate / Nitrite	mg/l N	<	6.00	6.00	to	10.00	10.00	to	20.00	>	20.00
Phosphorous	mg/l $CaCO_3$	<	0.01	0.01	to	0.03	0.03	to	0.25	>	0.25
Ammonium	mg/l	<	0.057	0.057	to	0.121	0.121		0.65	>	0.65

The explanations of how the cut-off values were decided for each of the water quality variables are as follows:

Electrical Conductivity (EC):
The agricultural guideline for irrigation is the most stringent. The ideal range in this guideline falls between 0 and 40 m^S/m. For the "unacceptable" limit, the guideline values, as provided for domestic use, were used as it is more stringent than the agricultural value.

pH:
The fitness for use for the pH category simply represents a combination of all the user-specific guidelines to form the most stringent.

Nitrate and Nitrite:
Nitrate/Nitrite concentrations are important in domestic and for irrigation use. However, it is more stringent for domestic use.

Ammonium:
The guidelines all indicate the target, chronic and acute concentration values in terms of un-ionised ammonia, NH_3. This meant that a conversion within the guidelines developed was needed. Conversion guidelines that were developed for the Modder/Riet Water Quality Assessment were used. The guideline is shown in **Appendix A**.

Chloride:
The most stringent guideline is for agricultural irrigation, although there are also guidelines for domestic use. This guideline will be carried over to the fitness-for-use categories because it is necessary to protect the crops farmed from toxic levels of chloride.

Phosphorous:
The only available guideline for phosphorus is for the ecological user group.

Sulphate:
The most stringent guideline is for domestic use, although there are also guidelines for livestock watering.

4.7 WATER QUALITY ASSESSMENT CATEGORY

The concluding water quality category was decided by making use of the status of each variable based on the median, 75^{th} percentile and 95^{th} percentile. Table 4.5 provides a summary of how the water quality assessment categories were assigned to each variable.

Table 4.5: Water Quality Assessment Category

Fitness for use Range in which the Variable Falls			Water Quality Assessment Category	Colour Code
Median	**75^{th} Percentile**	**95^{th} Percentile**		
Ideal	Ideal	Ideal	Ideal	Blue
Ideal	Ideal	Acceptable	Acceptable	Green
Ideal	Acceptable	Acceptable		
Acceptable	Acceptable	Acceptable		
Ideal	Ideal	Tolerable		
Ideal	Acceptable	Tolerable	Tolerable	Yellow
Acceptable	Acceptable	Tolerable		
Acceptable	Tolerable	Tolerable		
Tolerable	Tolerable	Tolerable		
Any other combination			Unacceptable	Red

For instance, if the median is in the ideal range, the 75^{th} percentile is in the acceptable range and the 95^{th} percentile is in the tolerable range, then the water quality assessment category is "tolerable"

This methodology thus tests a set of data in a consistent and unbiased manner, taking into consideration the groundwater quality, of each of the variables of concern, for the full range of fitness-for-use (median, the 75^{th} and the 95^{th} percentiles) of groundwater for a specific resource.

5. RESULTS OF WATER QUALITY STATISTICAL ANALYSIS

5.1 SURFACE WATER

5.1.1 Electrical Conductivity

Table 5.1 is the water quality assessment of the fitness of use of the electrical conductivity in the study area based on the median, 75th and 95th percentiles. The assessment indicates that the electrical conductivity values are within the ideal, acceptable and tolerable ranges.

Table 5.1: Surface Water Electrical Conductivity Assessment

Water Source	Description	Station	Median	75th Percentile	95th Percentile
Welbedacht	Welbedacht Dam	D2R004	23.65	32.73	40.91
Gariep	Gariep Dam	D3R002	18.00	19.10	21.51
Riet	Upper Riet (Tierpoort Dam)	C5R001	29.80	40.60	53.45
	Middle Riet (Kalkfontein Dam)	C5R002	44.20	51.20	100.80
	Lower Riet (Aucampshoop)	C5H016	101.90	137.00	193.00
Modder	Upper Modder (Rustfontein Dam)	C5R003	28.00	31.45	36.06
	Middle Modder (Krugersdrift Dam)	C5R004	36.80	47.50	56.87
	Lower Modder (Tweerivier)	C5H018	77.90	91.63	111.72

(See **Table 4.5** for reference to colours)

Table 5.2 is the concluding electrical conductivity assessment for the surface water sources in the study area, as calculated using the median, 75th and 95th percentile data sets in the water quality assessment as set out in **Table 5.1**. The table shows that for the Welbedacht Dam, Upper and Middle Riet River as well as the Lower and Middle Modder River, the electrical conductivity is within the acceptable range. EC in the Upper reaches of the Modder River and in the Gariep Dam is within ideal ranges. The Lower Riet River has slightly higher EC levels which are in the tolerable ranges (Please refer to **Chapter 6** for the discussion).

Table 5.2: Concluding Surface Water Electrical Conductivity Assessment

Water Source	Description	Station	Median	75th Percentile	95th Percentile	Concluding
Welbedacht	Welbedacht Dam	D2R004	B	B	G	G
Gariep	Gariep Dam	D3R002	B	B	B	B
Riet	Upper Riet (Tierpoort Dam)	C5R001	B	B	G	G
	Middle Riet (Kalkfontein Dam)	C5R002	G	G	G	G
	Lower Riet (Aucampshoop)	C5H016	G	G	Y	Y
Modder	Upper Modder (Rustfontein Dam)	C5R003	B	B	B	B

Water Source	Description	Station	Median	75th Percentile	95th Percentile	Concluding
	Middle Modder (Krugersdrift Dam)	C5R004	B	G	G	G
	Lower Modder (Tweerivier)	C5H018	G	G	G	G

(See **Table 4.5** for reference to colours)

5.1.2 Other Variables

Table 5.3 is the water quality assessment of the fitness-for-use of the water resources using the median values. The assessment indicates that most of the resources show a water quality that is “ideal” for use in the study area except for the phosphates which are within acceptable and tolerable ranges.

Table 5.3: Water Quality Assessment: Median

Water Source	Description	Station	pH	NO_3/NO_2	NH_4	PO_4	SO_4	Cl
Welbedacht	Welbedacht Dam	D2R004	7.97	0.13	0.05	0.04	14.53	6.92
Gariep	Gariep Dam	D3R002	7.90	0.38	0.04	0.03	8.73	4.06
Riet	Upper Riet (Tierpoort Dam)	C5R001	8.19	0.02	0.02	0.09	19.35	11.20
	Middle Riet (Kalkfontein Dam)	C5R002	8.35	0.06	0.05	0.02	29.47	27.94
	Lower Riet (Aucampshoop)	C5H016	8.22	0.16	0.04	0.02	125.90	177.15
Modder	Upper Modder (Rustfontein Dam)	C5R003	8.30	0.16	0.04	0.03	12.06	6.50
	Middle Modder (Krugersdrift Dam)	C5R004	8.45	0.02	0.04	0.03	19.00	25.80
	Lower Modder (Tweerivier)	C5H018	8.21	0.09	0.03	0.02	83.75	118.27

(See **Table 4.5** for reference to colours)

Table 5.4 is the water quality assessment of the fitness-for-use of the water resources in the study area based on the 75th percentile values. The assessment indicates that most of the values of the different variables show a water quality that is “ideal” or “acceptable”. However, the phosphates and ammonium levels are in the acceptable and tolerable ranges.

Table 5.4: Water Quality Assessment: 75th Percentile

Water Source	Description	Station	pH	NO_3/NO_2	NH_4	PO_4	SO_4	Cl
Welbedacht	Welbedacht Dam	D2R004	8.16	0.40	0.07	0.06	18.93	10.70
Gariep	Gariep Dam	D3R002	8.13	0.52	0.07	0.04	10.80	5.06
Riet	Upper Riet (Tierpoort Dam)	C5R001	8.37	0.23	0.08	0.14	23.32	15.10
	Middle Riet (Kalkfontein Dam)	C5R002	8.50	0.13	0.08	0.03	34.65	37.48
	Lower Riet (Aucampshoop)	C5H016	8.32	0.29	0.06	0.02	170.10	243.50
Modder	Upper Modder (Rustfontein Dam)	C5R003	8.37	0.30	0.07	0.05	13.86	7.98
	Middle Modder (Krugersdrift Dam)	C5R004	8.58	0.08	0.07	0.07	23.95	39.60
	Lower Modder (Tweerivier)	C5H018	8.32	0.27	0.05	0.02	103.90	142.07

(See **Table 4.5** for reference to colours)

Table 5.5 is the water quality assessment of the fitness-for-use for the study area based on the 95th percentile values. A number of the values of the different variables show a water quality that ranges between "ideal" and "tolerable" for use.

The phosphates and ammonium levels are generally within the tolerable ranges except for the upper reaches of the Riet River which can be highlighted as showing periods of time that the phosphate levels are within unacceptable ranges.

Table 5.5: Water Quality Assessment: 95th Percentile

Water Source	Description	Station	pH	NO_3/NO_2	NH_4	PO_4	SO_4	Cl
Welbedacht	Welbedacht Dam	D2R004	8.37	0.62	0.13	0.12	28.96	17.98
Gariep	Gariep Dam	D3R002	8.32	1.17	0.13	0.07	15.17	7.05
Riet	Upper Riet (Tierpoort Dam)	C5R001	8.59	0.51	0.21	0.34	29.80	26.12
	Middle Riet (Kalkfontein Dam)	C5R002	8.64	0.34	0.16	0.11	91.05	121.80
	Lower Riet (Aucampshoop)	C5H016	8.51	0.52	0.11	0.04	249.85	361.15
Modder	Upper Modder (Rustfontein Dam)	C5R003	8.51	0.43	0.13	0.10	16.65	9.70
	Middle Modder (Krugersdrift Dam)	C5R004	8.84	0.46	0.16	0.19	31.46	53.37
	Lower Modder (Tweerivier)	C5H018	8.42	0.48	0.15	0.05	142.02	189.82

(See **Table 4.5** for reference to colours)

Table 5.6 to **Table 5.11** is the concluding water assessment for nutrients in the study area. Nitrate/Nitrite levels in the study are in the ideal range. Ammonium is within acceptable and tolerable ranges. The major cause for concern is the phosphate levels in the upper reaches of the Riet River which range from tolerable to unacceptable.

Table 5.6: Concluding NO_3/NO_2 Water Quality Assessment

Water Source	Description	Station	Median	75th Percentile	95th Percentile	Concluding
Welbedacht	Welbedacht Dam	D2R004	B	B	B	B
Gariep	Gariep Dam	D3R002	B	B	B	B
Riet	Upper Riet (Tierpoort Dam)	C5R001	B	B	B	B
	Middle Riet (Kalkfontein Dam)	C5R002	B	B	B	B
	Lower Riet (Aucampshoop)	C5H016	B	B	B	B
Modder	Upper Modder (Rustfontein Dam)	C5R003	B	B	B	B
	Middle Modder (Krugersdrift Dam)	C5R004	B	B	B	B
	Lower Modder (Tweerivier)	C5H018	B	B	B	B

(See **Table 4.5** for reference to colours)

The results in **Table 5.7** show that the ammonium levels in the water sources in the study area range from acceptable to tolerable. The slightly high ammonium concentrations may be as a result of the surface runoff from agricultural areas. High ammonia concentrations also emanate from overflowing and/or dysfunctional waste water treatment works in the catchment.

Table 5.7: Concluding NH_4^+ Water Quality Assessment

Water Source	Description	Station	Median	75th Percentile	95th Percentile	Concluding
Welbedacht	Welbedacht Dam	D2R004	B	G	Y	Y
Gariep	Gariep Dam	D3R002	B	G	Y	Y
Riet	Upper Riet (Tierpoort Dam)	C5R001	B	G	Y	Y
	Middle Riet (Kalkfontein Dam)	C5R002	B	G	Y	Y
	Lower Riet (Aucampshoop)	C5H016	B	G	G	G
Modder	Upper Modder (Rustfontein Dam)	C5R003	B	G	Y	Y
	Middle Modder (Krugersdrift Dam)	C5R004	B	G	Y	Y
	Lower Modder (Tweerivier)	C5H018	B	B	Y	G

(See **Table 4.5** for reference to colours)

Table 5.8: Concluding PO_4 Water Quality Assessment

Water Source	Description	Station	Median	75th Percentile	95th Percentile	Concluding
Welbedacht	Welbedacht Dam	D2R004	Y	Y	Y	Y
Gariep	Gariep Dam	D3R002	G	Y	Y	Y
Riet	Upper Riet (Tierpoort Dam)	C5R001	Y	Y	R	R
	Middle Riet (Kalkfontein Dam)	C5R002	G	G	Y	Y
	Lower Riet (Aucampshoop)	C5H016	G	G	Y	Y
Modder	Upper Modder (Rustfontein Dam)	C5R003	G	Y	Y	Y
	Middle Modder (Krugersdrift Dam)	C5R004	G	Y	Y	Y
	Lower Modder (Tweerivier)	C5H018	G	G	Y	Y

(See **Table 4.5** for reference to colours)

Table 5.9 is the concluding water quality assessment, as calculated by using the median, 75th and 95th percentiles as set out in **Table 5.1** presenting the "overall" fitness-for-use of the pH of the water quality resources within the study area. **Table 5.10** and **Table 5.11** presents the same for Cl and SO_4 respectively. The results show that the water in the study area is generally of good quality.

Table 5.9: Concluding pH Water Quality Assessment

Water Source	Description	Station	Median	75th Percentile	95th Percentile	Concluding
Welbedacht	Welbedacht Dam	D2R004	B	B	B	B
Gariep	Gariep Dam	D3R002	B	B	B	B
Riet	Upper Riet (Tierpoort Dam)	C5R001	B	B	G	G
	Middle Riet (Kalkfontein Dam)	C5R002	B	B	G	G
	Lower Riet (Aucampshoop)	C5H016	B	B	G	G
Modder	Upper Modder (Rustfontein Dam)	C5R003	B	B	G	G
	Middle Modder (Krugersdrift Dam)	C5R004	B	G	G	G
	Lower Modder (Tweerivier)	C5H018	B	B	B	B

(See **Table 4.5** for reference to colours)

The Lower Riet River and the Lower Modder River have slightly higher Cl levels than the other water sources; with levels ranging from acceptable to tolerable (Please refer to **Chapter 6** for the discussion).

Table 5.10: Concluding Cl Water Quality Assessment

Water Source	Description	Station	Median	75^{th} Percentile	95^{th} Percentile	Concluding
Welbedacht	Welbedacht Dam	D2R004	B	B	B	B
Gariep	Gariep Dam	D3R002	B	B	B	B
Riet	Upper Riet (Tierpoort Dam)	C5R001	B	B	B	B
	Middle Riet (Kalkfontein Dam)	C5R002	B	B	G	G
	Lower Riet (Aucampshoop)	C5H016	Y	Y	Y	Y
Modder	Upper Modder (Rustfontein Dam)	C5R003	B	B	B	B
	Middle Modder (Krugersdrift Dam)	C5R004	B	B	B	B
	Lower Modder (Tweerivier)	C5H018	G	G	Y	Y

(See **Table 4.5** for reference to colours)

Table 5.11: Concluding SO_4 Water Quality Assessment

Water Source	Description	Station	Median	75^{th} Percentile	95^{th} Percentile	Concluding
Welbedacht	Welbedacht Dam	D2R004	B	B	B	B
Gariep	Gariep Dam	D3R002	B	B	B	B
Riet	Upper Riet (Tierpoort Dam)	C5R001	B	B	B	B
	Middle Riet (Kalkfontein Dam)	C5R002	B	B	B	B
	Lower Riet (Aucampshoop)	C5H016	B	B	G	G
Modder	Upper Modder (Rustfontein Dam)	C5R003	B	B	B	B
	Middle Modder (Krugersdrift Dam)	C5R004	B	B	B	B
	Lower Modder (Tweerivier)	C5H018	B	B	B	B

(See **Table 4.5** for reference to colours)

5.2 GROUNDWATER

The outcomes of the statistical analysis of the electrical conductivity data sets for groundwater are based on the data for the period 1971 to 2008.

Table 5.12 shows the groundwater assessment of the electrical conductivity for the stations in Bloemfontein, Edenburg, Dewetsdorp, Ikgomotseng, Reddersburg, Thaba Nchu and Wepener based on the median, 75^{th} and 95^{th} percentiles. The assessment indicates that most of the electrical conductivity values are within the "acceptable" range. The values for Ikgomotseng are within the tolerable and unacceptable ranges.

Table 5.12: Groundwater Electrical Conductivity Assessment for Bloemfontein, Edenburg, Dewetsdorp, Ikgomotseng, Reddersburg, Thaba Nchu and Wepener

Area	Median	75th Percentile	95th Percentile
Bloemfontein	79.00	85.70	146.04
Edenburg	103.75	129.65	130.28
Dewetsdorp	50.30	67.00	94.80
Ikgomotseng	220.00	420.50	439.50
Reddersburg	59.85	61.83	82.96
Thaba Nchu	68.90	73.00	92.26
Wepener	91.40	105.03	125.68

(See **Table 4.5** for reference to colours)

Table 5.13 is the concluding electrical conductivity assessment for the electrical conductivity in Bloemfontein, Edenburg, Dewetsdorp, Ikgomotseng, Reddersburg, Thaba Nchu and Wepener. The assessment shows that the electrical conductivity in all the areas are within acceptable ranges except for Ikgomotseng which is within unacceptable ranges (Please refer to **Chapter 6** for the discussion).

Table 5.13: Concluding Groundwater Electrical Conductivity Assessment for Bloemfontein, Edenburg, Dewetsdorp, Ikgomotseng, Reddersburg, Thaba Nchu and Wepener

Area	Median	75th Percentile	95th Percentile	Concluding water quality
Bloemfontein	G	G	G	G
Edenburg	G	G	G	G
Dewetsdorp	G	G	G	G
Ikgomotseng	Y	R	R	R
Reddersburg	G	G	G	G
Thaba Nchu	G	G	G	G
Wepener	G	G	G	G

(See **Table 4.5** for reference to colours)

6. DISCUSSION OF RESULTS

Water quality is determined by the activities in the catchment, the landuse and the geology. Water quality guidelines (Domestic, Agriculture and Aquatic Ecosystem) published by the DWA were used to develop combined guidelines for the water quality assessment.

The primary study area is located within the Karoo Super Group. Dewetsdorp, Reddersburg and Thaba Nchu are located in the Beaufort Group of the Karoo Super Group. Ikgomotseng and Edenburg are located in the Beaufort Group and more specifically in the Adelaide Formation of the Karoo Super Group. The sedimentary geology of Wepener consists of feldspatic sandstone and grit as well as green shales of the Molteno stage of the Stormberg Group. The Bloemfontein geology consists of sandstone, shale and mudstone of the lower stage of the Beaufort Group. The sedimentary geology, specifically shale and mudstone, are often associated with saline groundwater.

The main land use in the Caledon catchment is crop production (maize and wheat), the Orange River catchment is mainly used for stock grazing (River Health Programme, 2003: 32). Much of the area in the Riet and Modder River catchments is used for cattle and game farming in the west and sheep farming towards the east (up to 75% of the land- use is natural grassland and bossieveld). About 60% of the 22 000 square kilometres of the Caledon catchment is grassland and bossieveld. Dryland crop production, mainly wheat and maize, comprises almost 33% of the Caledon River catchment. Stock grazing is the main land-use for the Orange and Kraai River catchments.

Generally the surface water quality in the study area is of good quality. The EC is within the ideal to acceptable ranges. The assessment shows that the EC for the Caledon River (Welbedacht Dam), the Orange River (Gariep Dam) and the Modder River (Upper, Middle and Lower) are within the ideal and acceptable ranges. The Lower Riet River has higher EC which is in the tolerable range. This may be due to irrigation return flows which have a major impact on salinity in the lower Riet River (DWA, 2003).

An assessment of groundwater EC levels was also conducted for some of the towns in the study area (Bloemfontein, Thaba Nchu, Dewetsdorp, Edenburg, Ikgomotseng and Reddersburg). The results show that the EC in all the towns are within acceptable ranges except for Ikgomotseng where the EC is within unacceptable ranges. Industrial, chemical and mining activities as well as irrigation are often the factors responsible for elevated salts (DEAT, 2002). Furthermore, various sub-factors, such as geology, soil, land use and flow of water (i.e. conductivity increases as water flow decreases) also affect the salinity of water, thus influencing electrical conductivity. The high levels of EC in groundwater at Ikgomotseng, which is also known as Soutpan may be due to high levels of Na^+ and Cl^- ions from salts from Salt Mining which may be leaching into the groundwater. There are a number of salt lakes that are found in and around Ikgomotseng (Masilonyana IDP, 2008/9). **Figure 6.1** shows the DWA monitoring stations for Ikgomotseng.

Figure 6.1: DWA Monitoring Points for Ikgomotseng

An assessment of the nutrients showed that the water quality in the study area is of good quality. The levels of nitrite/nitrates in the study area are within ideal ranges. Ammonium and phosphate levels in the four rivers are mostly within tolerable ranges. The only cause for concern is the high levels of phosphates in the Upper Riet River as high nutrient levels lead to eutrophication. High phosphorous loads in water may result from domestic and industrial effluents or surface and subsurface drainage, nutrients in the irrigation return flows, wash-off and return flows from settlements. Drainage from agricultural land on which fertilizers have been applied is believed to represent the biggest contributor of phosphorous loading in this catchment. Although the detailed analysis of WWTWs falls outside the scope of this study, it is common knowledge that municipalities with their limited budgets and other resources are not managing WWTWs as they should be and therefore have a serious water quality impact on the receiving surface water resources. An assessment of the status of the WWTWs in the catchment showed phosphate levels for all the WWTWs were below the standard (10 mg/ℓ). Although the nutrient levels are below the standard, loads from treated wastewater in the catchment will in future have a negative impact in the Krugersdrift Dam, unless the discharge standard for orthophosphate is changed from the current 10mg/ℓ (general standard) to 1mg/ℓ (special standard).

The levels of nitrite/nitrates in the study area are within ideal ranges. Ammonium and phosphate levels in the four rivers are mostly within tolerable ranges except for the Lower reaches of the Modder and the Riet Rivers, which have ammonium and phosphate levels that are within acceptable ranges. The slightly high ammonium concentrations may be as a result of the surface runoff from agricultural areas. High ammonium concentrations also emanate from overflowing and/or dysfunctional waste water treatment works in the catchment.

Analysis of other variable (pH sulphates and chlorides) was also conducted. The results showed that generally the pH and sulphate levels are in the ideal and acceptable ranges. The chloride levels range between ideal and tolerable, with the Lower Riet River having slightly higher levels of chlorides, ranging from ideal to tolerable.

7. QUALITATIVE ASSESSMENTS

7.1 STATUS QUO

Flow regulation and increased salinity are recognised as the two main factors that have impacted (and continue to impact) negatively on the environmental health of the lower Orange River.

A number of potential interventions which could contribute to meeting the future water requirements of the Greater Bloemfontein area were identified from previous and ongoing studies, as well as from expert knowledge through the Preliminary Screening Workshop. The following categories of interventions were identified:

- Urban and agricultural Water Conservation and Water Demand Management (WC/WDM);
- Surface water interventions;
- Re-use of treated effluent;
- Groundwater interventions;
- Trading of water use authorisations; and
- Other options, such as re-use of mine water and alternate storage in the Caledon River.

7.2 SELECTION OF INTERVENTIONS

A Preliminary Screening Workshop was held in Bloemfontein on 29 October 2009. The workshop was attended by key stakeholders, including DWA officials from the Regional and Head Office, Bloem Water, representatives from MLM, Motheo District Municipality, Eskom, Department of Agriculture, Forestry and Fishery, and representatives from the Water User Associations. The objectives of the Preliminary Screening Workshop were to:

- Assess the acceptability of the various interventions identified in previous studies in terms of technical, financial, environmental, and socio-economic criteria;
- Ascertain which intervention or combinations thereof would warrant further investigations at reconnaissance or pre-feasibility level, and what aspects should be investigated in this study;
- Augment the existing information with specialist inputs from the DWA and other key stakeholders; and
- Identify risks and any other issues/concerns of stakeholders which could impact on the reconciliation of supply and requirement.

Each of the interventions was considered in isolation during the workshop, however it was stressed that other issues, such as those listed below would ultimately also be important in formulating the best scenario for reconciling supply and requirement:

- The importance of improving the assurance of supply;
- The cost and timing of implementing a large intervention versus a number of smaller interventions;
- The need for diversification of sources allowing some redundancy in the resource system;
- The need to lower the risks associated with system failure;
- Health risks; and
- The ability to incrementally implement interventions.

This screening of interventions was based on a number of criteria, namely:

- Potential scheme yields, inclusive of the impact of the ecological Reserve;
- Updated financial cost estimates and unit reference values (URVs);
- Socio-economic implications; and
- Ecological impact..

Table 7.1 lists the interventions that were discussed and screened out at the Preliminary Screening Workshop. Overall, 34 interventions were discussed and five interventions were screened out.

Table 7.1: Interventions Considered for the Interim Strategy

Ref	Intervention	Description of Intervention	URVs (R/m^3)	Selected for Further Investigation (Yes / No)
A1 & 2	Urban WC/WDM – Efficient use of water and loss management	The objective of WC/WDM is to ensure the optimal use of water and to minimise wastage. MLM has developed various water demand management strategies to achieve efficient WC/WDM, these include: • Network Losses Strategy • System Losses Strategy • Behind-Water meter Losses Strategy • Willingness to Pay Strategy		Yes. There will be no further augmentation of bulk water resources without WC/WDM being addressed first
B1	Agricultural WC/WDM	A number of WC/WDM options for improving agricultural water use efficiency have been proposed, including: • River release management • Improved irrigation practices • Reduce irrigation canal losses and utilise flow meters to monitor and manage flow in the canals • Selection of crop type suitable for a particular area • Crop deficit irrigation		No
C1	Utilising surplus capacity in the Orange River by pumping to Knellpoort Dam from Gariep Dam	Surplus volume in the Gariep Dam can be accessed via one of the following interventions: • Utilising dead storage by altering the operating rules; or • Raising Gariep Dam by 5 or 10 meters.	5.3 (7)	Yes
C2	Utilising surplus capacity in the Orange River by pumping to Knellpoort Dam from Vanderkloof Dam	Surplus volume in the Vanderkloof Dam can be accessed by utilising the dead storage by altering the operating rules to allow the water below the existing canal (bottom) inlets to be released to downstream users with no additional infrastructure being required.	6.7 (8.4)	Yes
C3	Utilising surplus capacity in the Orange River by pumping to Knellpoort Dam from Bosberg / Boskraai Dam	Construction of the proposed Bosberg / Boskraai Dam on the Orange River downstream of the confluence with the Kraai River. Water will then be pumped from the Bosberg / Boskraai Dam to the Knellpoort Dam.	4.2 (5.9)	Yes
C4	Modifications to Welbedacht Dam: Extend scour	Increasing the available yield from Welbedacht Dam by reducing the existing dead storage as a result of siltation in the dam.		Optimisation of the operation of Welbedacht Dam will be undertaken by a separate Bloem Water Study. Will not increase the yield of the

Ref	Intervention	Description of Intervention	URVs (R/m^3)	Selected for Further Investigation	
				Yes	No
				system	
C5	Modifications to the Caledon-Modder System	The yield of the Caledon-Modder System can be increased by one, several, or a combination of the following interventions: • Increase the capacity of Novo Pump Station • Raising of Knellpoort Dam (1, 2, or 4 m) • Increase the capacity of Tienfontein Pump Station • Construct a pump station and pipeline between Welbedacht Dam and Knellpoort Dam	< 1.5	Yes	
C6	Polihali Dam – Lesotho Highlands Phase 2	The LHWP comprises of a number of phases, with Phase II culminating in the construction of the Polihali Dam. Water from the Polihali Dam would then be delivered from Katse Dam via the existing Transfer Tunnel to Muela Hydro Power Station and thence via the existing Delivery Tunnel to the Ash River. It is proposed that Phase II would be commissioned by January 2020 and Phase III would only be required by 2054. It is proposed that the Phase II water is released for Bloemfontein up to the year 2050. This supply could delay capital expenditure on improvements to the existing bulk infrastructure supplying Bloemfontein.	1.9	Yes. The URVs must be based on the correct tariff	
D1	Planned direct re-use: New North Eastern WWTW	The MLM is in the design phase to construct a new WWTW to allow further development in the north, eastern, and western parts of Bloemfontein. This intervention entails pumping effluent, which has been treated to potable standards using Ultra Filtration, Reverse Osmosis, and Ultra-violet Radition, from the New North Eastern WWTW to the Maselspoort WTW or to the distribution reservoir on Navel Hill. The focus of this intervention is to abstract water for re-use at the New North Eastern WWTW.	4.1	Yes	
D2	Planned indirect re-use: Transfer to upstream of Mockes Dam	Treated effluent from the New North Eastern WWTW would be pumped over the escarpment into the stream feeding Mockes Dam. The treatment facilities at the Maselspoort Weir (a few kilometres downstream of Mockes Dam) will be extended with new treatment technology and equipment. Required treatment process includes Reverse Osmosis in order to remove the build-up of dissolved salts in the river system.	4.8	Yes	
D3	Planned indirect re-use: Krugersdrift Dam	All WWTWs for Bloemfontein, Botshabelo, Mangaung, and Thaba Nchu (except Welvaart WWTW) discharge their treated wastewater into the Krugersdrift Dam catchment area. Currently, no wastewater from Botshabelo or Thaba Nchu reaches Krugersdrift Dam, as it is intercepted at the Maselspoort Weir. The only water reaching the dam is excess surface run-off not intercepted by Mockes Dam and Rustfontein Dam, and the surplus wastewater from the Bloemfontein/Mangaung	5.0	Yes	

Ref	Intervention	Description of Intervention	URVs (R/m^3)	Selected for Further Investigation	
				Yes	No
		WWTW's. Water can be abstracted at Krugersdrift Dam and pumped back to Bloemfontein. The raw water at the Krugersdrift Dam will have to be purified using Ultra Filtration, followed by a Reverse Osmosis and Ultra-Violet radiation for disinfection, to purify water to potable standards. This treated water will then be pumped back to the main Bloem Water reservoir.			
D4	Planned direct re-use: Bloemspruit WWTW	The focus of this intervention is to utilise the existing treated effluent from the Bloemspruit WWTW for potable use and replace this with treated effluent discharged from the proposed New North Eastern WWTW. The treated wastewater from the Bloemspruit WWTW would be purified to potable standards (this will typically include Ultra Filtration, followed by a Reverse Osmosis, and Ultra-Violet radiation for disinfection) and then pumped to a reservoir serving the Greater Bloemfontein area.	3.7	Yes	
D5	Re-use of treated effluent: Direct use for irrigation	A dual system could be implemented where treated effluent is re-used in the city for the irrigation of municipal gardens, public open spaces, school fields, and green street reserves.		Yes	
E1	Groundwater abstraction at Ikgomotseng	This small community is located approximately 45 km north-west of Bloemfontein near the Krugersdrift Dam. Ikgomotseng derives their domestic water from the Krugersdrift Dam. It is proposed that 10 boreholes be drilled. The abstracted groundwater is to be pumped to the Ikgomotseng main reservoir for conjunctive use with the surface water (Krugersdrift Dam) as well as for dilution of the potential high fluoride concentrations or for treatment if necessary.	5.08	Yes	
E2	Groundwater abstraction at Bloemfontein	The city of Bloemfontein currently does not utilise groundwater resources for their water requirements. The Bainsvlei irrigation area is situated to the northern and western side of Bloemfontein. The water used for irrigation in this area is predominantly provided by groundwater resources. The area is a known source of groundwater in relative large volumes. It is therefore proposed that the area as a whole or a section of the area be utilised for the groundwater needs of Bloemfontein should it be required in the future	15.58		No
E3	Groundwater abstraction at Thaba Nchu	The Thaba Nchu area is situated approximately 58 km east from Bloemfontein. The area are characterised by group very small to medium sized communities that are depended on surface water (Bloem Water) and groundwater for their domestic water needs. An unknown number of boreholes are utilised for water supply purposes. For the groundwater intervention it is proposed that a typical rural water supply approach be followed for the small communities of Thaba Nchu.	5.35	Yes	

Ref	Intervention	Description of Intervention	URVs (R/m^3)	Selected for Further Investigation	
				Yes	No
E4	Groundwater abstraction at Reddersburg	The community of Reddersburg is located 60 km south-east of Bloemfontein. The current domestic water need for Reddersburg is derived mainly from surface water resources (Bloem Water) and to a lesser extent from groundwater resources of the commonage. The local municipality has an agreement with Bloem Water that a certain volume of water derived from surface water (pipeline) must be utilised on a monthly scale. The groundwater intervention proposed entails the drilling of eight new boreholes.	9.22	Yes	
E5	Groundwater abstraction at Edenburg	The community of Edenburg is located 60 km south-east of Bloemfontein. The current domestic water need for Edenburg is derived mainly from surface water resources (Bloem Water) and to a lesser extent from groundwater resources of the commonage. The local municipality has an agreement with Bloem Water that a certain volume of water derived from surface water (pipeline) must be utilised on a monthly scale. The groundwater intervention proposed entails the drilling of eight new boreholes.	10.08	Yes	
E6	Groundwater abstraction at Dewetsdorp	The community of Dewetsdorp is located 68 km south east of Bloemfontein. The current domestic water need for Dewetsdorp is derived mainly from surface water resources (Bloem Water) and to a lesser extent from groundwater resources of the commonage. The groundwater intervention proposed entails the drilling of seven new boreholes.	7.35	Yes	
E7	Groundwater abstraction at Wepener	The community of Wepener is located 104 km south east of Bloemfontein. The current domestic water need for Wepener is derived mainly from surface water resources (Bloem Water) and to a lesser extent from groundwater resources of the commonage. The groundwater intervention proposed entails the drilling of seven new boreholes.	7.52	Yes	
E8 & 9	Well field developments along the route of the existing pipelines	This intervention entails developing well fields along the route of existing pipelines, such as the Botshabelo / Thaba Nchu pipeline, Dewetsdorp pipeline, Edenburg pipeline, and the Caledon pipeline be investigated.	9.42 (De Hoek Reservoir) 10.30 (Lieuwkop off-take chamber)		No
F1	Water trading	Not all water allocated to agricultural users is currently being utilised. Therefore, there is potential for purchasing water rights from those agricultural users who are not fully utilising their allocations.			This is a long-term possible intervention
G1	Tunnel from the Caledon River	This scheme entails a flood structure in the vicinity of Jammersdrift Weir and a tunnel approximately 42 km long diverting flood water into the Modder Catchment. A dam in the Modder River catchment with a capacity of equivalent to at least the MAR of the Caledon River was proposed.			No

Ref	Intervention	Description of Intervention	URVs (R/m^3)	Selected for Further Investigation	
				Yes	No
G2	New dam on the Caledon River	Construction of an additional dam on the Caledon River.			No
G3	Transfer of mine water	This intervention entails abstracting water from closed gold mines in Welkom and/or Virginia, treating it to an acceptable standard, and then pumping it to the Greater Bloemfontein area.	4.6	Yes	
G4	Canal option (to be still developed)			Yes	

Only the selected interventions/schemes were considered for the qualitative assessment of the likely impacts of potential schemes on river salinity and the qualitative assessment of potential impacts of nutrients and urban pollution on the schemes.

7.3 QUALITATIVE ASSESSMENTS OF LIKELY IMPACTS OF POTENTIAL SCHEMES ON RIVER SALINITY

A Rapid Reserve Assessment for the Modder/Riet River catchment was completed recently, during which the water quality in this area was analysed in some detail.

The qualitative assessment of likely impacts of potential schemes on river salinity was based on the findings from the river salinity assessment in **Chapter 5** of this report.

Table 7.2 shows the qualitative assessment of likely impacts of the potential schemes on river salinity.

Table 7.2: Qualitative Assessment of Likely Impacts of Potential Schemes on River Salinity

Ref	Intervention	Description of Intervention	Source Salinity	Receiving Salinity	Interpretation
A1 & 2	Urban WC/WDM – Efficient use of water and loss management	The objective of WC/WDM is to ensure the optimal use of water and to minimise wastage. MLM has developed various water demand management strategies to achieve efficient WC/WDM, these include: • Network Losses Strategy • System Losses Strategy • Behind-Water meter Losses Strategy • Willingness to Pay Strategy	N/A	N/A	The Urban WC/WDM will have no impact on water quality.
C1	Utilising surplus capacity in the Orange River by pumping to Knellpoort Dam from Gariep Dam	Surplus volume in the Gariep Dam can be accessed via one of the following interventions: • Utilising dead storage by altering the operating rules; or • Raising Gariep Dam by 5 or 10 meters.	Gariep Dam	Knellpoort Dam/Modder River	Utilising surplus capacity in the Orange River by pumping to Knellpoort Dam from Gariep Dam will have no impact on water quality.
C2	Utilising surplus capacity in the Orange River by pumping to Knellpoort Dam from Vanderkloof Dam	Surplus volume in the Vanderkloof Dam can be accessed by utilising the dead storage by altering the operating rules to allow the water below the existing canal (bottom) inlets to be released to downstream users with no additional infrastructure being required.	Vanderkloof Dam	Riet River	Utilising surplus volume in the Vanderkloof Dam will have no impact on water quality.
C3	Utilising surplus capacity in the Orange River by pumping to Knellpoort Dam from Bosberg / Boskraai Dam	Construction of the proposed Bosberg / Boskraai Dam on the Orange River downstream of the confluence with the Kraai River. Water will then be pumped from the Bosberg / Boskraai Dam to the Knellpoort Dam.	Orange River	Knellpoort Dam/Modder River	Utilising surplus capacity in the Orange River by pumping to Knellpoort Dam from Bosberg / Boskraai Dam will have no impact on water quality.
C5	Modifications to the Caledon-Modder System	The yield of the Caledon-Modder System can be increased by one, several, or a combination of the following interventions: • Increase the capacity of Novo Pump Station • Raising of Knellpoort Dam (1, 2, or 4 m) • Increase the capacity of Tienfontein Pump Station • Construct a pump station and pipeline between Welbedacht Dam and Knellpoort Dam	Caledon River	Knellpoort Dam/Modder River	Modifying the Caledon-Modder System will have no impact on river salinity.
C6	Polihali Dam – Lesotho	The LHWP comprises of a number of phases, with Phase II	Upper Orange	Ash River/	Polihali Dam – Lesotho

Ref	Intervention	Description of Intervention	Source Salinity	Receiving Salinity	Interpretation
	Highlands Phase 2	culminating in the construction of the Polihali Dam. Water from the Polihali Dam would then be delivered from Katse Dam via the existing Transfer Tunnel to Muela Hydro Power Station and thence via the existing Delivery Tunnel to the Ash River. It is proposed that Phase II would be commissioned by January 2020 and Phase III would only be required by 2054. It is proposed that the Phase II water is released for Bloemfontein up to the year 2050. This supply could delay capital expenditure on improvements to the existing bulk infrastructure supplying Bloemfontein.	(Lesotho)	Caledon River	Highlands Phase 2 will have no impact on river salinity
D1	Planned direct re-use: New North Eastern WWTW	The MLM is in the design phase to construct a new WWTW to allow further development in the north, eastern, and western parts of Bloemfontein. This intervention entails pumping effluent, which has been treated to potable standards using Ultra Filtration, Reverse Osmosis, and Ultra-violet Radition, from the New North Eastern WWTW to the Maselspoort WTW or to the distribution reservoir on Navel Hill. The focus of this intervention is to abstract water for re-use at the New North Eastern WWTW.	N/A	N/A	Reverse osmosis will produce brine (reject) which will have to disposed of. Disposal of this reject from desalinisation can present a problem for the planned direct re-use at the New North Eastern WWTW. However, disposal of reject from reverse osmosis can present a problem.
D2	Planned indirect re-use: Transfer to upstream of Mockes Dam	Treated effluent from the New North Eastern WWTW would be pumped over the escarpment into the stream feeding Mockes Dam. The treatment facilities at the Maselspoort Weir (a few kilometres downstream of Mockes Dam) will be extended with new treatment technology and equipment. Required treatment process includes Reverse Osmosis in order to remove the build-up of dissolved salts in the river system.	Bloemfontein	Modder River	Nutrient enrichment could be a problem. Salinity must be assessed as WWTW return flow will be higher than the intake water. Disposal of reject from reverse osmosis can also present a problem.
D3	Planned indirect re-use: Krugersdrift Dam	All WWTWs for Bloemfontein, Botshabelo, Mangaung, and Thaba Nchu (except Welvaart WWTW) discharge their treated wastewater into the Krugersdrift Dam catchment area. Currently, no wastewater from Botshabelo or Thaba Nchu reaches Krugersdrift Dam, as it is intercepted at the Maselspoort Weir. The only water reaching the dam is excess surface run-off not intercepted by Mockes Dam and Rustfontein Dam, and the surplus wastewater from the	Krugersdrift Dam	Bloemfontein	Disposal of reject from reverse osmosis can present a problem for the planned indirect re-use at Krugersdrift Dam.

Ref	Intervention	Description of Intervention	Source Salinity	Receiving Salinity	Interpretation
		Bloemfontein/Mangaung WWTW's. Water can be abstracted at Krugersdrift Dam and pumped back to Bloemfontein. The raw water at the Krugersdrift Dam will have to be purified using Ultra Filtration, followed by a Reverse Osmosis and Ultra-Violet radiation for disinfection, to purify water to potable standards. This treated water will then be pumped back to the main Bloem Water reservoir.			
D4	Planned direct re-use: Bloemspruit WWTW	The focus of this intervention is to utilise the existing treated effluent from the Bloemspruit WWTW for potable use and replace this with treated effluent discharged from the proposed New North Eastern WWTW. The treated wastewater from the Bloemspruit WWTW would be treated to potable standards (this will typically include Ultra Filtration, followed by a Reverse Osmosis, and Ultra-Violet radiation for disinfection) and then pumped to a reservoir serving the Greater Bloemfontein area.	N/A	N/A	Disposal of the reject can present a problem for the planned direct re-use at the Bloemspruit WWTW
D5	Re-use of treated effluent: Direct use for irrigation	A dual system could be implemented where treated effluent is re-used in the city for the irrigation of municipal gardens, public open spaces, school fields, and green street reserves.	WWTW	Groundwater	Re-use of treated effluent for irrigation will have no impact on salinity.
E1	Groundwater abstraction at Ikgomotseng	This small community is located approximately 45 km north-west of Bloemfontein near the Krugersdrift Dam. Ikgomotseng derives their domestic water from the Krugersdrift Dam. It is proposed that 10 boreholes be drilled. The abstracted groundwater is to be pumped to the Ikgomotseng main reservoir for conjunctive use with the surface water (Krugersdrift Dam) as well as for dilution of the potential high fluoride concentrations or for treatment if necessary.	Groundwater	Surface Water	Electrical Conductivity seems to be problematic at Ikgomotseng.
E3	Groundwater abstraction at Thaba Nchu	The Thaba Nchu area is situated approximately 58 km east from Bloemfontein. The area is characterised by a group of very small to medium sized communities that are depended on surface water (Bloem Water) and groundwater for their domestic water needs. An unknown number of boreholes are utilised for water supply purposes. For the groundwater intervention it is proposed that a typical rural water supply approach be followed for the small communities of Thaba Nchu.	Groundwater	Surface Water	There are no groundwater EC problems at Thaba Nchu.
E4	Groundwater abstraction at	The community of Reddersburg is located 60 km south-east of	Groundwater	Surface Water	There are no groundwater

Ref	Intervention	Description of Intervention	Source Salinity	Receiving Salinity	Interpretation
	Reddersburg	Bloemfontein. The current domestic water need for Reddersburg is derived mainly from surface water resources (Bloem Water) and to a lesser extent from groundwater resources of the commonage. The local municipality has an agreement with Bloem Water that a certain volume of water derived from surface water (pipeline) must be utilised on a monthly scale. The groundwater intervention proposed entails the drilling of eight new boreholes.			EC problems at Reddersburg.
E5	Groundwater abstraction at Edenburg	The community of Edenburg is located 60 km south-east of Bloemfontein. The current domestic water need for Edenburg is derived mainly from surface water resources (Bloem Water) and to a lesser extent from groundwater resources of the commonage. The local municipality has an agreement with Bloem Water that a certain volume of water derived from surface water (pipeline) must be utilised on a monthly scale. The groundwater intervention proposed entails the drilling of eight new boreholes.	Groundwater	Surface Water	There are no groundwater EC problems at Edenburg.
E6	Groundwater abstraction at Dewetsdorp	The community of Dewetsdorp is located 68 km south east of Bloemfontein. The current domestic water need for Dewetsdorp is derived mainly from surface water resources (Bloem Water) and to a lesser extent from groundwater resources of the commonage. The groundwater intervention proposed entails the drilling of seven new boreholes.	Groundwater	Surface Water	There are no groundwater EC problems at Dewertsdorp
E7	Groundwater abstraction at Wepener	The community of Wepener is located 104 km south east of Bloemfontein. The current domestic water need for Wepener is derived mainly from surface water resources (Bloem Water) and to a lesser extent from groundwater resources of the commonage. The groundwater intervention proposed entails the drilling of seven new boreholes.	Groundwater	Surface Water	There are no groundwater EC problems at Wepener.
G3	Transfer of mine water	This intervention entails abstracting water from closed gold mines in Welkom and/or Virginia, treating it to an acceptable standard, and then pumping it to the Greater Bloemfontein area.	Welkom	Modder River	Water quality could be a problem in terms of trace metals and salinity from gold mines. One of the major concerns of gold mining is the impact on the quality of local water resources. Of particular concern to

Ref	Intervention	Description of Intervention	Source Salinity	Receiving Salinity	Interpretation
					downstream users is uranium pollution of ground- and surface water often associated with gold in the mined reefs (Winde. F, 2006).

7.4 QUALITATIVE ASSESSMENT OF POTENTIAL IMPACTS OF NUTRIENTS AND URBAN POLLUTION

7.4.1 Nutrients

Inorganic nutrients are elements essential to life and provide the chemical constituents on which the entire food web is based. Catchment nutrient loads are the principal drivers of ecological processes in receiving waters. In aquatic systems, nitrogen (N) and phosphorus (P) are the two nutrients that most commonly limit maximum biomass of algae and aquatic plants (primary producers), which occurs when concentrations in the surrounding environment are below requirements for optimal growth of algae, plants and bacteria (UNEP-GEMS, 2006). Productivity of aquatic ecosystems can, therefore, be managed by regulating direct or indirect inputs of N and P with the aim of either reducing or increasing primary production.

Phosphorus and nitrogen are considered to be the primary drivers of eutrophication of aquatic ecosystems, where increased nutrient concentrations lead to increased primary productivity. Rivers and streams are major routes of transfer of nitrogen and phosphorus, and they integrate point and non-point sources of nutrients. Some systems are naturally eutrophic, whereas others have become eutrophic as a result of human activities (‘anthropogenic or cultural eutrophication’) through factors such as runoff from agricultural lands containing fertilizers and the discharge of municipal waste into rivers and lakes (UNEP-GEMS, 2006).

7.4.2 Status of the WWTWs

Although the detailed analysis of WWTWs falls outside the scope of this study, it is common knowledge that municipalities with their limited budgets and other resources are not managing WWTWs as they should be and therefore have a serious water quality impact on the receiving surface water resources. According to the latest statistics it is estimated that 30 069 (5%) of the population in the Mangaung LM has inadequate or no sanitation services (DWA, 2009). **Table 7.3** summarises the WWTWs in the study area.

Table 7.3: WWTWs in the Study Area

WWTW	WMA	Catchment Management Area
Bainsvlei	Upper Orange	Discharge to Irrigation Ponds
Bloemdustria	Upper Orange	No Discharge takes place at Plant
Bloemspruit	Upper Orange	Vaal, Harts & Skoonspruit CMA
Botshabelo	Upper Orange	Modder & Riet CMA
Northern Works	Upper Orange	Orange, Caledon & Kraai CMA
Thaba Nchu	Upper Orange	Modder & Riet CMA
Welvaart	Upper Orange	Discharge CMA undetermined

The 2009 analysis showed the phosphate levels for all the WWTWs in the study were below the standard. **Figure 7.1** to **Figure 7.6** show the phosphate levels for the different WWTWs.

Bainsvlei WWTWs

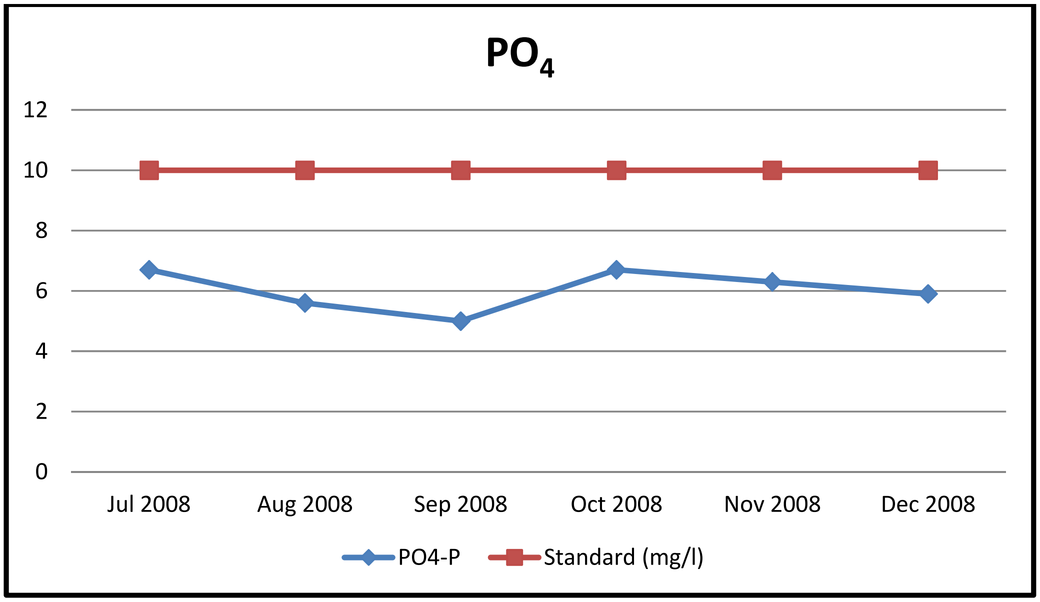


Figure 7.1: Phosphate Levels at the Bainsvlei WWTWs

Bloemdustria WWTWs

No effluent quality data was was available for the Bloemdustria WWTWs when the assessment was conducted (DWA, 2009).

Bloemspruit WWTWs

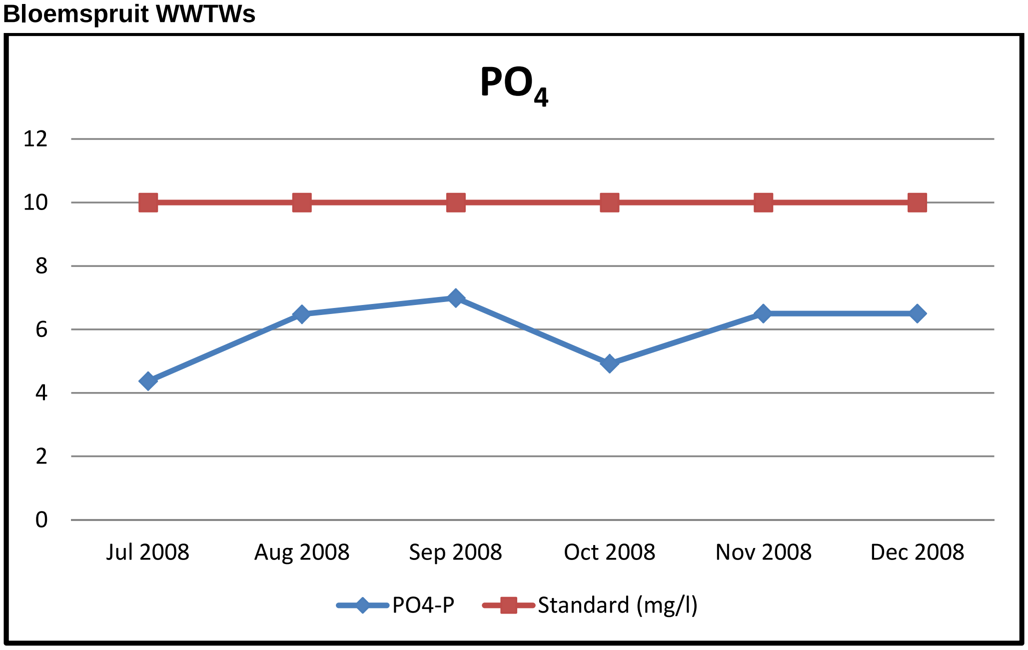


Figure 7.2: Phosphate Levels at the Bloemspruit WWTWs

Botshabelo WWTWs

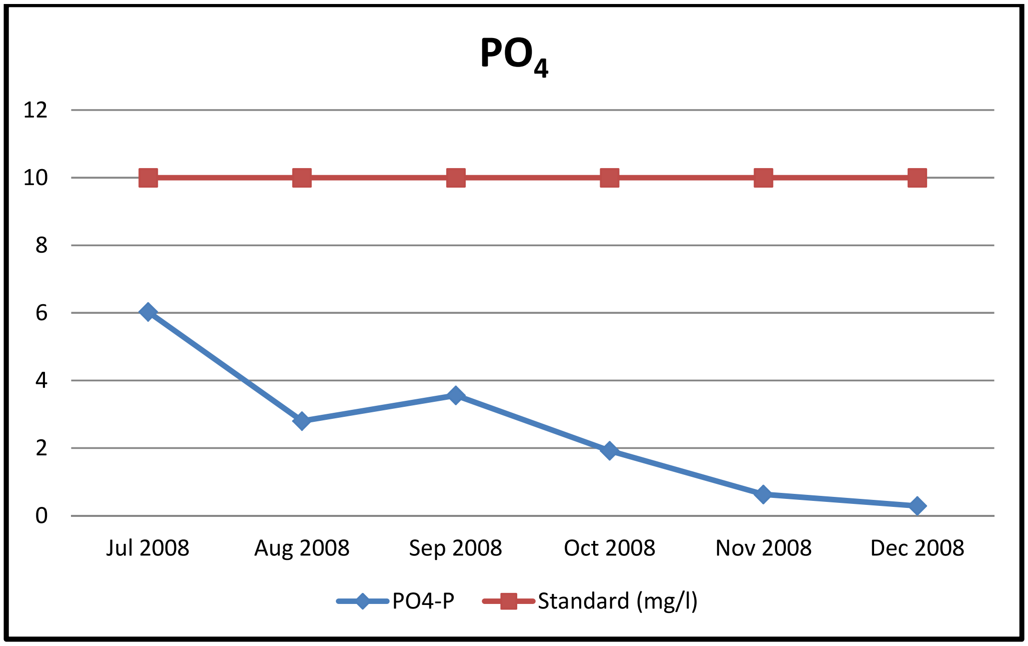


Figure 7.3: Phosphate Levels at the Botshabelo WWTWs

Northern Works WWTWs

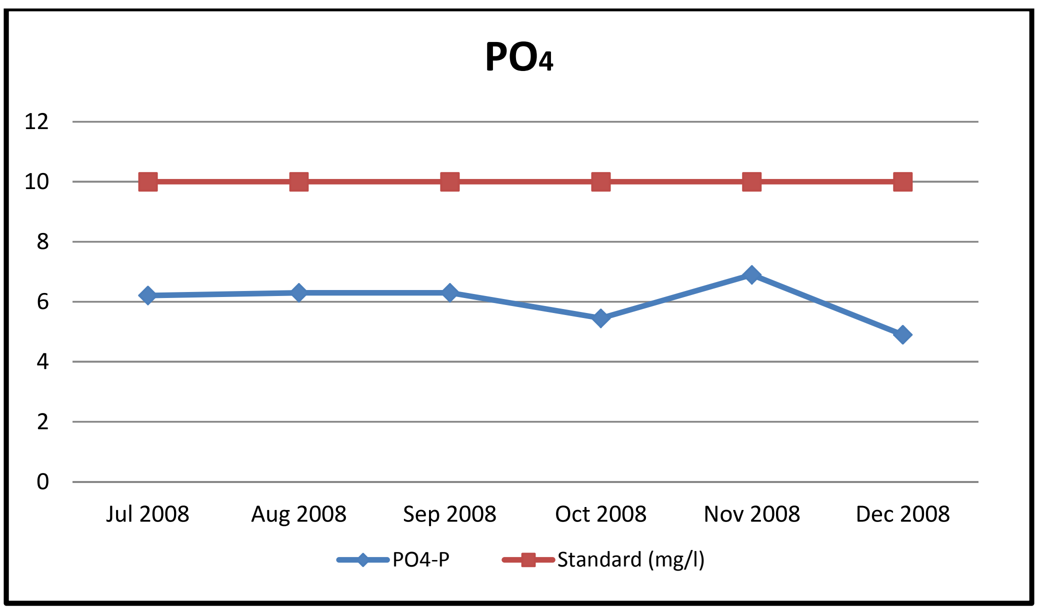


Figure 7.4: Phosphate Levels at the Northern Works WWTWs

Thaba Nchu WWTWs

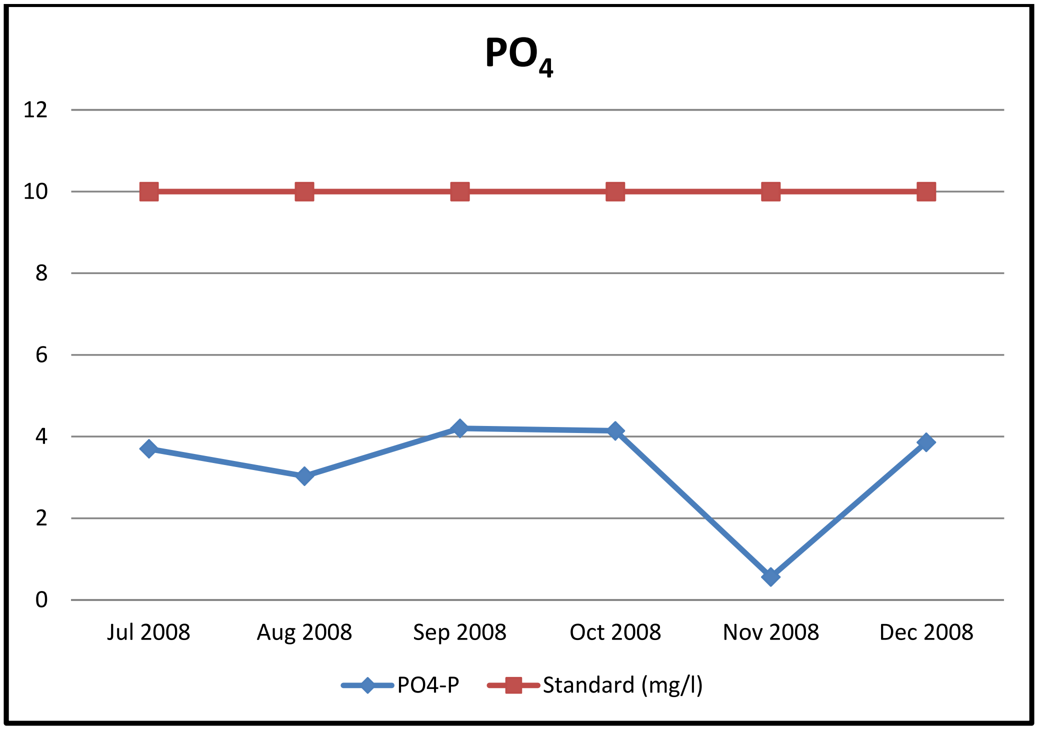


Figure 7.5: Phosphate Levels at the Thaba Nchu WWTWs

Welvaart WWTWs

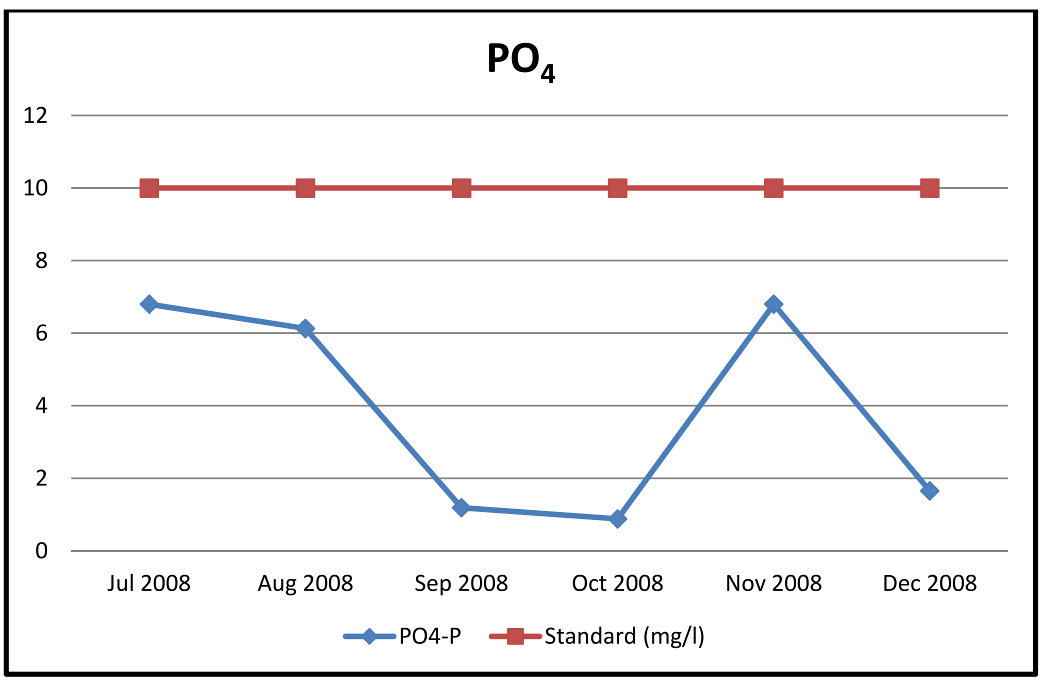


Figure 7.6: Phosphate Levels at the Bainsvlei WWTWs

Although the nutrient levels are below the standard, loads from treated wastewater in the catchment will in future have a negative impact in the Krugersdrift Dam, unless the discharge standard for orthophosphate is changed from the current 10mg/ℓ (general standard) to 1mg/ℓ (special standard).

7.5 URBAN POLLUTION

Nearly all solid water pollution in South Africa's River system is derived from Urban areas (urban pollution) (WRC, 1998). Urban Pollution comprises of storm water pollution and pollution from litter. Litter consists of plastics, paper, metals, glass, vegetation, animals and construction material that are clogging the drainage systems (WRC, 1998). Storm water runoff from streets and urban litter do not contain high nutrient concentrations, therefore they are not expected to have an impact on the potential schemes.

Table 7.4 shows the qualitative analysis of the impacts of nutrients and urban pollution on water quality.

Table 7.4: Qualitative Analysis of the Impacts of Nutrients and Urban Pollution

Ref	Intervention	Description of intervention	Source Salinity	Receiving Salinity	Comments
A1 & 2	Urban WC/WDM – Efficient use of water and loss management	The objective of WC/WDM is to ensure the optimal use of water and to minimise wastage. MLM has developed various water demand management strategies to achieve efficient WC/WDM, these include: • Network Losses Strategy • System Losses Strategy • Behind-Water meter Losses Strategy • Willingness to Pay Strategy	N/A	N/A	Urban WC/WDM will have no impact on water quality.
C1	Utilising surplus capacity in the Orange River by pumping to Knellpoort Dam from Gariep Dam	Surplus volume in the Gariep Dam can be accessed via one of the following interventions: • Utilising dead storage by altering the operating rules; or • Raising Gariep Dam by 5 or 10 meters.	Gariep Dam	Knellpoort Dam/Modder River	Utilising surplus capacity in the Orange River by pumping to Knellpoort Dam from Gariep Dam will have no impact on water quality.
C2	Utilising surplus capacity in the Orange River by pumping to Knellpoort Dam from Vanderkloof Dam	Surplus volume in the Vanderkloof Dam can be accessed by utilising the dead storage by altering the operating rules to allow the water below the existing canal (bottom) inlets to be released to downstream users with no additional infrastructure being required.	Vanderkloof Dam	Riet River	Utilising surplus capacity in the Orange River by pumping to Knellpoort Dam from Vanderkloof Dam will have no impact on water quality.
C3	Utilising surplus capacity in the Orange River by pumping to Knellpoort Dam from Bosberg / Boskraai Dam	Construction of the proposed Bosberg / Boskraai Dam on the Orange River downstream of the confluence with the Kraai River. Water will then be pumped from the Bosberg / Boskraai Dam to the Knellpoort Dam.	Orange River	Knellpoort Dam/Modder River	Utilising surplus capacity in the Orange River by pumping to Knellpoort Dam from Bosberg / Boskraai Dam will have no impact on water quality.
C5	Modifications to the Caledon-Modder System	The yield of the Caledon-Modder System can be increased by one, several, or a combination of the following interventions:	Caledon River	Knellpoort Dam/Modder River	Modifications to the Caledon-Modder System will have no impact on

Ref	Intervention	Description of intervention	Source Salinity	Receiving Salinity	Comments
		• Increase the capacity of Novo Pump Station • Raising of Knellpoort Dam (1, 2, or 4 m) • Increase the capacity of Tienfontein Pump Station • Construct a pump station and pipeline between Welbedacht Dam and Knellpoort Dam			water quality. Up to the Krugersdrift Dam, the Caledon River transfer already drowns the natural flow. Increasing it will have no effect. The buffering effect of the dam renders any change in water quality very small. The difference between the water quality in the Caledon and in the Krugersdrift Dam is small.
C6	Polihali Dam – Lesotho Highlands Phase 2	The LHWP comprises of a number of phases, with Phase II culminating in the construction of the Polihali Dam. Water from the Polihali Dam would then be delivered from Katse Dam via the existing Transfer Tunnel to Muela Hydro Power Station and thence via the existing Delivery Tunnel to the Ash River. It is proposed that Phase II would be commissioned by January 2020 and Phase III would only be required by 2054. It is proposed that the Phase II water is released for Bloemfontein up to the year 2050. This supply could delay capital expenditure on improvements to the existing bulk infrastructure supplying Bloemfontein.	Upper Orange (Lesotho)	Ash River/ Caledon River	The Polihali Dam – Lesotho Highlands Phase 2 will have no impact on water quality
D1	Planned direct re-use: New North Eastern WWTW	The MLM is in the design phase to construct a new WWTW to allow further development in the north, eastern, and western parts of Bloemfontein. This intervention entails pumping effluent, which has been treated to potable standards using Ultra Filtration, Reverse Osmosis, and Ultra-violet Radiation, from the New North Eastern WWTW to	N/A	N/A	Reverse Osmosis produces brine (reject) which will have to disposed of. Disposal of this reject from desalinisation can present a problem for the

Ref	Intervention	Description of intervention	Source Salinity	Receiving Salinity	Comments
		the Maselspoort WTW or to the distribution reservoir on Navel Hill. The focus of this intervention is to abstract water for re-use at the New North Eastern WWTW.			planned direct re-use at the New North Eastern WWTW.
D2	Planned indirect re-use: Transfer to upstream of Mockes Dam	Treated effluent from the New North Eastern WWTW would be pumped over the escarpment into the stream feeding Mockes Dam. The treatment facilities at the Maselspoort Weir (a few kilometres downstream of Mockes Dam) will be extended with new treatment technology and equipment. Required treatment process includes Reverse Osmosis in order to remove the build-up of dissolved salts in the river system.	Bloemfontein	Modder River	Planned indirect re-use: Transfer to upstream of Mockes can result in enrichment in the receiving water body. Up to the Mockes Dam/ Maselspoort, the nutrient concentration will increase. Disposal of the reject from desalinisation process can present a problem.
D3	Planned indirect re-use: Krugersdrift Dam	All WWTWs for Bloemfontein, Botshabelo, Mangaung, and Thaba Nchu (except Welvaart WWTW) discharge their treated wastewater into the Krugersdrift Dam catchment area. Currently, no wastewater from Botshabelo or Thaba Nchu reaches Krugersdrift Dam, as it is intercepted at the Maselspoort Weir. The only water reaching the dam is excess surface run-off not intercepted by Mockes Dam and Rustfontein Dam, and the surplus wastewater from the Bloemfontein/Mangaung WWTW's. Water can be abstracted at Krugersdrift Dam and pumped back to Bloemfontein. The raw water at the Krugersdrift Dam will have to be purified using Ultra Filtration, followed by a Reverse Osmosis and Ultra-Violet radiation for disinfection, to purify water to potable standards. This treated water will	Krugersdrift Dam	Bloemfontein	Planned indirect re-use at Krugersdrift Dam can result in enrichment of the receiving water body especially Krugersdrift Dam. Disposal of reject from desalinisation process can present a problem.

Ref	Intervention	Description of intervention	Source Salinity	Receiving Salinity	Comments
		then be pumped back to the main Bloem Water reservoir.			
D4	Planned direct re-use: Bloemspruit WWTW	The focus of this intervention is to utilise the existing treated effluent from the Bloemspruit WWTW for potable use and replace this with treated effluent discharged from the proposed New North Eastern WWTW. The treated wastewater from the Bloemspruit WWTW would be purified to potable standards (this will typically include Ultra Filtration, followed by a Reverse Osmosis, and Ultra-Violet radiation for disinfection) and then pumped to a reservoir serving the Greater Bloemfontein area.	N/A	N/A	The planned direct re-use at Bloemspruit WWTW will have no effect on water quality. However the disposal of reject from desalinisation can present problems.
D5	Re-use of treated effluent: Direct use for irrigation	A dual system could be implemented where treated effluent is re-used in the city for the irrigation of municipal gardens, public open spaces, school fields, and green street reserves.	WWTW	Groundwater	Re-use of treated effluent: Direct use for irrigation will have no impact on water quality. The treated effluent as such should not pose any health problems. There should not be any salinity impacts
E1	Groundwater abstraction at Ikgomotseng	This small community is located approximately 45 km north-west of Bloemfontein near the Krugersdrift Dam. Ikgomotseng derives their domestic water from the Krugersdrift Dam. It is proposed that 10 boreholes be drilled. The abstracted groundwater is to be pumped to the Ikgomotseng main reservoir for conjunctive use with the surface water (Krugersdrift Dam) as well as for dilution of the potential high fluoride concentrations or for treatment if necessary.	Groundwater	Surface Water	Groundwater abstraction at Ikgomotseng will have no impact on water quality.
E3	Groundwater abstraction at Thaba Nchu	The Thaba Nchu area is situated approximately 58 km east from Bloemfontein. The area are	Groundwater	Surface Water	Groundwater abstraction at Thaba Nchu will have

Ref	Intervention	Description of intervention	Source Salinity	Receiving Salinity	Comments
		characterised by group very small to medium sized communities that are depended on surface water (Bloem Water) and groundwater for their domestic water needs. An unknown number of boreholes are utilised for water supply purposes. For the groundwater intervention it is proposed that a typical rural water supply approach be followed for the small communities of Thaba Nchu.			no impact on water quality
E4	Groundwater abstraction at Reddersburg	The community of Reddersburg is located 60 km south-east of Bloemfontein. The current domestic water need for Reddersburg is derived mainly from surface water resources (Bloem Water) and to a lesser extent from groundwater resources of the commonage. The local municipality has an agreement with Bloem Water that a certain volume of water derived from surface water (pipeline) must be utilised on a monthly scale. The groundwater intervention proposed entails the drilling of eight new boreholes.	Groundwater	Surface Water	Groundwater abstraction at Reddersburg will have no impact on water quality
E5	Groundwater abstraction at Edenburg	The community of Edenburg is located 60 km south-east of Bloemfontein. The current domestic water need for Edenburg is derived mainly from surface water resources (Bloem Water) and to a lesser extent from groundwater resources of the commonage. The local municipality has an agreement with Bloem Water that a certain volume of water derived from surface water (pipeline) must be utilised on a monthly scale. The groundwater intervention proposed entails the drilling of eight new boreholes.	Groundwater	Surface Water	Groundwater abstraction at Edenburg will have no impact on water quality
E6	Groundwater abstraction at Dewetsdorp	The community of Dewetsdorp is located 68 km south east of Bloemfontein. The current domestic water need for Dewetsdorp is derived mainly from surface water resources (Bloem Water) and to a	Groundwater	Surface Water	Groundwater abstraction at Dewetsdorp will have no impact on water quality

Ref	Intervention	Description of intervention	Source Salinity	Receiving Salinity	Comments
		lesser extent from groundwater resources of the commonage. The groundwater intervention proposed entails the drilling of seven new boreholes.			
E7	Groundwater abstraction at Wepener	The community of Wepener is located 104 km south east of Bloemfontein. The current domestic water need for Wepener is derived mainly from surface water resources (Bloem Water) and to a lesser extent from groundwater resources of the commonage. The groundwater intervention proposed entails the drilling of seven new boreholes.	Groundwater	Surface Water	Groundwater abstraction at Wepener will have no impact on water quality
G3	Transfer of mine water	This intervention entails abstracting water from closed gold mines in Welkom and/or Virginia, treating it to an acceptable standard, and then pumping it to the Greater Bloemfontein area.	Welkom	Modder River	Transfer of mine water will have no impact on water quality.
G4	Canal option (to be still developed)				

8. CONCLUSION

The water quality in terms of the EC (salinity) in the study area is generally of good quality except for Ikgomotseng where the groundwater EC levels are within unacceptable ranges. This may be due to the high levels of Na^{+} and Cl^{-} in the area. The high EC values in the Riet River may be as a result of irrigation return flows. The potential schemes will generally have no impact on river salinity. However, disposal of brine from reverse osmosis can present a problem.

An assessment of the nutrients showed that the water quality in the study area is of good quality. The levels of nitrite/nitrates in the study area are within acceptable ranges. Ammonium and phosphate levels in the four rivers are mostly within tolerable ranges. The only cause for concern is the high levels of phosphates in the Upper Riet River as high nutrient levels lead to eutrophication.

Although the nutrient levels for the WWTWs are below the standard, loads from treated wastewater in the catchment will in future have a negative impact on the Krugersdrift Dam, unless the discharge standard for orthophosphate is changed from the current 10mg/ℓ (general standard) to 1mg/ℓ (special standard). Storm water runoff from streets and urban litter do not contain high nutrient concentrations, therefore they are not expected to have an impact on the potential schemes. Therefore nutrients and urban pollution are not expected to have an impact on water quality, but the disposal of the reject from reverse osmosis may present a problem.

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Appendix A

Guideline for Ammonium

Guideline for Ammonium:

The data received from DWA gave concentrations of ammonium (NH_4). The guidelines all indicate the target, chronic and acute concentration values in terms of un-ionised ammonia, NH_3. This meant that a conversion within the guidelines developed here is needed.

The percentage of total ammonia that is un-ionised is a function of the water temperature and the pH of the water. Within the guidelines (reference # 7) a table is given listing the percentage of total ammonia that is un-ionised for varying pH and temperature combinations (where total ammonia is the sum of ammonium and un-ionized ammonia). Through analyzing the pH data results on Table 5.2, and considering that the target guideline is given in terms of the 90^{th} percentile, it is assumed that an average pH of 8.5 would suffice. The temperature was estimated to be 20°C through looking at the data received from DWA. Very few of the data points had data on temperature, but those that did showed temperature values fluctuating around this value.

A pH of 8.5 and a water temperature of 20°C indicate that the percentage of total ammonia that is un-ionised is 11. Subsequently an adjustment on the guidelines used in this document was made.

The guidelines used were converted from the target, chronic and acute concentration guidelines, which are as follows:

TWQR and Criteria	**Un-ionised Ammonia** (mg/l NH_3)
Target Water Quality Range (TWQR)	***< 0.007***
Chronic Effect Value (CEV)	0.015
Acute Effect Value (AEV)	0.100

The above values were converted to form the following guideline:

Colour	**Range (mg/l)**	**Effects on the ecology**
Blue	0 to 0.057	The 90th percentile has to be within this range, based on the TWQR. This is range at which un-ionised ammonia is not at toxic levels. No health or aesthetic effects on aquatic life except the most sensitive species.
Green	0.057 to 0.121	The upper limit of this range indicates the chronic effect value. Increasing effects on the respiratory systems of animals. Some fish are able to adapt to high concentrations of ammonia.
Yellow	0.121 to 0.65	Chronic effects include a reduction in hatching success, reduction in growth rate and morphological development, and pathological changes in tissue of gills, liver and kidneys.
Red	0.65 to 0.81	Increasing seriousness of the above symptoms. Toxicity levels of the water are reaching the acute value (upper limit of this range).
Purple	Greater than 0.81	Acute toxicity to fish may cause a loss of equilibrium, hyper-excitability, an increased breathing rate, an increased cardiac output and oxygen intake, and in extreme cases convulsions, coma and death.

Guidelines deduced from reference # 7

Please note that another value was used in the developed guidelines to form 5 separate ranges. It was used as the limit between the yellow and red ranges and equates to a value for un-ionized ammonia of about 0.08 mg/l.