

The current water quality situation at clinics in the Limpopo Province and subsequent management suggestions

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ABSTRACT

South Africa's water resources are, in global terms, scarce and extremely limited (DWAF, 2004). Groundwater is a valuable source of potable water in South Africa. It was found that most of the health facilities in the Limpopo Province depend on groundwater as sole source of potable water.

Groundwater quality is to a great extent influenced by the dominant land use in the vicinity of an aquifer. It is therefore important to carefully manage possible pollution sources of anthropogenic origin. This may be seen as pro-active water quality management that may result in significant saving on water treatment.

This aim of this study is to obtain a regional view of the water quality situation at clinics and other health facilities in the Limpopo Province. It was found that the general water quality at health facilities in the Province is questionable. It is of concern to note that 56% of health facilities use water that is unacceptable for human consumption.

Water quality may be managed by introducing appropriate treatment options to treat the water to ideal water quality standards. This dissertation explores some treatment options used at health facilities in the Province. The efficiency of these treatment systems is also investigated.

Key words: Water quality, Reverse osmosis, Water treatment, Clinics, Limpopo Province.

Die huidige waterkwaliteitsituasie by klinieke in die Limpopo Provinsie en gepaardgaande bestuursvoorstelle

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UITTREKSEL

Suid-Afrika se water is volgens wêreldstandaarde baie skaars en beperk. Grondwater is 'n baie waardevolle bron van drinkwater in Suid-Afrika. Dit is bevind dat die meeste van die gesondheidsorgfasiliteite in die Limpopo Provinsie van grondwater afhanklik is as primêre waterbron.

Grondwaterkwaliteit word swaar beïnvloed deur die dominante grondgebruik in die nabye omgewing van die waterbron. Dit is baie belangrik om besoedelingsbronne van menslike oorsprong streng te bestuur. Die bestuur van besoedelingsbronne is 'n vorm van pro-aktiewe bestuur wat kan lei tot beduidende besparings met betrekking tot waterkwaliteit.

Hierdie studie het dit ten doel om 'n regionale oorsig te bekom van die waterkwaliteitsituasie by klinieke en ander gesondheidsorgfasiliteite in die Limpopo Provinsie. Die resultate wys dat 56% van die gesondheidsorgfasiliteite moet klaarkom met water wat nie geskik is vir menslike gebruik nie. Die algemene waterkwaliteit by gesondheidsorgfasiliteite in die Provinsie is bedenklik.

Waterkwaliteit kan bestuur word deur watersuiweringstelsels te installeer. Hierdie suiweringstelsels behoort die water voldoende te suiwer. Hierdie verhandeling verken van die watersuiweringstelsels wat tans by fasiliteite in die provinsie gebruik word. Die effektiwiteit van hierdie stelsels word ook ondersoek.

Sleutelwoorde: Waterkwaliteit, Tru-osmose, Watersuiwering, Klinieke, Limpopo Provinsie.

LIST OF ABBREVIATIONS

Abbreviation	Explanation
CDC	Centre for Disease Control
CSIR	Council for Scientific and Industrial Research
DALYs	Disability adjusted life years
DNA	Deoxyribonucleic acid
DOM	Dissolved organic matter
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EC	Electrical conductivity
GA	General Authorisation
GDP	Gross domestic product
GLTP	Greater Limpopo Trans-frontier Park
GMCA	Greater Mapungubwe Trans-frontier Conservation Area
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MIEX	Magnetic ion exchange
N	Nitrogen
NWA	National Water Act
NWP	National Water Policy
RO	Reverse osmosis
SANAS	South African National Accreditation System
SANS	South African National Standards
TDS	Total dissolved solids
TH	Total hardness
THMs	Tri-halomethanes
THPC	Total heterotrophic plate count
UV	Ultra-violet
VIPs	Ventilated Improved Toilets
WHO	World Health Organisation

1 INTRODUCTION

South Africa's water resources are, in global terms, scarce and extremely limited (South Africa, 2004). Water is one of the most precious and valuable natural resources in South as it is vital for socio-economic growth, sustainability of developmental projects and general survival of humans and all other living creatures. It is reported that approximately two thirds of the South African population depends on groundwater for their domestic needs (South Africa, 2004).

According to Braune (2000:7) South Africa is one of the twenty most water stressed countries in the world when applying the United Nations definition of water scarcity. Braune (2000:7) also states that groundwater historically contributed about 15% of total bulk water supply.

It has been government policy since 1994 that all South Africans should have the benefit of equitable and sustainable social and economic development. In order to promote economic and social progress, one needs a sustainable water supply. South Africa is a country with limited water resources and it has realised that it is facing an imminent water crises. Many laws existed that had not been in line with this view of the government and in response the government introduced the National Water Policy for South Africa (NWP) as adopted by the cabinet in 1997 (South Africa, 2004).

The NWP was preceded by 28 fundamental principles and objectives for a new water law. Principle 7 in particular is of note:

The objective of managing the quantity, quality and reliability of the Nation's water resources is to achieve optimum, long-term, environmentally sustainable social and economic benefit for society from their use (South Africa, 2004).

The fundamental objectives for managing South Africa's water resources are the following (South Africa, 2004):

- To achieve equitable access to water,
- To achieve sustainable use of water,
- To achieve efficient and effective water use.

As a measure to achieve the fundamental objectives in the Limpopo Province, the Department of Health initiated a water supply project to ensure a reliable and adequate water supply to all government health institutions in the Province. Due to the mostly arid nature of the Limpopo Province, the Province regularly experiences water stress. According to Sello (2009), the Limpopo Province is the Province

with the third lowest household access to water. This implies that these health facilities involved in this study are sometimes also the only water supply to a community. This water supply mainly consists of boreholes accessing underground aquifers.

Many of the aquifers utilised in this Province can be classified as sole source aquifers, supplying 50% or more of the domestic water in the absence of any reasonable alternative (Vivier, 2006). Vivier (2006) found that some of the water sampled at clinics in the Limpopo Province with their own water supply, 44% of the clinics was classified as having either poor or dangerous water quality. This poses a significant health risk to susceptible individuals.

Groundwater is easily polluted if not well managed and the cost of restoring it to a potable standard for domestic use is very expensive. South Africa is facing a situation where the available ground water reserves will become depleted if water extraction and water quality is not properly monitored and managed. Once groundwater is polluted, it is very expensive and time consuming to rehabilitate. Protection of groundwater both in supply and quality has thus become a national priority and sustainability of water for basic needs has been identified as the most important principle of water management.

This water quality study is an initiative of the Department of Health, Limpopo Province, to determine the status of groundwater quality of boreholes at health facilities in the Province. Such information is required to assist the Department in planning their future activities in an on-going water quality management programme. Water quality as here referred to describes the microbial, chemical and physical properties of water in relation to its fitness for use. Fitness for use embraces the purpose of drinking, food preparation, bathing and laundry, as prescribed by DWAF (1998a).

Some of the clinics surveyed are at risk of substantially polluting their groundwater resources due to inappropriate on site sanitation systems (Vivier, 2006), while others have water of inherently low quality. Proper sanitation and pollution management is of dire importance at all health facilities in the Province in order to manage and minimise the impact these facilities may have on groundwater quality. To monitor this risk, water quality data is needed. However, only limited water quality data for health facilities had existed in the Province.

In order to remedy the water quality problem faced at certain clinics, a water quality study was done at health facilities throughout the Province. The water quality data was collected in a data base from which

health facilities will be identified as having water quality problems. Certain mitigating measures as well as certain management possibilities will be proposed for the identified facilities.

This poses the following question:

- *What is the current water quality status at the various health facilities in the Limpopo Province and what can be done to remedy the situation?*

In order to answer the research question, the following sub-questions need to be answered:

- a) Which health facilities suffer water quality problems and where are they located?
- b) What mitigating measures can be implemented?
- c) What is the effectiveness of mitigating measures?

It is expected that there will be significant finds pertaining to water quality at the health institutions researched.

The research procedure will be as follows:

- Obtain existing water quality data
- Enter data into database
- Evaluate data
- Obtain more data if necessary
- Identify and map the problem areas
- Make mitigation suggestions (water treatment options)
- Implement mitigation measures
- Evaluate mitigation measures
- Make long term management proposals

In order to better understand the challenges that exist at the health facilities in the Limpopo Province, a comprehensive literature study follows in the next chapter. A limited number of parameters were chosen as indicators of water quality. A number of water treatment options are available for the treatment of contaminated water. Some of the available water treatment options are also researched. To serve as background, the study area is described with regard to climate, geology, geo-hydrology and social factors.

2 LITERATURE REVIEW

2.1 Water quality

Water Quality can be described as the microbial, physical and chemical properties of water that determine its fitness for use. Many of the properties are controlled or influenced by substances which are either dissolved or suspended in the water (DWAF, 1998a).

Microbial quality refers to the presence of organisms that cannot be seen by the naked eye such as protozoa, bacteria and viruses (DWAF, 1998a). This report will focus on coliform bacteria as an indication of contamination of groundwater supplies by on site sanitation.

The chemical quality of the water refers to the nature and concentration of dissolved substances such as salts, metals and organic chemicals. Many chemical substances in water are essential as part of the daily required intake, but at high concentrations they make water unpalatable and cause illnesses (DWAF, 1998a).

The physical quality of water refers to properties that may be determined by physical methods such as electrical conductivity, pH and turbidity measurement. The physical quality mainly affects the aesthetic quality of the water (DWAF, 1998a).

Certain water quality criteria were identified as being of immediate concern and will be researched in this report. These criteria are:

- Bacterial contamination of drinking water (Total coliforms)
- Total Hardness of the drinking water
- Total Dissolved Solids / Electric Conductivity
- Fluoride
- Nitrates

These parameters represent certain key aspects of water quality and can in general be used to evaluate the quality of water. Total coliforms is generally used to indicate the general hygienic quality of the water tested and to evaluate the integrity of the distribution system while **Total hardness** is used to indicate the presence of elements that contribute to scaling and possible damage to infrastructure (DWAF, 1998a). **Total dissolved solids / Electric conductivity** is used to indicate the concentration of dissolved elements

in the water. Fluoride was chosen as a parameter because it is an essential part of the human diet, but it may have detrimental effects on human health if consumed in excessive quantities (DWAF, 1998a). The Nitrate concentration in water may indicate the presence of faecal pollution, therefore it was also chosen as a parameter to be studied.

A brief discussion on each of the criteria is provided below. It may be noted that this study will discuss three prominent standards used in South Africa to evaluate the quality of drinking water. These standards are the 1996 Department of Water Affairs and Forestry - South African Water Quality Guidelines: Volume 1 – Domestic Use (DWAF, 1996); the 1998 The Department of Water Affairs and Forestry - Quality of domestic water supplies, Volume 1: Assessment Guide (DWAF, 1998a) and the 2006 South African National Standard: Drinking Water - SANS 241:2006. These three standards are discussed for comparative purposes (Standards South Africa, 2006).

2.1.1 Total coliforms

A wide variety of pathogenic viruses, protozoa and bacteria may be transmitted by water. These micro-organisms cause diseases such as gastroenteritis, giardiasis, hepatitis, typhoid fever, cholera, salmonellosis, dysentery and eye, ear, nose and skin infections, which have worldwide been associated with polluted water (DWAF, 1996).

Indicator organisms are generally used for routine monitoring of the potential presence of pathogens in water.

Total coliform bacteria are frequently used to assess the general hygienic quality of water and to evaluate the efficiency of drinking water treatment and the integrity of the distribution system. They should not be detectable in treated water supplies. If found, they indicate inadequate treatment, post-treatment contamination and / or after-growth or an excessive concentration of nutrients. In some instances they may indicate the presence of pathogens responsible for the transmission of infectious diseases (DWAF, 1996).

Total coliforms comprise a heterogeneous group which include bacteria from the genera *Escherichia*, *Citrobacter*, *Enterobacter*, *Klebsiella*, *Serratia* and *Rahnella*. Although most of these bacteria are of faecal origin, some bacteria classified as coliforms are not of faecal origin (DWAF, 1996).

The total coliform group include bacteria of faecal origin and indicate the possible presence of bacterial pathogens such as *Salmonella spp.*, *Shigella spp.*, *Vibrio cholerae*, *Campylobacter jejuni*, *C. coli*, *Yersinia enterocolitica* and *pathogenic E. coli*, especially when detected in conjunction with other faecal coliforms. These organisms can cause diseases such as gastroenteritis, salmonellosis, dysentery, cholera and typhoid fever (DWAF, 1996). A person who has contracted a water-related infectious disease should receive medical attention.

Total coliform counts are primarily used in the evaluation of water treatment processes. They indicate microbial growth in the distribution system or post-treatment contamination of drinking water (DWAF, 1996).

Table 1 is a summary of the possible effects of Total coliforms. This table originates from the DWAF Water Quality Guidelines published in 1996. The health effects of the various concentrations of Total coliforms are presented in this table.

Table 1: Effects of Total coliforms on Human Health (DWAF, 1996)

Total Coliform Range (count / 100ml)	Effects
Target water quality range 0 – 5	Negligible risk of microbial infection
5 – 100	Indicative of inadequate treatment, post-treatment contamination or growth in the distribution system. Risk of infectious disease transmission with continuous exposure and a slight risk with occasional exposure.
> 100	Indicative of poor treatment, post-treatment contamination or definite growth in the water distribution system. Significant and increasing risk of infectious disease transmission.

Table 2 illustrates the effects of Total coliforms as found in the Quality of Domestic Water Supplies – Volume 1: Assessment Guide (DWAF, 1998a). It may be noted that according to this standard, the Total coliform count should be less than 10 per 100ml for the water to be classified as safe for human consumption. The SANS 241:2006 water quality standard corresponds to this value. It may be noted that the Total coliform count doesn't necessarily correspond to aesthetic aspects of water. The 1996 Water quality guideline suggests a target water quality range of between 0 and 5 counts per 100ml. This is stricter than the 1998 guideline as well as the SANS 241:2006 drinking water quality standard (DWAF, 1998a; Standards South Africa, 2006).

Table 2: Total coliforms guideline (DWAF, 1998a)

Total coliforms range (Counts/100ml)	Drinking		Food preparation	Bathing	Laundry
	Health	Aesthetic			
0	No detectable chance of infection	No effects	No detectable chance of infection	No effects	No effects
0 – 10	Insignificant chance of infection	No effects	Insignificant chance of infection	Insignificant effects	Insignificant effects
10 – 100	Clinical infections unlikely in healthy adults, but may occur in sensitive groups	No effects	Clinical infections unlikely in healthy adults, but may occur in sensitive groups	Insignificant effects	Insignificant effects
100 – 1000	Clinical infections common, even with once-off consumption	No effects	Clinical infections common, even with once-off consumption	Slight risk	Slight risk
> 1000	Serious health effects common in all users	No effects	Serious health effects common in all users	Possibility of infection	Possibility of infection

2.1.2 Total hardness

The current definition of **total hardness** is the sum of the calcium and magnesium concentrations, expressed as mg/l of calcium carbonate. Other metals such as strontium, iron, aluminium, zinc and manganese may occasionally contribute to the hardness of water, but the calcium and magnesium hardness usually predominates. Temporary hardness is due to the presence of bicarbonates of calcium and magnesium and can be removed by boiling, whereas permanent hardness is attributed to other salts such as sulphate and chloride salts, which cannot be removed by boiling (DWAF, 1996).

Excessive hardness of water can give rise to scaling in plumbing and household heating appliances and hence has adverse economic implications. It also poses a nuisance in personal hygiene. Excessive softness on the other hand, may lead to aggressive and corrosive water qualities which are of concern where copper plumbing installations are used (DWAF, 1996).

The natural hardness of water is influenced by the geology of the catchment area and the presence of soluble calcium and magnesium minerals. Total hardness of water varies and ranges from 0 - 1 000 mg CaCO₃ /l.

Water hardness depends on whether it is caused by bicarbonate salts or non-bicarbonate salts, such as chloride, sulphate and nitrate. Bicarbonate salts of calcium and magnesium precipitate on heating and cause scaling in hot water systems and appliances, whereas the non-bicarbonate salts do not precipitate on heating (DWAF, 1996).

Table 3 illustrates the effects of Total hardness in water. Water with a Total hardness expressed as mg/l CaCO₃ of between 0 and 300 is considered ideal for human consumption. Water with a very low Total hardness may be harmful to appliances as can be seen in the fifth column of the following figure. It is therefore recommended that Total hardness concentration be between 50 and 150 mg/l CaCO₃ in order to obtain a balance between usability for drinking as well as well as other household purposes.

Table 3: (Total) hardness guideline (DWAF, 1998a)

Total hardness as CaCO ₃ (mg/l)	Drinking		Food preparation	Bathing	Laundry
	Health	Aesthetic			
0 – 25 (very soft)	No effects	No effects	No effects	Ideal lathering of soap	Ideal lathering, but corrosion of appliances
25 – 50 (soft)	No effects	No effects	No effects	Insignificant impairment of lathering	Insignificant impairment of lathering, but some corrosion of appliances
50 – 100 (moderately soft)	No effects	No effects	No effects	Insignificant impairment of lathering	Insignificant impairment of lathering. Some protection against corrosion
100 – 150 (slightly hard)	No effects	No effects	Slight scaling of appliances	Lathering slightly impaired	Lathering slightly impaired
150 – 200 (moderately hard)	No effects	No effects	Some scaling of appliances	Lathering impaired	Lathering impaired, some scaling
200 – 300 (hard)	Insignificant effects	Insignificant effects	Scaling of appliances	Increased impairment of lathering	Lathering impaired, increased scaling
300 – 600 (very hard)	Possible chronic effects in sensitive groups only	Effect on taste	Severe scaling of appliances	Lathering severely impaired	Lathering severely impaired, severe scaling
> 600 (extremely hard)	Chronic effects in sensitive groups only	Marked effect on taste	Very severe scaling of appliances	Lathering severely impaired	Lathering severely impaired, extreme scaling

2.1.3 Total Dissolved Solids / Electrical Conductivity

The total dissolved solids (TDS) is used as a measure of the amount of various inorganic salts dissolved in water. The TDS concentration is directly proportional to the electrical conductivity (EC) of water. Since EC is much easier to measure than TDS, it is routinely used as an estimate of the TDS concentration (DWAF, 1996).

Electrical conductivity (EC) is a measure of the ability of water to conduct an electrical current. This ability is a result of the presence of ions in water such as carbonate, bicarbonate, chloride, sulphate, nitrate, sodium, potassium, calcium and magnesium, all of which carry an electrical charge. Most organic compounds dissolved in water do not dissociate into ions, consequently they do not affect the EC (DWAF, 1996).

For most natural waters electrical conductivity is related to the dissolved salt concentration by a conversion factor ranging from 5.5 - 7.5. The average conversion factor for most waters is 6.5.

Low concentrations of particularly calcium and magnesium salts have nutritional value, although water with an extremely low TDS concentration may be objectionable because of its flat, insipid taste. Health effects related to TDS are minimal at concentrations below 2000 - 3000 mg/l TDS. In contrast, high concentrations of salts impart an unpleasant taste to water and may also adversely affect the kidneys. Some of the physiological effects which may be directly related to high concentrations of dissolved salts include (DWAF, 1996):

- laxative effects, mainly from sodium sulphate and magnesium sulphate.
- adverse effects of sodium on certain cardiac patients and hypertension sufferers;
- effects of sodium on women with toxemia associated with pregnancy; and
- some effects on kidney function.

Bathing and washing in water with excessively high concentrations of TDS may give rise to excessive skin dryness and hence discomfort. Soap may lather poorly or with difficulty.

Table 4 illustrates the health effects of Total Dissolved Solids and EC. The 1996 DWAF water quality guideline sets the target range for EC between 0 and 70 mS/m and the corresponding target for TDS at 0 to 450 mg/l.

Table 4: Effects of TDS and EC on Human Health, Aesthetics, Household Distribution Systems (DWAf, 1996).

TDS Range (mg/l)	EC Range (mS/m)	Aesthetic / Economic Effects	Health Effects
Target Water Quality Range 0 - 450	0 - 70	<p>The taste threshold for dissolved solids in water is in the region of 45 mS/m (300 mg/l TDS), hence a slight salty taste may be detected above the concentration. The threshold varies according to the salt composition.</p> <p>Water with extremely low TDS concentrations may be objectionable because of its flat and insipid taste.</p> <p>No effects on plumbing or appliances.</p>	<p>No health effects associated with the electrical conductivity of water are expected < 45 mS/m (300 mg/l TDS).</p> <p><i>The upper limit of this range takes into account the higher water consumption which may be expected in hot climates.</i></p>
450 – 1000	70 – 150	<p>Water has noticeable salty taste, but is well tolerated. No effects on plumbing or appliances.</p>	No health effects are likely.
1000 - 2000	150 – 300	<p>Water has a marked, salty taste and would probably not be used on aesthetic grounds if alternative supplies are available.</p> <p>Some effect on plumbing and appliances such as increased corrosion or scaling may be expected.</p>	Consumption of water does not appear to produce adverse health effects in the short term.
2000 - 3000	300 - 450	<p>Water tastes extremely salty. Corrosion of plumbing and appliances is expected to increase.</p>	Short term consumption may be tolerated, but with probable disturbance of the body's salt balance.
> 3000	> 450	<p>Water tastes extremely salty and bitter. Effects such as corrosion and/ or scaling will increase.</p>	Short term consumption leads to disturbance of the body's salt balance. At high concentrations, noticeable health effects can be expected.

Table 5 illustrates the effects of EC for different domestic uses of water as found in the 1998 DWAF drinking water quality guideline. This table is colour coded in order to assign a water quality class to water based on various uses. This table corresponds to the table found in the 1996 guideline by the same government department.

Table 5: Electrical conductivity (EC) and Total Dissolved Solids (TDS) guideline (DWAF, 1998a)

Electrical conductivity range EC: mS/m (TDS: mg/l)	Drinking		Food preparation	Bathing	Laundry
	Health	Aesthetic			
EC: <70 mS/m (TDS: < 450 mg/l)	No effects	Water tastes fresh	No effects	No effects	No effects
EC: 70 – 150 (TDS: 450 – 1000)	Insignificant effect in sensitive groups	Water tastes good	Insignificant effect in sensitive groups	No effects	No effects
EC: 150 – 370 (TDS: 1000 – 2400)	Slight possibility of salt overload in sensitive groups	Water has a distinctly salty taste	Slight possibility of salt overload in sensitive groups	No effects	Insignificant corrosion
EC: 370 – 520 (TDS: 2400 – 3400)	Possible health risks to all individuals	Water tastes extremely salty	Possible health risks to all individuals	Impaired soap lathering	Slightly corrosive
EC: > 520 (TDS: > 3400)	Increasing risk of dehydration	Tastes extremely salty and bitter	Increasing risk of dehydration	Impaired soap lathering	Corrosive

It is clear from the table above that the EC of domestic water should ideally be within 0 to 150 mS/m and the corresponding TDS value should be in the range of 0 to 1000 mg/l.

2.1.4 Fluoride

Common fluoride minerals are fluor-spar and fluor-apatite, a calcium fluoro- 2 phosphate. Others of importance include various fluoro-silicates and mixed fluoride salts, such as cryolite.

Typically the concentration of fluoride in (DWAF, 1996):

- unpolluted surface water, is approximately 0.1 mg/l;
- ground water, is commonly up to 3 mg/l, but as a consequence of leaching from fluoride containing minerals to ground water supplies, a range of 3 - 12 mg/l may be found;
- sea water, is approximately 1.4 mg/l.

Fluoride is present in many foods, and water is not the only source thereof. Drinking water is estimated to contribute between 50% - 75% of the total dietary fluoride intake in adults. In domestic water supplies as well as industrial supplies used in the food and beverage industries, the fluoride concentration in the water should not exceed approximately 0.7 mg/l (DWAF, 1996). The Quality of Domestic Water Supplies: Volume 1 Assessment Guide as well as the SANS 241:2006 Drinking water quality standards allow a Fluoride concentration of up to 1 mg/l in drinking water (DWAF, 1998a; Standards South Africa, 2006).

Fluoride is a relatively stable anion which is difficult to remove from water to the required concentration range. Although calcium fluoride is relatively insoluble, its solubility is an order of magnitude higher than the levels which need to be achieved by treatment. The methods for the removal of fluoride include (DWAF, 1996):

- Adsorption in a bed of activated alumina;
- Removal in ion exchange columns along with other anions; and
- Removal in membrane processes such as reverse osmosis and electro dialysis together with virtually all other ions.

If fluoride is ingested, it is almost completely absorbed, where after it is distributed throughout the body. Most of the fluoride is retained in the skeleton and a small proportion in the teeth. Fluoride accumulates most rapidly in the bones of the young, but continues to accumulate up to the age of 55. It is excreted primarily in urine. The rate of fluoride retention decreases with age, and most adults are considered to maintain a steady state whereby accumulation of toxic amounts of fluoride is avoided by a balance between skeletal sequestration and renal excretion. The difference between concentrations

of fluoride that protect tooth enamel and those that cause discolouration is marginal. Discolouration of dental enamel and mottling occurs at concentrations in the range of 1.5 - 2.0 mg/l in persons whose teeth are undergoing mineralisation. Generally, children up to seven years of age are susceptible (DWAF, 1996).

High doses of fluoride interfere with carbohydrate, lipid, protein, vitamin, enzyme and mineral metabolism. Skeletal fluorosis may occur when concentrations of fluoride in water exceed 3 - 6 mg/l and becomes crippling at intakes of 20 - 40 mg/day. This is equivalent to a fluoride concentration of 10 - 20 mg/l, for a mean daily water intake of two litres. Systemic toxicity and interference with bone formation and metabolism occur at high concentrations.

Chronic effects on the kidneys have been observed in persons with renal disorders and rarer problems, including effects on the thyroid gland, which may occur with long-term exposure to high fluoride concentrations. Acute toxic effects at high fluoride doses include haemorrhagic gastroenteritis, acute toxic nephritis and injury to the liver and heart- muscle tissues. Many symptoms of acute fluoride toxicity are associated with the ability of fluoride to bind to calcium. Initial symptoms of fluoride toxicity include vomiting, abdominal pain, nausea, diarrhoea and convulsions (DWAF, 1996).

Table 6 illustrates the health effects of fluoride as found in the 1996 DWAF drinking water quality guideline. The target water quality range for fluoride as set out in this guideline is between 0 and 1mg/l. Levels higher than 1mg/l may pose health risks to individuals.

Table 6: Effects of Fluoride on Aesthetics and Human Health (DWAf, 1996)

Fluoride range (mg/l)	Effects
Target water quality range 0 – 1.0	The concentration in water necessary to meet requirements for healthy tooth structure is a function of daily water intake and hence varies with annual maximum daily air temperature. A concentration of approximately 0.75 mg/l corresponds to a maximum daily temperature of approximately 26°C - 28°C. No adverse health effects or tooth damage occurs.
1.0 – 1.5	Slight mottling of dental enamel may occur in sensitive individuals. No other health effects are expected.
1.5 – 3.5	The threshold for marked dental mottling with associated tooth damage due to softening of enamel is 1.5mg/l. Above this, mottling and tooth damage will probably be noticeable in most continuous users of the water. No other health effects occur.
3.5 – 4.0	Severe tooth damage especially to infants' temporary and permanent teeth; softening of the enamel and dentine will occur on continuous use of the water. Threshold for chronic effects of fluoride exposure, manifest as skeletal effects. Effects at this concentration are detected mainly by radiological examination.
4.0 – 6.0	Severe tooth damage especially to the temporary and permanent teeth of infants; softening of the enamel and dentine will occur on continuous use of the water. Skeletal fluorosis occurs after long term exposure.
6.0 – 8.0	Severe tooth damage as above. Pronounced skeletal fluorosis occurs after long term exposure.
> 8.0	Severe tooth damage as above. Crippling skeletal fluorosis is likely to appear after long-term exposure.
> 100	Threshold for the onset of acute fluoride poisoning, marked by vomiting and diarrhoea.
> 2000	The lethal concentration of fluoride is approximately 2000 mg/l.

Table 7 further illustrates the effects of fluoride for different domestic uses of water. It is clear from the figure that the concentration of fluoride in water should ideally be kept within 0 and 1 mg/l in order to avoid effects on the health of consumers. This table can be found in the 1998 DWAf drinking water quality guideline.

Table 7: Fluoride guideline (DWAF, 1998a)

Fluoride range (mg/l)	Drinking		Food preparation	Bathing	Laundry
	Health	Aesthetic			
< 0.7	No health effects	No effects	No effects	No effects	No effects
0.7 – 1.0	Insignificant health effects in sensitive groups and insignificant tooth staining	No effects	Insignificant health effects in sensitive groups	No effects	No effects
1.0 – 1.5	Increasing effects in sensitive groups and tooth staining	No effects	Increasing effects in sensitive groups	No effects	No effects
1.5 – 3.5	Possible health effects on all individuals and marked tooth staining	No effects	Possible health effects in all individuals	No effects	No effects
> 3.5	Increasing risk of health effects and severe tooth staining	No effects	Increasing risk of health effects	No effects	No effects

2.1.5 Nitrate

Under oxidising conditions nitrite is converted to nitrate, which is the most stable positive oxidation state of nitrogen and far more common in the aquatic environment than nitrite.

Nitrate in drinking water is primarily a health concern in that it can be readily converted in the gastrointestinal tract to nitrite as a result of bacterial reduction (DWAF, 1996).

Concentrations of nitrate in water are typically less than 5 mg/l of nitrate-nitrogen (or, alternatively, 22 mg/l nitrate). A significant source of nitrates in natural water results from the oxidation of vegetable and animal debris and of animal and human excrement. Treated sewage wastes also contain elevated concentrations of nitrate (DWAF, 1996).

Nitrate tends to increase in shallow groundwater sources in association with agricultural and urban runoff, especially in densely populated areas. Nitrate, together with phosphates, stimulate plant growth. In aquatic systems elevated concentrations generally give rise to the accelerated growth of algae and the occurrence of algal blooms. Algal blooms may subsequently cause problems associated with malodours and tastes in water and the possible occurrence of toxicity (DWAF, 1996).

Interactions with nitrate are present with all conditions associated with the presence or breakdown of organic matter. For example, enrichment of waters with dissolved organic carbon can increase the rate of de-nitrification by providing an energy source for the denitrifying bacteria (DWAF, 1996).

Upon absorption, nitrite combines with the oxygen-carrying red blood pigment, haemoglobin, to form methaemoglobin, which is incapable of carrying oxygen. This condition is termed methaemoglobinaemia. The reaction of nitrite with haemoglobin can be particularly hazardous in infants under three months of age and is compounded when the intake of Vitamin C is inadequate (DWAF, 1996).

Metabolically, nitrates may react with secondary and tertiary amines and amides, commonly derived from food, to form nitrosamines which are known carcinogens. A diet, adequate in Vitamin C, partially protects against the adverse effects of nitrate/nitrite. Methaemoglobinaemia in infants can only be mitigated by blood transfusion (DWAF, 1996).

Table 8: Effects of Nitrate/Nitrite on Human Health (DWAF, 1996)

Nitrate / nitrite range (as mg/l N)	Effects
Target water quality range 0 - 6	No adverse health effects
6 – 10	Rare instances of methaemoglobinaemia in infants; no effects in adults. Concentrations in this range generally well tolerated.
10 – 20	Methaemoglobinaemia may occur in infants. No effects in adults.
> 20	Methaemoglobinaemia occurs in infants. Occurrence of mucous membrane in adults.

Table 8 illustrates the health effects of nitrate / nitrite in water. This table can be found in the 1996 DWAF drinking water quality guideline. This guideline indicates that the ideal levels of Nitrate as N is in the range of 0 to 6mg/l.

Table 9 illustrates the effects of nitrate / nitrite in water used as domestic water as found in the 1998 DWAF drinking water quality guideline.

Table 9: Nitrate and Nitrite guideline (DWAF, 1998a)

Nitrate & Nitrite range mg/l as N or (mg/l as NO ₃)	Drinking		Food preparation	Bathing	Laundry
	Health	Aesthetic			
< 6 mg/l as N (< 26 mg/l as NO ₃)	Negligible health effects	No aesthetic effects	Negligible health effects	No effects	No effects
6 – 10 mg/l as N (26 – 44 mg/l as NO ₃)	Insignificant risk	No aesthetic effects	Insignificant risk	No effects	No effects
10 – 20 mg/l as N (44 – 89 mg/l as NO ₃)	Slight chronic risk to some babies	No aesthetic effects	Slight chronic risk to some babies	Insignificant risk	No effects
20 – 40 mg/l as N (89 – 177 mg/l as NO ₃)	Possible chronic risk to some babies	No aesthetic effects	Possible chronic risk to some babies	Slight risk to babies only	No effects
> 40 mg/l as N (> 177 mg/l as NO ₃)	Increasing acute health risk to babies	No aesthetic effects	Increasing acute health risk to babies	Possible health risk to babies	No effects

2.3 Influence of water quality on human health

According to Vivier (2006:25), the most significant impacts with regard to poor sanitation are ground- and surface water pollution, which in turn affects human and aquatic health negatively.

Vivier (2006:25) also states that according to available global evidence, the two most important ways in which environmental quality has a negative impact on the health of the poor is through water and indoor air pollution. Respiratory infection and diarrhoeal diseases are the two biggest causes of death among the poorest 20 % of the world's countries as ranked by national Gross Domestic Product (GDP) per capita. Morris (2004) writes that a child dies every 15 seconds due to water related diseases and that countless children do not attend school because of ill health, lack of sanitation facilities, or the amount of time they spend fetching water for their communities.

The World Health Organisation (WHO) states that there are 1.7 million deaths every year which can be attributed to unsafe water, sanitation and hygiene, mainly through infectious diarrhoea. This reflects the global impact of waterborne diseases. The vast majority of these deaths are among children under five years of age. An estimated 4 billion cases account for over 82 million Disability Adjusted Life Years (DALY's), representing 5.7 % of the global burden of disease and placing diarrhoeal diseases as the third highest cause of morbidity and sixth highest cause of mortality (Prüss and Havelaar, 2001).

After HIV/AIDS, homicide/violence, tuberculosis and road traffic accidents, diarrhoeal diseases rank as the fifth most important cause of mortality in the entire population in South Africa (Editorial, 2003). Diarrhoeal diseases account for 10.2 % (10 786) deaths in the under 5-age group (Bradshaw et al., 2002; Bradshaw et al., 2003).

The mortality rate associated with diarrhoeal diseases is relatively low. The mortality rate does, therefore, not reflect the large number of infected individuals who suffer from clinical manifestations that range from mild discomfort to severe illness, with far-reaching socio-economic implications (Pegram et al., 1998).

2.3.1 The influence of microbiological aspects

Vivier (2006:25) writes that contaminated drinking water supplies are a major source of waterborne diseases worldwide. In the United States, the concept of waterborne diseases was poorly understood until the late 19th century. During the Civil War (1860 – 1865), encamped soldiers often disposed of their waste upriver, but drew drinking water from downriver. This practice resulted in widespread dysentery. In fact, dysentery, together with typhoid fever was the leading cause of death among

soldiers of all armies until the 20th century (Rusin et al., 2000). In 1890, more than 30 people out of every 100 000 in the United States died of typhoid. By 1907, water filtration was becoming more common in most US cities and in 1914 chlorination was introduced. Because of these new practices, the national typhoid death rate in the United States dropped from 36 to 5 cases per 100 000 people between 1900 and 1928 (Rusin et al., 2000).

The transmission of disease by drinking water was confirmed for the first time in 1876 by John Snow (Vivier, 2006:26). He associated cholera infections with drinking water derived from a hand pump in Broad Street, London. The pioneering discovery was made possible largely by the easy diagnosis of infected individuals. For many years to come, waterborne diseases were almost exclusively associated with bacterial pathogens (Grabow, 1996). More recently, epidemiological data began to reveal that pathogens other than bacteria, notably viruses, are also transmitted by water. The typical example was the hepatitis A virus (Grabow, 1996).

The possible health outcomes associated with exposure to waterborne pathogens are diverse, ranging from no infection to asymptomatic infection, mild to severe illness or mortality. Some of these organisms are opportunistic pathogens that pose little or no threat to healthy adults, but can cause disease in sensitive populations (Vivier, 2006:26).

Typically, investigations of health outcomes associated with waterborne pathogens focus on gastrointestinal illness. However, waterborne pathogens can also cause infections in other organs or systemic illness such as hepatitis, aseptic meningitis, typhoid fever, and respiratory infections. Some of these infections have chronic sequelae that are often overlooked in discussions about waterborne disease (Vivier, 2006:26).

Table 10 gives an overview of Feachem's environmental classification of excreta-related diseases (Feachem et al., 1983). Water borne pathogens are categorized into four main groups of organisms namely viruses, bacteria, protozoa and helminth (Anon, 1999).

Most pathogenic waterborne agents of concern are enteric organisms such as Shigella, Norwalk like viruses and Cryptosporidium that infect and multiply in the gastrointestinal tract of humans. These agents are excreted by faeces and are transmitted by the ingestion of faecal contaminated water or food. Faeces from infected individuals may contain as many as 10⁶ PFU (plaque forming units) of entero-viruses per gram of faeces and 10¹⁰ rotaviruses per gram (Tyrrell & Kapikian, 1982).

Table 10: Organisms associated with water borne transmission (Feachem et al., 1983)

Category	Environmental transmission features	Major examples of infection	Environmental transmission focus
I: Non Bacterial faeco-oral disease	Non Latent Low to medium persistence Unable to multiply High infectivity No intermediate host	Viral: Hepatitis A and E, Rora-virus diarrhoea, Noro-virus diarrhoea Protozoan: Amoebiasis, Cryptosporidiosis, Giardiasis Helmintic: Enterobiasis, Hymenolepiasis	Persona Domestic Wastewater
II Bacterial Faeco-oral disease	Non latent Medium to high persistence Able to multiply Medium to low infectivity No intermediate host	Campylo-bacteriosis Cholera Pathogenic E. coli infection Salmonellosis Typhoid Yersiniosis	Personal Domestic Wastewater Crops
III Geohelminthiasis	Latent Very persistent Unable to multiply No intermediate host Very high infectivity	Ascariasis Hookworm infection Strongyloideiasis Trichuriasis	Peri-domestic Wastewater Crops
IV Taeniasis	Latent Persistent Able to multiply Very high infectivity Cow or pig intermediate host	Taeniasis	Peri-domestic Wastewater Fodder crops
V Water based helminthiasis	Latent Persistent Able to multiply High infectivity Intermediate aquatic hosts	Schistosomiasis Clonorchiasis Fasciolopsiasis	Wastewater Fish Aquatic species Aquatic vegetables
VI Excreta related insect-vector disease		Bancroftian filiarsis transmitted by Culex quinquefasciatus	Wastewater
VII Excreta related rodent vector disease		Leptospirosis	Wastewater

2.3.2 The influence of chemical aspects

According to Rota (2004), the South African Initiative on the World Commission on Dams report listed some 50 eutrophic dams in which nutrients are present in such excess that dissolved oxygen content of the water reduces to the point that living organisms begin to die. Water quality in some river systems has deteriorated to such an extent that conventional purification processes cannot treat the water to acceptable standards (Rota, 2004). Impacts of eutrophication can be summarised as follows (Van Ryneveld et al., 2001):

- Increased cost of water treatment (increased use of chemicals and shorter filter run);
- Formation of tri-halomethanes (THMs) (carcinogenic and cannot be removed by conventional drinking water treatment processes);
- Taste and odour problems in drinking water caused by blue-green algae;
- Extensive anaerobic hypo-limnia in lakes with the resultant adverse effects on lake biota such as oxygen-dependent organisms and lake chemistry such as increased concentrations of iron and manganese;
- Aesthetic problems associated with massive growth of algae and aquatic macro-phytes or both, and when these decay;
- Interference with the recreational uses of water bodies such as swimming, boating, fishing and waterskiing;
- Skin irritations in swimmers;
- Loss of livestock as a result of algal toxins produced by certain algae;
- Fish deaths in saline lakes due to toxin producing algal blooms;
- Adverse effects on adjacent real estate development.

Vivier (2006) writes that excessive nutrients (specifically nitrates) cause problems in themselves in that high nitrates can cause health problems for young infants, especially when contaminated groundwater is used in formula milk. Nitrate can occur naturally in surface and groundwater at a level that does not generally cause health problems. High levels of nitrate in groundwater often result from improper borehole construction, borehole location, overuse of chemical fertilizers, septic systems, or improper disposal of human and animal waste (CDC, 2003). Microbial action in soil or water decomposes wastes containing organic nitrogen first into ammonia, which is then oxidised to nitrite and nitrate. Because nitrite is easily oxidised to nitrate, nitrate is the compound predominantly found in ground- and surface waters. Nitrate toxicity causes methemo-globinemia, and infants younger than 4 months of age are at particular risk of nitrate toxicity from contaminated water. Pregnant women may also be

more sensitive to the induction of clinical methemo-globinemia by nitrites or nitrates at or near the 30th week of pregnancy (CDC, 2003). It has also been reported that nitrates can pass through the mother's milk and affect babies directly (CDC, 2003). Links between high nitrate levels and gastric cancer, congenital deformities, and headaches have also been reported (Jackson, 1998).

The Centre for Disease Control and Prevention in the USA has recommended that persons who use drinking water that contains nitrate levels > 10 mg/L should have alternative sources of drinking water or appropriate treatment of existing supplies (CDC, 2003).

2.4 Intervention strategies

Several intervention strategies exist to manage water resources. Institutional intervention strategies as well as technical intervention strategies are investigated.

2.4.1 Institutional intervention strategies

2.4.1.1 Water use licensing at health facilities

The registration of a water use is required in terms of section 26 (1)(c) and 34(2) of the National Water Act (36/1998) (NWA). There are several reasons why water users are required to register their water use with the Department of Water Affairs. The most important reasons are:

- to manage and control water resources for planning and development;
- to protect water resources against over-use, damage and impacts; and
- to ensure fair allocation of water among users.

Permissible water use is described in section 22 of the National Water Act (36/1998) as (DWAF, 2009):

- A schedule 1 water use;
- The continuation of an existing lawful water use;
- A water use authorised under a General Authorisation; and
- A licensed water use.

Schedule 1 as mentioned above refers to schedule 1 of the NWA which lists a range of permissible water uses. A Schedule 1 water use does not need to be registered or licensed (DWAF, 2009).

The following water use detailed in Schedule 1 need not be registered (DWAF, 2009):

- Taking water directly from any water resource to which a person has lawful access, for:
 - Reasonable domestic use in a person's household;
 - small gardening (but not for commercial purposes); and
 - the watering of animals (but not for commercial purposes, thus excluding feedlots), provided that the use is not excessive in relation to the capacity of the water resource and the needs of other users.
- Storing and using run-off water from a roof;
- In emergency situations, taking water from any water resource for human needs or fire fighting;

- Recreation, if a person has lawful access to that water resource;
- Discharge of waste or water containing waste or run-off water (including storm water) into a canal, sea outfall or other conduit, provided these are controlled by persons that have been authorised to purify, treat or dispose of this wastewater.

Existing Lawful Use refers to any lawful use of water authorised by or under any law which has taken place at any time during the period from 1 October 1996 to 30 September 1998, i.e. the two years before the National Water Act (36/1998) came into effect. Existing Lawful Users will be required to register their use in terms of a Notice issued under the Registration Regulations (DWAf, 2009). Registration is the process of officially notifying the Department of a water use.

Water users should register a water use that fall under a general authorisation. General Authorisations apply only to new water uses that have taken place after 1 October 1999 when the Act was fully promulgated. This means that General Authorisations are not retro-active or “back-dated”.

The General Authorisations describe the conditions under which a water use must be registered. Water users must acquaint themselves with the terms and conditions of the General Authorisations, as there are specific conditions applicable to certain water use.

For a new water use that has started after 8 October 1999 and does not fall within the areas or limits set out in the General Authorisation, the water user must approach the Department for a license. Any new water user who does not comply with the terms and conditions of the General Authorisations must approach the Department for a license. The areas excluded from the General Authorisation are listed in table 4.1 (attached) (DWAf, 2004). Should a facility be connected to a municipal sewer system, the individual facility need not be registered or licensed with the Department. The municipality needs to register or obtain a license with the Department.

Those users engaging in a waste discharge related water use identified in Section 21 (e), (f), (g), (h) and (j) were required to register their water use by 31 August 2009 as specified in Government Gazette 32209, dated 6 May 2009. Registration may be seen as the first step in establishing an entity as a water user with the Department of Water Affairs.

The requirements for registration are outlined in the General Authorisations that were published in Government Gazette No. 399 and 26187, dated 26 March 2004. These requirements are as follows (DWAF, 2004):

Disposal of domestic and/or biodegradable industrial wastewater

4.9. A person who-

(a) owns or lawfully occupies property registered in the Deeds Office as at the date of this notice;

(b) lawfully occupies or uses land that is not registered or surveyed, or

(c) lawfully has access to land on which the use of water takes place,

may on that property or land, outside of the areas set out in Table 4.1, dispose of -

(i) up to 1 000 cubic metres of domestic and/or biodegradable industrial wastewater, on any given day-

(aa) into a wastewater pond system; or

(bb) into an evaporation pond system;

(ii) domestic wastewater or biodegradable wastewater into a wastewater irrigation system as set out under General Authorisation 2 above;

(iii) wastewater to an on-site disposal facility -

(aa) for grey water generated by a single household;

(bb) up to one cubic metre of biodegradable industrial wastewater on any given day; or

(cc) domestic wastewater to a communal conservancy tank serving no more than 50 households;

(iv) domestic wastewater generated by a single household not permanently linked to a central waste collection, treatment and disposal system to an on-site disposal facility; and

(v) storm water runoff from any premises not containing waste or wastewater from industrial activities and premises,

if the disposing of wastewater-

(aA) does not impact on a water resource or on any other person's water use, property or land; and

(bB) is not detrimental to the health and safety of the public in the vicinity of the activity.

Should a water use not fit into the General Authorisation above, the water use should be licensed with the Department of Water Affairs.

Table 11: Subterranean government water control areas excluded from General Authorisation for disposal of waste

Primary drainage region	Tertiary/ Quaternary drainage region	Description of subterranean government water control area	Government Notice No.	Government Gazette Date
H	H30	Baden	136	1967-06-16
A	A30	Bo-Molopo	1324	1963-08-30
C	C30	Bo-Molopo	1993	1965-12-17
D	D41	Bo-Molopo	R634	1966-04-29
A	A24	Crocodile River Valley	208	1981-10-23
A	A21	Crocodile River Valley	18	1983-02-18
A	A21, A22	Kroondal-Marikana	180	1963-06-17
G	G10,G30	Lower Berg River Valley/Saldanha	185	1976-09-10
A, B	A60,B50,B31	Nyl River Valley	56	1971-03-26
G	G30	Strandfontein	2463	1988-12-09
M	M10,M20,M30	Uitenhage	260	1957-08-23
G	G30	Wadrif	992	1990-05-11
G	G20	Yzerfontein	27	1990-02-09
G	G30	Graafwater	1423	1990-06-29
A	A70	Dendron-Vivo	813	1994-04-29
A	A60	Dorpsrivier	312	1990-02-16
C	C24	Ventersdorp	777	1995-06-02

Registration forms consist of Part 1 and Part 2 as well as supplementary forms.

- Part 1 forms – information on the water user and the property where the water use takes place.
- Part 2 forms – information about the water use.
- Supplementary forms – additional information that may be needed.

One Part 1 form and one or more Part 2 forms must be completed to register a water use.

The Provincial Government or the body that is responsible for the health facilities in the Limpopo Province should register with the Department of Water Affairs. This may be done by completing the following registration form:

- DW 758 Company, Business or Partnership; National or Provincial Government.

Thereafter, each health facility not connected to a municipal sewer system should complete the following forms:

- DW 767 Disposing of waste in a manner which may detrimentally impact on a water resource.
- DW 901 Property where water use occurs.
- DW 902 Details of property owner.
- DW 904 Compliance management information: Actual/Monitored Waste Discharge Details applicable for sections 21 (e) and (g).
- DW 905 Supporting technical information for waste disposal facilities (21g water uses).

After completion of all the forms, it should be submitted to the regional office of the Department of Water Affairs. The Department will then evaluate the application.

2.4.2 Technical intervention strategies

According to Greenlee *et al.* (2009) approximately 0.8% of the world's water reserves are considered fresh water. About a further 1% of the earth's water is made up of brackish water, salty water found as surface water in estuaries and groundwater found in salty aquifers. As stated earlier in this thesis, South Africa may be considered a country under water stress.

The health facilities included in this study, regularly only have brackish groundwater or contaminated groundwater as sole water supply. Several intervention strategies exist to combat this problem. The following treatment options are well recognised as ways to improve water quality:

- Reverse osmosis
- Ion Exchange
- Ultraviolet treatment
- Chlorination

These treatment options are discussed below:

2.4.2.1 Reverse Osmosis

According to Nicolaisen (2002), membrane technology is a widely accepted means of producing various qualities of water from surface water, groundwater, sea water or brackish water. Reverse osmosis is a technique of hyper-filtration that allows for the removal of particles as small as ions from solutions. This technique is used to purify water by the removal of salts and other dissolved ions and impurities, which result in improved colour, taste, overall quality of the water, to meet water quality demands of a country or region.

During the process of reverse osmosis, a semi-permeable membrane allows the fluid being purified to pass through it, whilst rejecting the contaminants present. Most of these technologies use a process known as 'cross flow' to allow the membrane to clean itself. A driving force generated from a pump pushes the fluid through the membrane, and the larger the pump, the larger the driving force. Nicolaisen (2002) writes that in many cases one membrane process is followed by another in order to produce water of increasing quality in order to meet various standards.

Reverse osmosis is capable of rejecting bacterial substances, salts, sugars, proteins, particles, dyes and other solutes that have a molecular weight greater than 150-250 Daltons. The separation of ions from solution is aided by the presence of charges on the solutes. Dissolved ions with larger charges, such as salts, are more likely to be rejected by the membrane than those that are not charged, such as organic compounds. Larger charges are more likely to be rejected than smaller charges.

Reverse osmosis plants vary in size to accommodate different applications. Small low-pressure reverse osmosis modules fed from a domestic supply-line, reliably produce potable water for household consumption and are easily replaced after one to three years if the membrane becomes fouled through scaling. Large-scale treatment is achieved with banks of reverse osmosis modules in parallel. Most large-scale processes however require high levels of design, operator and maintenance skills. Furthermore, all processes produce a concentrated waste stream of the salts removed from the water and may cause disposal difficulties.

2.4.2.2 Ion exchange

Ion exchange is a water purification technique that involves two similar principles, namely water softening and de-ionisation. Water softening is the process of removing ions from water and replacing them with sodium ions and chloride ions. Its common application is at homes to reduce water hardness and improve taste. In the de-ionisation process, ions present in the water are removed and replaced by H^+ and OH^- ions which can combine with water. This process also removes hardness and improves taste, and it is used in circumstances where extremely pure water is required. During ion exchange in water softening, resins (little beads that are charged) are coated with NaCl. Water flows over the beads, and the ions in the water are attracted to the resin. The ions on the water attach themselves to the resin, and knock off the ions that are already attached. The resin is exhausted when all the replacement ions are gone. Regeneration of the resins involves application of a strong solution of the replenishment ions to the resin. This process removes the ions that came from the water and regenerates the resin (Apell & Boyer, 2010).

Apell and Boyer (2010) have found that hardness in water is commonly of economic concern to water users. Excessive hardness in water may result in infrastructure damage as stated in the previous section (DWAF, 1996). Lime softening is sometimes used for softening of water, but it does have limitations, according to Apell and Boyer (2010). Lime softening for example, is limited by the solubility of calcite and the removal of carbonate hardness. Cation exchange is an alternative for the removal of hardness and has been extensively used for point-of-use softening of water (Apell & Boyer, 2010). It was also found that cation exchange treatment may be beneficial as a pre-treatment for membrane treatment processes.

Anion exchange, in particular magnetic ion exchange (MIEX) is an alternative to coagulation for the removal of Dissolved Organic Matter (DOM) from water. MIEX resin is designed to be used as slurry in a complexly mixed flow reactor or fluidised bed reactor. This implies that a MIEX reactor is used as a pre-treatment process to treat unfiltered water at the beginning of a treatment train. MIEX was found to be very effective in the removal of DOM from untreated water. Apell and Boyer (2010) found that MIEX pre-treatment has the potential to reduce membrane fouling by DOM.

Cation exchange is used to remove calcium and other divalent cations to prevent the precipitation of sparingly soluble minerals, such as calcium sulphate and calcium carbonate. It was also found that fouling of membrane treatment technology may largely be reduced by the use of cation

exchange as a pre-treatment. Combined anion and cation exchange is expected to substantially decrease membrane fouling by simultaneously removing DOM and divalent cations (Apell & Boyer, 2010).

Nitrate is a common problem in raw water supply, but is not readily removed from domestic water supplies. Some reduction of nitrate may be achieved using slow sand filtration, but the method is not reliable. Biological reduction of nitrate to nitrogen gas (de-nitrification) is feasible in the presence of a suitable carbon source, but the increase in carbonaceous matter is not compatible with a high quality water supply. Non-specific methods of removing nitrate include (DWAF, 1996) the passing of the raw water through an ion exchange column with a selective affinity for nitrates. This method may be attractive on a small / household scale where only water used for drinking purposes is treated.

2.4.2.3 Ultraviolet treatment

Ultraviolet treatment was first used to disinfect drinking water in the early 1900s but was abandoned shortly thereafter due to high cost, reliability concerns and the advent of chlorination. Electromagnetic radiation is an effective agent for micro-organism inactivation in the wavelengths ranging from 240 to 280nm by causing fatal damage to their nucleic acid. It was found that the most potent wavelength for DNA damage is 260nm. The inactivation of microorganisms by UV is proportional to the intensity multiplied by the time of exposure. The product of the intensity and the exposure time is termed the UV dose. The actual UV dose received by the micro-organism depend on a number of factors, such as the flow-rate of the water through the UV system, the transmission efficiency of the water and the geometry of the UV radiation chamber (Wolfe, 1990; Naunovic et al., 2008).

Wolfe (1990) found that by comparing the performance of UV treatment to Chlorination as a method of disinfection in the field, UV was a more potent virucide than chlorine. It was also found that UV was comparable to chlorination for the inactivation of heterotrophic plate count bacteria in water that had been treated with granular activated carbon. Wolfe (1990) also recognises the need for a post-disinfectant, in order to maintain the integrity of the treated water, seeing that UV does not have a residual effect similar to chlorine. Free chlorine may be added for residual maintenance prior to storage of the product water.

UV treatments systems are also prone to fouling and therefore need regular maintenance. Wolfe (1990) found that bio-fouling may occur on the lamp surface which may reduce the efficiency of the lamp. The biggest challenge, according to Wolfe (1990) is to reliably determine the correct UV dose to be applied in order to effectively disinfect water. It is also recognised that bacterial re-growth may occur after disinfection. This may occur when the water is exposed to light. In these conditions, bacteria may repair their damaged DNA in a process called photo-reactivation (Wolfe, 1990).

The efficiency of UV treatment depends on the absorption of UV light into the micro-organisms. Anything that prevents UV light from entering the micro-organism thereby preventing UV light from reacting with the microorganism will impair the disinfection. Conditions that interfere with the disinfection process include chemical and biological films that develop on the surface of the lamp; clumping, or aggregation of microorganisms, which has a protective effect; turbidity, colour, dissolved organics and in-organics and short circuiting of the water flowing through the exposure chamber. UV disinfection however appears to be independent of water temperature and pH. The chemical composition of the water entering the UV treatment units have to be monitored and managed and regular maintenance should be conducted on the units to ensure optimal performance of the treatment units (Wolfe, 1990).

2.4.2.4 Chlorination

Chlorination is a widely accepted method of disinfection of drinking water. Chlorination is a very efficient and cost effective disinfectant which and has been used for more than 150 years in this application. The first application of chlorine as a disinfectant was in 1850 by John Snow when he attempted to disinfect the Broad Street water pump in London after an outbreak of cholera. Simms Woodhead used a bleach solution as a disinfectant to treat drinking water in Maidstone, Kent, England in 1897 following a typhoid outbreak (Christman, 1998).

The continuous use of chlorination as a treatment method began in the early 1900's in Great Britain where it greatly reduced typhoid deaths. The large scale use of chlorination in the United States of America started in 1908 in Jersey City, New York. Other cities and towns soon followed (Christman, 1998).

According to Christman (1998), chlorine's most important attributes are its broad-spectrum

germicidal potency and persistence in water distribution systems, providing residual protection against microbial re-growth. It also is used to control taste and odour problems by oxidizing many naturally occurring substances such as foul-smelling algae secretions, odours from decaying vegetation, hydrogen sulphide and ammonia.

Christman (1998) further writes that Chlorinated drinking water's chief benefit is the protection of public health through the control of waterborne diseases. It plays a paramount role in controlling pathogens in water that cause human illness, as evidenced by the virtual absence of waterborne diseases such as typhoid and cholera in developed countries.

Christman (1998) found that untreated or inadequately treated drinking water supplies, remain the greatest threat to public health, especially in developing countries, where nearly half the population drinks contaminated water. In these countries, diseases such as cholera, typhoid and chronic dysentery are endemic and kill young and old alike. In 1990, over three million children under the age of five died of diarrheal diseases. Unfortunately, the availability of safe drinking water in many areas is practically nonexistent, due to poverty, poor understanding of water contamination, and lack of a treatment and delivery infrastructure.

The World Health Organisation still regards chlorination as the best disinfectant and Christman (1998) is of meaning that this will not change in the near future.

3 STUDY AREA

The study area comprises of the Limpopo Province. In order to obtain background knowledge on the Province, the climate and topography of the Province is described. The geology, social factors and basic geo-hydrological principals are also investigated.

3.1 Environmental overview of study area

3.1.1 Climate and topography

Climate is largely influenced by topographical features. The dominant topographical feature of the Limpopo Province is the Drakensberg range to the east, which is orientated from north to south at an elevation of 1 500 to 1 800 metres above sea level. Other mountain ranges in the Province include the Waterberg range to the west as well as the Soutpansberg range to the north.

To the west of the Limpopo Province, the headwaters of the Limpopo-Olifants system flows firstly in a generally northward direction before turning eastward towards Mozambique and then on to the Indian Ocean. The continental divide (1 600m above sea level), which lies at a right angle to the Drakensberg, separates the Orange-Vaal drainage system from the Limpopo-Okavango-Zambezi system. To the west of this continental divide, the land mass tilts to the Atlantic Ocean and to the east of the divide the land mass tilt towards the Indian Ocean. The whole of the Limpopo Province falls within the latter drainage region – the Limpopo-Okavango-Zambezi system (Midgley *et al.*, 1994).

The Witwatersrand in Gauteng Province, with its mining, industrial and commercial activities, forms a very important part of the continental divide. To the north and west of the Witwatersrand the landscape gradually changes from rolling hills to gently sloping and finally to flat terrain. When appraising the water resources of the main stem of the Limpopo River, one should bring into account the run-off contributions from neighbouring Zimbabwe and Botswana (Midgley *et al.*, 1994).

According to Midgley *et al.* (1994) the Mean Annual Precipitation (MAP) in the Province reaches as much as 2,000 mm or more along the Drakensberg and the Soutpansberg, but the annual average rainfall generally averages between 800 and 1,000 mm in the mountainous areas and drops to about half this value along the lower lying Limpopo and Olifants Rivers. Mean Annual Evaporation (MAE) is generally about 1,400 mm along the Drakensberg, rising as one proceeds northwards, westwards or

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eastwards to more than 2,000 mm. Mucina and Rutherford (2006) state that outside of the Kalahari regions most of the Savannah experiences a MAP of between 500 mm and 750 mm. Most of the Savannah has its rainfall concentrated in mid-summer.

The rivers in the study area are non-perennial and flow only for short periods after heavy rain events. According to the South African Aquifer System Management Classification system, the aquifers in the study area are generally classified as Sole Source Aquifer Systems, which can be defined as:

“An aquifer which is used to supply 50 % or more of domestic water for a given area, and for which there are no reasonably available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.” (Parsons, 1995).

Mining development, as well as agriculture, compete for the scarce natural water resources in the Limpopo-Olifants basin. This is even more pronounced in the upper Olifants River and the north-western parts of the Limpopo River systems. Minerals mined in the Limpopo Province include coal, chromium, platinum group metals, iron ore, phosphates and fluorspar (Midgley *et al.*, 1994).

The average summer maximum temperature for the region is often between 26°C and 32°C. In winter the maximum temperatures remain above 18°C. Frost may occur in winter in some parts of the study area. Only the lower-lying parts of the Mopane, Lowveld and Sub-Escarpment Savannah Bioregions can be regarded as frost free.

3.2 Geological overview of study area

3.2.1 Basic geological formations in study area

The geological history of South Africa is a long and complex one going back some 3 700 million years (Ma). The foundation upon which the geological formations of South Africa have subsequently developed is the Kaapvaal Craton, which occupies the north-eastern part of the country (Wilson, 2010; Mucina & Rutherford, 2006:442). This ancient crustal block is made up largely of Archaean tonalitic and trondhjemitic gneisses and granitoids, along with lesser volumes of metamorphosed volcano-sedimentary rocks known as greenstone belts. The greenstone occurrences are economically important, hosting many gold, antimony, copper, zinc, iron, asbestos, talc, mercury, magnesite, barite and gemstone deposits (Wilson, 2010).

Viljoen and Reimold (1999) identify the Murchison Range, the Phalaborwa Complex and the eastern Bushveld complex as geological features important to mining activities in the Province.

The town of Gravelotte is at the centre of the Murchison Range. The Murchison Belt, like the Barberton Belt, hosts a number of small gold deposits. It also hosts a number of small antimony-gold deposits. This belt contains deposits of zinc, copper, pegmatites, emeralds, beryl, lithium, tantalum, feldspar, corundum and mica (Viljoen & Reimold, 1999:109).

The Phalaborwa Complex is an ancient igneous intrusion into the granitic rocks that form part of the Kaapvaal Craton. These older granites form the very flat topography of the Lowveld whereas the rocks of the Phalaborwa Complex are more resistant to erosion and provide topographic relief in the form of small hills around the town of Phalaborwa (Viljoen & Reimold, 1999:112).

The Barberton Super-group is the most significant gold-producing greenstone belt in South Africa, whilst the Murchison Belt, made up of rocks of the Gravelotte Group, continues to be an important source of antimony, gold, zinc and copper. The Archaean granites and gneisses are generally poorly mineralised, but do host some pegmatite minerals (including quartz, feldspar, mica, beryllium, spodumene, lepidolite, tantalum, scheelite and tin), corundum, graphite, copper and gold in places. Both the gneisses and greenstones have been folded, faulted and intruded by younger igneous bodies (Wilson, 2010).

The geological feature that dominates the Limpopo-Olifants River basin is the Bushveld Igneous Complex which is very rich in minerals. The Rustenburg Layered Suite comprises of the mafic rocks of the Bushveld Igneous Complex. This Suite is renowned for its vast platinum-group deposits. Also to be found in the south-western as well as the north-western regions of this basin are vast coalfields containing possibly more than 66% of the known coal reserves in Africa (Midgley *et al.*, 1994; Viljoen & Reimold, 1999:116).

Further to the north of the Province, the Limpopo belt can be found. This belt is situated between the Zimbabwe and Kaapvaal Cratons and straddles the northern border between Zimbabwe and South Africa and stretches as far south as Bandelierkop. This belt represents a classic example of a late Archaean, high-grade metamorphic gneiss terrain (Viljoen & Reimold, 1999:126).

The Potgietersrus (Mokopane) area is characterised by the occurrence of so-called red beds. These are formations that contain iron oxides hence the red colour from which its name is derived. Waterberg Group rocks are largely a red-bed succession and outcrop in a number of locations in the Kaapvaal Craton including the Warmbad-Vaalwater-Ellisras (Belabela-Vaalwater-Lephalale) area and the Soutpansberg.

The following map (Figure 1) illustrates the dominant geology in the Limpopo Province.

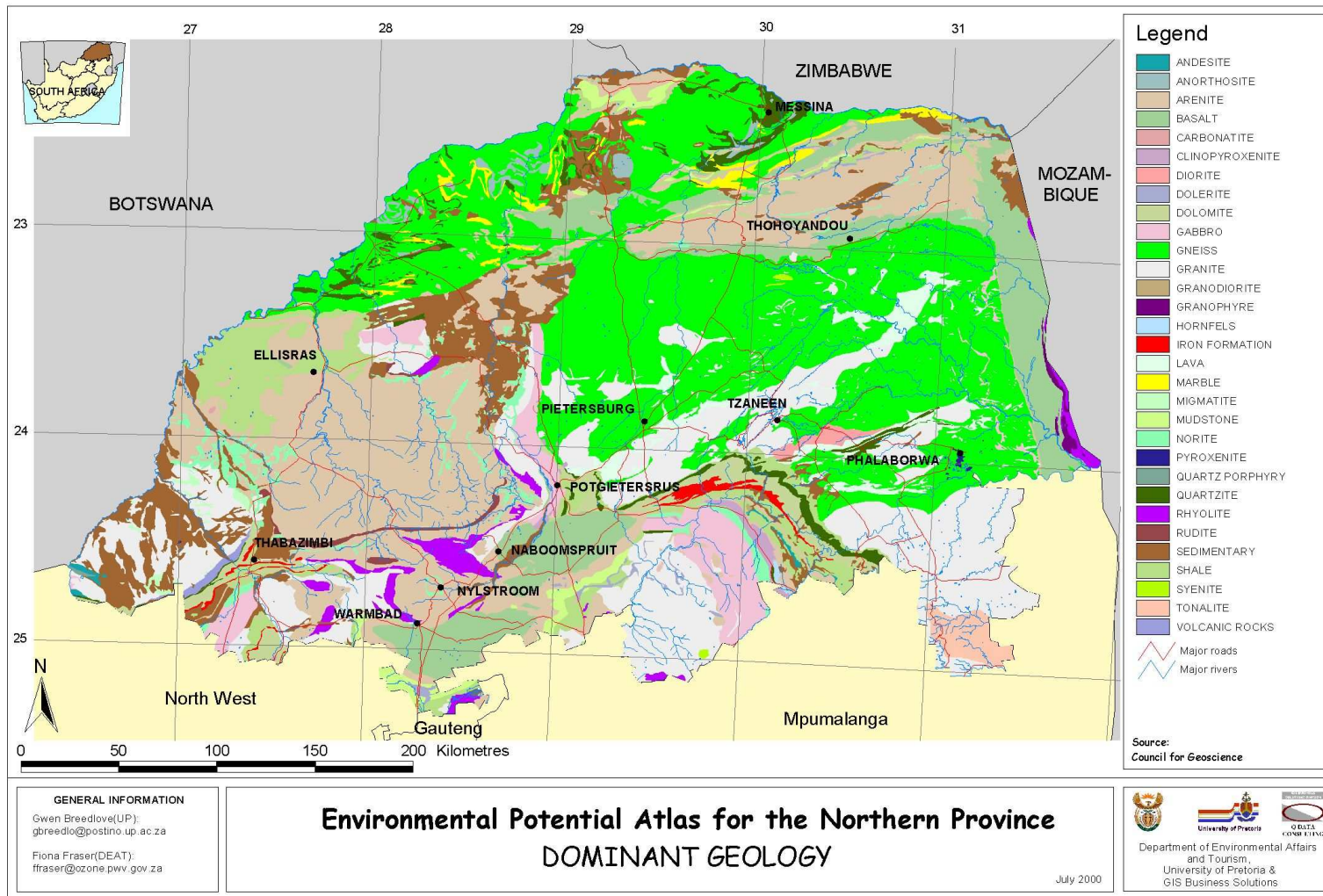


Figure 1: Dominant Geology of the Limpopo Province (South Africa, 2000a)

3.2.2 Basic geo-hydrological principles

A hydrologic system is defined as a structure or volume in space, surrounded by a boundary, that accepts water and other inputs, operates on them internally and produces them as outputs. The global hydrologic cycle can be represented as a system containing three subsystems; the atmospheric water system, the surface water system and the subsurface water system (Todd & Mays, 2005:14). Groundwater is part of the latter system.

Water bearing formations of the earth's crust act as conduits for the transmission and as reservoirs for the storage of water. The storage capacity of the groundwater reservoirs combined with small flow rates provide large, extensively distributed sources of water supply (Todd & Mays, 2005:15). Practically all groundwater originate as surface water. Groundwater is the water found in the saturated zone. This is the zone where the soil is saturated with water, hence the term groundwater. Water in the saturated zone is protected against evaporation and is therefore an excellent reservoir for the storage of water, far better than surface storage such as dams etc. Groundwater in general is also mostly uncontaminated, but once contaminated it is very difficult and expensive to rehabilitate.

Groundwater occurs in many types of geological formations; those known as aquifers are most important. Todd & Mays (2005:36) define an aquifer as a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Aquifers may be divided into unconfined and confined aquifers. Unconfined aquifers may be described as aquifers in which the water table may vary in undulating form and in slope depending on various factors such as areas of recharge, discharge, pumpage of wells and permeability of the sub-surface structures. Confined aquifers, also known as artesian or pressure aquifers, occur where groundwater is confined under pressure greater than atmospheric pressure by overlying relatively impermeable strata (Todd & Mays, 2005:56; Brassington, 2007:3).

The project on which this study is based mostly makes use of groundwater as the primary water supply to health facilities involved. In some cases the health facilities are connected to a municipal or community water supply. These facilities then rely on groundwater as a backup water supply. Health facilities may also have more than one borehole serving as a water supply, also for backup purposes.

The need for backup boreholes is mostly determined by the supply potential of the aquifer into which the borehole is drilled.

Vivier (2006) found that most of the groundwater contamination observed at health facilities may be attributed to inadequate sanitation practices on site. This poses a water quality management challenge to the Department of Health which is being eradicated on an ongoing basis.

3.3 Social factors

The National Health Act (63/2003) promotes the protection, improvement and maintenance of the health of the population (South Africa, 2003). Vivier (2006) states that one of the objectives of the Act is to protect, respect, promote and to fulfil the rights of the people of South Africa to an environment that is not harmful to their health and well-being.

3.3.1 Demographics

According to the National Census of 2001, Limpopo is home to 11.8% of South Africa's population. Measured by its total current income, Limpopo is ranked sixth of all the provinces in South Africa in terms of total income. In per capita income terms, however, the Limpopo Province is the poorest. Limpopo is marred by high poverty rates, inequalities in the distribution of income between various population subgroups, and unemployment (Punt, 2005).

Punt (2005) also writes that the Limpopo Province is divided into six district municipalities, namely Bohlabela, Capricorn, Mopani, Sekhukhune, Vhembe and Waterberg. These district municipalities were demarcated as directed by the Local Government Municipal Structures Act (117/1998). Bohlabela and Sekhukhune are so-called 'trans-frontier' district municipalities as they stretch across the provincial border with Mpumalanga. None of the municipal districts or cities in Limpopo has metropolitan status; hence all urban areas are either classified as small cities or towns. Several of the former homelands fall within Limpopo's boundaries. This includes Venda (part of Vhembe), Gazankulu (parts of Bohlabela, Mopani and Vhembe) and Lebowa (parts of all district municipalities except Vhembe) (Punt, 2005).

Figure 2 illustrates the district municipalities in the Limpopo Province.

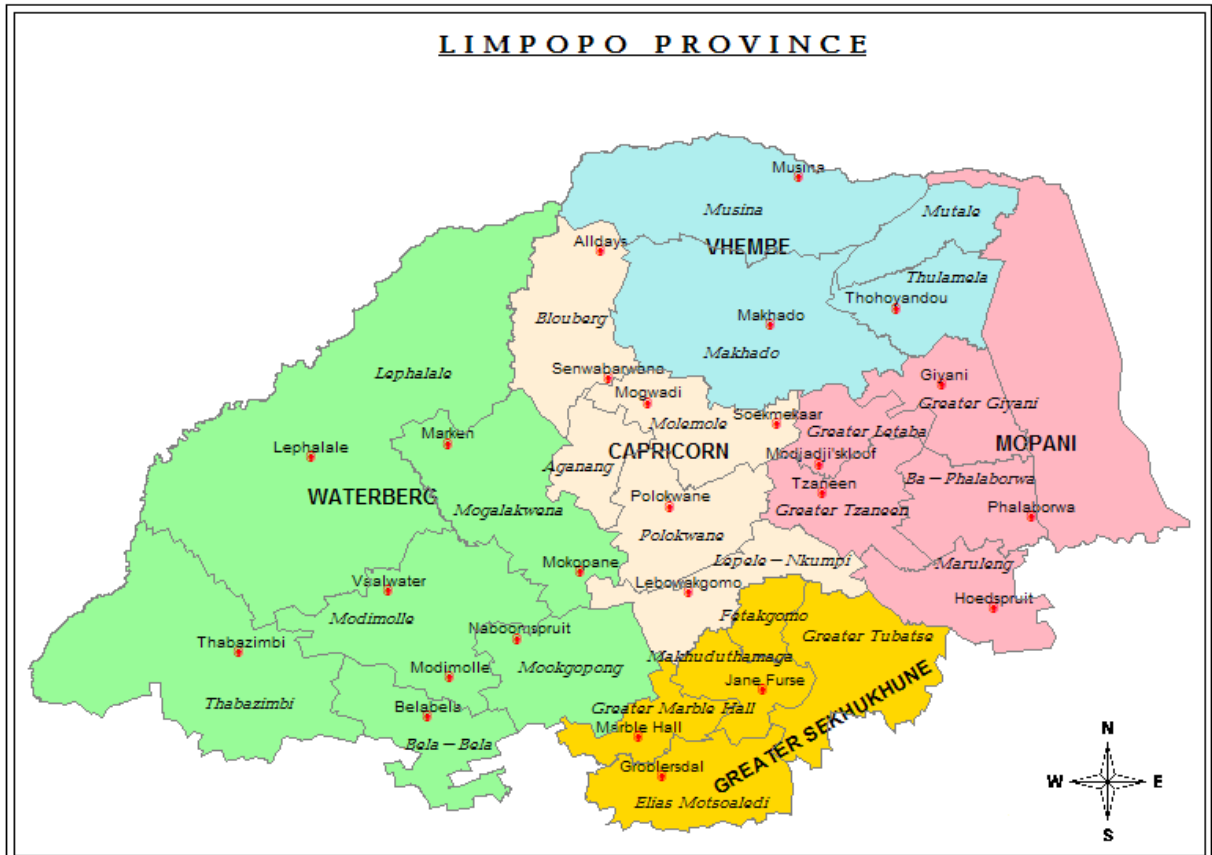


Figure 2: District municipalities of Limpopo Province (Anon, 2010)

Table 12 (Punt, 2005) and pie chart in Figure 3 illustrate the demographics of the Limpopo Province in the year 2000.

Table 12: Demographics of Limpopo Province in the year 2000 (Punt, 2005)

District municipality	African	Coloured	Asian	White	Total	Percentage (%)
Bohlabela	1 166 385	7 250		21 989	1 195 624	21.5
Capricorn	993 007	3 874	15 897	23 656	1 036 434	18.6
Mopani	797 024	5 437			802 461	14.4
Sekhukhune	720 868	3 347			724 215	13.0
Vhembe	1 178 018		8 634	15 238	1 201 890	21.6
Waterberg	548 403		1 766	53 170	603 339	10.8
Total	5 403 705	19 908	26 297	114 053	5 563 963	
Percentages	97	0.4	0.4	2.0		100

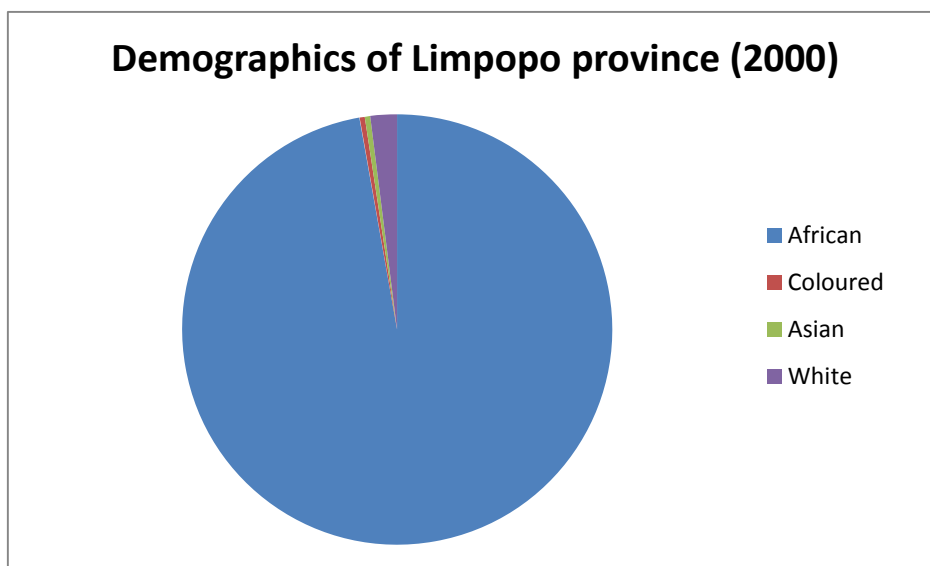


Figure 3: Pie chart illustrating the demographics of the Limpopo Province in 2000 (Punt, 2005)

As can be seen from Table 13, Vhembe (21.6%) and Bholabela (21.5%) are the largest in terms of population size, followed by Capricorn (18.6%), Mopani (14.4%), Sekhukhune (13.0%), and finally Waterberg (10.8%). About 97.1% of the population is classified as African. White people make up 2.0% of the population, while Coloured and Asian people make up 0.4% and 0.5% respectively (Punt, 2005).

Table 13: Population distribution by urban / rural areas in 2000 (Punt, 2005)

	African	Coloured	Asian	White	Total	Percentage
Secondary / small towns	600 240	9311.0	26 296	97901.0	733 748	13.2
Rural areas	4 803 465	10597.0		16153.0	4 830 215	86.8
Total	5 403 705	19 908	26 296	114 053	5 563 962	

Table 13 shows the number of people in urban and rural areas for the year 2000. Most Asian and White people live in urban areas, while just over half of the Coloured people live in rural areas. By far the greatest majority of Africans live in rural areas. Since the Province has a very large African population, the overall urban-rural split is 13.2% versus 86.8%. Compared to the national average urban-rural split, Limpopo has a very large rural population (Punt, 2005).

Parsons (2005) found that in 2003 Limpopo Province contributed approximately 6.5% to the National GDP, while 11.8% of the South African population live in this Province. This implies that the per capita GDP in Limpopo is expected to be less than the national average.

3.3.2 General land use

Several factors have influenced the development of South Africa and subsequent land use patterns. These factors include rainfall patterns, distribution of mineral deposits, the locality of ports and harbours as well as dominant trade routes.

As can be seen from the map in Figure 4, the Province is covered to a great extent by extensive farming, labelled as vacant/unspecified. Conservation areas are prevalent in the Province followed by cultivated land, subsistence farming and then by built up land as land uses. It may be said that the Limpopo Province mostly has a rural character. Conservation may include state owned areas which are intended for conservation purposes or private farms that were converted to game farms.

The Province boasts two trans-frontier game reserves namely the Great Limpopo Trans-frontier Park (GLTP) and the Greater Mapungubwe Trans-frontier Conservation Area (GMCA). The GLTP consists of the Kruger National Park in South Africa, the Limpopo National Park in Mozambique and the Gonarezhou National Park, the Manjinji Pan Sanctuary and the Malapati Safari Area in Zimbabwe. The GMCA consists of the Mapungubwe National Park in South Africa, the Tuli block in Botswana and the Tuli-circle Safari Area in Zimbabwe.

Figure 4 illustrates the major land uses in 2000.

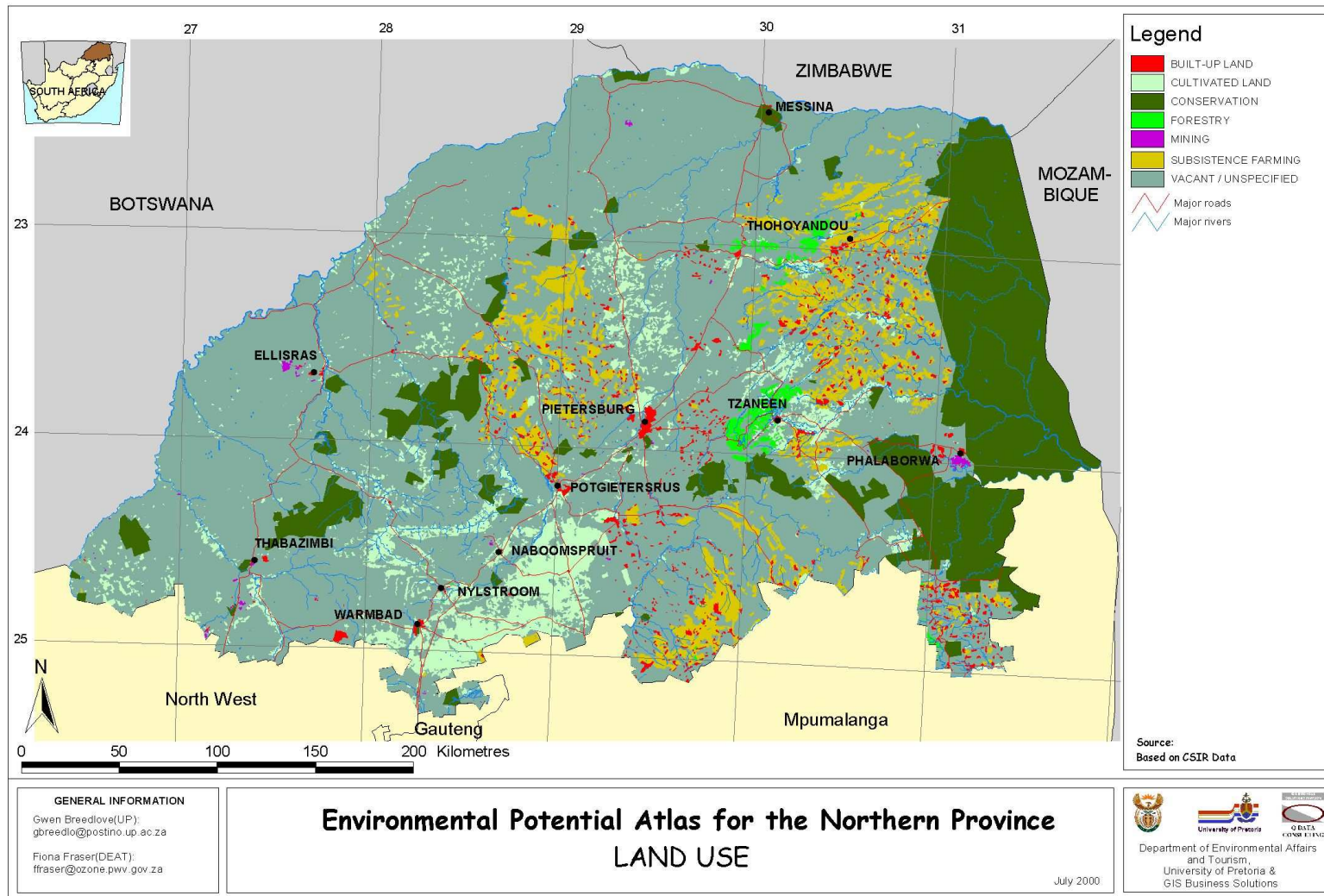


Figure 4: General land use of the Limpopo Province (South Africa, 2000b)

The Limpopo Province covers an area of 12,46 million hectares. This is 10,2 % of the total area of the Republic of South Africa. The Province has abundant agricultural resources and it is noted for the production of livestock, fruits and vegetables, cereals and tea. Agriculture is however subject to limiting environmental factors. The most limiting resource in the Province is water. Irrigation is needed for about 137,000 hectares of which 58,000 hectares are in the hands of black small-scale farmers (Department of Agriculture, 2010).

There are still two distinct types of agricultural production systems:

- the large scale commercial farming system and
- the small holder farming system.

Commercial farmers who practice large scale farming use the most advanced production technology. These commercial farmers operate large farms, which are well organized and situated on prime land. At present, there are approximately 5,000 commercial farming units in Limpopo Province (Department of Agriculture, 2010).

The smallholder farms are located mostly in the former homeland areas and they cover approximately 30% of the provincial land surface area. Farming under the smallholder systems is characterized by low level of production technology and small size of farm holding of approximately 1,5 hectares per farmer; with production primarily for subsistence and little marketable surplus (Department of Agriculture, 2010).

It was estimated that there were approximately 303,000 smallholder farmers in Limpopo Province by 2000 with women constituting 80% of these smallholder farmers (Department of Agriculture, 2010). It was found that 89% of the population of Limpopo Province can be classified as rural. Agriculture therefore plays a major role in the economic development of rural areas of the Province (Department of Agriculture, 2010).

Based on the characteristics of the soils, climate and topography, the land is suitable for the following:

- 37,7% suitable for arable farming
- 50,1% suitable for grazing
- 12,2% suitable for wildlife.

The total land area of the Province is 11,960,600 hectares of which 88,2 % (10,548,290 ha) constitute farmland. Of the total farmland, 14,7% constitutes potential arable land in developing agriculture in the former homeland and 14% constitutes commercial agriculture. Dry land cultivation on a commercial basis is only possible on the Springbok flats. Irrigation farming is therefore predominant in the Province (Department of Agriculture, 2010).

3.3.3 Sanitation practices

The prevalent sanitation practices in an area may be related to dominant land use of that area. Agricultural areas are often sparsely populated and formal sanitation systems employed in these districts. Conservation areas generally employ environmentally friendly sanitation practices. Areas that are more densely populated for example, community centres, small towns, and informal settlements more often make use of pit latrines. The concentration of pit latrines in these areas may also be quite high, increasing the risk of microbial pollution of groundwater in these areas.

Vivier (2006) found that the majority of clinics within the Limpopo Province are reliant on groundwater as the only source of potable water and also that the majority of aquifers in the study area can be classified as sole source aquifers, supplying 50 % or more of domestic water in the absence of any reasonable alternative. Forty-nine percent of clinics have their own water supply (borehole), and are mostly serviced with septic tanks and Ventilated Improved Toilets (VIPs) or a combination of soak-aways, VIPs, and pit latrines (Vivier, 2006).

Vivier (2006) also found that clinics with nitrate concentrations in excess of 85 mg/l were serviced by pit latrines, VIPs or a combination of the two systems when her study was done in 2005. Vivier found no relationship between elevated nitrate concentrations and water levels or geology type.

Although the Department of Water Affairs and Forestry seek to promote the development and implementation of cleaner sanitation and waste disposal practices in rapidly developing areas, it does not always occur in practice as evidenced by the survey. The groundwater policy and strategy document states that the use of pit latrines, septic tanks and soak-aways will be discouraged in urban, peri-urban and high population density rural settlement situations (DWAF, 2000). The policy and strategy document further states that the Department places a general ban on waste disposal and other polluting activities within 200 meters of the recharge zone for major aquifers and sole source

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aquifers (DWAF, 2000). Vivier (2006) however found that from the 2005 data it was evident that in practice the above is neither implemented nor enforced.

The literature is virtually unanimous in stating that the final choice of sanitation technology should lie with the people who will use it and who will be responsible for operating and maintaining it. It was interesting to note that the majority of respondents indicated that they would prefer ecological sanitation to the Ventilated Improved Toilet (VIP) system. The social preference is however not reflected in the Vivier's (2006) findings where only 3 % of the clinics had eco toilets compared to 23 % with VIP's.

In 2007, Statistics South Africa found that 87.1% the population of the Limpopo Province had access to a toilet of some sort. This means that 12.9% of the population had no access to basic sanitation facilities. The percentage of the provincial population without access to basic sanitation decreased from 22.8% in 2001 to 12.9% in 2007. This is a significant improvement.

The following table summarises the percentage of households by type of toilet facility (Statistics South Africa, 2007).

Table 14: Percentage of households by type of toilet facility - Census 2001 and Community Survey 2007 (Statistics South Africa, 2007)

Type of sanitation	Year	Percentage
Flush toilet	2001	16.8
	2007	20.2
Chemical toilet	2001	1.3
	2007	0.1
Pit latrine with ventilation (VIP)	2001	8
	2007	10.5
Pit latrine without ventilation	2001	50.4
	2007	56.3
Bucket toilet system	2001	0.6
	2007	0.1
None	2001	22.8
	2007	12.9

It may be noted that the South African Government aims to provide at least a ventilated pit latrine to all households in the country by 2014 (South Africa, 2010).

4 MATERIALS AND METHODS

4.1 Status quo analysis

4.1.1 History of project

The Limpopo Province Health Water and Sanitation project started in 1999 with the installation of water supply systems to rural health facilities when the Department of Health initiated a water supply project all its clinics in the 1999/2000 budget year. The purpose of the survey that was conducted was to evaluate the water supply problems at the facilities, and to determine the number of clinics that did not have a reliable water supply (Crosby, 2009).

In 1999 when the initial survey was conducted, the Health Facilities were categorized into five broad groups (Crosby, 2009).

1. Facilities with NO water supply – most urgent
2. Facilities with a irregular supply – urgent
3. Facilities with a supply that requires work – i.e. existing borehole not working
4. Facilities with their own regular supply – own borehole
5. Facilities with regular community supply – municipal water

Previous phases of the project focused on the group 1, 2, and 3 clinics, and were addressed in order of priority as the urgency of the water supply shortage became apparent at each facility.

Based on this investigation, a program was initiated to develop a sustainable water supply to each Health Facility in the Province. The following table (Table 15) presents a summary of the Health Facilities at which water supply actions have been conducted.

Table 15: Number of facilities where water supply actions were taken

Year	Number of Health facilities at which water supply actions were conducted
2000	43
2001	28
2002	58
2003	109
2004	37
2005	41
2006	66
2007	47
2008	70
Total	499

In 2003 issues regarding the water quality at the Health Facilities were raised as a concern. The CSIR conducted an investigation into suitable treatment mechanisms that would meet the requirements of a rural Health Facility. Based on their findings it was recommended that reverse osmosis technology be utilized to clarify water at Health Facilities where water quality does not meet the recommended drinking water standards as prescribed by the Department of Water Affairs and Forestry (Crosby, 2009:10).

A comprehensive survey of the water quality at all the Health Facilities was conducted during the 2005 budget year. Based on the findings, trial water treatment units were installed at 6 Health Facilities in 2006 (see Table 16). The water treatment units should sufficiently treat water for all the drinking water requirements at the facility.

Table 16: Background - Water treatment at Health facilities

Count	Clinics	District	Treatment Action
1	Rebone	Waterberg	Drinking water treatment
2	Ramapudu	Sekhukhune	Drinking water treatment
3	Middlewater	Mopani	Drinking water treatment
4	The Oaks	Sekhukhune	Drinking water treatment
5	Mulala	Vhembe	Drinking water treatment
6	Magalies	Sekhukhune	Drinking water treatment

During the 2008/2009 financial year a total of 50 facilities were identified as priority for receiving water treatment units. Once project actions started it became apparent that more facilities could be

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addressed as UV technology was suitable to address water quality concerns where TDS values were within an acceptable range.

A company called VSA Leboa was tasked with the installation of water treatment plants. This included small Reverse Osmosis (RO) systems as well as small Ultra Violet (UV) Light Treatment systems. The following table (Table 17) represents the clinics where water treatment systems were installed by VSA Leboa.

Table 17: Clinics where water treatment systems were installed by VSA Leboa

HEALTH FACILITY	UNIT serial no.	CO-ORDINATES
RO Treatment systems		
Buffelshoek Capricorn	001	S23.14925 E28.92419
Magalies	002	S24.56255 E29.64407
Ramupudu	003	S25.05100 E29.50733
Middelwater	004	S23.41531 E30.20564
Rebone	005	S23.43210 E28.61001
Mulala	007	S22.47600 E30.87700
The Oaks	008	S24.36267 E30.66800
Folothodwe	009	S22.58815 E30.42727
Wayeni	010	S23.24119 E30.21867
Sekhiming	011	S23.43034 E30.56104
De Vrede	012	S22.91736 E29.02086
Indermark	013	S23.07858 E29.11073
My Darling	014	S23.08314 E28.79856
Madombidzha	015	S23.11483 E29.81940
Seakamela (Avon)	016	S23.14132 E29.10150
Mudimel	017	S22.79836 E29.95647
Madimbo	018	S22.45178 E30.56282
Ntlhaveni D	019	S22.86925 E30.88506
Shingwedzi	020	S23.00139 E30.73722
Masakona	021	S23.27358 E30.24417
Makgato	022	S23.50556 E29.66342
Tshiungani	023	S22.49861 E30.58042
MAKHUVA (NEW)	024	S23.57840 E30.96730
Matswi	025	S23.58583 E30.35767
Nyavana (Shihoko)	026	S23.65586 E30.47828
Dzumeri	027	S23.57638 E30.70860
Ziets	028	S23.02167 E28.70611
Lesfontein (Sekhung)	029	S23.14932 E28.78547
Lekhureng	030	S23.57325 E28.92033
Uitkyk	031	S23.39602 E28.97510
Mankgale	032	S23.989222 E29.786417
Mamushi	033	S24.05951 E29.69539
Motsepe	034	S24.28361 E29.85747

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Spitskop	035	S23.88833 E29.87444
Mankotswana (Mooiplaas)	036	S24.41492 E29.74728
Nchabaleng	037	S24.42799 E29.81078
Seroka	038	S24.50800 E29.93100
Makepsvlei	039	S24.93037 E29.04581
Eerstegeluk New	040	S24.72927 E30.13215
Van Der Merwes Kraal	041	S24.66442 E29.44483
Elandskraal Old	042	S24.71383 E29.41089
Moeding	043	S24.95350 E29.45750
Witfontein (Mamaneng)	044	S25.02425 E29.03596
Goedgedacht	045	S25.06067 E29.71783
Matsepe New	046	S25.02442 E29.50699
Kwarrielaagte	047	S25.31952 E29.26190
Seleka	048	S23.21484 E27.90820
Dithabaneng	049	S24.37045 E29.57765
Kheyi	050	S23.57964 E30.87383
Mapela	051	S23.95575 E28.84756
Segole	052	S23.60242 E28.64022
Weltevreden	053	S23.56078 E28.59906
Bochabelo	054	S23.43053 E30.51278
Ngove (Nguve)	055	S23.36150 E30.72150
Ambergate	056	S23.51674 E28.93679
Manamela	057	S23.703527 E29.27750
Mamaila	058	S23.35114 E30.24269
Olifantshoek	059	S23.33464 E30.27503
Msengi	060	S23.34564 E30.37014
Rotterdam	061	S23.40072 E30.27447
Moletlane New	062	S24.36306 E29.33569
Mokamole	063	S23.96259 E28.61321
Nkhuri	064	S23.21333 E30.55439
Mavambe New	065	S23.00367 E30.64894
Ikageng	066	S24.57083 E29.87383
Homulani	067	S23.87506 E31.06017
Marulaneng	068	S24.95147 E29.41017
Hlaneki	069	S23.28144 E30.50933
Manenzhe	070	S22.46932 E30.68103
Phaahla New	071	S24.69321 E29.73968
Mamone	072	S24.71100 E29.80300
Probeeren	073	S24.62072 E29.72819
Moutse East	074	S25.15122 E29.10517
Makanye (Calais)	075	S23.89819 E29.72392
Soetfontein	076	S24.10000 E29.60528
Chalema New	077	S23.76391 E28.74560
Kromhoek	078	S22.93269 E29.02653
Shivulani	079	S23.142916 E30.702583
Fetakgomo	080	S24.424611 E29.782000
Nthabalala New	081	S23.27764 E29.97283
Chuene	082	S24.19141 E29.48597
Marishane	083	S24.72744 E29.74683
Matlala New	084	S24.88483 E29.55417
Gideon	085	S22.90083 E28.67778

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Abbotspoort	086	S23.45050 E28.08689
Bavaria	087	S23.52411 E28.83294
Tshamahanzi	088	S24.07572 E28.98011
Moletje	089	S23.73769 E29.30262
Maphelle	090	S23.46842 E30.31203
Ngove	091	S23.36068 E30.72009
Tswaing	092	S24.47547 E29.67553
Eenzaam	093	S24.95333 E29.88600
Schoonoord	094	S24.75483 E30.01017
Kutama	095	S23.06319 E29.63544
Boschkloof	096	S24.80411 E30.09358
Ooghoek	097	S23.62542 E30.53358
Mokgwathi Clinic	098	S23.58583 E30.58294
Balepi (Pholotji)	099	S24.03067 E28.89297
Mahwelereng Zone 1	100	S24.14003 E28.98375
Masisi New	101	S22.42250 E30.86333
Matiyani	102	S22.74606 E30.97781
Botlakwa Hospital - Maternity ward	103	S23.49235 E29.74225
Lebaka	104	S23.46333 E30.36733
Tshikuwi	105	S22.90214 E29.95008
Matsa	106	S22.87417 E29.99683
Toverfontein	107	S22.90308 E28.77442
Dikgale Drop In	108	S23.74889 E29.77443
UV Treatment systems		
Mtiti	UV001	S23.10169 E30.89800
Mukula	UV002	S22.85833 E30.58778
Valdezia	UV003	S23.10011 E30.17971
Fondwe	UV004	S22.91758 E30.25919
Murangoni	UV005	S22.91689 E30.37158
Dakari (Hasam)	UV006	S23.09458 E30.48043
Kuruleni	UV007	S23.14564 E30.35966
Morapalala	UV008	S23.60319 E30.41778
Charlie Rangaan	UV009	S23.47710 E30.55219
Mattanau	UV010	S23.42494 E28.79839
Mavele	UV011	S23.66850 E30.42594
Morutji	UV012	S23.67025 E30.36711
Percy	UV013	S23.48083 E29.18611
Khahu	UV014	S22.83622 E30.24732
Mankuwe	UV015	S23.46780 E28.55959
Beaconsfield	UV016	S22.92147 E30.11881
Mphambo	UV017	S23.08405 E30.67062
Kibi	UV018	S22.83644 E28.84697
Musina	UV019	S22.34200 E30.04363
TOTAL number of units installed by VSA Leboa		126

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Other companies were also used for the installation of water treatment systems at hospitals in the Province. The following table summarises the treatment systems installed at hospitals in the Limpopo Province.

Table 18: List of water treatment plants at Hospitals

Date visited	Hospital	Type of treatment plant
21-07-2010	Bela Bela	Water Softener
24-06-2010	Botlokwa	Ion exchange
30-06-2010	C.N. Phatudi	Water Softener
19-06-2010	Dilokong	Water Softener
02-07-2010	Donald Fraser	Water Softener
06-07-2010	Elim	Water Softener
06-07-2010	F.H. Odendaal North	Water Softener
29-06-2010	George Masebe	Chlorination
02-07-2010	Hellen Franz	Reverse Osmosis
29-07-2010	Letaba	Water Softener
16-07-2010	Magatle	Water Softener
15-06-2010	Mecklenburg	Water Softener
21-06-2010	Mokopane	Water Softener
30-06-2010	Musina	Ultraviolet Water Steriliser
25-06-2010	Nchabeleng	Reverse Osmosis
05-07-2010	Penge	Sand filter
30-07-2010	Phalaborwa	Water Softener
07-07-2010	Philadephia	Water Softener
09-07-2010	Polokwane	Water Softener
17-06-2010	Sekororo	Sand filter
09-07-2010	Seshego	Water Softener
27-07-2010	Siloam	Water Softener
25-06-2010	St. Ritas	Water Softener
20-07-2010	Thabazimbi	Water Softener
27-07-2010	Tshilidzini	Water Softener
29-06-2010	W . F. Knobel	Water Softener
23-07-2010	Witpoort	Water Softener

Water quality data was collected since the commencement of the project. Most of this data is contained in the water quality database. The current study started in 2008 and continues to date. Monthly water quality management reports are rendered to the Department of Health in the Limpopo Province.

4.1.2 Sampling

Three field teams are tasked with regular water quality sampling. These field teams are tasked by project managers to sample certain facilities. Sampling mostly consists of routine sampling or ad hoc sampling. Ad hoc sampling takes place whenever a special request for sampling is received from a dedicated call centre or whenever project managers deem it necessary.

Scheduling for routine water quality sampling is based on the following:

- The water quality as determined in the latest sample for a specific facility.
- The age of the previous sample – if available water quality data for a facility is older than 3 years, then the facility is eligible for water quality sampling.
- Whether the facility has available water quality data or not.

All sampling is done according to accepted sampling protocols. As part of the Health Water and Sanitation project, an official sampling guideline (Stander, 2010) was developed. This guideline is based on the Sampling Guide made available by the Department of Water Affairs and Forestry in 1998 (DWAf, 1998b). All the field teams involved in water quality sampling should strictly adhere to this guideline in order to ensure sample integrity.

4.1.3 Laboratory analysis

The primary laboratory used for water quality analysis is Capricorn Veterinary Laboratory in Polokwane, Limpopo Province. This laboratory is SANAS accredited. This laboratory was chosen because of its strategic geographic location in Polokwane. In some isolated cases, other laboratories were used, but in all cases the laboratories were SANAS accredited.

The water quality results are usually received two weeks after the water samples were submitted for analysis.

4.1.4 Sample integrity

In order to verify the accuracy of a laboratory, one can follow one of two methods. One is to submit duplicate samples of the same water sample to the same laboratory under different labels. The results are then compared to see if they correspond in order to determine consistency. The other method is to

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take duplicate samples of the same water source and submit it to different laboratories. The results are then compared in order to assess the reliability of the primary laboratory.

A difference in results obtained from different laboratories for the same water sample may be attributed to different techniques used by the laboratories involved in analysing the water samples. Differences between laboratory results may also be attributed to a human factor present in the analysis of water samples. It is known that no two laboratory personnel will obtain the exact same results from the same set of samples. A certain measure of uncertainty is therefore present in laboratory results. The question is whether this uncertainty or inconsistency is of concern. The inconsistency shouldn't be of great concern as long as the level of uncertainty is relatively small if compared to the available water quality standards.

Duplicate sampling was conducted on 5 February 2009 at Charlie Rangane health facility. Two samples of the same water source were submitted to Capricorn Veterinary Laboratory for analysis. The results are represented in Table 19:

Table 19: Duplicate Sampling - Charlie Rangane

Sample Number	Date Sampled	Laboratory	Facility	EC [mS/m]	Total Hardness	Fluoride [mg/l]	Nitrate as N [mg/l]
2-09/154	2009/02/05	Capricorn Vetlab	Charlie Rangane	106.4	438.86	0.35	5.42
1-09/154	2009/02/05	Capricorn Vetlab	Charlie Rangane	105.8	480.88	0.35	6.14

As can be seen from the results in Table 19, there seems to be some inconsistency. Regarding Electrical Conductivity (EC) there seems to be an inconsistency of 0.6%. An inconsistency of 8.7% applies to Total hardness and an inconsistency of 11.7% for Nitrate as N. No inconsistency is observed with the fluoride concentration.

The inconsistency of 0.6% observed with EC is of no concern when compared to the SANS 241:2006 drinking water quality standards as water is classified as Class 1 (with regard to EC) for all values less than 150 mS/m. As can be seen from the results in Table 19, the EC values are both well below 150 mS/m. The inconsistency observed for Total Hardness (TH) and for Nitrate as N is also negligible when compared to the DWA Drinking Water Quality Guideline (DWAF, 1998a).

Duplicate sampling was also conducted at Selepe health facility on 14 July 2009. In this case a sample of the same source was sent to different laboratories. One sample was sent to Capricorn Veterinary Laboratory (the default laboratory in Polokwane) and the other was sent to Clean Stream Scientific Services in Pretoria.

Table 20 represents the duplicate samples:

Table 20: Duplicate sampling – Selepe

Sample Number	Date Sampled	Laboratory	Facility	EC [mS/m]	Total Hardness	Fluoride [mg/l]	Nitrate as N [mg/l]
2-09/1098	2009/07/14	Capricorn Vetlab	Selepe	98.7	405.95	0.1	1.87
24050	2009/07/14	Clean Stream	Selepe	104.4	413.73	0.18	2.73

Based on the results above, there seems a measure of unreliability. Regarding Electrical conductivity (EC) a difference of 5.4% is observed. A difference of 1.9% applies to total hardness and a difference of 44% is observed with Fluoride. A difference of 31% between the values for Nitrate as N is observed for the samples submitted to the different laboratories.

The inconsistency observed for EC, TH and Nitrate as N is acceptable when compared to the SANS 241:2006 Drinking Water Quality Standards (Standards South Africa, 2006). The inconsistency observed for fluoride is however of concern as the value obtained from Capricorn Veterinary Laboratories renders the water classifiable as Class 1 according to SANS 241:2006 (Standards South Africa, 2006). The result obtained from Clean Stream Scientific Services for fluoride renders the water classifiable as Class 2 according to SANS 241:2006 (Standards South Africa, 2006). This is not acceptable.

4.1.5 Database development and status

The data management tool is used to manage water quality data and forms part of a project and data management system and database developed for the Department of Health, specifically for the Clinic water and Sanitation Programme. This system was developed over the past four years.

This database, as part of the project and data management system was created by Integrity Engineering. The database has the functionality to integrate different management aspects into one database.

Regarding water quality, different parameters can be entered into the database. The parameters include the following:

- pH
- Electric Conductivity (mS/m)
- Total Dissolved Solids – TDS
- Total Alkalinity
- Calcium
- Magnesium
- Sodium
- Potassium
- Silicon
- Aluminium
- Iron
- Manganese
- Chloride
- NO₃ as N (Nitrate as Nitrogen)
- Sulphates (SO₄)
- Fluoride
- Ion balance
- Carbonates (CaCO₃)

These parameters were chosen in order to accurately indicate the quality of the water that is analyzed. The database is continuously being populated and updated in order to optimise its functionality. The following reporting functions are to be implemented:

- **Map with the water quality distribution** of facilities in the Limpopo Province. The map will be able to show the latest water quality at the facilities in the form of a coloured dot. The dot should depict the acceptability of water quality at facilities. The colours of the dots should correspond to the colours of the graphs in the following paragraphs.
- **Pie-chart for latest water quality** – this function will show the latest available water quality for all the health facilities in the form of a pie-chart. The number of facilities per water class will be shown as a percentage.
- **Report containing facilities with unacceptable water quality** – this reporting function will show all the facilities that have unacceptable water quality according to the SANS 241:2006 standards (Standards South Africa, 2006). This report will assist in determining which facilities require urgent attention regarding drinking water quality.
- **Report containing facilities with Class 2 water quality** – this reporting function will show facilities that have water quality rated as Class 2 according to the SANS 241:2006 standards (Standards South Africa, 2006).
- **Report containing facilities with Class 1 water quality** – this reporting function will show facilities that have water quality rated as Class 1 according to the SANS 241:2006 standards (Standards South Africa, 2006). Class 1 reflects water quality that is fit for lifetime human consumption.
- **Latest Water Quality results graph** – this graph will use the data available in the database to show the latest water quality results for specific parameters. This graph will be able to show the latest Water Quality either at all the facilities or at individual facilities or at a selection of facilities.
- **Latest Pre-treatment results graph** - this graph will use the data available in the database to show the latest pre treatment water quality results for specific parameters. The database will use selected water quality parameters to create a graph to show a visual interpretation of the current status of Latest Pre-treatment results.
- **Latest Post-treatment results graph** – this graph will use the data available in the database to show the latest post treatment water quality results for specific parameters. The database will use selected water quality parameters to create a graph to show a visual interpretation of the current status of Latest Post-treatment results.
- **Report showing facilities with outdated water quality data** - this report should show facilities of which the available water quality samples are older than a certain [definable] threshold, for

example 2 years. This reporting function will help in determining which facilities should be prioritised in routine sampling.

- **Report showing facilities for which no water quality data is available** – this report should show facilities for which there is no water quality data available in the database. This reporting function will allow project managers to determine which facilities should receive priority in routine water quality sampling.

The database is already able to store photographs of facilities. The database is continuously being optimised therefore making it a very useful management tool.

The database currently consists of 1243 usable water quality samples. Data include microbiological water quality results as well as physical and chemical water quality results. These samples were taken from 2003 to date. The database also has a function to store unlinked data. Unlinked data comprises of data that was transferred from the previous database (pre-2003) to the current database that is not linked to a health facility. The database has 264 unlinked water quality data reports. This data needs to be linked with the facilities in the database in order to be able to utilise the data.

4.1.6 Data manipulation and reporting

As part of routine reporting for the project, the latest available water quality data is regularly extracted from the database. Data integrity is ensured by ensuring that there are no duplicate samples per facility and that only the latest water quality sample is used.

The latest water quality data is then compared to the SANS 241:2006 drinking water quality standards (Standards South Africa, 2006). Should the SANS 241:2006 standard not contain information on a given element or parameter, then it is compared to the Quality of domestic water supplies – Volume 1: Assessment guide (DWA, 1998a). The facility is then assigned a water quality class. The water quality class can either be good, marginal or unacceptable. Table 21 illustrates how the relevant water quality classes related to one another:

Table 21: Comparison between different water quality classes

Assigned class	SANS 241:2006	DWA 1998
Good	Class 1	Class 0
		Class 1
Marginal	Class 2	Class 2
Unacceptable	Unacceptable	Class 3
		Class 4

The table above illustrates the similarities between the classes assigned for the purpose of this study, the SANS 241:2006 Drinking water quality standard and the Quality of domestic water supplies – Volume 1: Assessment guide (DWAF, 1998a). The SANS 241:2006 standard states that the classifications of class 1 and class 2 are respectively analogous to the classifications green and yellow used to differentiate among water qualities available for drinking purposes and described in Quality of domestic water supplies – Volume 1: Assessment guide (Standards South Africa, 2006:3).

The data is then used to determine the percentage of facilities that have good, marginal and unacceptable water quality respectively. This finding is presented as a pie chart in the monthly water quality report delivered to the client.

The efficiency of the water treatment systems installed at health facilities is also investigated on a monthly basis. All the facilities that have water treatment plants are investigated as a whole. This can be seen as a kind of blanket reporting intended to evaluate the efficiency of water treatment in general. The question asked here is: *Is there an improvement in water quality at facilities that have water treatment plants?* The answer is without a doubt, yes. The results are discussed elsewhere in this document. The need for detail reporting on the efficiency was however identified and will be investigated in the next chapter.

5 RESULTS

5.1 Water quality at health facilities in Limpopo Province

As stated earlier in this Document, the database consists of data dating as far back as 2003 and totals to 1243 usable water quality samples. Of these samples, 150 samples are of waste water sources. These samples are therefore excluded from this study. The latest available water quality data is used in this study. The following sections will discuss the latest available data for the health facilities involved.

By evaluating the latest available water quality data per facility and comparing this data to the SANS 241:2006 Drinking water quality standards (Standards South Africa 2006) and to the Quality of domestic water supplies – Volume 1: Assessment guide (DWAF, 1998a), the following bar graph (Figure 5) may be presented to illustrate the percentage of facilities that have either good, marginal or unacceptable concentrations of the following parameters: Total coliforms, Nitrate as N, Fluoride, Total Hardness and Electric conductivity. Table 22 represents the water quality data used for this analysis.

Table 22: Water Quality Status – August 2010

Criterion	No of sites tested	Sites with ideal levels		Sites with marginal levels		Sites with unacceptable levels	
		Number	%	Number	%	Number	%
Total coliforms	484	292	60	47	10	143	30
Electric conductivity	351	273	78	41	12	37	11
Total hardness	349	239	68	59	17	51	15
Nitrate as N	335	275	82	28	8	32	10
Fluoride	356	297	83	28	8	31	9

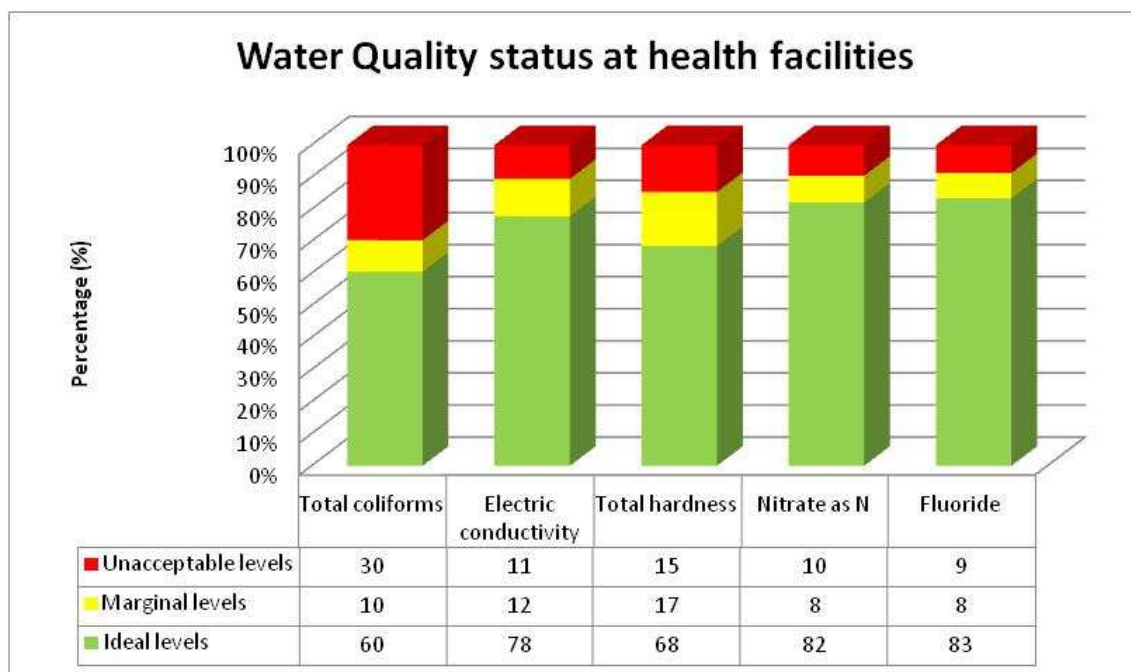


Figure 5: Water Quality Status Graph – August 2010

A total of 484 health facilities were sampled for total coliforms. Of these, 60% had ideal levels of coliforms, 10% had marginal levels of coliforms and 30% had unacceptable levels of coliforms present. These high levels of coliforms may be attributed to inadequate on-site sanitation systems or the improper placement of on-site sanitation systems (Vivier, 2006). To have 30% of health care facilities with unacceptable levels of Total coliforms is quite alarming taking into account that individuals with compromised immune systems are at their most susceptible to infection when visiting a health facility. These individuals come to health facilities primarily to seek treatment and are then exposed to water that does not conform to nationally accepted standards. Their health and well being is risked by visiting facilities with unacceptable water quality.

A total of 351 health facilities were sampled for Electric Conductivity (EC). Of these facilities that were sampled, 78% had ideal EC levels, 12% had marginal EC levels and 11% had unacceptable EC levels. The EC value of water may be closely related to the geology of an area as well as the climatic conditions of that area. Water in contact with granite may have an EC of around 5 mS/m whereas water in contact with sedimentary rock may have an EC of between 30 and 170 mS/m. In arid areas, such as most of the Limpopo Province, groundwater may have a naturally high EC value (DWAF, 1998a). High EC values may have detrimental effects on the health of users as discussed in section 2.1.3.

A total of 349 health facilities were sampled for Total Hardness. Of these facilities that were sampled, 68% had ideal TH levels, 17% had marginal TH levels and 15% had unacceptable TH levels. Total hardness is a measure of the calcium and magnesium concentrations in water. Total Hardness is

usually calculated to determine if water may have detrimental effects on the water infrastructure. The hardness of water is also a measure of how well soap will lather if this water is used (DWAF, 1998a).

A total of 335 health facilities were sampled for Nitrate. Of these facilities that were sampled, 82% had ideal Nitrate levels, 8% had marginal Nitrate levels and 10% had unacceptable levels of Nitrate present. High Nitrate concentrations may be a result of intensive land use or insufficient sanitation practices in the vicinity of the health facility (DWAF, 1998a). High nitrate concentrations may have detrimental health effects as discussed in sections 2.1.5 and 2.3.2.

A total of 356 health facilities were sampled for Fluoride. Of these facilities that were sampled, 83% had ideal Fluoride levels, 8% had marginal Fluoride levels and 9% had unacceptable levels of Fluoride present. The fluoride levels in water may generally be attributed to the exposure of groundwater to certain geological formations in the vicinity of the borehole used as water supply to a facility. The intake of water with high fluoride concentrations may also have harmful effects on the user as discussed in section 0. Fluoride may prove especially difficult to remove from water as fluoride is a very electro-negative element which readily forms complexes with many metals (DWAF, 1998a).

The parameters used above are but a handful of parameters that are used to evaluate the overall quality of water. Most of the available water quality results contain data on other parameters as well. When comparing water quality data to available water quality standards, each available parameter is individually compared to the standard in order to eventually assign a water quality class to the specific sample. Per water quality sample, each parameter is assigned a class according to the standards used. The overall class of the sample is then determined by the worst class obtained by an individual parameter in the sample.

After comparing the latest available water quality data primarily to the SANS 241:2006 Drinking Water Quality Standards (Standards South Africa, 2006), each facility is assigned a water quality class or classification based on the available water quality data. The following pie-graph (Figure 6) illustrates the percentage of facilities with good, marginal or unacceptable water quality available as drinking water.

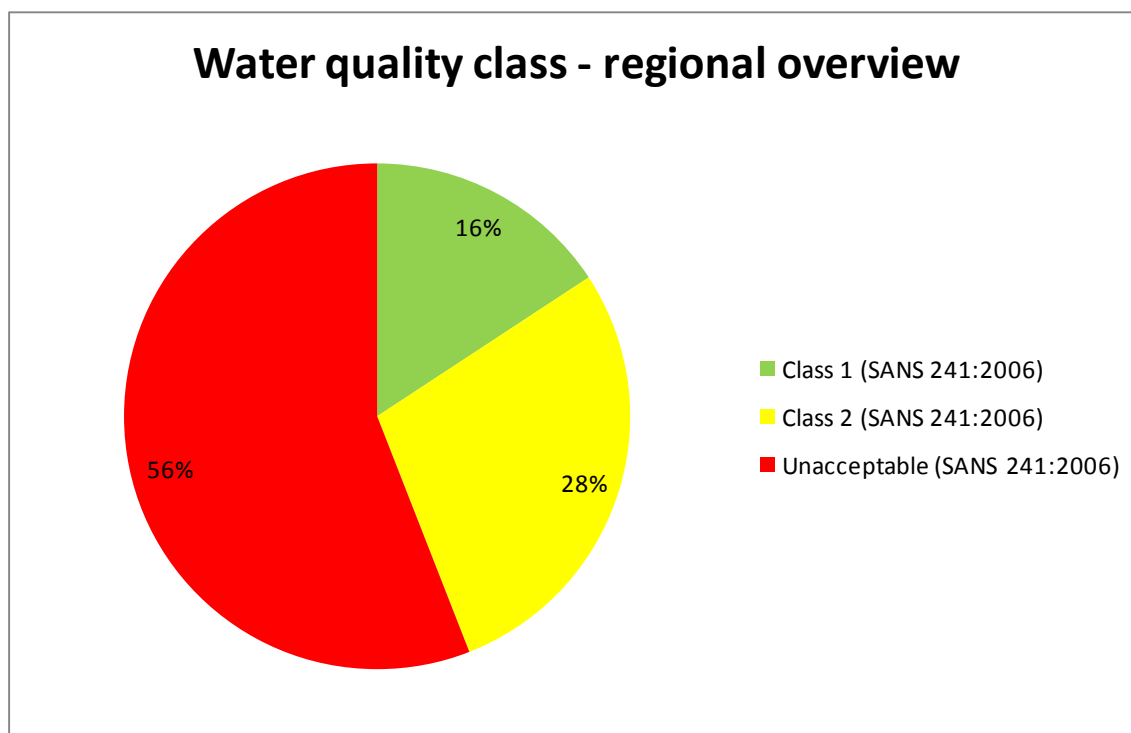


Figure 6: Pie-graph showing the water quality status at health facilities in the Limpopo Province

The pie-graph (Figure 6) shows that out of the 311 facilities with available water quality data, 16% have water acceptable for lifetime consumption (Class 1 - SANS 241:2006), 28% of the facilities have water fit for consumption for a limited period (Class 2 - SANS 241:2006) and that 56% of the facilities have water unfit for human consumption (SANS 241:2006). It is interesting to note that the results presented by the pie-graph (Figure 5) do not correspond to the data presented by the bar-graph in Figure 5. This illustrates the shortcomings of only using a limited set of parameters to evaluate water quality. This discrepancy may be the result of parameters other than the parameters discussed, being of unacceptable quality and therefore rendering the water quality unacceptable.

The following map shows the spatial distribution of the health facilities with water quality relating to Figure 6 above.

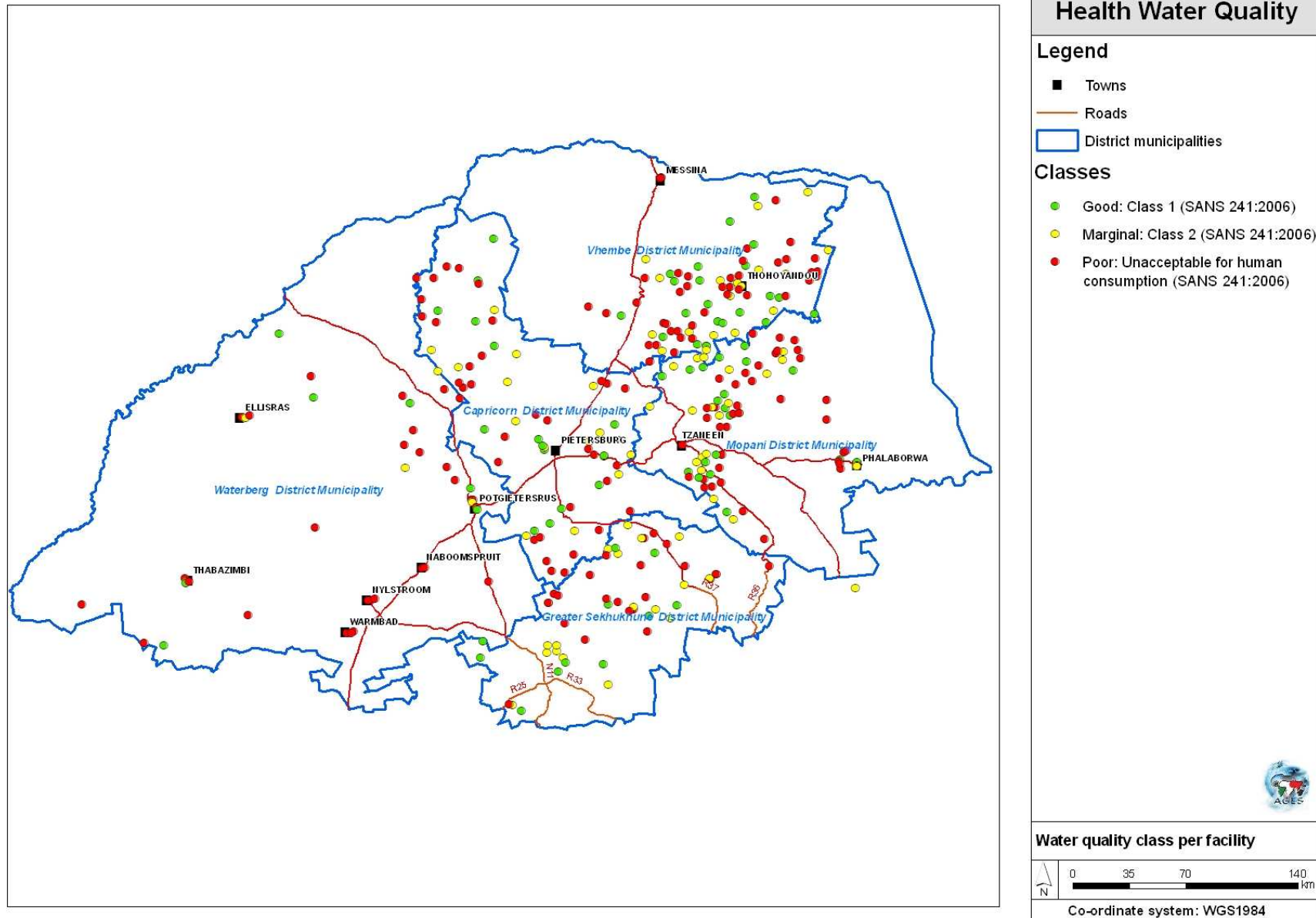


Figure 7: Water Quality Class per Facility in Limpopo Province

As an indication of whether the water treatment systems installed at health facilities are working in general, all facilities that have water treatment systems were grouped together. All the latest pre-treatment results were grouped and compared to all the latest post-treatment results. Table 23 and Figure 8 depict the latest grouped pre-treatment results.

Table 23: Pre-treated water quality results

Criterion	No of sites tested	Sites with ideal levels		Sites with marginal levels		Sites with unacceptable levels	
		Number	%	Number	%	Number	%
Total coliforms	43	21	49	18	42	4	9
Electric conductivity	71	47	66	18	25	6	8
Total hardness	68	28	41	19	28	21	31
Nitrate as N	68	41	60	8	12	19	28
Fluoride	70	60	86	2	3	8	11

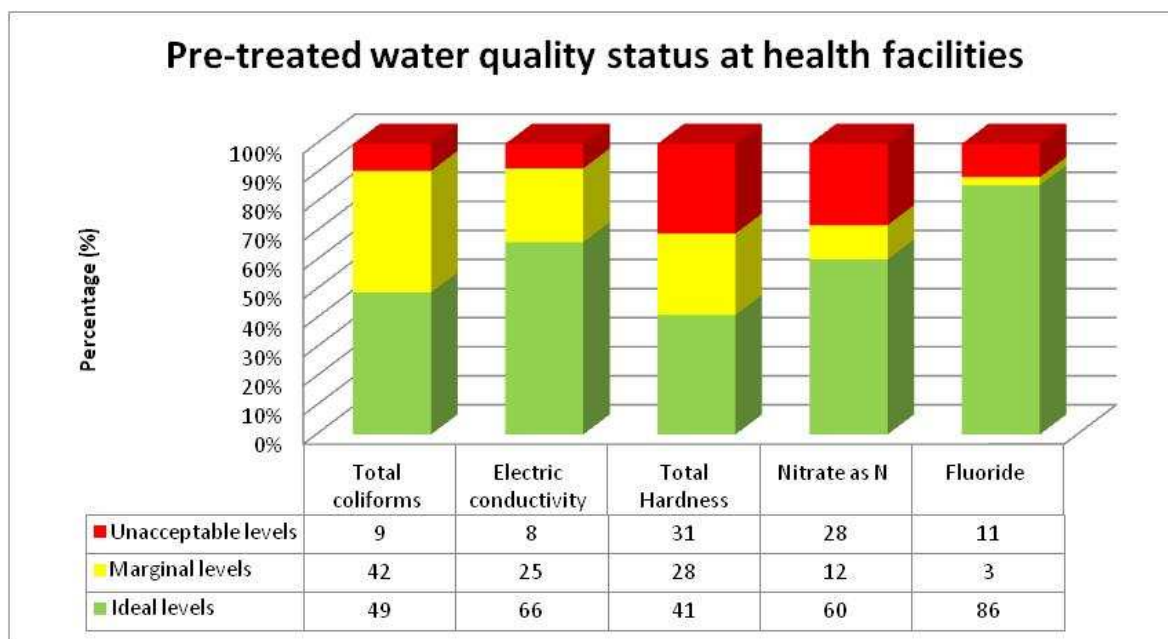


Figure 8: Pre-treated water quality graph

It may be noted that a significant number of facilities have unacceptable levels of Total hardness and Nitrate as N. A large number of facilities also have marginal levels of Total coliforms, Electrical conductivity and Total Hardness present in their drinking water.

In order to obtain an overview of whether water treatment is effective in general, a number of facilities that are fitted with water treatment systems, were analysed. The post-treatment results were interpreted for the chosen parameters and compared to SANS 241:2006. Table 24 and Figure 9 depict the latest grouped post-treatment results.

Table 24: Post-treated water quality results

Criterion	No. of sites tested	Sites with ideal levels		Sites with marginal levels		Sites with unacceptable levels	
		Number	%	Number	%	Number	%
Total coliforms	47	32	68	10	21	5	11
Electric Conductivity	47	44	94	2	4	1	2
Total Hardness	47	40	85	6	13	1	2
Nitrate as N	47	31	66	10	21	6	13
Fluoride	47	47	100	0	0	0	0

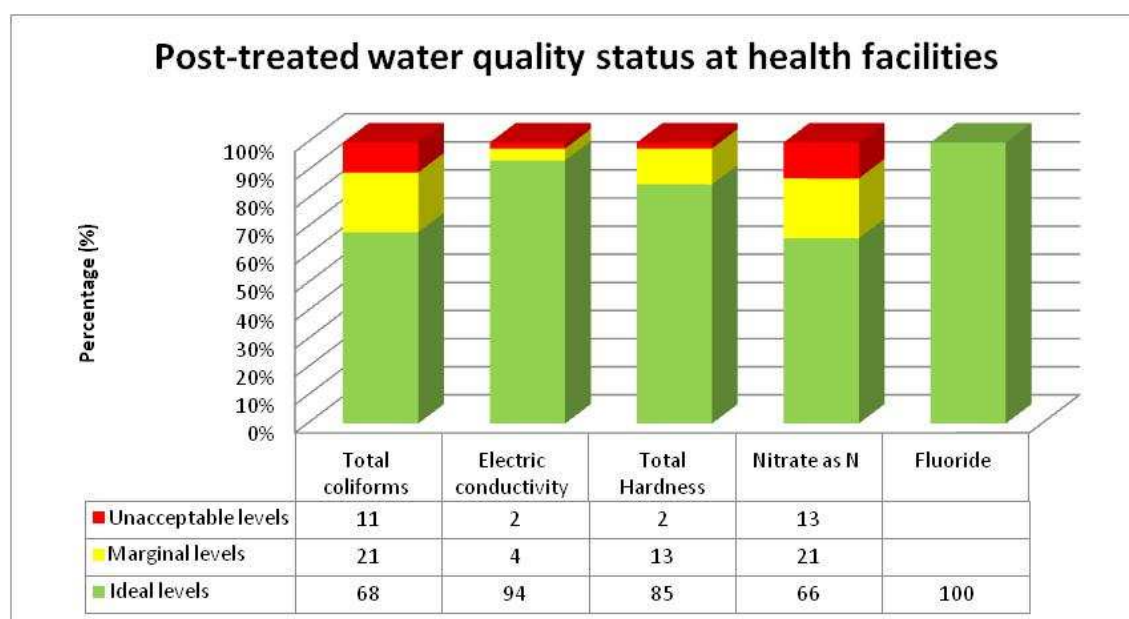


Figure 9: Post-treated water quality graph

When analysing the graph presented as Figure 9, it may be noted that the water treatment systems are efficient in removing fluoride to such an extent as to render fluoride within the water quality standard as set out in SANS 241:2006. According to the results obtained for the selected parameters, the water treatment systems are also efficient in removing Total Dissolved Solids (TDS) represented here as Electric Conductivity. Total Hardness is also reduced to some extent. The levels of Nitrate as N and Total coliforms are reduced to some extent.

In order to further evaluate the efficiency of the different water treatment systems, water quality results are further analysed and discussed per water treatment option in the next section.

5.2 Efficiency of intervention strategies

5.2.1 Institutional intervention strategies

According to Crosby (2010), none of the rural clinics have water registrations for Section 21(a) water uses, the reason being that the water use is of such a low daily quantity that it does not necessitate a registration under the National Water Act (36/1998). These water uses all take place under the General Authorisation (DWAF, 2004) for the abstraction of water.

5.2.2 Technical intervention strategies

5.2.2.1 Reverse Osmosis

As stated in Section 4.1.1 of this thesis, a company called VSA Leboa was tasked with the installation of water treatment systems, specifically Reverse Osmosis (RO) and Ultraviolet (UV) treatment systems. The complete list of facilities is represented in Table 17 on page 52. The efficiency of these facilities will now be investigated.

The latest available post-treatment water quality results were analysed and classified according to SANS 241:2006 water quality standards. The results are presented in Figure 11.

Table 25: Post RO results

Criterion	No of sites tested	Sites with ideal levels		Sites with marginal levels		Sites with unacceptable levels	
		Number	%	Number	%	Number	%
Total Coliforms	41	22	54	11	27	8	20
Electric Conductivity	50	46	92	4	8	0	
Total Hardness	50	43	86	7	14	0	
Nitrate as N	49	28	57	11	22	10	20
Fluoride	50	49	98	0	0	1	2

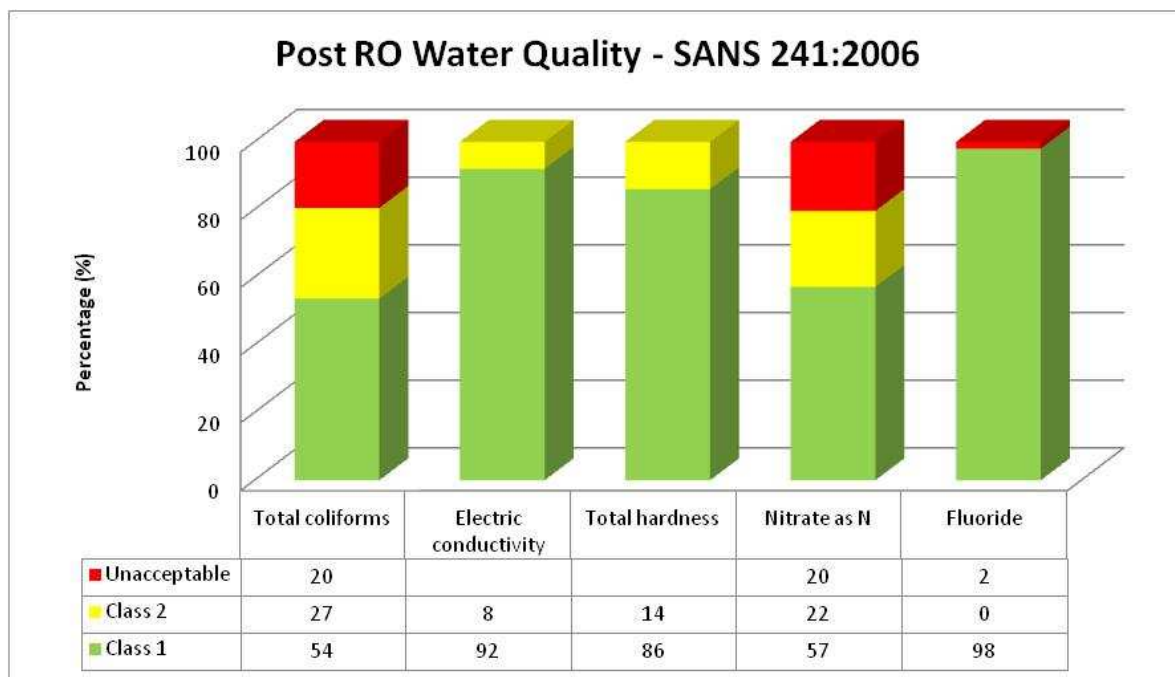


Figure 10: Post-RO graph (SANS 241:2006)

The RO systems are effective in reducing Fluoride, Total Dissolved Solids (TDS) represented here as Electrical conductivity (EC), as well as elements contributing to Total Hardness. Of the systems tested, 98% were effective in removing Fluoride while 2% of the systems failed to remove Fluoride from the water being treated. This may be due to fouling of the RO membranes or due to operator error (Agenson & Urase, 2006). The RO systems were efficient in removing TDS in 92% of the facilities tested and 8% of the systems included in this study, produced water of Class 2 in quality with regard to TDS (EC). Total Hardness was reduced to produce Class 1 water by 86% of the RO systems and 14% of the systems produced water of Class 2 in quality. The RO systems are not as efficient in removing Nitrate as N or Total coliforms. The RO systems are however effective in removing Nitrate as N and Total coliform bacteria from 57% and 54% of the samples respectively.

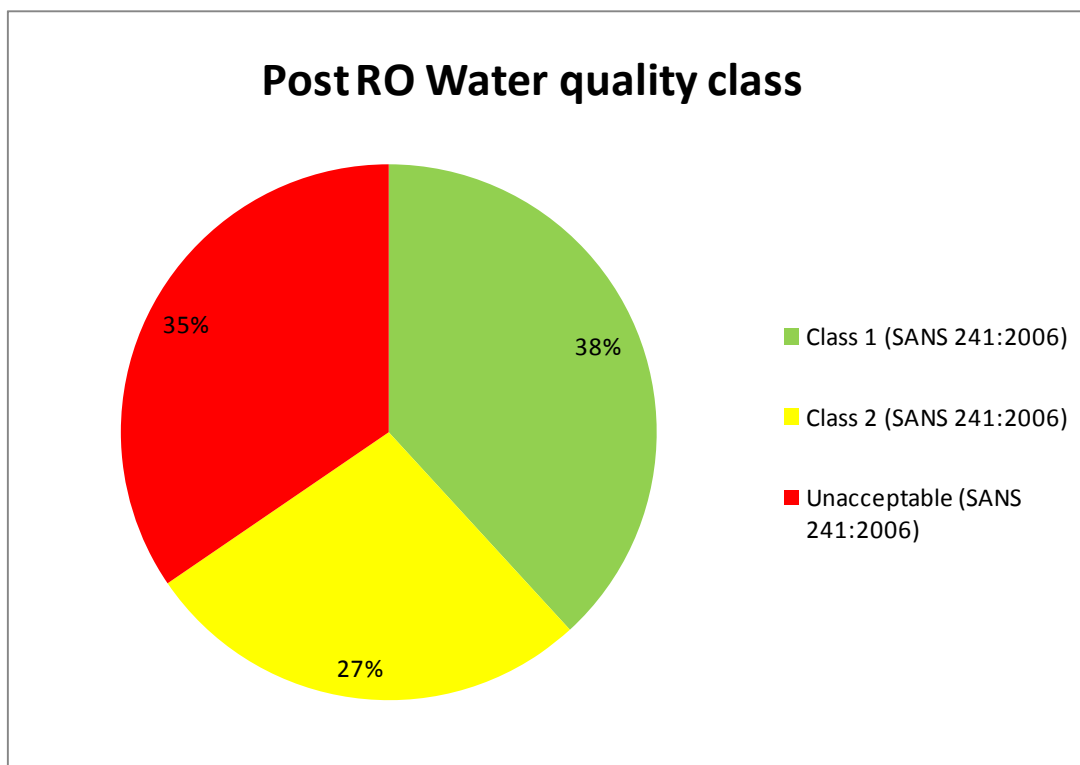


Figure 11: Post-RO results - Water quality class (including microbial constituents)

According to the data analysed, an alarming number of 35% of the RO systems return water that is of an unacceptable quality. The remaining RO systems produce water of either Class 2 quality (27%) or Class 1 (38%) quality. One should expect that all of the RO systems should return Class 1 water, but this is clearly not the case.

From these results it can be deduced that while the RO treatment units are effective in removing certain elements from the drinking water, it is not always efficient in producing water of impeccable quality. Agenson and Urase (2006) found that the fouling of membranes could severely limit the efficiency of membranes and may possibly result in the decline of permeate quality. The effects of the fouling of membranes may be limited by regular maintenance either by cleaning the membranes or by replacing the membranes. The replacement of the membranes is inevitable in time, seeing that the membranes only have a limited lifespan. The quality of the raw water entering a RO plant to a great extent, determines the lifetime of the membrane (Agenson & Urase, 2006).

5.2.2.2 Ion exchange

Ion exchange is a treatment option commonly used to remedy water with a high Total Hardness. Ion exchange systems are being used at some hospitals in the study area. The hospitals using this treatment option are listed in Table 26.

Table 26: List of existing Ion exchange water treatment plants

Date visited	Hospital	Type of treatment
21-07-2010	Bela Bela	Water Softener
24-06-2010	Botlokwa	Ion exchange
30-06-2010	C.N. Phatudi	Water Softener
19-06-2010	Dilokong	Water Softener
02-07-2010	Donald Fraser	Water Softener
06-07-2010	Elim	Water Softener
06-07-2010	F.H. Odendaal North	Water Softener
29-07-2010	Letaba	Water Softener
16-07-2010	Magatle	Water Softener
15-06-2010	Mecklenburg	Water Softener
21-06-2010	Mokopane	Water Softener
30-07-2010	Phalaborwa	Water Softener
07-07-2010	Philadelphia	Water Softener
09-07-2010	Polokwane	Water Softener
09-07-2010	Seshego	Water Softener
27-07-2010	Siloam	Water Softener
25-06-2010	St. Ritas	Water Softener
20-07-2010	Thabazimbi	Water Softener
27-07-2010	Tshilidzini	Water Softener
29-06-2010	W. F. Knobel	Water Softener
23-07-2010	Witpoort	Water Softener

Some of the treatment units mentioned above were not in working order when last visited by a field team. Treatment units not functioning are the units at Bela Bela, Witpoort, Thabazimbi, Magatle, Philadelphia, Donald Frazer, and Dilokong. The Ion exchange systems are used to either treat all the water supplied to the hospital or just the water supplied to the boilers. The efficiency of the working treatment systems can however not be reported on as not enough data was available at the time of the study.

5.2.2.3 Ultraviolet treatment

A total of 19 facilities were fitted with UV treatment units. The macro-chemical composition of the water available at these facilities is ideal. These facilities were fitted with UV treatment systems due to microbiological constituents in the water rendering the water unsafe for human consumption. The available data was compared to and classified according to the SANS 241:2006 drinking water standards. The results are presented in Figure 12. The data available on these units are not older than two years.

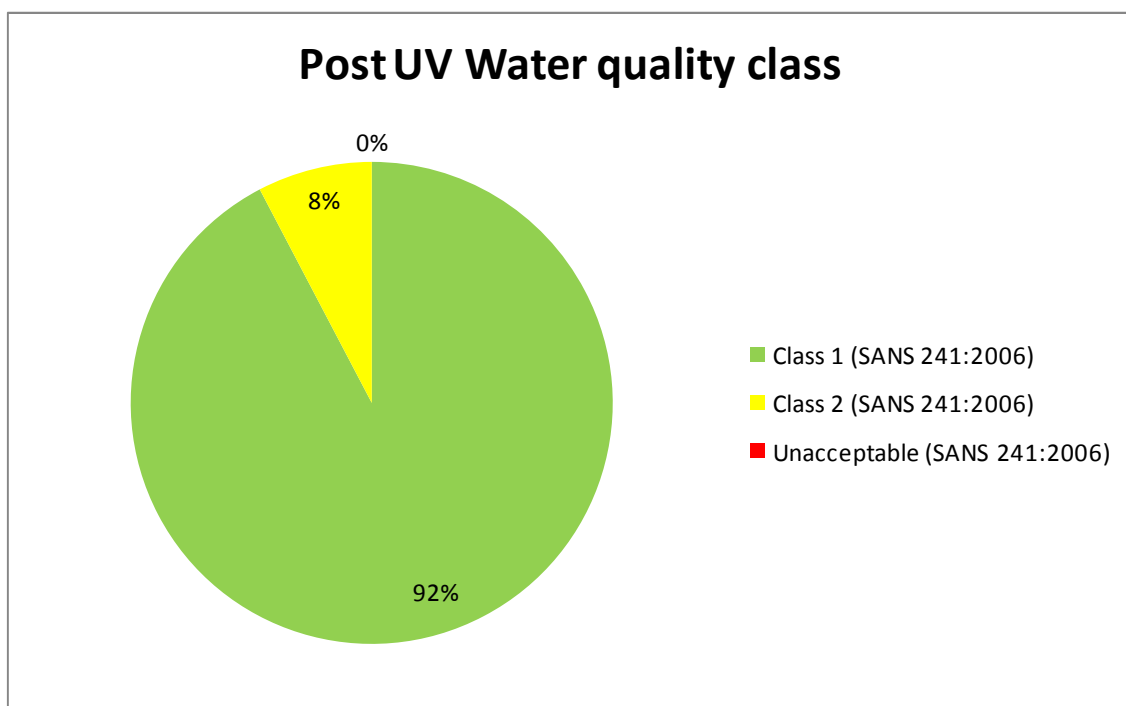


Figure 12: Post-UV results - Water quality class

The SANS 241:2006 standards are very strict with regards to microbiological constituents in water. The SANS 241:2006 standard states that the alert level of Total coliform bacteria in water be 10 counts per 100ml and that the *E. Coli* and Thermo-tolerant (faecal) coliform bacteria counts per 100ml of water should be zero. The SANS 241:2006 alert level for Total Heterotrophic Plate Count is 5000 counts per 100ml.

The Total Heterotrophic Plate Count (THPC) is a measure used to determine the efficiency of water treatment, as well as if there is any after-growth in the water distribution system (Standards South Africa, 2006). Figure 12 shows 54% of the UV water treatment units produced water of Class 1 in quality, while 46% of the UV treatment systems tested rendered the water Class 2 in quality and that none of the systems produced water that is unacceptable

for human consumption.

It should be kept in mind that UV treatment does not exhibit a residual disinfection effect as Chlorine treatment does. Water is disinfected as it comes in contact with UV light and is then again susceptible to infection and subsequent microbiological growth. The samples are typically collected at the nearest tap, which is in turn mostly connected to a conservation tank where the treated water is stored. Given the warm climate of the Limpopo Province and the humid conditions in the conservancy tank, it provides an ideal environment for microbiological growth.

One of the UV treatment systems (8%), high Total Heterotrophic Plate Count and high Total coliforms are to blame for the seemingly low quality of the treated water. This may be an indication of contamination at the point where the sample is collected or of microbiological growth in the storage tank. Care should be taken to keep the storage tanks in good condition and the tap where water is decanted, should be kept clean and free of algal growth. Weideman (2010) found that the Total Heterotrophic Plate Count increases in the water whenever the water is not used for longer periods. Weideman (2010) also recommends that a volume of at least 200 litres be used from the systems in order to ensure that excessive microbiological growth does not take place.

5.2.2.4 Chlorination

Chlorination has been fitted as a treatment method mostly in conjunction with other treatment systems. Chlorine is used as a disinfectant at some hospitals in the study area. Hospitals were added to the project quite recently resulting in very little data being available. The water treatment systems at most of the hospitals visited were not functioning properly. This may be attributed to lack of maintenance and operator incompetence. Helena Franz Hospital is the only facility using chlorine for which sufficient data is available. This facility is subsequently discussed in the following case study.

5.3 Case study: Helena Franz Hospital

As a study relating to the efficiency of a larger water treatment plant, the water treatment plant at Helena Franz Hospital was chosen as a case study.

5.3.1 Background and objectives

Helena Franz Hospital is a rural hospital at Senwabarwana near Bochum in the Capricorn District with site coordinates S 23.28381 E 29.11313. This hospital has received a water treatment plant which uses Reverse Osmosis (RO) technology to purify water for use in the hospital. All the water entering the hospital is treated in this plant. This plant is regularly monitored in order to determine the efficiency thereof and to determine whether the water produced by this plant is suitable for human consumption as well as for use in the high pressure boilers at the hospital.

A water quality monitoring programme was implemented from January 2010 to May 2010. Sampling was done weekly for the period mentioned. The objective of the monitoring was to evaluate the water quality as well as the reporting of results for several sampling points in the water purification plant as well as at the adjacent waste water treatment works. Eight sampling points were identified:

- SP01 - Raw water entering the plant
- SP02 - Post dosing
- SP03 - Post Reverse Osmosis (RO Product)
- SP04 - Post Cl dosing
- SP05 - Brine (RO waste water)
- SP06 - Post CIP Process (not for regular sampling)
- WW01 - Pre Waste Water Treatment Works
- WW02 - Post Waste Water Treatment Works

Figure 13 is a diagram representing the water treatment plant at Helena Franz hospital. Raw water enters the plant at sampling point 1 (SP01). Water entering the plant originates from three production boreholes. Raw water is stored in reservoirs on the hospital site. The water then passes through a pre-filtering process designed to prolong the production life of the RO membranes. Sampling point 2 (SP02) is situated between the pre-filtering and the RO stage. The pre-filtered water then passes through the RO membranes before being stored in the RO product tank. Sampling point 3 (SP03) is situated directly after the RO membranes. The treated water is then

pumped to an elevated tank which stores the treated product water. Before entering the tank, the treated water is dosed with Chlorine which acts as a disinfectant. Sampling point 4 can be found after the point where the product water is dosed with chlorine. The elevated tank serves as a reservoir of treated water for use in the hospital, as well as in the high pressure boilers used at the hospital.

Water treatment plants that make use of membrane technology produce a concentrated waste water stream. The waste water generated by the water treatment plant at Helena Franz, is sent to the local waste water treatment works by means of the hospital sewerage link. The waste water generated by the water treatment plant may be sampled at Sampling point 5 (SP05). Sampling point 6 (SP06) is used to sample the waste water generated by the flushing process known as the CIP-process.

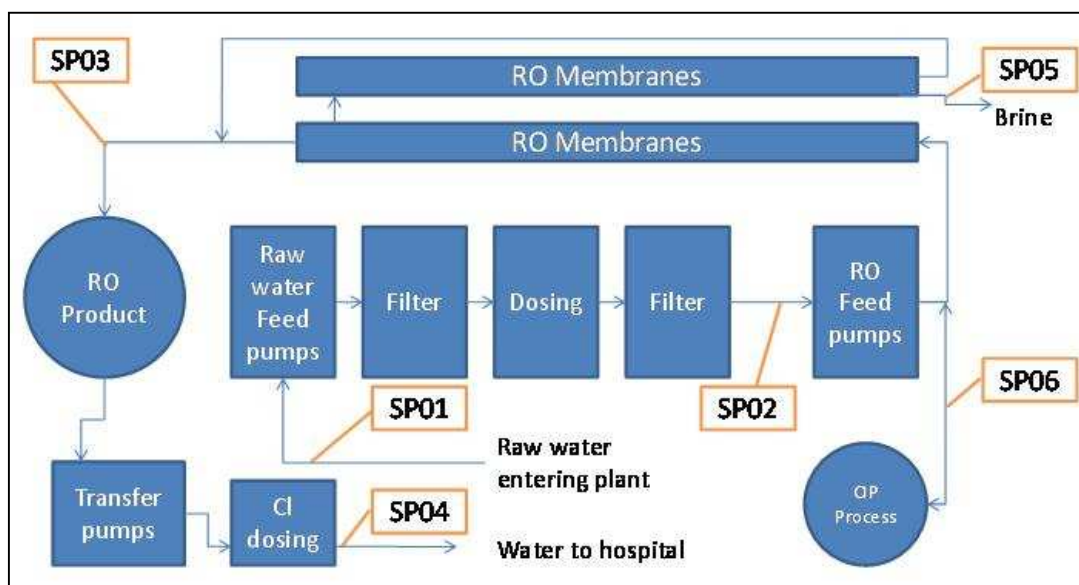


Figure 13: Sampling diagram for Helena Franz Hospital

The pictures presented here as Figure 14 to Figure 21 depict the sampling points in the treatment plant as well as the sampling points at the waste water treatment works. This study is concerned with potable water at health facilities and will therefore not discuss the water quality results obtained at the waste water treatment works.

The map presented as Figure 22 illustrates the geographical position of Helena Franz hospital.



Figure 14: Sampling Point 1 (SP01)



Figure 15: Sampling Point 2 (SP02)



Figure 16: Sampling Point 3 (SP03)



Figure 17: Sampling Point 4 (SP04)



Figure 18: Sampling Point 5 (SP05)



Figure 19: Sampling Point 6 (SP06)



Figure 20: Sampling Point 7 (WW01) S 23.27500° E 29.10835°



Figure 21: Sampling Point 8 (WW02) S 23.27363° E 29.10514°

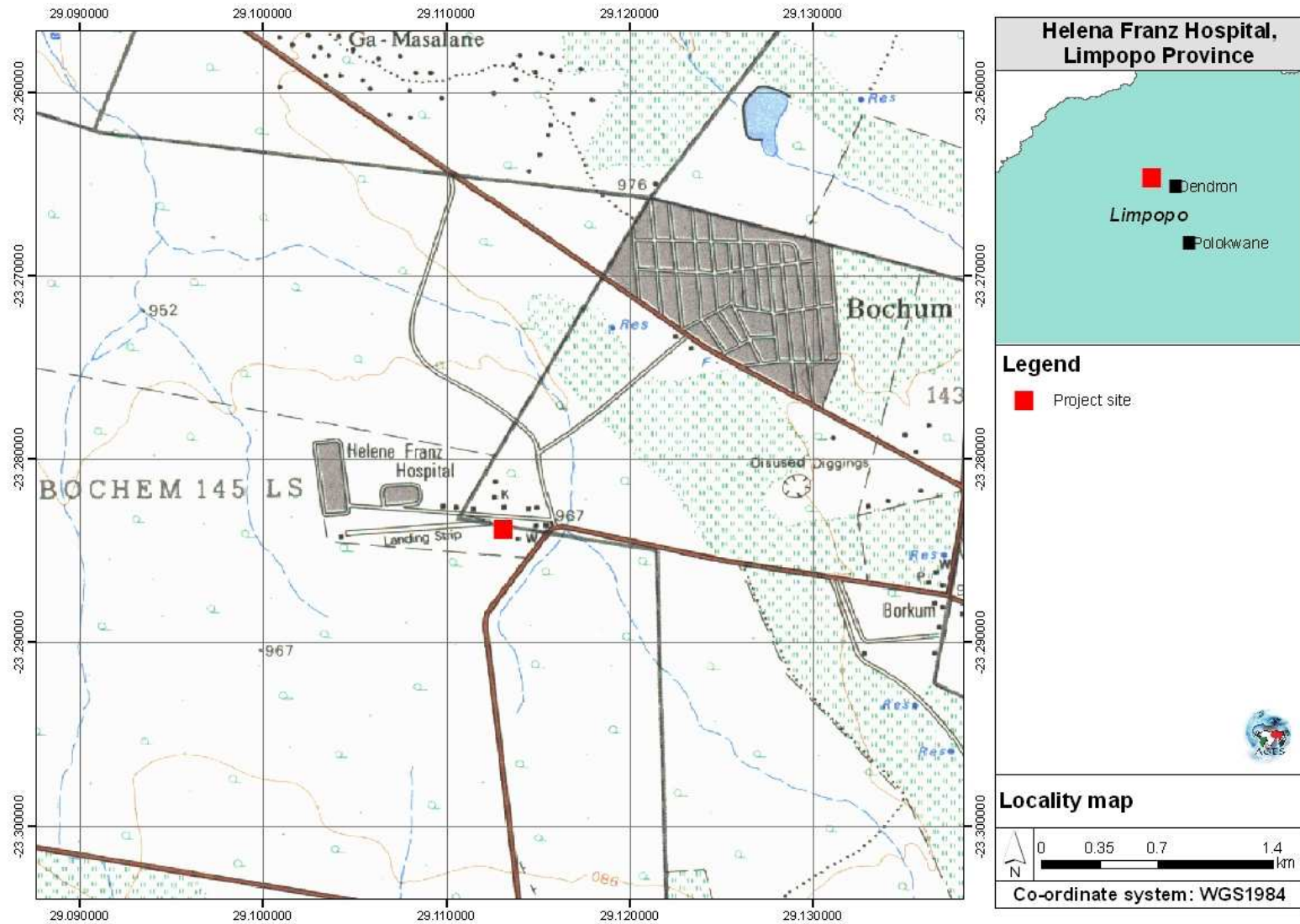


Figure 22: Map showing locality of Helena Franz Hospital

5.3.2 Sampling and Water Quality Parameters

Samples have been taken at the sampling points stated previously since December 2009. The samples were submitted to Capricorn Veterinary Laboratories in Polokwane within reasonable time. Samples were analysed for the following parameters:

- pH
- Conductivity (EC)
- Total Dissolved Solids (TDS)
- Bicarbonate alkalinity
- Total Hardness
- Calcium
- Iron
- Magnesium
- Manganese
- Potassium
- Sodium
- Chloride
- Fluoride
- Nitrate as N
- Nitrite as N
- Sulphate
- Total Heterotrophic Plate Count
- Total Coliforms
- Faecal Coliforms
- E.coli

5.3.3 Results

The water quality results for Helena Franz were analysed and compared to the SANS 241:2006 drinking water quality standards as well as to the DWA Quality of Domestic Water Supplies Volume 1: Assessment Guide. The treated water (final product water) was found to be of good quality (SANS 241:2006 Class 1) and fit for human consumption. The following graphs depict the change over time for chosen water quality parameters.

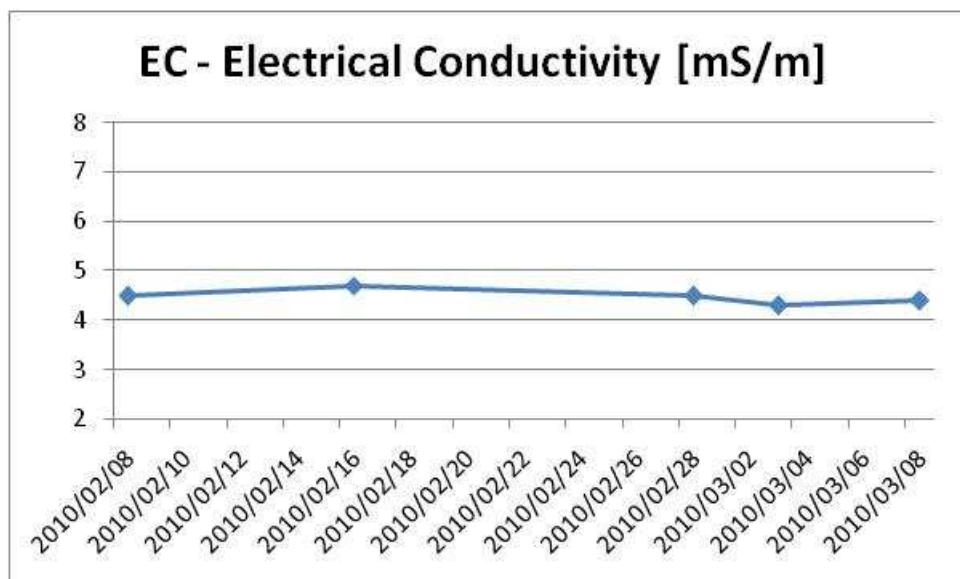


Figure 23: Helena Franz - EC values over time

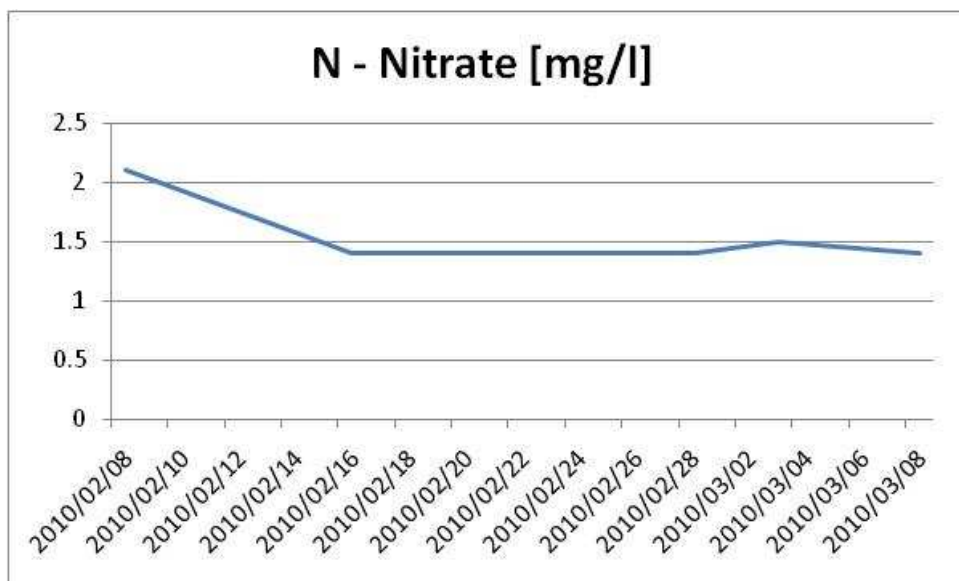


Figure 24: Helena Franz - Nitrate values over time

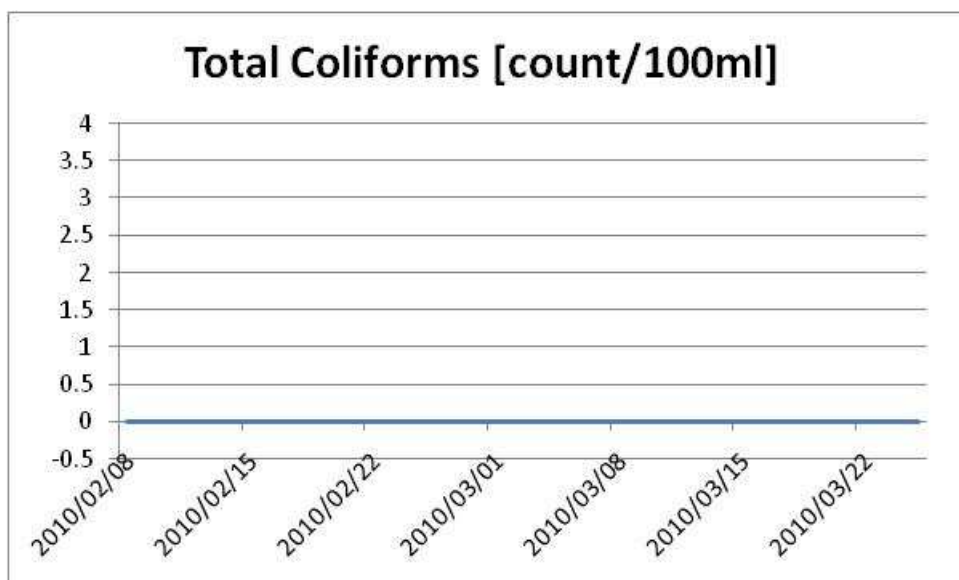


Figure 25: Helena Franz - Total Coliforms over time

EC and Nitrate as N are used as indicators to demonstrate the performance of the plant over time. Figures 1 to 3 show consistent performance of the water treatment plant. The water treatment plant is 100% effective in removing Coliform bacteria. The Plant also drastically reduces macro chemical parameters.

EC was chosen as an indication of the presence of inorganic salts in the water. EC is therefore used to determine if the water is fresh or salty (DWAF, 1998a). Water with ideal water quality may be described as Class 1 according to the SANS 241:2006 Drinking Water Quality Standard (Standards South Africa, 2006). In order for water to be classified as Class 1 water, the conductivity should be less than 150 mS/m and the TDS should be less than 1000 mg/l. The

treated water is well within the SANS 241:2006 standards for water used for lifetime consumption. Nitrate as N was chosen as a parameter to be assessed in order to determine if there may be pollution of the water related to the decay of plant, human or animal wastes. The presence of high levels of Nitrate as N may usually be attributed to intensive land use activities, be it high population density or intensive agricultural activities. According to the SANS 241:2006 drinking water standards, water may be classified as Class 1 if the water has a Nitrate and Nitrite as N concentration of less than 10 mg/l. The concentration of Nitrate as N in the product water is also well within the allowable limits of the SANS 241:2006 water quality standards for lifetime consumption.

Total coliform count was chosen as a parameter to be assessed in order to indicate the presence of microbial growth in the drinking water and to evaluate treatment processes, where present, as well as to assess the health risk posed to water users. The Quality of Domestic Water Supplies: Volume 1 Assessment Guide states that a Total coliform count of less than 10 per 100ml is ideal. The treated water at Helena Franz has as a Total coliform count of zero.

Figures 13 to 15 show the decrease in concentration for specific parameters. For comparative purposes the data from Sampling Point 1 (SP01) and Sampling Point 4 (SP04) are used. The following graphs represent the data obtained for the 3 March 2010 sampling occasion.

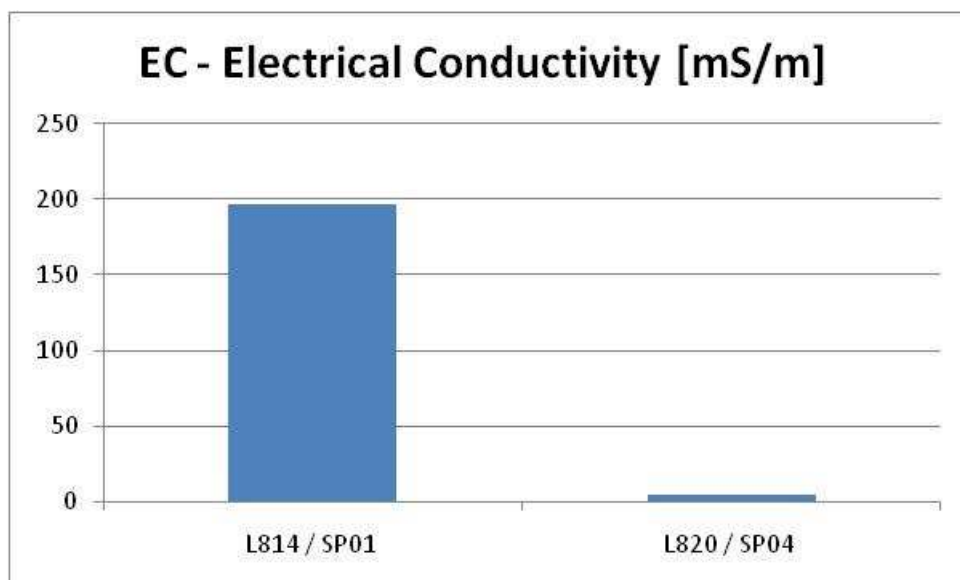


Figure 26: Helena Franz - Graph showing reduction in EC from Sampling Point 01 (SP01) to Sampling Point 04 (SP04) on 3 March 2010

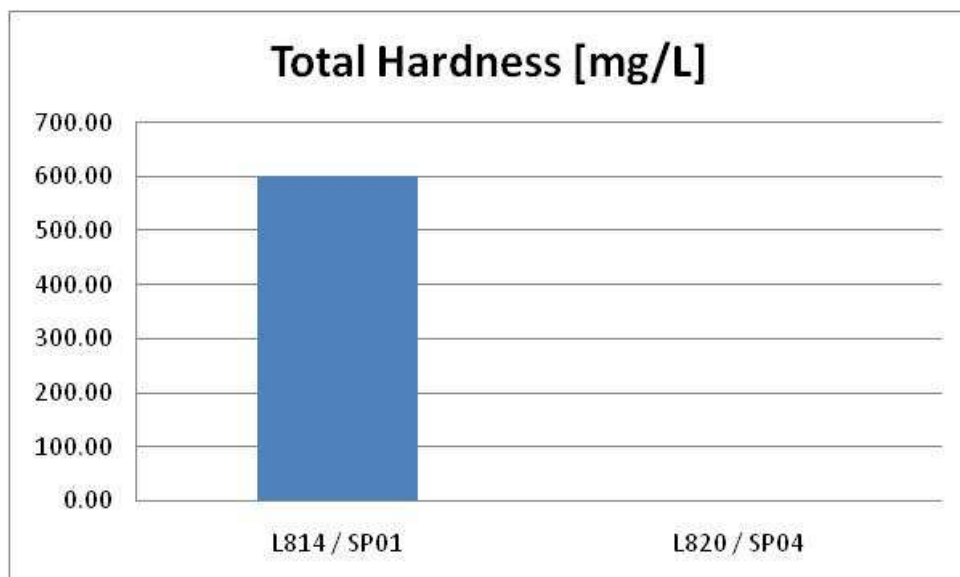


Figure 27: Graph showing the reduction in the Total Hardness of the water from SP01 to SP04 on 3 March 2010

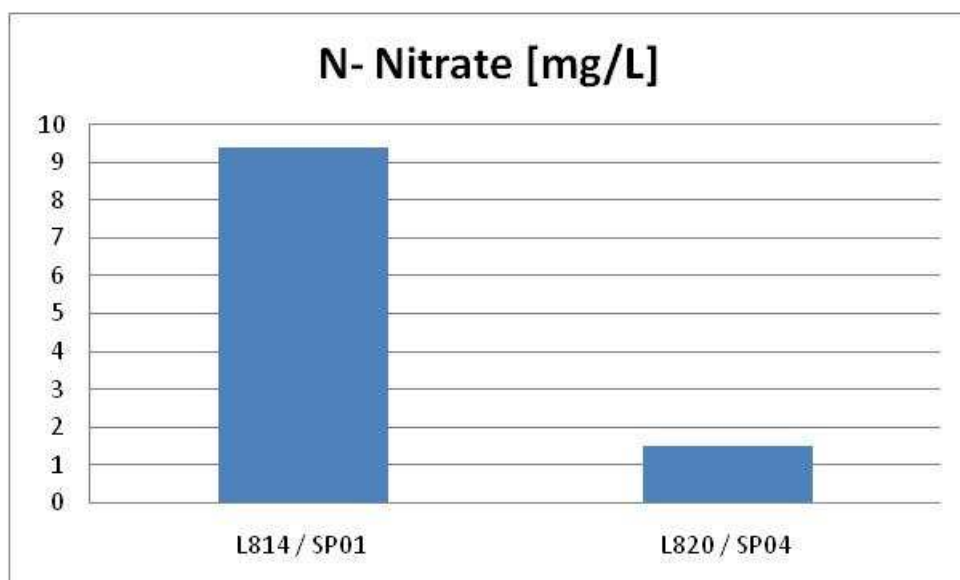


Figure 28: Graph showing the reduction in Nitrate concentration from SP01 to SP04 on 3 March 2010

It is clear from the graphs that the water treatment plant at Helena Franz is effective in reducing Electrical Conductivity, Nitrates and Total Hardness. This Reverse Osmosis Plant is also very effective in reducing the concentrations of various other substances found in raw water at Helena Franz.

It may be noted that water with a very low total hardness, i.e. water which is very soft, may be corrosive to appliances and water distribution infrastructure. Water with a Total hardness (as CaCO₃) of less than 50 mg/l may be classified as very soft.

5.3.4 Conclusion and Recommendation

It may be concluded that the water treatment plant installed at Helena Franz Hospital is effective in treating the raw water obtained from boreholes, in order to make the water fit for human consumption. The treated water is rated as Class 1 water according to SANS 241:2006 drinking water quality standards. This water is fit for lifetime human consumption.

6 SYNTHESIS

6.1 Conclusion

In the introduction of this study, the following question was asked:

- *What is the current water quality status at the various health facilities in the Limpopo Province and what can be done to remedy the situation?*

In order to answer the research question above, the following sub-questions were asked:

- a) Which health facilities suffer water quality problems and where are they located?
- b) What mitigating measures can be implemented?
- c) What is the effectiveness of mitigating measures?

Regarding which health facilities suffer water quality problems and their locality, the data showed that 56% of the facilities for which data exist have water of unacceptable quality. Of the remaining facilities, 28% have water that may be classified as Class 2 and only 16% have water that may be classified as Class 1 according to the SANS241:2006 water quality standards. It is clear from the results obtained from this study that there are significant water quality challenges at health facilities in the Limpopo Province. The poor quality of water at these facilities may be attributed to a number of factors, either natural or anthropogenic. The deterioration of water quality with regard to microbial constituents is often related to the prevalent sanitation practices, or lack thereof, in a specific area. This poses significant water quality challenges to the Department of Health in the Limpopo Province. A complete list of facilities and their associated water quality class can be found in Appendix 8.2. A map indicating the regional distribution of the said facilities is attached as Appendix 8.3.1.

In the introduction of this study, a question was asked regarding mitigating measures to be implemented in order to remedy the water quality situation. The water quality challenges faced at many health facilities were addressed by installing mainly two water purification options where necessary. The one water purification option is a Reverse Osmosis (RO) water purification system which purifies water to drinkable standards as prescribed in the relevant drinking water quality standards. These systems have maintenance challenges that can be overcome by careful management and proper operator training. The second water purification option is Ultraviolet (UV) treatment of the water where coliform bacteria are present. This form of treatment is being used in conjunction with RO treatment units to obtain optimal results. It is imperative however to ensure that proper maintenance is performed at the RO and UV treatment plants respectively. Regular maintenance at water treatment plants is

necessary to ensure the effective operation of the treatment systems. It was found however that some microbial growth occurs in the storage tanks after disinfection. This may be remedied by adding chlorine to the water in the form of chlorine tablets. The chlorine should prove to have a residual disinfection effect. Other water treatment options such as Nano-filtration, Ion exchange and Ozone treatment may also be applied in order to sufficiently purify the water at certain health facilities.

The water quality situation at every health facility is unique. The water quality may also vary over time. A practical approach with regard to water treatment will be to custom-design water treatment options per facility. This is common with larger systems that supply water to larger facilities such as hospitals. The smaller treatment systems that are comparable to household water treatment systems are often generic in design in order to inhibit maintenance costs.

Another question asked in the Introduction of this study is: *What is the effectiveness of mitigating measures?* Water quality results obtained from facilities that have been fitted with water purification systems show positive results as seen in the previous section of this study. There are some concerns however about the performance consistency of the treatment units that are fitted at certain health facilities. These reliability concerns may be mitigated by regular maintenance and proper operator training.

The small RO units that are installed at health facilities require some operator input to ensure the efficiency of the treatment units. It is however not economically viable to employ an operator at all the health facilities where these small systems are installed. The Department therefore rely on the personnel already employed at the health facilities to operate the water treatment systems. It was found that the clinic staff often reluctant to take responsibility for the operation of the treatment units. This may, to some degree, explain the challenges that are faced regarding the efficiency of the water treatment systems. At this stage the water treatment systems are serviced and maintained by field teams specifically tasked to do the required maintenance. This implies a cost burden on the Department of Health. Should clinic personnel be willing to take responsibility for some of the routine maintenance of the treatment units, considerable savings in maintenance costs can be expected.

Regarding rural water supply, particular challenges for the groundwater sector, are a more effective planning and cost-effective development of hundreds of small, localized schemes from groundwater, the introduction of a wider range of low-cost, appropriate technologies for community supplies, the integration of different development needs and the massive awareness- and capacity building required at both the community level and its support structures. Developing people clearly needs a much more

long- term and planned commitment than developing water (Braune, 2000).

The contamination of our groundwater reserves are of great concern. These resources should be protected in order to ensure viable water resources for future generations. Vivier (2006) writes that source water protection is founded on the “precautionary principle”. Prevention is an essential feature of effective drinking water quality management. Preventive strategies are those actions and activities that are required to eliminate hazards or reduce their impacts to acceptable levels and are based on best practise management. Rob *et al.*, (2005) writes that ensuring the safety of a water supply entails a wide-range program of protection, treatment and monitoring, with barriers to the entry and transmission of contaminants (particularly microorganisms). Catchment management and source water protection provides the first barrier for the protection of water quality. Best practise management of land use and water resources in catchments, is essential to a safe water supply (Edzwald & Kelley, 1998). Whether water is drawn from surface catchments or underground sources, it is important that the characteristics of the local catchment or aquifer be understood and the activities that could lead to water pollution be identified and managed (Rob *et al.*, 2005).

According to Wright (1999), informal settlements should be considered in the same light as other sources of urban pollution such as industry, waste disposal sites, cemeteries etc. The local authority should be responsible for mandatory routine water quality monitoring wherever major aquifers are involved. Sampling should be done at least every six months and annual reports should be submitted to the Department of Water Affairs office responsible for the management of regional water resources.

6.2 Recommendations – Way Forward

Having assessed the water quality situation at health facilities in the Limpopo Province it may be concluded that challenges do exist. In order to remedy the water quality situation at health facilities, the following way forward is recommended.

6.2.1 Sampling

The sampling of drinking water quality at health facilities is of great importance to ensure that the drinking water complies with the available drinking water quality standards. The sampling of drinking water is the sole responsibility of the Department of Health in the Limpopo Province. It is recommended that the following be considered with regard to sampling:

- The facilities identified with **unacceptable water quality** should be re-sampled in the near future in order to confirm the water quality of the said facilities. The samples should be analysed for physical, macro chemical as well as microbiological quality. Should the water quality be confirmed to be unacceptable, then further remedial actions will be investigated.
- Facilities for which no data is available should be sampled in order to have a complete database with available water quality results for all facilities.
- Facilities with samples older than 3 years should also be re-sampled in order to keep the available data up to date. It will then be possible to suggest detailed and site specific management and mitigating solutions for the water quality challenges faced at the health facilities in the Limpopo Province.
- The facilities identified with Class 2 (SANS 241:2006) water should receive attention after the above mentioned actions have been completed. The reason for the state of water quality should be determined and subsequent management solutions proposed based on the findings of the research.
- Systematic water quality surveys should be conducted at all health facilities in the Limpopo Province in order to get an ongoing representation of the water quality status of all the health facilities.

6.2.2 Duplicate sampling

Duplicate sampling is a measure to ensure the accuracy of the primary laboratory that is used for water sample analysis. It is recommended that duplicate sampling be conducted yearly. Duplicate sampling may be done in two ways. The first is to submit two samples of the same source to the primary laboratory. This will evaluate the consistency of the primary laboratory. The second method is to submit a sample of the same water source to two laboratories, the primary laboratory as well as a secondary laboratory. This will serve to indicate the accuracy of the primary laboratory. Only SANAS accredited laboratories may be used for water quality analysis.

6.2.3 Water treatment installations

The installation of water treatment systems at health facilities depends on the prevalent water quality situation at the facility. Once a facility is earmarked for a water treatment system, re-sampling should take place prior to the design of the water treatment system. The re-sampling will serve to confirm the water quality at the health facility. By confirming the water quality at the health facility, a correct and efficient system may be designed from start. A slight overdesign of the system might be in order seeing that an overdesign may result in savings in maintenance costs. All available water treatment options should be investigated with regard to the specific water quality found at each facility.

It should be kept in mind that most of the health facilities in the study area are in rural areas. These facilities are often in very remote areas which pose logistical challenges. The water treatment systems should be designed keeping this in mind. The water treatment systems should preferably be easy to operate and should not require excessive maintenance, except for reasonable routine maintenance.

6.2.4 Operator training

Most of the water treatment systems available on the market today require some operator input from time to time. The scale of the water treatment plant will determine the frequency of maintenance as well as the level of skill required to operate or maintain it. Water treatment plants generally constitute a sizeable investment. Keeping this in mind and aiming to ensure effective operation of water treatment plants, operator competence is of utmost importance. It is therefore imperative to properly train plant operators. In a case where a small water treatment plant is being used, two of the clinic personnel may be nominated to serve as plant operators. In a case where large scale water treatment takes place, two full time operators should be trained and employed in order to run the water treatment plant to its full potential. This has proved to be very efficient at Helena Franz Hospital.

6.2.5 Pro-active water management

Most of the water quality management actions taken at present are reactive measures. The ideal would be to move towards pro-active water quality management. Water pollution or contamination always has a source. This source may be natural or anthropogenic. One can start by identifying the source of water pollution and then eliminating or managing the pollution source. Environmental best practice is performed when eliminating pollution at the source.

A way forward would be to identify all the facilities with unacceptable water quality. These facilities must then be investigated in the form of a desktop study. Possible pollution sources such as population density, land use, sanitation practices, topography, geology and agricultural practices should be investigated during such a desktop study. The sanitation practices on site, as well as the disposal of waste (including medical hazardous waste), are of great concern as it may contribute to groundwater contamination. Once all possible pollution sources have been identified and mitigated, one can consider installing water treatment systems.

6.2.6 Expand project to a national scale

Taking into account the health risks that water of unacceptable quality poses to human health, especially individuals with compromised immune systems, water quality should be monitored on a regular basis. This is of utmost importance at health facilities. Given the success of the water quality monitoring programme in the Limpopo Province, it has the potential to be expanded to a national scale. Expanding the project to a national scale will enable the construction and population of a national water quality database with specific reference to health facilities. This promises immense research potential and will serve as a very important management tool.

As stated earlier in this study, groundwater is a very important source, if not the only source of potable water to rural health facilities. Rural communities are by implication also very dependent on groundwater. In order to ensure that groundwater remains a viable and safe source of potable water, it needs to be conserved to ensure water security in rural communities.

The conservation of groundwater will be augmented by regular sampling. The data that will be generated by national water quality monitoring, will serve as an early warning system to responsible authority enabling it to make informed and calculated management decisions.

7 REFERENCES

ACTS see SOUTH AFRICA.

ANON. 1999. Committee Report: Emerging pathogens – bacteria. *Journal of the American Water Works Association*, 91: 101 – 109.

APELL, J.N. & BOYER, T.H. 2010. Combined ion exchange treatment for removal of dissolved organic matter and hardness. *Water Research*, 44:2419-2430.

AGENSON, K.O. & URASE, T. 2006. Change in membrane performance due to organic fouling in nano-filtration (NF) / reverse osmosis (RO) applications. *Separation and purification technology*, 55:147-156.

ANON. 2010. District municipalities of the Limpopo Province. [Web:] http://www.limpopo-dlgh.gov.za/maps/Predined_maps/Predined_maps/Limpopo.bmp [Date of use: 8 November 2010].

BRADSHAW, D., SCHNEIDER, M., LAUBSCHER, R., and NOJILANA, B. 2002. Cause of death profile, South Africa 1996. Burden of Disease Research Unit Report May 2002. South African Medical Research Council.

BRADSHAW, D., BOURNE, D., and NANNAN, N. 2003. What are the leading causes of death among South African children? MRC Policy Brief No 3, December 2003.

BRASSINGTON, R. 2007. *Field hydrogeology. The geological field guide series. Third edition.* Chichester: John Wiley & Sons.

BRAUNE, E. 2000. Towards comprehensive groundwater resource management in South Africa. (*In* Sililo, O., ed. *Groundwater: Past achievements and Future Challenges.* Rotterdam: Balkema.)

References

CHRISTMAN, K. 1998. The history of chlorine. Water quality and health council. [Web:] <http://www.waterandhealth.org/drinkingwater/history.html> [Date of use: 10 November 2010].

CROSBY, R. 2009. Sustainable, Reliable and Potable Water Supply, Eradication of Sanitation Backlog with Appropriate Technology at Health Facilities in Limpopo 2009 / 2010. AGES internal report.

CROSBY, R. 2010. Telephone conversation with the author. Potchefstroom.

CDC (Centre for Disease Control). 1996. Memorandum of EPI-AID Trip report: Epidemic Dysentery in South Africa. No 96 – 26. Food and Diarrhoeal Disease Branch.

DEPARTMENT OF AGRICULTURE. 2010. Limpopo Provincial Government. Background information on Limpopo Province. [Web:] http://www.la.gov.za/backup_old_site/index.php?Entity=Background . [Date of use: 7 October 2010].

DWAF. 1996. The Department of Water Affairs and Forestry. South African Water Quality Guidelines: Volume 1 – Domestic Use. Second Edition.

DWAF. 1998a. The Department of Water Affairs and Forestry. Quality of domestic water supplies. Volume 1: Assessment Guide. Second Edition.

DWAF. 1998b. The Department of Water Affairs and Forestry. Quality of domestic water supplies. Volume 2: Sampling Guide. Second Edition.

DWAF. 2000a. Environmental Potential Atlas for the Northern Province – Dominant Geology. [Web:] <http://www.environment.gov.za/Enviro-Info/prov/np/npgeol.jpg> [Date of use: 10 September 2010].

DWAF. 2000b. Environmental Potential Atlas for the Northern Province – Land use. [Web:] <http://www.environment.gov.za/Enviro-Info/prov/np/npluse.jpg> [Date of use: 10 September 2010].

References

DWAF. 2000c. The Department of Water Affairs and Forestry. Policy and strategy for groundwater quality management in South Africa. First Ed. Report No W.1.0. Pretoria.

DWAF. 2000d. Policy and Strategy for the groundwater quality management in South Africa. Report Number W.1.0: 1st Ed. Pretoria: Government Printer.

DWAF. 2004a. National Water Resource Strategy. First Edition. Pretoria: Government Printer.

DWAF. 2004b. Revision of General Authorisation in terms of section 39 of the National Water Act, 1998 (Act. No. 36 of 1998). Government Notice No. 399 of 26 March 2004. Government Gazette No. 26187. Pretoria: Government Printer. 26-28p

DWAF. 2009. Registration Guide. Application for a License or Registration of a Water Use. A guide to completing registration or license application forms for waste discharge related water uses under the National Water Act (Act No. 36 of 1998).

EDITORIAL. 2003. Top 20 specific causes of premature mortality burden (YLLs) by sex, South Africa, 2000. AIDS Bulletin, 12: 13 – 20.

EDZWALD, J.K., AND KELLEY, M.B. 1998. Control of Cryptosporidium: From reservoirs to clarifiers to filters. *Water Science and Technology*, 37(2):1-8.

FEACHEM, R., BRADLEY, D., GARELICK, H., & MARA, D.D. 1983. Sanitation and disease: health aspects of excreta and wastewater management. Chichester: John Wiley & Sons.

GRABOW, W.O.K. 1996. Waterborne disease: update on water quality assessment and control. *Water SA*, 22: 193 – 202.

GREENLEE, L.F., LAWLER, D.F., FREEMAN, B.D., MARROT, B. & MOULIN, P. 2009. Reverse osmosis desalination: Water sources, technology and today's challenges. *Water Research*, 43:2317-2348.

References

JACKSON, B.M. 1998. Are we exaggerating the dangers of groundwater pollution from on-site sanitation systems such as pit latrines? *Borehole Water Journal*, 40: 18 – 21.

MIDGLEY, D.C., PITMAN, W.V. & MIDDLETON, B.J. 1994. *Surface Water Resources of South Africa 1990*. First edition. WRC Report No. 298/1.1/94.

MORRIS, K. 2004. Silent emergency of poor water and sanitation. *The Lancet*, 363:954.

MUCINA, L. & RUTHERFORD, M.C. (eds.) 2006. *The Vegetation of South Africa, Lesotho and Swaziland*. Strelizia 19. Pretoria: South African National Biodiversity Institute.

NAUNOVIC, Z., LIM, S. & BLATCHLEY E.R. 2008. Investigation of microbial inactivation efficiency of a UV disinfection system employing an examiner lamp. *Water Research*, 42:4838-4846.

NICOLAISEN, B. 2002. Developments in membrane technology for water treatment. *Desalination*, 153:355-360.

PARSONS, R. 1995. *A South African Aquifer System Management Classification*. WRC Report No. KV 77/95.

PEGRAM, G.C, ROLLINS, N., and ESPEY, Q. 1998. Estimating the costs of diarrhoea and epidemic dysentery in KwaZulu-Natal and South Africa. *Water SA*, 24: 11 – 20.

PRÜSS, A., & HAVELAAR, A. 2001. The global burden of disease study and applications in water, sanitation and hygiene. (In: Fewtrell, L., and Bartram, J., eds. *Water Quality: Guidelines, Standards and health*. World Health Organisation Water Series.) , London: IWA Publishing.

PUNT, C. 2005. A profile of the Limpopo Province: Demographics, poverty, inequality and unemployment. Background paper 2005:1(9). Background series of the provincial decision-making enabling project. Elsenburg.

References

ROB, C. LOË, D.E., & KREUTZWISER, R.D. 2005. Closing the groundwater protection implementation gap. *Geoforum*, 36:241 – 256.

ROTA, L. 2004. SA could move from a water-stressed to a water-scarce category. *Engineering News*, 24(12): 28 – 29.

RUSIN, P., ENTRIQUEZ, C.E., JOHNSON, D., and GERBA, C.P. 2000. Environmentally transmitted pathogens. In: *Environmental Microbiology*, London: Academic Press.

SELLO, E. 2009. Section B: District and Province Profiles – Limpopo Province. (In: Day, C., Barron, P., Monticelli, F. And Sello, E. *District Health Barometer, Year 2007/2008*. ISBN: 1-919839-63-1) Westville: Health Systems Trust.

SOUTH AFRICA. 1998. *Local Government Municipal Structures Act, No. 117 of 1998*. Pretoria: Government Printer.

SOUTH AFRICA. 1998. *National Water Act, No. 36 of 1998*. Pretoria: Government Printer.

SOUTH AFRICA. 2003. *National Health Act, No. 63 of 2003*. Government Gazette Vol. 469, No 26595. Cape Town: Government Printer.

SOUTH AFRICA. 2010. *Millennium Development Goals. Country report 2010*. Pretoria.

STANDARDS SOUTH AFRICA. 2006. *South African National Standard: Drinking Water. SANS 241:2006 Edition 6.1*. ISBN 0-626-18876-8. Pretoria: Standards South Africa.

STANDER, J.H. 2010. *Water sampling protocol. AGES internal sampling protocol developed for the Department of Health, Limpopo Province*.

STATISTICS SOUTH AFRICA. 2007. *Basic results. Community survey 2007*. [Web:] <http://www.statssa.gov.za/publications/CS2007Basic/CS2007Basic.pdf> [Date of use: 7 October

References

2010].

TODD, D.K. & MAYS, L.W. 2005. Groundwater hydrology. Third edition. Hoboken: John Wiley & Sons.

TYRRELL, D.A. and KAPIKIAN, A.Z. 1982. Virus infections of the gastro-intestinal tract. New York: Marcel Dekker Inc.

VAN RYNEVELD, M.B., MARJANOVIC, P.D., FOURIE, A.B., and SAKULSKI, D. 2001. Assignment of a financial cost to pollution from sanitation systems, with particular reference to Gauteng. WRC Report No 631/1/01.

VILJOEN, M.J. & REIMOLD, W.U. 1999. An introduction to South Africa's Geological and Mining Heritage. Randburg: Mintek.

VIVIER, J.C. 2006. Development of an impact assessment methodology and decision making tool to assist in the evaluation of site suitability for on-site sanitation systems. Potchefstroom Campus of the North West University.

WEIDEMAN, R. 2010. Letter to Department of Health, Limpopo Province, 30 August. Polokwane.

WILSON, M.G.C. 2010. A Brief Overview of the Economic Geology of South Africa. Council for Geo-science. [Web:] http://www.geoscience.org.za/index.php?option=com_content&task=view&id=454&Itemid=406 [Date of use: 10 September 2010].

WOLFE, R.L. 1990. Ultraviolet disinfection of potable water. Current technology and research needs. *Environment, Science, Technology*, 24(6):766-773.

WRIGHT, A. 1999. Groundwater contamination as a result of developing urban settlements. Water Research Commission. WRC Report No. 514/1/99. ISBN 1 86845 469 X.

8 APPENDICES

8.1 SANS241:2006 Drinking water quality standards

1	2	3	4	5
Determinand	Unit	Class I (recommended operational limit)	Class II (max. allowable for limited duration)	Class II water consumption period, ^a max.
Physical and organoleptic requirements				
Colour (aesthetic)	mg/L Pt	< 20	20 – 50	No limit ^b
Conductivity at 25 °C (aesthetic)	mS/m	< 150	150 – 370	7 years
Dissolved solids (aesthetic)	mg/L	< 1 000	1 000 – 2 400	7 years
Odour (aesthetic)	TON	< 5	5 – 10	No limit ^b
pH value at 25 °C (aesthetic/operational)	pH units	5,0 – 9,5	4,0 – 10,0	No limit ^c
Taste (aesthetic)	FTN	< 5	5 – 10	No limit
Turbidity (aesthetic/operational/indirect health)	NTU	< 1	1 – 5	No limit ^d
Chemical requirements — macro-determinand				
Ammonia as N (operational)	mg/L	< 1,0	1,0 – 2,0	No limit ^d
Calcium as Ca (aesthetic/operational)	mg/L	< 150	150 – 300	7 years
Chloride as Cl ⁻ (aesthetic)	mg/L	< 200	200 – 600	7 years
Fluoride as F ⁻ (health)	mg/L	< 1,0	1,0 – 1,5	1 year
Magnesium as Mg (aesthetic/health)	mg/L	< 70	70 – 100	7 years
(Nitrate and nitrite) as N (health)	mg/L	< 10	10 – 20	7 years
Potassium as K (operational/health)	mg/L	< 50	50 – 100	7 years
Sodium as Na (aesthetic/health)	mg/L	< 200	200 – 400	7 years
Sulfate as SO ₄ ²⁻ (health)	mg/L	< 400	400 – 600	7 years
Zinc as Zn (aesthetic/health)	mg/L	< 5,0	5,0 – 10	1 year

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1	2	3	4	5
Determinand	Unit	Class I (recommended operational limit)	Class II (max. allowable for limited duration)	Class II water consumption period, ^a max.
Chemical requirements — micro-determinand				
Aluminium as Al (health)	µg/L	< 300	300 – 500	1 year
Antimony as Sb (health)	µg/L	< 10	10 – 50	1 year
Arsenic as As (health)	µg/L	< 10	10 – 50	1 year
Cadmium as Cd (health)	µg/L	< 5	5 – 10	6 months
Total Chromium as Cr (health)	µg/L	< 100	100 – 500	3 months
Cobalt as Co (health)	µg/L	< 500	500 – 1 000	1 year
Copper as Cu (health)	µg/L	< 1 000	1 000 – 2 000	1 year
Cyanide (recoverable) as CN ⁻ (health)	µg/L	< 50	50 – 70	1 week
Iron as Fe (aesthetic/ operational)	µg/L	< 200	200 – 2 000	7 years ^b
Lead as Pb (health)	µg/L	< 20	20 – 50	3 months
Manganese as Mn (aesthetic)	µg/L	< 100	100 – 1 000	7 years
Mercury as Hg (health)	µg/L	< 1	1 – 5	3 months
Nickel as Ni (health)	µg/L	< 150	150 – 350	1 year
Selenium as Se (health)	µg/L	< 20	20 – 50	1 year
Vanadium as V (health)	µg/L	< 200	200 – 500	1 year
Chemical requirements — organic determinand				
Dissolved organic carbon as C (aesthetic/health)	mg/L	< 10	10 – 20	3 months ^c
Total trihalomethanes (health)	µg/L	< 200	200 – 300	10 years ^d
Phenols (aesthetic/health)	µg/L	< 10	10 – 70	No limit ^e
<p>^a The limits for the consumption of class II water are based on the consumption of 2 L of water per day by a person of mass 70 kg over a period of 70 years. Columns 4 and 5 shall be applied together.</p> <p>^b The limits given are based on aesthetic aspects.</p> <p>^c No primary health effect – low pH values can result in structural problems in the distribution system.</p> <p>^d These values can indicate process efficiency and risks associated with pathogens.</p> <p>^e When dissolved organic carbon is deemed of natural origin, the consumption period can be extended.</p> <p>^f This is a suggested value because trihalomethanes have not been proven to have any effect on human health.</p>				

8.2 List of facilities and their associated water quality class

Sample Number	Date Sampled	Facility Name	Latitude	Longitude	Sample Class (SANS 241:2006)
CL-113	2006-03-09	Aa Van Der Merweskraal	-24.66443	29.44501	Unacceptable
2-10/745	2010-03-31	Abbotspoort	-23.4505	28.08689	Unacceptable
CL-274	2005-01-01	Aldays	-22.68309	29.10583	Class2
8-09/982	2009-06-24	Ambergate	-23.51674	28.93679	Unacceptable
CL - 444	2006-07-12	Bakenberg	-23.86478	28.75603	Unacceptable
CL - 437	2006-07-11	Balepi (Pholotji)	-24.03067	28.89297	Class2
4-10/772	2010-04-07	Bavaria	-23.52411	28.83294	Class1
9-09/1243	2009-08-13	Beaconsfield	-22.92147	30.11881	Class2
CL-396	2006-06-28	Bela-Bela	-24.88592	28.28873	Unacceptable
CL-320	2006-06-28	Bele Bela New	-24.87656	28.32427	Class2
1-10/1463	2010-07-19	Bellevue	-23.41211	30.42064	Unacceptable
9-08/730	2008-07-18	Ben Farm	-23.91614	31.03731	Class1
CL - 457	2006-07-14	Bergplaats (Vhambelani)Maelula	-22.97927	30.14747	Class2
2-09/1079	2009-07-13	Bismark	-24.20472	30.50194	Unacceptable
CL - 019	2006-02-28	Block14 (Mankgale)	-23.98879	29.78582	Unacceptable
CL-192	2005-01-01	Blouberg	-23.14248	29.00828	Class2
2-09/1168	2009-07-30	Bochabelo	-23.43053	30.51278	Unacceptable
CL - 408	2006-07-06	Bokwalakwa	-24.14908	28.95136	Class2
CL - 295	2006-05-09	Bolobedu	-23.62342	30.34625	Unacceptable
4-10/1271	2010-06-23	Boschkloof	-24.80411	30.09358	Unacceptable
CL-116	2006-03-09	Boschplaats	-24.44836	29.55397	Unacceptable
2-09/985	2009-06-25	Botlokwa	-23.49235	29.74225	Unacceptable
CL - 205	2006-04-10	Bungeni	-23.20298	30.19752	Class2
CL - 004	2006-02-21	Burgerrecht	-22.98733	28.95339	Class2
CL-115	2006-03-09	Byldrift	-24.54583	29.50369	Unacceptable
CL - 285	2006-05-02	CN Phatudi	-24.02655	30.28098	Unacceptable
2008/V007	2008-06-03	Calais	-24.13552	30.33522	Class1
3-09/1079	2009-07-13	Carlotta	-23.998	30.31733	Class2
4-10/745	2010-03-31	Chalema New	-23.76391	28.7456	Unacceptable
1-09/153	2009-02-05	Charlie Rangane	-23.4771	30.55219	Class2
11-09/2034	2009-12-08	Chuene	-24.19141	29.48597	Unacceptable
CL - 215	2006-04-12	Dakari (Hasam)	-23.09458	30.48043	Class2
22/2006	2006-01-15	Damani Old	-22.83472	30.51331	Class1
CL - 330	2006-06-02	Dan Village	-23.90436	30.27156	Unacceptable
CL-212	2005-01-01	Davhana	-23.20973	30.45625	Class2
L260/6-08	2008-06-26	De Vrede	-22.91736	29.02086	Class2
CL - 195	2006-05-06	Dichoeng	-24.7527	29.88787	Unacceptable
2008/CS80	2008-12-08	Dichoeng New	-24.7408	29.88629	Class2
CL - 358	2006-05-30	Dikgalaopeng	-24.98539	29.45714	Class2
3-09/1228	2010-06-18	Dilokong	-24.61415	30.17049	Class2
CVL09/016	2009-02-19	Dithabaneng	-24.37045	29.57765	Class1

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1-10/1342	2010-07-02	Donal fraser	-22.88653	30.47902	Class2
CL - 287	2006-05-08	Duiwelskloof	-23.69746	30.1412	Unacceptable
CL - 402	2006-06-29	Dwaalboom	-24.72313	26.81012	Unacceptable
8-09/293	2009-02-27	Dzumeri	-23.57638	30.7086	Unacceptable
2009/CS055	2009-03-24	Eensaam	-24.95333	29.886	Class1
2009/UIS00	2009-01-06	Eerstegeluk New	-24.72927	30.13215	Class1
6-10/1118	2010-05-20	Eisleben	-23.51861	29.8415	Class1
2008/CS43	2008-11-20	Elandsdoorn New	-25.28496	29.21345	Class1
2009/UIS01	2009-01-13	Elandskraal New	-24.71479	29.41113	Class1
CL-313	2006-06-26	Elandskraal old	-24.7142	29.41202	Class2
1-10/1329	2010-07-01	Eldorado	-22.89861	28.83028	Unacceptable
CL - 204	2006-04-07	Elim	-23.15409	30.05617	Class2
CL - 421	2006-07-07	Ellisras	-23.67809	27.70333	Unacceptable
CL - 420	2006-07-07	Ellisras 1	-23.68152	27.72298	Unacceptable
CL-422	2006-07-07	Ellisras 2	-23.66789	27.74581	Unacceptable
CL-397	2006-06-28	FH Odendaal Noord	-24.7014	28.42212	Unacceptable
6-08/596	2008-06-13	Folofhodwe	-22.58815	30.42727	Class1
3-09/147	2009-02-04	Fondwe	-22.91758	30.25919	Class2
2-09/982	2009-06-24	Ga Manamela New	-23.70284	29.22935	Unacceptable
CL - 447	2006-07-12	George Masebe	-23.87583	28.69568	Unacceptable
2008/V008	2008-06-09	Gideon	-22.90083	28.67778	Unacceptable
CL - 101	2006-03-31	Giyani	-23.31261	30.72328	Class2
1-10/1118	2010-05-20	Goedertrou	-23.40075	28.91244	Class2
5-09/2034	2009-12-08	Goedgedacht	-25.06067	29.71783	Unacceptable
CVL09/011	2009-01-29	Goedgedacht	-25.06067	29.71783	Class1
CL - 289	2006-05-08	Grace Mugobeni	-23.7165	30.4365	Class2
2009/UIS04	2009-02-20	Grootdraai	-23.11775	28.70778	Unacceptable
69605	2009-03-06	Groothoek (DR Machupe)	-24.31258	29.335	Class1
7-10/1118	2010-05-20	Helderwater	-23.28194	30.29619	Class1
2-09/1174	2010-06-07	Hele Franz	-23.28381	29.11313	Class1
6-09/2051	2009-12-09	Hlaneki	-23.28144	30.50933	Unacceptable
6-09/2052	2009-12-09	Hlaneki	-23.28144	30.50933	Class1
CL - 210	2006-04-11	Homo A	-23.30444	30.80531	Class2
4-09/2051	2009-12-09	Homulani	-23.87506	31.06017	Unacceptable
2008/V006	2008-06-03	Ikageng	-24.57083	29.87383	Unacceptable
L256/2-08	2008-06-26	Indermark	-23.07858	29.11073	Unacceptable
CL-299	2006-05-09	Iteleng	-23.39806	30.11417	Unacceptable
1-10/1231	2010-06-18	Jakhalskuil	-23.83317	28.60781	Unacceptable
CL - 136	2006-06-02	Jamela	-23.96025	30.36969	Class2
3-10/1331	2010-07-01	Jane Furse New	-24.74348	29.86488	Unacceptable
CL - 194	2006-04-06	Jane Furse Old	-24.76383	29.86767	Unacceptable
5-10/1118	2010-05-20	Julesburg	-24.06953	30.32853	Unacceptable
CI-020	2006-02-28	Kganya (Boyne)	-23.94722	29.79861	Unacceptable
CL - 161	2007-02-11	Kgapane	-23.64075	30.21775	Unacceptable
7-09/1243	2009-08-13	Khakhu	-22.83622	30.24732	Class2
H14-1075	2004-05-14	Kheyi	-23.57969	30.87362	Unacceptable
CL - 343	2006-06-07	Khujwana	-23.93017	30.2395	Class2

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1-10/1461	2010-07-19	Kibi	-22.83644	28.84697	Unacceptable
4-09/1806	2009-11-10	Klipfontein (Mokamole)	-23.96275	28.61325	Class2
CL - 010	2006-02-23	Kranzplaas	-23.48622	28.91639	Class1
CL - 102	2006-03-31	Kremetart	-23.32235	30.68181	Class2
2-10/772	2010-04-07	Kromhoek	-22.93269	29.02653	Unacceptable
2-09/147	2009-02-04	Kuruleni	-23.14564	30.35966	Class2
2-10/1278	2010-06-23	Kutama	-23.06319	29.63544	Unacceptable
9-09/1103	2009-07-16	Kwarrielaagte	-25.31952	29.2619	Class2
2009/CS058	2009-03-24	Lambani	-22.72121	30.83168	Class1
CL-319	2006-06-28	Leah Mokone Old	-24.885	28.31167	Class2
CL - 100	2006-03-31	Lebaka	-23.46333	30.36733	Class2
1-09/1079	2009-07-13	Leboeng (Swaranang)	-24.51	30.64733	Unacceptable
Cl - 154	2006-03-22	Lebowa Kgomo	-24.2955	29.5285	Unacceptable
CL - 120	2006-03-17	Lebowakgomo Public works	-24.31367	29.5605	Class2
CL - 096	2006-07-08	Ledwaba	-24.27244	29.42183	Class1
3-09/983	2009-06-24	Lekhureng	-23.57325	28.92033	Unacceptable
CL - 311	2006-05-11	Lenyenyene Old	-23.97419	30.26783	Class2
1-08/166	2008-02-25	Lenyenyene New	-23.97415	30.26783	Class2
CL - 344	2006-06-07	Lephephane	-23.98683	30.1945	Class2
1-09/1624	2009-10-08	Lesfontein (Sekhung)	-23.14932	28.78547	Unacceptable
CL - 308	2006-05-11	Letaba	-23.87417	30.26933	Class2
CL - 255	2006-04-26	Letsitele New	-23.88854	30.3836	Class2
CL - 237	2006-04-19	Levubu Old	-23.09581	30.286	Class2
CL-026	2006-03-03	Louis Trichardt	-23.0373	29.90747	Class2
CL - 303	2006-05-09	Lulekani	-23.86462	31.07726	Unacceptable
CL - 134	2006-06-12	Maake New	-24.01536	30.25436	Unacceptable
6-09/293	2009-02-27	Madimbo	-22.45178	30.56282	Unacceptable
H19-0249	2008-06-13	Madombidzha	-23.11483	29.8194	Class1
5-09/1079	2009-07-13	Madumane	-23.62936	30.39964	Class2
CL - 149	2006-03-23	Mafefe	-24.19525	30.09989	Unacceptable
Cl-323	2005-01-01	Magalies	-24.56255	29.64407	Unacceptable
CL - 351	2006-06-09	Mahale	-23.69461	30.96836	Unacceptable
CL - 409	2006-07-06	Mahwelereng Zone 1	-24.14003	28.98375	Unacceptable
CL - 410	2006-07-06	Mahwelereng Zone 2	-24.13981	28.99181	Unacceptable
CL - 011	2006-02-24	Maja	-24.18297	29.53705	Unacceptable
CL - 042	2006-03-09	Makakhulele	-22.89242	30.91166	Unacceptable
2-09/2051	2009-12-09	Makanye (calais)	-23.89819	29.72392	Unacceptable
13-09/1103	2009-07-16	Makepsvlei	-24.93037	29.04581	Unacceptable
CVL09/009	2009-01-21	Makgato	-23.50556	29.66342	Class1
CL - 298	2006-05-09	Makgopa (Ga Mookgo)	-23.6167	30.4689	Class2
2009/UIS02	2009-01-10	Makhado	-22.90081	30.03442	Class1
CL - 345	2006-06-07	Makhushane	-23.96572	31.04428	Class2
10-09/293	2009-02-27	Makhuva	-23.58217	30.96467	Unacceptable
CL - 070	2006-03-10	Makuleke	-22.86522	30.91454	Class2
CL - 238	2006-04-20	Makuya	-22.65	30.83031	Unacceptable
3-09/1106	2009-07-17	Malamulele	-23.01322	30.701	Class2
CL - 060	2006-03-02	Mamabolo A	-23.87953	29.82042	Class2

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CL - 016	2006-03-02	Mamabolo J	-23.80583	29.79961	Unacceptable
2-09/1243	2009-08-13	Mamaila	-23.35114	30.24269	Unacceptable
CL - 436	2006-07-10	Mamaselela	-24.0062	28.87253	Class2
CL - 290	2006-05-08	Mamitwa	-23.73194	30.40944	Class2
7-09/2034	2009-12-08	Mamone	-24.711	29.803	Unacceptable
CL - 235	2006-04-19	Mamotshwa (Mahlahlela)	-23.852	29.80589	Unacceptable
6-09/178	2009-02-11	Mamushi	-24.05951	29.69539	Unacceptable
CL - 214	2006-04-12	Manavhela	-23.10033	30.45217	Class2
CL - 291	2006-05-05	Mandlakazi	-23.73233	30.37119	Unacceptable
2-10/786	2010-04-08	Manenzhe	-22.46932	30.68103	Unacceptable
CL - 229	2006-04-25	Manganeng New	-24.68464	29.95716	Class2
15-09/178	2009-02-11	Mankotswana (Mooiplaas)	-24.41492	29.74728	Unacceptable
7-08/730	2008-07-18	Mankuwe	-23.4678	28.55959	Class2
CL - 158	2006-03-23	Mankweng	-23.89196	29.72422	Unacceptable
CL-087	2005-01-01	Manotwane Old	-24.35622	29.94908	Unacceptable
CL-034	2006-06-06	Manyima	-23.27639	30.01833	Class2
CL - 347	2006-06-08	Mapayeni	-23.34911	30.81833	Class2
2-10/852	2010-04-19	Mapela	-23.95575	28.84756	Class1
6-10/1271	2010-06-23	Maphelle	-23.46842	30.31203	Unacceptable
CL - 305	2006-05-10	Maphuta Malatjie	-23.92533	31.03717	Class1
11-09/1067	2009-07-09	Maraba	-23.78644	29.17183	Unacceptable
CL - 423	2006-07-07	Marapong	-23.65853	27.62908	Class2
1-10/719	2010-03-29	Marishane	-24.72744	29.74683	Class2
4-09/1079	2009-07-13	Mariveni	-23.88753	30.34878	Class2
CL - 206	2006-04-10	Marseilles New	-23.22203	30.33668	Class2
4-09/2034	2009-12-08	Marulaneng	-24.95147	29.41017	Unacceptable
2-09/148	2009-02-04	Masakona	-23.27358	30.24417	Unacceptable
9-9/2034	2009-12-08	Mashabela	-24.43869	30.00483	Unacceptable
CL-040	2006-03-07	Mashamba	-23.23567	30.15333	Unacceptable
3-09/1229	2009-07-28	Mashashane	-23.93	29.13306	Unacceptable
CL - 381	2006-07-07	Mashau	-23.16883	30.21753	Class2
2009/UIS02	2009-01-28	Mashishimale New	-23.9734	30.99341	Class2
CL - 156	2006-03-22	Mashite New	-24.31167	29.69467	Unacceptable
2008/V003	2008-05-22	Masisi New	-22.42203	30.86179	Class2
Cl - 177	2006-03-22	Matamanyane	-23.66635	29.34658	Class2
CL - 150	2006-02-23	Mathabatha New	-24.20567	29.87133	Unacceptable
CL - 069	2006-03-10	Matiyani	-22.74606	30.97781	Class2
CL - 362	2006-06-08	Matlala	-24.83216	29.50233	Unacceptable
CL - 268	2006-04-26	Matlala Capricorn	-23.74639	29.05611	Class2
CL-023	2006-03-02	Matoks Old	-23.47722	29.70972	Unacceptable
1-10/1056	2010-05-19	Matsepe New	-25.02442	29.50699	Class2
CL - 359	2006-05-30	Matsepe Old	-25.02339	29.49703	Class1
4-09/1106	2009-07-17	Matsheka	-22.87872	30.73908	Class2
4-09/153	2009-02-05	Matswi	-23.58583	30.35767	Class2
10-09/982	2009-06-24	Mattanau	-23.42494	28.79839	Class2
6-09/1243	2009-08-13	Mavambe New	-23.00367	30.64894	Class2
14-09/154	2009-02-05	Mavele	-23.6685	30.42594	Class1

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CL-041	2006-03-07	Mawani	-23.78083	30.55194	Class2
CL - 388	2006-07-14	Mbilwe	-22.92922	30.46897	Class2
CL - 382	2006-07-07	Mbokota	-23.20013	30.09879	Class2
2-09/1219	2010-06-15	Mecklenburg	-24.38536	30.07249	Unacceptable
CL - 044	2006-03-09	Mhinga	-22.79386	30.90321	Unacceptable
CL - 339	2006-06-06	Middelwater	-23.41531	30.20564	Class2
CL - 364	2006-06-08	Mmotoaneng	-24.92231	29.62081	Unacceptable
2-09/1624	2009-10-08	Mmutlane	-24.34783	30.14586	Class2
2008V004	2008-06-03	Modjadji 5	-23.62267	30.3262	Class1
6-09/1103	2009-07-16	Moeding	-24.9535	29.4575	Unacceptable
CVL09/002	2009-01-28	Moeding	-24.9535	29.4575	Class1
3-09/1097	2009-07-15	Moganyaka	-24.99633	29.40283	Unacceptable
CL - 283	2006-05-02	Mogapeng	-24.07119	30.28658	Unacceptable
CL - 312	2006-05-11	Mogoboya	-24.01444	30.19728	Class2
CL - 01	2006-02-02	Mogodi (Wurtsdorp)	-23.32758	29.23472	Unacceptable
1-10/1441	2010-07-16	Mogoto New	-24.34096	29.28796	Class2
10-09/1781	2009-11-04	Mogoto Old	-24.34836	29.26489	Class1
CL - 331	2006-06-02	Mohlaba	-23.93103	30.28911	Unacceptable
CL - 132	2006-06-01	Moime (Motjeneng)	-23.97567	30.24553	Class2
4-09/1240	2010-06-21	Mokopane	-24.15208	28.98611	Class1
CL-017	2005-01-01	Molepo	-24.03576	29.74108	Unacceptable
9-09/1061	2009-07-08	Moletlane New	-24.36306	29.33569	Unacceptable
CL - 008	2006-02-23	Montz	-23.32614	28.69103	Class2
CL-315	2006-06-27	Mookgaphong	-24.52475	28.70833	Class2
9-09/153	2009-02-05	Morapalala	-23.60319	30.41778	Class2
6-09/153	2009-02-05	Morutji	-23.67025	30.36711	Class2
CL - 354	2006-05-30	Motetema New	-25.09825	29.46608	Class2
CL - 159	2006-03-23	Mothiba	-23.85756	29.636	Unacceptable
CL - 261	2006-05-03	Motlolo	-24.50936	30.17469	Unacceptable
8-09/178	2009-02-11	Motsepe	-24.28361	29.85747	Unacceptable
3-08/730	2008-07-18	Motswana (Matshana)	-24.48005	30.30858	Class1
CL - 163	2006-03-29	Motupa	-23.68228	30.29767	Unacceptable
4-10/867	2010-04-20	Moutse East	-25.15122	29.10517	Class1
4-09/1168	2009-07-30	Mphambo	-23.08405	30.67062	Class2
6-09/1106	2009-07-17	Mphephu	-22.87481	30.13825	Unacceptable
12-09/1168	2009-07-30	Msengi	-23.34564	30.37014	Unacceptable
10-09/154	2009-02-05	Mtititi	-23.10169	30.898	Unacceptable
H25-0054	2008-06-13	Mudimeli	-22.79836	29.95647	Class2
CL-030	2006-06-06	Muila	-23.36661	29.97922	Unacceptable
11-09/147	2009-02-04	Mukula	-22.85833	30.58778	Class2
CL - 233	2006-04-19	Muledane New	-22.99233	30.45733	Unacceptable
CL - 067	2006-03-08	Mulenzhe	-22.9965	30.52383	Unacceptable
CL - 373	2006-07-06	Mulima	-23.30911	30.04608	Class2
2-09/293	2009-02-27	Murangoni	-22.91689	30.37158	Unacceptable
CL - 110	2006-04-06	Musina	-22.34356	30.04502	Unacceptable
CL - 216	2006-04-12	Muswana	-23.1505	30.62964	Class2
CL - 203	2006-04-07	Mutale	-22.7365	30.52111	Unacceptable

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CL - 386	2006-07-10	Muwaweni	-23.31717	30.11567	Class2
CVL10/006	2009-01-19	My Darling	-23.08314	28.79856	Class1
CL - 263	2006-05-03	Naboom Koppies New	-24.5584	30.3516	Class2
CI-263	2005-01-01	Naboom Koppies Old	-24.557	30.34906	Unacceptable
CL - 306	2006-05-10	Namakgale Old	-23.94067	31.04083	Unacceptable
13-09/178	2009-02-11	Nchabaleng	-24.44005	29.80071	Unacceptable
CL - 337	2006-06-06	Ndengeza	-23.31611	30.406	Class2
19-09-179	2009-02-11	Ndlovu Private Medical HC	-25.28402	29.19363	Class2
8-10/1271	2010-06-23	Ngobe (Nguve)	-23.3615	30.7215	Unacceptable
CL - 288	2006-05-08	Nkambako	-23.73546	30.47826	Unacceptable
1-10/1269	2010-06-23	Nkhensani	-23.3125	30.69215	Class2
CL-211	2005-01-01	Nkhensani New	-23.3105	30.69057	Unacceptable
6-09/1168	2009-07-30	Nkhuri	-23.21333	30.55439	Unacceptable
CL - 145	2006-03-22	Nkomo B	-23.41747	30.77789	Class2
CL - 309	2006-05-11	Nkowankowa	-23.8867	30.29304	Class2
CL - 013	2006-02-27	Nobody	-23.89003	29.66753	Class2
CL - 400	2006-06-28	Northam	-24.95264	27.26433	Class2
2-10/1061	2010-05-20	Nthabalala New	-23.27764	29.97283	Unacceptable
CL - 043	2006-03-09	Ntlhaveni C	-22.91456	30.87044	Unacceptable
9-09/148	2009-02-04	Ntlhaveni D	-22.86925	30.88506	Unacceptable
15-09/153	2009-02-05	Nyavana (Shihoko)	-23.65586	30.47828	Class2
CL-398	2006-06-28	Nylstroom LA	-24.70366	28.40659	Unacceptable
4-09/1243	2009-08-13	Olifantshoek	-23.33464	30.27503	Unacceptable
CL - 167	2006-03-03	Ooghoek	-23.62542	30.53358	Unacceptable
CL - 443	2006-07-11	Paulus	-23.75333	28.65953	Unacceptable
CL - 228	2006-04-13	Paulus Masha New	-24.45217	29.73633	Unacceptable
4-10/852	2010-04-22	Percy	-23.48083	29.18611	Class2
CL - 178	2006-03-29	Perskebult	-23.80111	29.35833	Class2
CL - 242	2006-04-06	Pfanani	-22.95272	30.42953	Unacceptable
CL - 198	2006-04-06	Phaahla Old	-24.69764	29.73542	Class1
CL - 391	2006-07-14	Phadzima	-22.94711	30.18947	Class2
CL-399	2006-06-28	Phagameng LA	-24.69377	28.4432	Class2
1-09/1260	2009-08-13	Phalaborwa	-23.9325	31.13617	Unacceptable
CL-301	2006-05-10	Phalaborwa Buss Stop	-23.94883	31.13626	Unacceptable
CL-300	2006-05-10	Phalaborwa PHC	-23.95117	31.13717	Class2
CL - 259	2006-05-03	Phasha	-24.32822	30.00456	Unacceptable
CL - 370	2006-06-14	Pheeha	-23.45056	30.0464	Class2
CL - 241	2006-04-20	Phiphidi	-22.9525	30.38817	Unacceptable
CL - 412	2006-07-05	Potgietersrus (Ruiteweg)	-24.18378	29.00994	Unacceptable
CL - 262	2006-05-03	Praktiseer New	-24.58423	30.31969	Unacceptable
21835	2009-05-06	Praktiseer Old	-24.57767	30.31433	Class2
CL - 389	2006-07-14	Rabali	-22.88021	30.09326	Class2
CL - 144	2006-03-20	Rakgoatha	-24.3495	29.3685	Unacceptable
CL-022	2006-03-03	Ramokgopa	-23.46653	29.81592	Class2
CL - 353	2006-05-30	Ramupudu	-25.051	29.50733	Class2
CL - 335	2006-06-06	Ratanang (Randzanani)	-23.43639	30.63478	Class2
CL - 403	2006-06-29	Regorogile 1	-24.58092	27.38276	Class2

Appendices

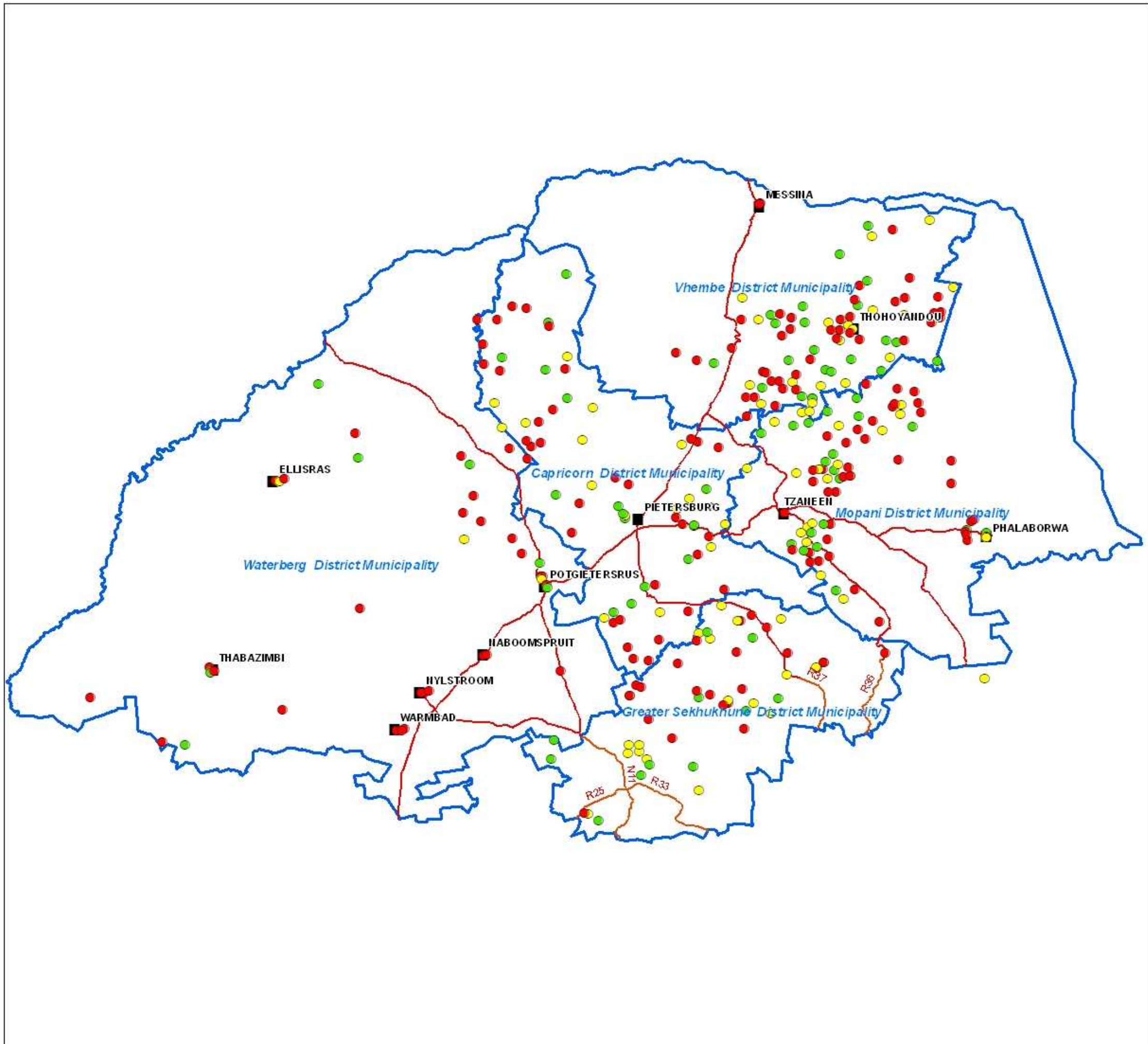
CL - 404	2006-07-11	Regorogile 2	-24.59878	27.39531	Unacceptable
CL - 383	2006-07-07	Riverplaats	-23.23203	30.05428	Class2
CL-314	2006-06-26	Roedtan	-24.59626	29.07898	Class1
1-09/1856	2009-11-17	Rooiberg	-24.78507	27.73632	Unacceptable
10-09/1168	2009-07-30	Rotterdam	-23.40072	30.27447	Unacceptable
2-10/1118	2010-05-20	Rozenkranz	-23.49481	28.9844	Unacceptable
CL - 292	2006-05-08	Runnymede	-23.65989	30.44786	Class2
2008/V010	2008-06-09	Sadu	-23.30603	28.76161	Class2
1-10/1199	2010-06-08	Sambandou	-22.73764	30.65792	Class2
4-10/1118	2010-05-20	Schoongezicht	-23.33635	29.04339	Class2
2-10/1271	2010-06-23	Schoonoord	-24.75483	30.01017	Unacceptable
H11-1992	2008-07-08	Seakamela (Avon)	-23.14132	29.1015	Class1
CL - 252	2006-04-24	Seapole	-23.49636	30.46014	Unacceptable
CL - 152	2006-03-23	Sebayeng Old	-23.77683	29.69433	Class2
5-09/1062	2009-07-08	Segole	-23.60242	28.64022	Class1
CL - 018	2006-02-28	Sehlale	-23.99836	29.80628	Class2
1-08/644	2008-06-26	Sekgopo	-23.61772	29.98153	Class2
2-10/1224	2010-06-17	Sekororo	-24.2515	30.44767	Unacceptable
2008/005	2008-06-02	Sekororo Old	-24.20783	30.408	Class1
2-10/867	2010-04-20	Seleka	-23.21484	27.9082	Class2
1-09/1097	2009-07-15	Selepe	-24.35444	29.93258	Class2
CL-250	2006-04-24	Seloane	-23.69583	30.92683	Class2
3-10/1118	2010-05-20	Semenya	-23.69681	29.40672	Class2
CL - 332	2006-06-06	Senobela	-23.55117	30.39731	Class2
11-09/178	2009-02-11	Seroka	-24.508	29.931	Unacceptable
2009/UIS00	2009-01-05	Seroka	-24.508	29.931	Class1
2009/UIS29	2009-01-31	Seshego Zone 1	-23.85997	29.38942	Class1
CL - 180	2006-03-29	Seshego Zone 2	-23.84617	29.39128	Class2
CL - 179	2006-03-29	Seshego Zone 3	-23.8392	29.3834	Class1
CL - 360	2006-06-18	Setlabosoane	-24.67389	29.46992	Class2
CL - 234	2006-04-19	Shayandima	-23.00511	30.42669	Class2
CL - 293	2006-05-08	Shihoko	-23.65556	30.47833	Unacceptable
CL - 284	2006-05-02	Shiluvana	-24.0435	30.37533	Unacceptable
CL - 047	2006-03-29	Shimange	-23.38998	30.58787	Unacceptable
7-09/154	2009-02-05	Shingwedzi	-23.00139	30.73722	Unacceptable
4-10/786	2010-04-08	Shivulani (Dumaz)	-23.1415	30.70211	Unacceptable
CL - 415	2006-07-06	Shongoane	-23.56767	28.10367	Class2
CL - 162	2006-03-28	Shotong	-23.631	30.29853	Unacceptable
3-09/1451	2009-09-09	Sibasa	-22.94645	30.49146	Class1
H27-0138	2008-07-25	Siloam	-22.89266	30.19429	Unacceptable
CL - 091	2006-03-07	Slypsteen New	-24.44629	29.4055	Class2
CL-091	2005-01-01	Slypsteen Old	-24.45183	29.40267	Class1
CL - 089	2006-03-06	Smugglers Union	-24.5385	29.43117	Unacceptable
2-09/178	2009-02-05	Spitskop	-23.88833	29.87444	Unacceptable
2008/V024	2008-10-23	Spitspunt New	-24.9689	28.92894	Unacceptable
CL - 401	2006-06-29	Swartklip	-24.93775	27.15589	Unacceptable
3-09/1245	2009-08-12	Taaiboschgroet	-22.84608	28.91726	Unacceptable

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1-09/1781	2009-11-04	Taung	-24.45517	30.39633	Class2
2009/UIS06	2009-03-15	Thabazimbi LA	-24.6064	27.39007	Class1
CL-405	2006-06-30	Thabazimbi Old	-24.59871	27.4069	Unacceptable
21833	2009-05-01	The Willows	-24.36	30.62144	Unacceptable
2008/033	2008-11-10	Thengwe	-22.71333	30.55958	Class1
CL-248	2006-04-21	Thohoyandou	-22.96602	30.47799	Unacceptable
2009/CS061	2009-03-24	Thomo	-23.24797	30.78614	Unacceptable
CL - 240	2006-04-20	Thondotshivashe	-22.9035	30.43033	Class2
CL-036	2006-06-07	Tiyani	-23.30633	30.29458	Class2
CL - 007	2006-02-22	Toverfontein	-22.90308	28.77442	Unacceptable
CL - 236	2006-04-19	Tshakhuma	-23.04836	30.30219	Class2
6-10/745	2010-03-31	Tshamahanzi	-24.07572	28.98011	Unacceptable
CL-244	2006-04-21	Tshaulu	-22.79583	30.743	Unacceptable
CL - 204	2006-04-07	Tshehlwaneng New	-24.78904	29.97361	Class2
CL-243	2006-04-21	Tshifundi (Tshififi)	-22.81475	30.69861	Unacceptable
CL - 387	2006-07-14	Tshikuwi	-22.90214	29.95008	Unacceptable
CL-249	2006-04-21	Tshilidzini	-22.9947	30.41415	Unacceptable
1-10/963	2010-05-07	Tshilwavhusiku	-23.09672	29.73847	Unacceptable
CL - 213	2006-04-12	Tshimbupfe	-23.15683	30.469	Class2
CL - 202	2006-04-07	Tshiombo	-22.805	30.50111	Class2
4-09/293	2009-02-27	Tshiungani	-22.49861	30.58042	Unacceptable
2008/164	2008-06-12	Tswinga New	-23.02263	30.47555	Class1
2-09/1805	2009-11-10	Uitkyk	-23.39602	28.9751	Unacceptable
CL-433	2006-07-10	Vaalkop	-24.00506	28.93253	Class2
2009/UIS02	2009-01-18	Vaalwater Old	-24.29443	28.11132	Class1
4-09/147	2009-02-04	Valdezia	-23.10011	30.17971	Class2
2009/UIS01	2009-01-13	Van Der Merweskraal	-24.66442	29.44483	Class1
CL - 307	2006-05-11	Van Velden	-23.835	30.16427	Class2
CL-082	2005-01-01	Vhurivhuri	-22.70253	30.76511	Unacceptable
CL - 375	2006-07-06	Vleifontein Old	-23.21654	29.99481	Unacceptable
CL-413	2006-07-05	Voortrekker	-24.19624	29.01405	Class2
CL486	2005-01-01	Vyeboom	-23.15369	30.38806	Class1
CL - 267	2006-04-26	WF Knobel	-23.63409	29.12057	Unacceptable
CL - 376	2006-07-06	Waterval	-23.16019	30.06933	Class2
CL - 380	2006-07-07	Wayeni	-23.24119	30.21867	Class2
7-09/1066	2009-07-09	Weltevreden	-23.56078	28.59906	Unacceptable
9-09/1067	2009-07-09	Weltevreden	-23.56078	28.59906	Unacceptable
11-09/1103	2009-07-16	Witfontein (Mamaneng)	-25.02425	29.03596	Class2
CL - 417	2006-07-06	Witpoort	-23.33447	28.01118	Unacceptable
CL - 310	2006-05-11	Xikukwani	-23.238	30.70395	Unacceptable
2009/CS054	2009-03-24	Zaaiplaats	-25.17105	29.74566	Class2
1-09/2013	2009-12-07	Zebediela	-24.48189	29.40445	Unacceptable
2008/V009	2008-06-09	Zeits	-23.02167	28.70611	Unacceptable

8.3 Maps

8.3.1 Map indicating distribution of Health Facilities per Water Quality Class




Health Water Quality

Legend


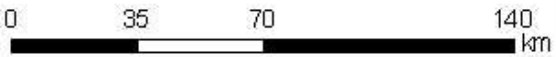
- Towns
- Roads
- District municipalities

Classes

- Good: Class 1 (SANS 241:2006)
- Marginal: Class 2 (SANS 241:2006)
- Poor: Unacceptable for human consumption (SANS 241:2006)



Water quality class per facility

Co-ordinate system: WGS1984