

**AN EXPLANATION  
OF THE 1: 500 000  
GENERAL HYDROGEOLOGICAL MAP**

**PHALABORWA 2330**



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**&**

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## **Foreword**

Groundwater in South Africa as a whole is under-utilised, although some local over-exploitation does occur. Groundwater schemes can be implemented quickly and cheaply, and are in particular effective in conjunctive use and dispersed scenarios. With increasing pressure on scarce surface water resources, and with the priority of supplying potable water to disadvantaged rural and urban communities, it is clear that groundwater will play an increasing important role in South Africa's economic and social prosperity.

A major obstacle to the realisation of this prosperity is that insufficient information about groundwater is reaching the planners, decision makers, users and other affected parties. In an attempt to rectify this situation, groundwater information locked away in expert's minds and computer databases is being made available on maps. The first step in this program at the regional level is the preparation of the "General Hydrogeological Maps" at the scale of 1: 500 000.

The main purpose of the General Hydrogeological Maps, of which the accompanying map sheet is an example, is to display in an easily understood format what is known about basic hydrogeological properties. These General Maps represent the synthesis of the most up-to-date data and geohydrologist's knowledge. Thus, these maps are also very useful in identifying areas where additional data should be collected and further investigations need to be conducted.

Groundwater maps – the best available information for the best possible planning, development and management of a strategic resource – will ultimately benefit all South Africans.

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## **Preface**

With the exception of air, water can with little doubt, be defined as Man's most precious resource. It is said that to deny Man food, his body can sustain life for weeks, but refuse him water and death is likely to come within a few days. The availability of water to even the remotest area is thus vital to maintain this indispensable condition for human existence.

An estimated 3% of fresh water available on Earth occurs on the surface and 97% occurs underground (Johnson Division, 1975). Owing to the lack of perennial streams in the desert to semi-desert parts two-thirds of South Africa's surface area is largely dependent on groundwater. To tap and develop this vast amount of underground stored water, a keen knowledge of a region's environment, and above all, its diversified geology, is of the utmost importance in order to comprehend how and where groundwater occurs.

The Phalaborwa Hydrogeological Map and the accompanying explanatory brochure introduce the current state of the groundwater knowledge and the basic geohydrological characteristics of the map area. It needs to be explained that within the map's confines, dissimilar and divergent conditions occur, which, to various degrees, may impact on groundwater. Under these circumstances, groundwater occurrence can vary. Groundwater occurrence is thus referred to in this brochure.

The primary aim of the General Hydrogeological Map is to produce a synoptic overview of the geohydrological character of an area. The main map thus features borehole yield, aquifer type, groundwater quality, and groundwater use, which are superimposed against a slightly subdued surface lithological background. The brochure discusses these topics in more detail, as well as issues such as geological controls on groundwater yield and quality, borehole siting methods, groundwater management, groundwater levels, suggestions for future studies, etc. It is hoped that both the groundwater scientist and the interested layman will find the product useful. The map and brochure will hopefully also be informative to planners, especially in the light of the Reconstruction and Development Programme, and it will play a constructive role in general groundwater education and groundwater awareness building.

Groundwater has always been an important source of water supply to many people and localities in the map area. Water consumers, in many areas, are solely reliant on groundwater for domestic and stock watering purposes. There is a change in focus to utilise groundwater for irrigational purposes due to the high yields intercepted in the underlying aquifers. It is hoped that this map and brochure will serve as a basis for future specialised groundwater maps and groundwater studies as suggested in the brochure.

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## **DATA AND REPORTS**

**DWA (Pretoria)**

National groundwater and water quality  
databases

**GCS (PTY) Ltd**

Hydrogeological Reports

**Council for Geoscience (Pretoria)**

Geological information

**Municipalities for the map area**

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## ABBREVIATIONS

KNP                      Kruger National Park

TWQR	Target Water Quality Range
DWA	Department of Water Affairs
DWAF	Department of Water Affairs & Forestry
EC	Electrical conductivity
HARMEAN	Harmonic mean
Mamsl	metre above mean sea level
Mbgl	metre below ground level
NGDB	National Groundwater Data Base
SANS	South African National Standard
SACS	South African Committee Stratigraphy
TWQR	Target Water Quality Range
TDS	Total dissolved salts
UNESCO	United Nations Educational, Scientific and Cultural Organisation
VSA	VSA Geoconsultants Group
WMS	Water Management System
WRPS	Water Resource Planning Systems

## SYMBOLS AND UNITS

Km <sup>2</sup>	square kilometre
l/s	litres per second
m	metre
Ma	million years
Meq	milli-equivalents
mg/l	milligrams per litre
mS/m	milliSiemens per metre
m <sup>3</sup>	cubic metre
pH	logarithm of the hydrogen ion concentration in moles per litre
s	seconds
%	percentage

## CHEMICAL SYMBOLS

Al	Aluminium
As	Arsenic
Cd	Cadmium
Ca	Calcium
Cl	Chloride
Cu	Copper
F	Fluoride
Fe	Iron
T.H.	Total hardness
Mg	Magnesium
Mn	Manganese
No <sub>3</sub>	Nitrate
No <sub>2</sub>	Nitrite
N	Nitrate (No <sub>3</sub> ) + Nitrite (No <sub>2</sub> )
K	Potassium
Na	Sodium

SO<sub>4</sub>  
Si  
Zn

Sulphate  
Silica  
Zinc

## 1. INTRODUCTION

The Phalaborwa 2330 Hydrogeological Map at a scale of 1: 500 000 forms part of the General Hydrogeological Map Series of South Africa, which comprise 23 map sheets. It represents the first general synthesis of the groundwater resources of the area bordered by latitudes 23° and 25° south and longitudes 30° and 34° east. The map area covers a large portion of the Lowveld, which includes a considerable part of the Kruger National Park (KNP). The area is well known for its tourist attractions, such as the beautiful scenery and sites along the Drakensberg and escarpment as well as the many game lodges and farms. Besides its tourist industry, the area mainly supports a variety of agricultural activities and game farming. Although a number of bulk water supply schemes are established in the map area, a large portion of the well-distributed population still depends on groundwater as the only source of supply.

### 1.1 Aims and Objectives

The main aim of this map and accompanying explanation brochure is to serve as a general reference for the planning, development, and management of groundwater resources as well as for educational purposes.

This map illustrates general hydrogeological conditions on a relatively large scale and can thus **not** be used to determine specific local conditions, for example, siting of individual boreholes. Site-specific detailed investigations will still be required to determine local conditions. The map and accompanying explanation brochure will, however, provide general guidelines as to which detailed investigations are required and what expected hydrogeological conditions are likely to occur.

The main features shown on the map are borehole yield, aquifer type, groundwater quality, groundwater use, and lithology. This brochure provides supplementary information on these topics and also discusses topics such as the siting of boreholes, the management of groundwater schemes, and the protection of groundwater from over-abstraction and contamination.

### 1.2 Aquifer legend

The hydrogeological map utilises an adapted international UNESCO classification (UNESCO, 1983). The adoptions were made in order to better depict the features of South African hydrogeological conditions. The main aquifer legend changes were:

- The removal of the division between local/discontinuous aquifers and extensive aquifers. (This division is superfluous because the majority of South African aquifers fall into the local/discontinuous category.)
- The addition of a “fractured and intergranular” mode of occurrence because of its prevalence.
- The differentiation of low yielding aquifers into an appropriate mode of occurrence. The UNESCO legend does not differentiate between fractured or intergranular when yields are very low, and places everything together as a “low-yielding” or “poor” aquifer. Since so many of the South African aquifers are low yielding it was considered important to specify what type of aquifer it was.
- Specifying numerically what is meant by “low yield,” “moderate yield,” etc.

Four classes of groundwater occurrence were used:

Class A = Intergranular

Class B = Fractured

Class C = Karst

Class D = Intergranular and Fractured

It should be noted that these classes indicate the type of aquifer that may be found. The boundaries of individual aquifers are not shown. A particular aquifer class depicted on the map could well contain a myriad of individual aquifers. In addition, it should be noted that the aquifer type mapped was the principal aquifer rather than the shallowest. In other words, the principal aquifer is regarded as the aquifer with the highest borehole yields and the best quality water. If the top most aquifer was a saturated silt layer, for example, with low yields it would be ignored if the under-lying bedrock provided higher borehole yields.

The “Intergranular and Fractured” class usually refers to an aquifer SYSTEM with an upper weathered layer containing water in pore spaces and a lower hard rock layer containing water in fractures. Large quantities of water are often stored in the weathered layer, but the transmissivity of this layer is often too low to allow water to be abstracted economically from it. The water in the weathered zone does, however, feed the fractures, from which economically abstraction is possible.

Each aquifer class is sub-divided into groups according to the representative borehole yields. On the main map, a class is represented by a specific colour and each group by a different tone (intensity) of that colour. The borehole yield ranges, and possible use of the boreholes are:

> 5.0 ℓ/s	High yield, suitable for urban supply or large-scale irrigation
2.0 – 5.0 ℓ/s	Moderately high yield, suitable for domestic supply to small towns or small-scale irrigation.
0.5 – 2.0 ℓ/s	Moderately low yield, suitable for domestic supply to rural settlements or irrigation of community food plots.
0.1 – 0.5 ℓ/s	Low yield, suitable for domestic supply to single homesteads or small rural villages or stock watering. Boreholes in this range are mostly equipped with hand- or wind pumps.
< 0.1 ℓ/s	Very low yield, suitable for domestic supply to small single homesteads. Suitable for hand pump installations only.

Table 1 depicts the hydrogeological classification used for the Phalaborwa Map. It shows that the water bearing properties of rock formations are associated with four main classes of water-bearing interstices defined as:

Table 1: Hydrogeological Classification of groundwater occurrence and borehole yields in the map area. (After Orpen, 1994).

CLASS A				CLASS B			CLASS C			CLASS D					
INTERGRANULAR				HARD, CONSOLIDATED ROCK MATERIAL											
<p>A water saturated zone, generally unconsolidated but occasionally semi-consolidated. Groundwater is stored and transmitted through intergranular interstices in porous and permeable medium.</p>				<p>Fissured and fractured bedrock resulting from decompression and/or tectonic forces. Groundwater flow predominantly through fractures, faults, joints and fissures (acting as conduits), and micro-fissures in the bedrock, Rock matrix provides storage.</p>											
				<p>Where the principal water strike is in a fracture or in the contact between two different rock types, interporosity groundwater flow can occur within the rock matrix (double-porosity matrix). Groundwater is stored and transmitted in fractures, fissures and/or joints.</p>			<p>In the case of carbonate rocks groundwater is stored and transmitted through incipient fissures and fractures enhanced through chemical dissolution. Some groundwater storage can also be expected in in-situ weathered residuum. Frequently extensive in area</p>			<p>Fractured zone overlain by varying thicknesses of weathered saturated material. Storage and flow in both. Also able to pass vertically with relative ease between the two portions. Fractures act as conduits during abstraction, vertical recharge from intergranular zone. This situation also allows for circumstances where the intergranular portion serves primarily a storage function, the water being transmitted mainly through the fractured portion. This is a common feature of many South African Intergranular &amp; Fractured Aquifers. Occurs when the often substantial quantities of water stored in the intergranular voids of weathered rock can only be economically abstracted via fractures penetrated by boreholes drilled into the underlying fractured aquifer.</p>					
Group	Typical borehole yield		Colour code	Group	Typical borehole yield		Colour code	Group	Typical borehole yield		Colour code	Group	Typical borehole yield		Colour code
	Range	ℓ/s			Range	ℓ/s			Range	ℓ/s			Range	ℓ/s	
a1	Un-economical	0.0-0.1		b1	Un-economical	0.0-0.1		c1	Un-economical	0.0-0.1		d1	Un-economical	0.0-0.1	
a2	Very low	0.1-0.5		b2	Very low	0.1-0.5		c2	Very low	0.1-0.5		d2	Very low	0.1-0.5	
a3	Low	0.5-2		b3	Low	0.5-2		c3	Low	0.5-2		d3	Low	0.5-2	
a4	Moderate	2-5		b4	Moderate	2-5		c4	Moderate	2-5		d4	Moderate	2-5	
a5	High	>5		b5	High	>5		c5	High	>5		d5	High	>5	
<p>Alluvial deposits of limited extent along river terraces such as sand and gravel. Weathered crystalline rock with the principle water strike in the weathered intergranular zone</p>				<p>Sedimentary rocks of arenaceous origin. Acid volcanic rocks and other igneous rocks with very limited overlying residual weathered products.</p>			<p>Carbonate rocks including dolomite, limestone of marine origin</p>			<p>Sedimentary. Igneous and Metamorphic rocks with significant thicknesses of overlying saturated residual weathering.</p>					
INTERGRANULAR				FRACTURED			KARST			INTERGRANULAR AND FRACTURED					

### 1.3 Mapping Methodology

Sources of information and data used for the compilation of the map include the National Groundwater Data Base (NGDB) and Water Management System (WMS) both situated at the Department of Water Affairs (DWA), databases of the former Lebowa and Gazankulu homelands as well as that of VSA Geoconsultants, various geohydrological reports, field visits and borehole surveys. An inset map at a scale of 1: 2 000 000 appearing on the main map indicates the distribution density of the borehole-based information.

*Table 2: Number of borehole records extracted and evaluated from the NGDB, WMS and other sources:*

BOREHOLE RECORDS EXTRACTED AND EVALUATED				
NGDB AND OTHER SOURCES		WMS		
Total number of borehole records	Total number of borehole yields	Total number of EC values	Total number of nitrate and fluoride values	Total number of complete chemical analyses
3783	3366	2284	1760	2284

The lithostratigraphy of the area, obtained from the 1: 250 000 published Geological Map Series i.e. 2330 Tzaneen and 2430 Pilgrims Rest, was regrouped and, where necessary, simplified to lithological types to form the base of the main map. These types are displayed as grey ornaments on the map. The geological units are provided with black codes, which, for reasons of countrywide uniformity, do not always coincide with the codes on the said published geological maps, but are internal Departmental adaptations. The geological units and codes are explained on a chronostratigraphical column on the map.

The mapping and initial delineation of groundwater-occurrence-boundaries, based on borehole yield data and the hydrogeological classification, was achieved by superimposing the available individual borehole yields, colour-coded according to the borehole yield range (refer Table 1 and the legend shown on the main map), over the lithological base map and determining the median yield of the different lithologies. Refining of the groundwater-occurrence-boundaries and the identification of regional patterns and trends was done through visual inspection; experience and knowledge of the area; information contained in geohydrological reports as well as the geology and related structures. Where supported by sufficient evidence and reason based on experience, the aquifer characteristics of geohydrologically well-defined areas were extrapolated into areas of data scarcity.

A similar approach was used in the compilation of the 1: 1 500 000 scale groundwater quality map, using data from the WMS. The quality is depicted on the map in terms of its salinity expressed as a function of the Electrical Conductivity (EC) value as well as individual boreholes with excessively high values of nitrate (expressed as N) and fluoride concentrations. The EC intervals as well as the nitrate and fluoride values shown are taken from the DWA guidelines (DWA, 1993) for human and stock water consumption.

Two other inset maps, both at a scale of 1: 2 500 000, depict the surface elevation above sea level and the mean annual precipitation as derived from data provided by the Chief Directorate: Surveys and Mapping (Department of Land Affairs) and the Computing Centre for Water Research (CCWR) at the University of Natal (Pietermaritzburg), respectively.

Schematic hydrogeological cross-sections illustrating typical groundwater occurrence are also presented on the map. These cross-sections place the emphasis on the relationship between groundwater occurrence and geology.

Areas of major groundwater abstraction for domestic, irrigation and/or mining purposes are depicted on the main map as a full red circle of various sizes depending on the volume abstracted annually. Also depicted on the main map are areas that are extensively irrigated, as well as thermal and cold springs.

Extensive use was made of the ArcInfo Geographic Information System for cartographic compilation, data display and manipulation.

## **2. PHYSICAL ENVIRONMENT**

### **2.1 General**

The Kruger National Park is an important feature of the Phalaborwa map area. European game hunters penetrated the area, which is now the National Park around 1870 after the game of the Highveld had all but been wiped out. In 1884, President Kruger suggested that the time had come to do something about the fast-disappearing wild life of the Transvaal. By 1898 this had led to the birth of the Sabi Game Reserve with its primary purpose of protecting the animals from hunting. It was not until 1926 that the Kruger National Park was formed, with its broader objective of encouraging the viewing of the animals of the area, as well as protecting them from hunting. Artificial water supply to game in the Park had its origin in 1929 when consecutive years of drought and subsequent emigration of game out of the Park forced the building of dams and drilling of boreholes respectively in the early nineteen thirties. The first five boreholes ever were drilled in 1933 of which Kompatiti no.1 near Pretoriuskop, is after all these years still in use. The Kruger National Park Boundaries are depicted in Figure 1.

### **2.2 Climate**

The mean annual evaporation increases across the map area from less than 1400 mm in the east to 1600 - 1800 mm in the west. Mean annual surface temperature increases from 15.0-17.5 °C in the east of the map area to > 22.5°C in the west of the map area.

Rainfall tends to be high along the escarpment, where 2000 mm a year has been recorded. In the Highveld regions, rainfall generally averages at 1500 mm per annum, and in the Lowveld, it drops to 600 mm per annum. There are isolated areas with rainfall between 300-400 mm per annum (Figure 2). The mean average evaporation increases from <1400mm in the south to between 1600 and 1800mm in the north and to between 1800mm to 2000mm in the Kruger Park along the border with Mozambique (Figure 3).

### **2.3 Terrain morphology**

The area can be divided into 12 different terrain morphological units (Kruger, 1983) as depicted in Figure 4 and Table 3 respectively.

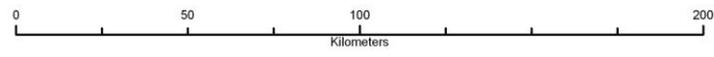
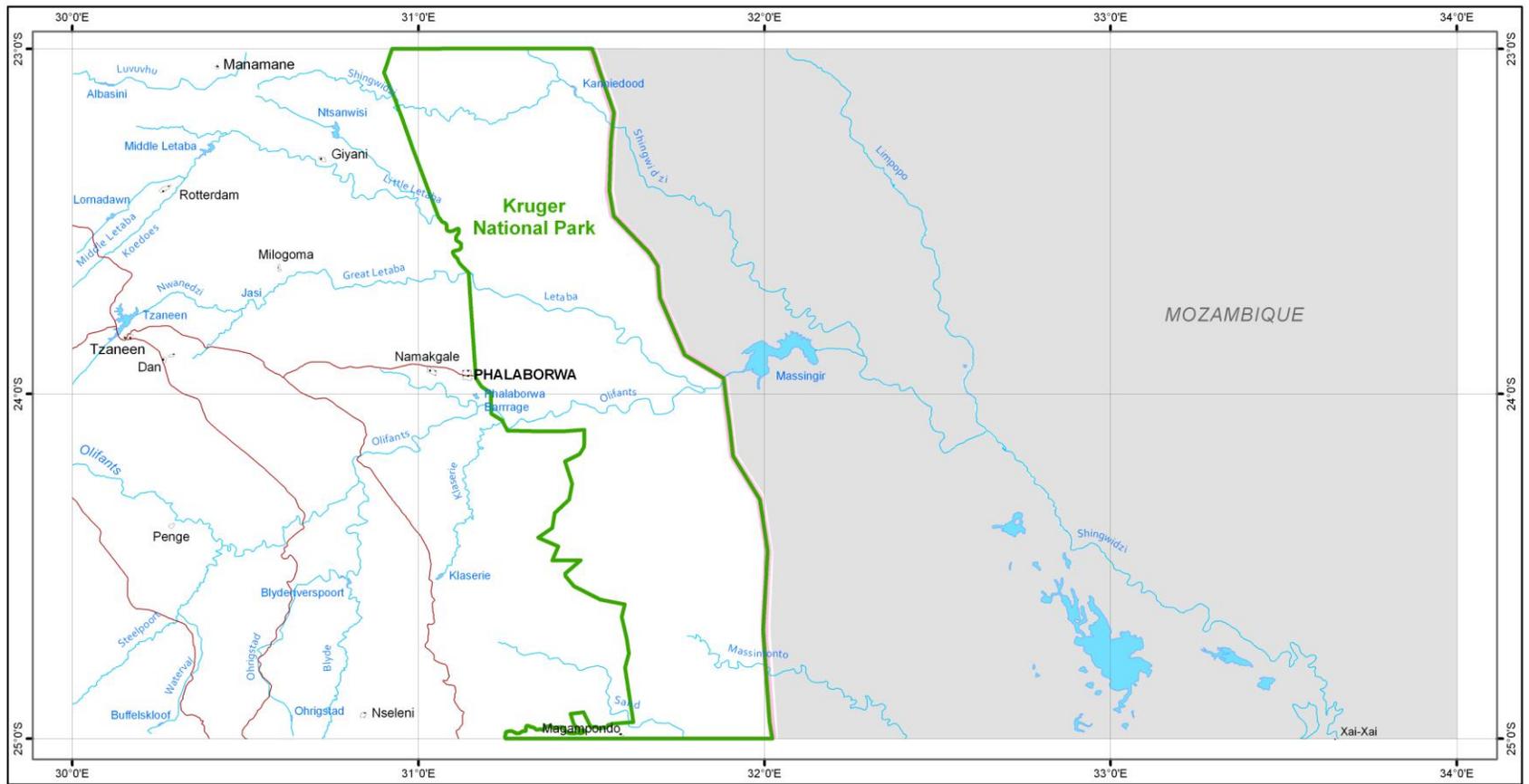


Figure 1: Map of the Kruger National Park boundaries

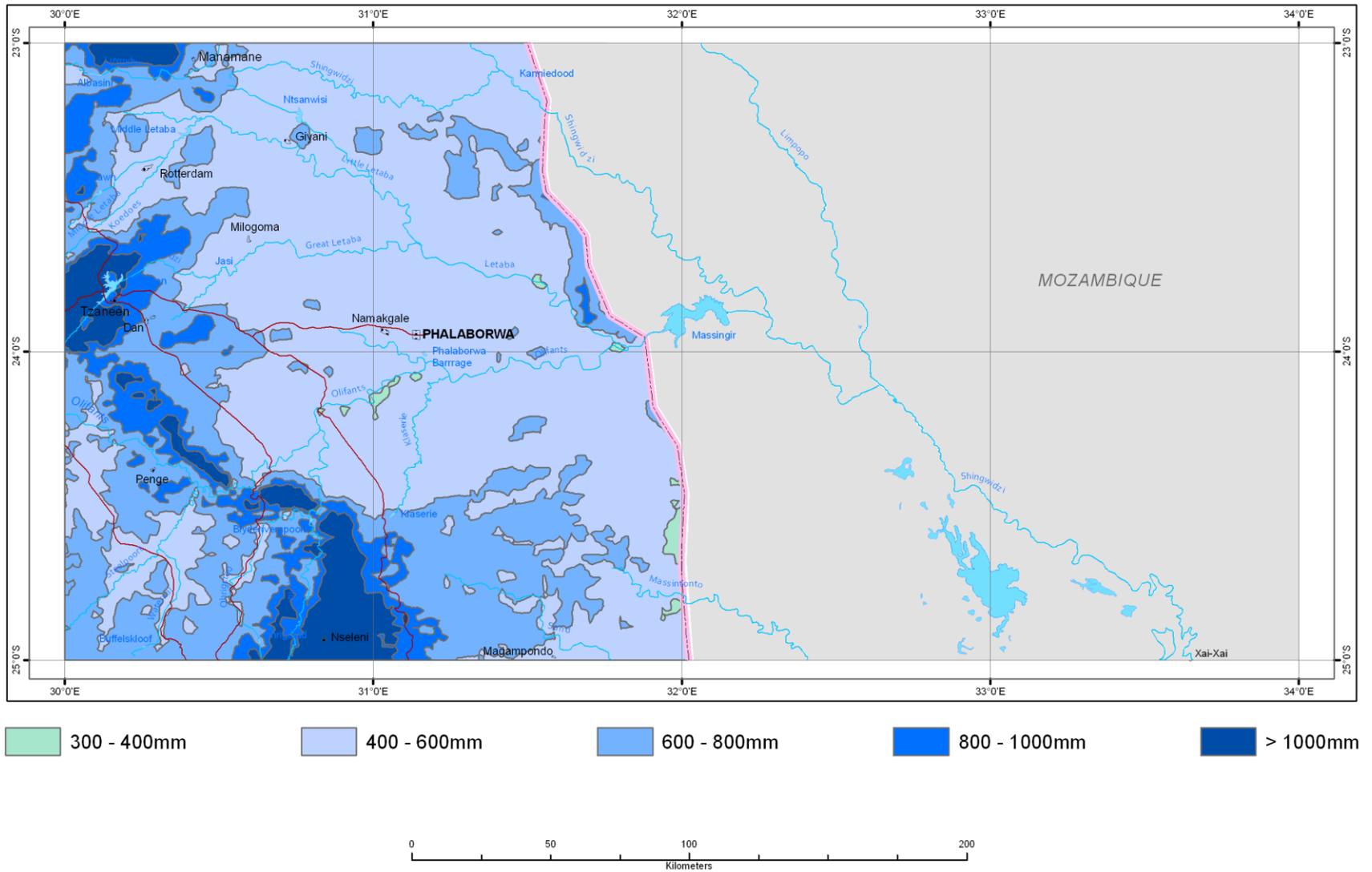


Figure 2: Mean annual precipitation

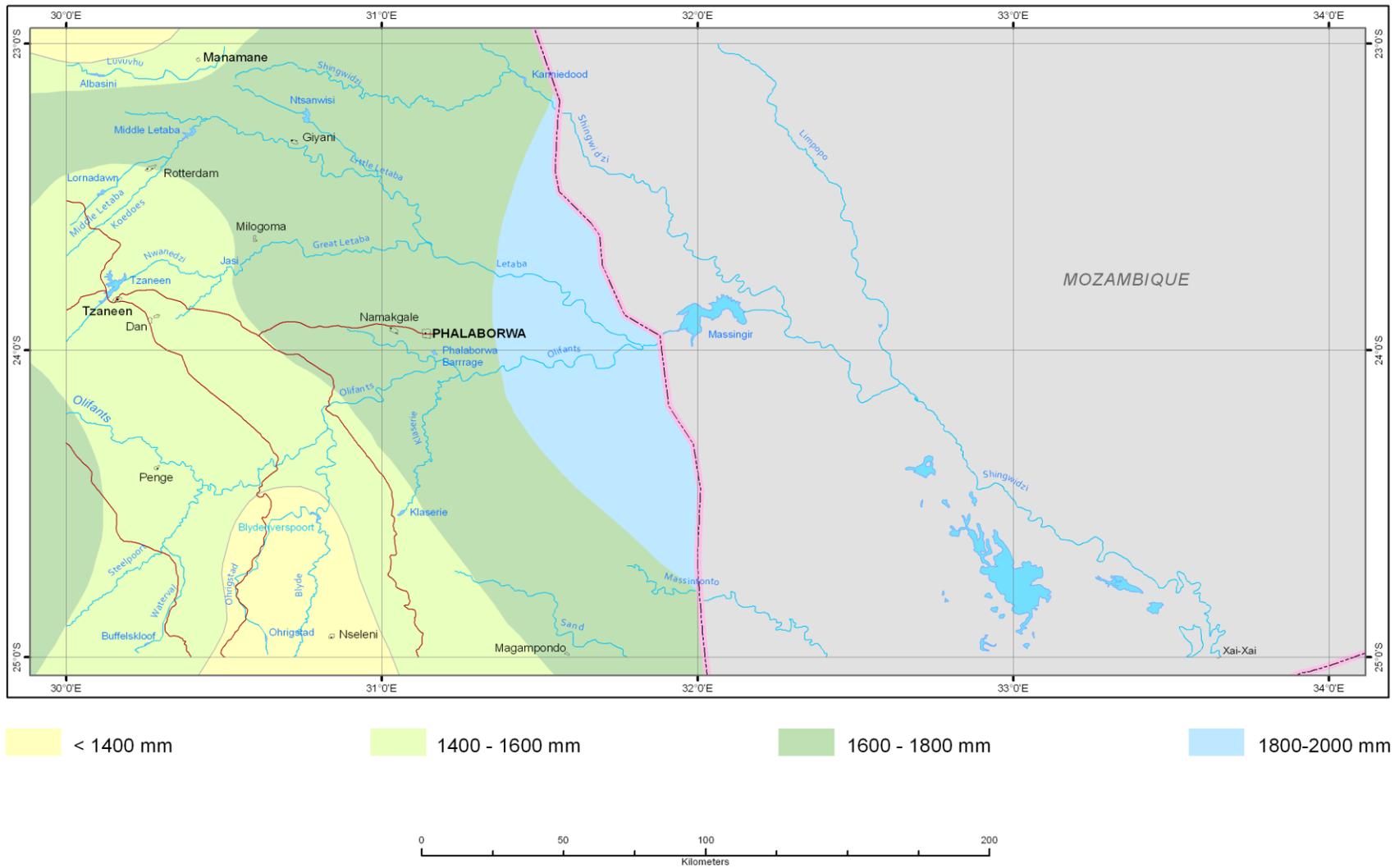


Figure 3: Mean annual evaporation

## 2.4 Topography

A large part of the study area comprises low-lying flat or slightly undulated terrain with average elevations between 600 m in the northwest, and 300 m in the northeast. Conspicuous ridges like the Murchison Range, Mangombe Hills, Soutpansberg, and the Lebombo Mountains rising up to 400 m above the surrounding countryside occasionally break the monotonous landscape. The terrain rises sharply to the southwest where the spectacular northern side of the Drakensberg escarpment occurs. In the Drakensberg area altitudes reach 2000 m. Altitudes decrease from the northwest to the southeast (Figure 5).



*Plate 1: View from God's Window looking eastwards across the Lowveld towards the National Kruger Park. The Lowveld comprises mostly crystalline basement rocks (Photograph: T Maluleke)*

## 2.5 Surface Water

The Olifants and Letaba Rivers and its tributaries that consist of the Steelpoort, Waterval, Orighstadt, Blyde, Klaserie, Shingwedzi and the Klein, Middle, Great and Koedoes Rivers respectively cut the area. The general direction of surface water drainage is eastwards to the Limpopo River. Figure 6 displays the drainage region of the study area. Major dams are also depicted in Figure 6.



*Plate 2: View of the Olifants River where it exits the mountainous Transvaal Sequence at Manoutsa Park and enters the Lowveld area on its way to the National Kruger Park (Photograph: T Maluleke)*



Table 3: Explanation for Figure 4 (After Kruger, 1983)

BROAD DIVISION	MAP SYMBOL	DESCRIPTION	SLOPE FORM	RELIEF (m)	DRAINAGE DENSITY (km/km <sup>2</sup> )	STREAM FREQUENCY (streams/km <sup>2</sup> )	% OF AREA WITH SLOPES <5%
A Plains with low relief	1	Plains	Straight	0-130	Low-medium 0-2	Low-medium 0-6	>80%
	3	Slightly undulating plains	Straight	0-130	Low-medium 0-2	Low-medium 0-6	>80%
B Plains with moderate relief	5	Slightly irregular plains	Concave/straight	30-210	Low-medium 0-2	Low-medium 0-6	>80%
	7	Moderately undulating plains	Concave/straight	30-210	High 3-3.5	High 6-10.5	>80%
	9	Extremely irregular plains (almost hilly)	Concave/convex	30-210	Low-medium 0-2	Low-medium 0-6	>80%
	11	Strongly undulating plains	Concave/convex	30-210	Low-medium 0-2	Low-medium 0-6	>80%
C Lowlands, hills and mountains with moderate and high relief	12	Lowlands with hills	Concave/straight	30-450	Low-medium 0-2	Low-medium 0-6	50-80%
D Open hills, lowlands and mountains with moderate to high relief	18	Hills and lowlands	Concave/straight	130-450	Medium 0.5-2	Low-medium 0-6	20-50%
	19	Parallel hills and lowlands	Concave/straight	130-450	Medium 0.5-2	Low-medium 0-6	20-50%
E Closed hills and mountains with moderate and high relief	23	Hills	Concave/straight	130-450	Medium 0.5-2	Medium-high 1.5-10.5	<20%
	27	Low mountains	Convex/Concave/straight	450-900	Medium 0.5-2	Medium-high 1.5-10.5	<20%
	29	High mountains	Convex/Concave/straight	900+	Medium 0.5-2	Medium-high 1.5-10.5	<20%

\*Total length of drainage channels per km<sup>2</sup>

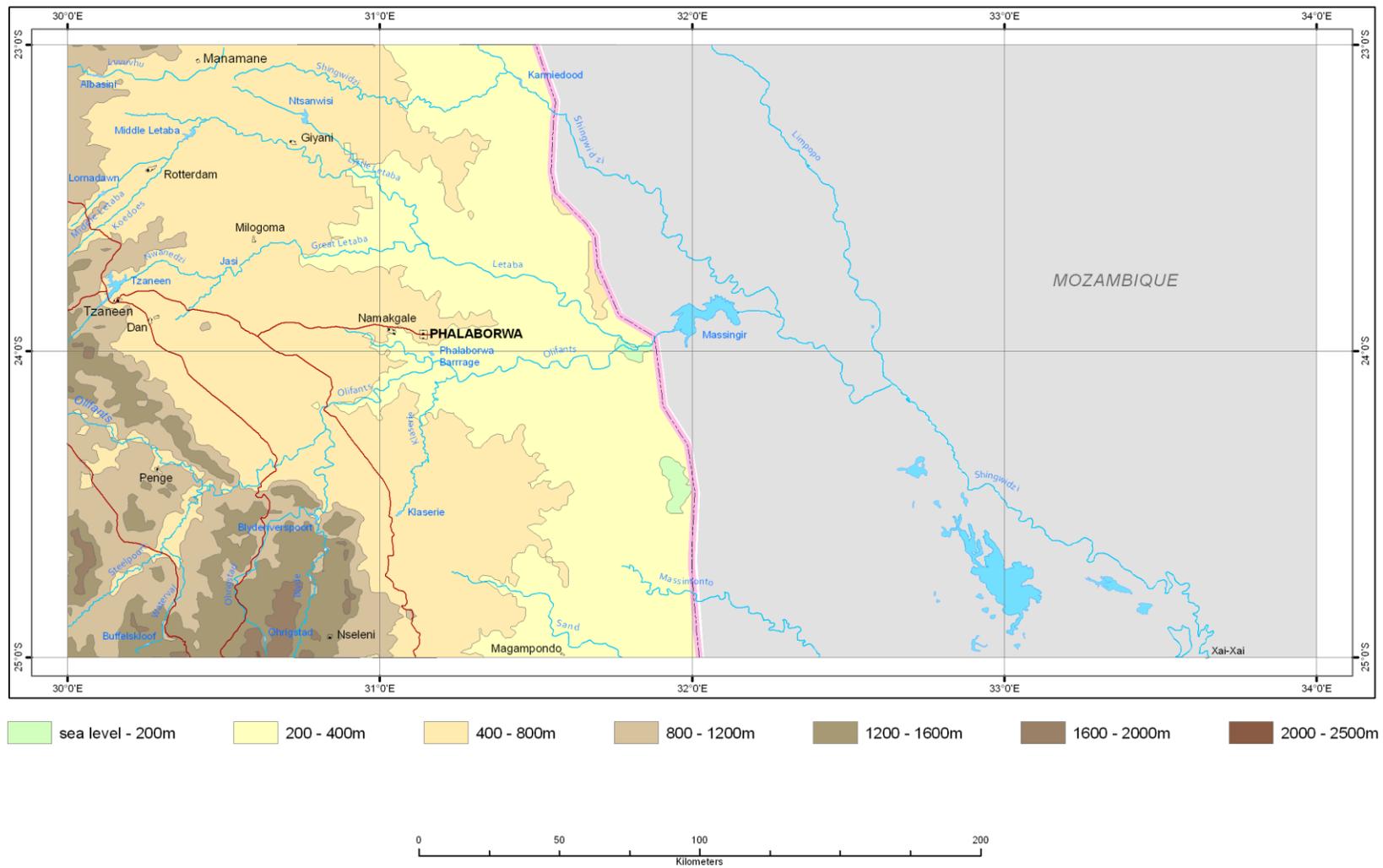


Figure 5: Elevation above mean sea level

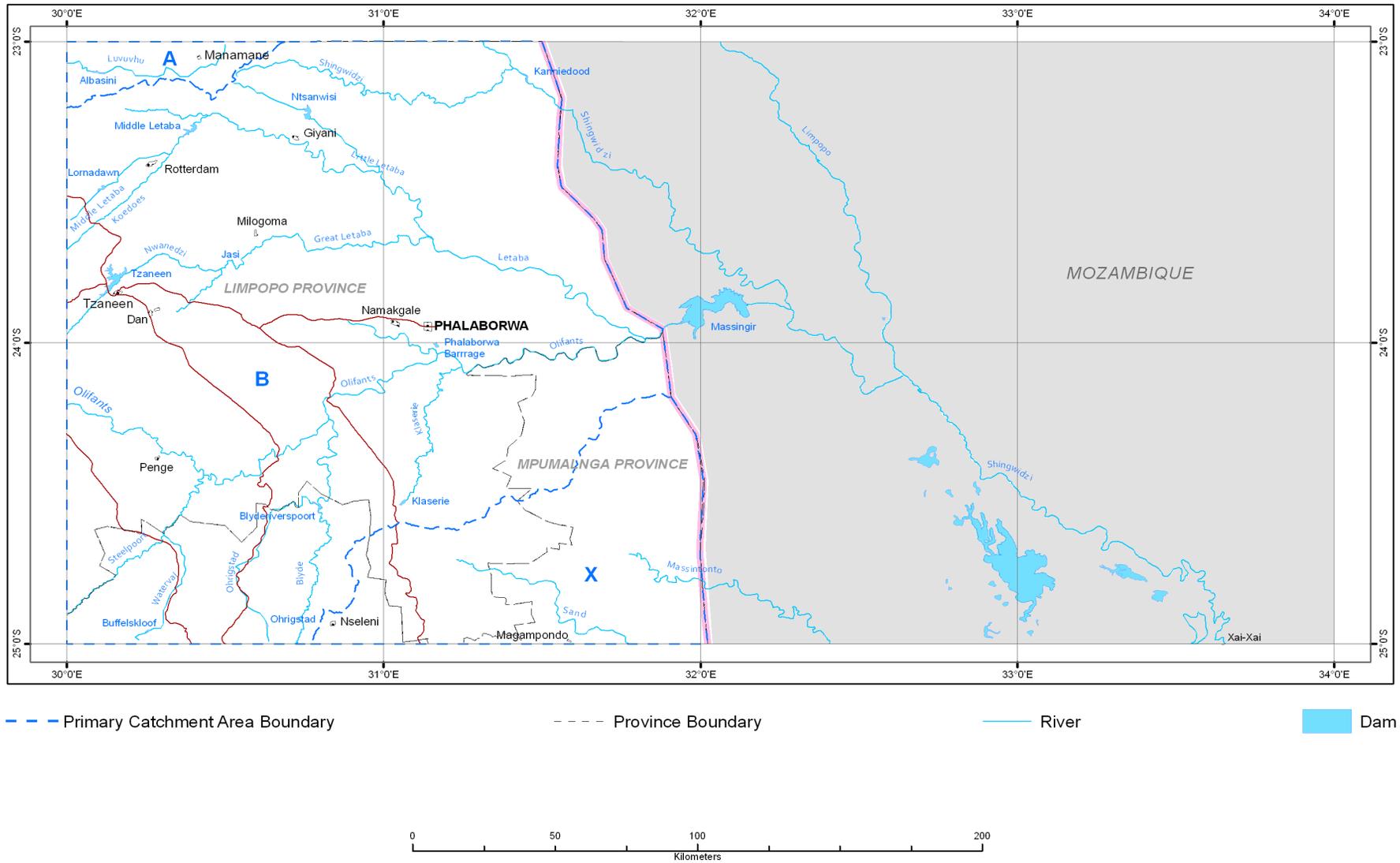


Figure 6: Drainage regions and major dams

## 2.6 Geology

The simplified geology of the area is shown in Figure 7.

### 2.6.1 Swazian

The oldest lithostratigraphic unit within the map area is the **Goudplaats Gneiss (Zgo)**. The Goudplaats Gneiss Formation comprises grey biotite gneiss, layered gneiss, migmatite and leucogranite. These rocks exhibit a strong foliation, and have apparently undergone several phases of mobilisation. The Goudplaats Gneiss is regarded as the sialic basement to the Bandelierskop Complex and the various greenstone belts. The reported isotopic ages for the Goudplaats Gneiss are also not conclusive as they are widely scattered, ranging from 2 652 to 3295 Ma (Barton et al. 1983). The majority of the northwest area is covered by these ancient rocks and has been intensively intruded by dykes. It is the most prevalent outcrop to the north of Tzaneen and Phalaborwa.

Another extremely old formation, the **Makhutswi Gneiss (Zma)** (3268 Ma) has developed south of the Murchison greenstone belt and is lithologically very similar to the Goudplaats Gneiss (Schutte, 1986). It consists of Biotite Gneiss and is characterized by its homogeneity although xenoliths of schist, amphibolite and banded ironstone do occur in the gneiss (Schutte, 1986). It is thought that the Makhutswi Gneiss is separated from the Goudplaats Gneiss by a major zone of weakness along which a crustal break-up probably occurred (Brandl, 1987). It forms much of the outcrops in the central part of the mapped area.

The **Murchison Supergroup** comprises the Giyani, Gravelotte and Pietersburg Groups that occur either as elongated to irregular shaped belts, or as trains (boudinage) of xenoliths (Brandl, 1987). The rocks of which this group is composed show typical characteristics of Archaean greenstone belts that have developed in an environment in which the unstable sialic crust was beginning to break up.

The **Pietersburg Group** are the oldest group of the Murchison Supergroup and consist mainly of ultramafic schist. This group is represented by large scattered xenoliths in the Duiwelskloof area. No age determinations are available for the Pietersburg Group, but it is generally thought to have an age in excess of 3000 Ma (Brandl, 1987). Two small areas of outcrop are found to the northwest and northeast of Tzaneen.

The **Giyani Group** builds a series of low hills and ridges, known as the Sutherland Range in the valley of the Little Letaba River to the northeast of Tzaneen. The succession is made up of ultramafic schist and amphibolite with subordinate metasedimentary rocks, iron formation and acid metalava (Brandl, 1987). Most of these lithologies have been subjected to medium grade metamorphism. These rocks outcrop over much of the central part of the mapped area - west and east of Phalaborwa. Outcrops of this Group are found throughout the northern part of the map area.

The youngest group of the Murchison Supergroup, the **Gravelotte Group (Zy)**, appears to be a typical volcanic succession consisting of basic to ultrabasic lavas at the base and more acid volcanic rocks at the top. Interlayered in these rocks are various schists, conglomerate, quartzite, grit and banded iron formation. The oldest units of the Gravelotte Group form the southeastern part of the Murchison Range and younger formations occur progressively further to the northwest (Walraven, 1989).

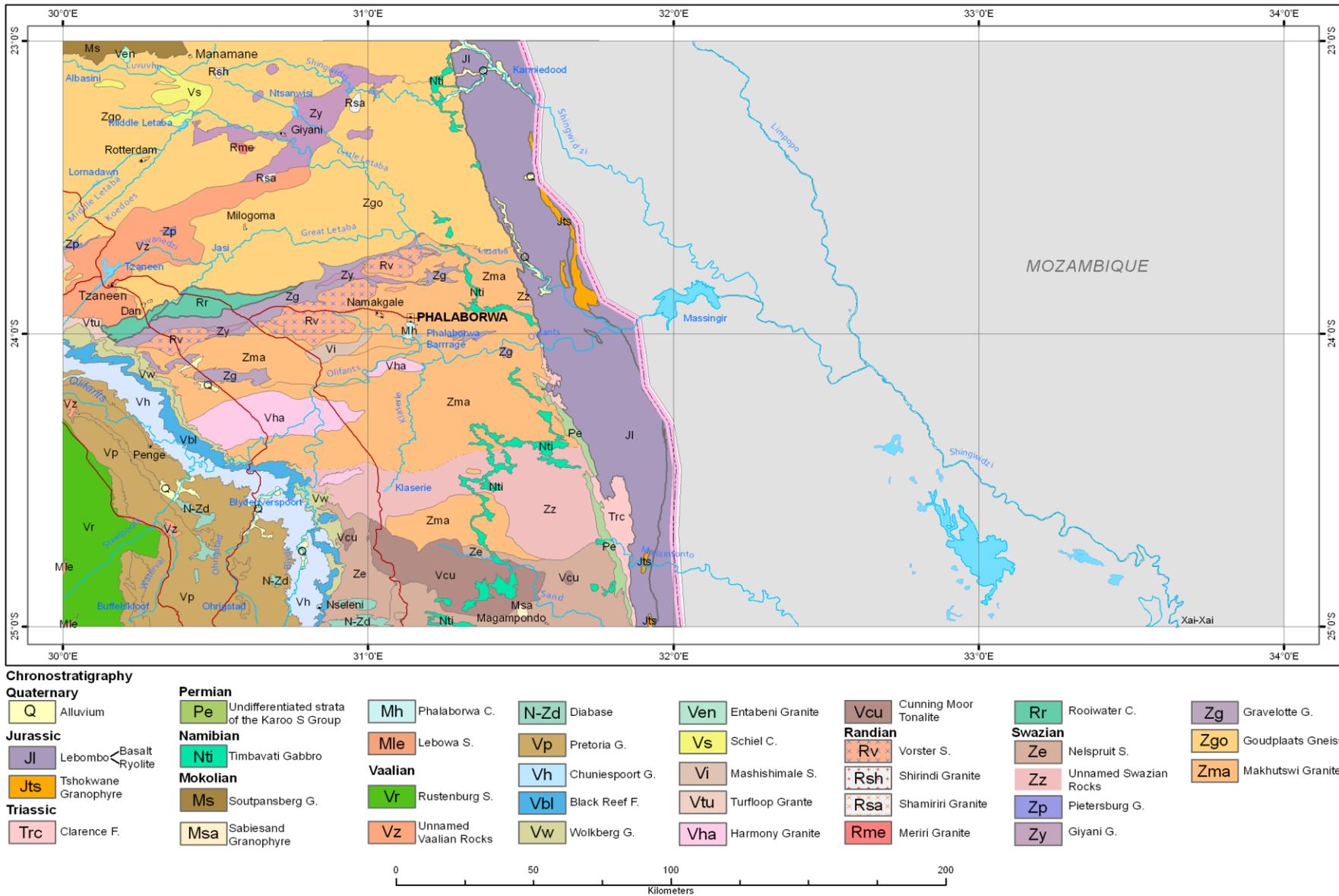


Figure 7: Simplified geology of the area

The **Unnamed Swazian (Zz)** basement migmatites and gneisses occur around the Timbavati River area. They outcrop over a large area between Graskop and Phalaborwa. These rocks have been dated at 2774 Ma old.

In the southern part of the map area a suite of granites and gneisses takes the place of the migmatite and the biotite gneiss. These rocks are referred to as the **Nelspruit Granite Suite** and are dated at 3160 Ma. These rocks consist of medium to coarse-grained, biotite bearing, porphyritic granite as well as migmatite and gneiss.

### 2.6.2 Randian

The **Rooiwater Complex (Rr)** comprises hornblende-rich and plagioclase-rich gabbros with magnetite layers and diorite. It outcrops to the south of Tzaneen in a belt extending towards Phalaborwa. The Rooiwater Complex has intrusive relations with the final event in the History of the Murchison Range (SACS, 1980).

The **Meriri Granite (Rme)** comprises fine- to medium-grained leucocratic biotite granite, and is gneissose in places. A small area of outcrop is found to the west of Giyani.

The **Shamiriri Granite (Rsa)** consists of, typically, grey massive medium-grained, in places coarse grained, porphyritic biotite granite. Small areas of outcrop are found to the east and south of Giyani.

The **Shirindi Granite (Rsh)** consists of medium-grained, grey to light-grey, leucocratic granite. A small area of outcrop is found to the northwest of Giyani. Pegmatite and aplite are characteristically absent from the Shirindi Granite.

The **Vorster Suite (Rv)** comprises medium-grained muscovite-biotite granite that is porphyritic in places. Extensive areas of outcrop are found to the north and west of Phalaborwa. These granites have to a large extent been intruded by gabbros and diabases of younger age. Dykes trending north south, east west, northeast and southwest occur.

### 2.6.3 Vaalian

The **Cunning Moor Tonalite (Vcu)** comprises a medium to coarse-grained sphene-bearing tonalite. Although generally massive, foliation of the tonalite is seen in some part of the intrusion, notably near its margins (Walraven, 1989). It outcrops over a considerable area to the east of Graskop.

The **Harmony Granite (Vha)** consists of a white, coarse-grained plagioclase granite that is very coarse-grained and pegmatic near its margins. It outcrops over a sizeable area between Phalaborwa and the Drakensberg.

The **Turfloop Granite (Vtu)** is a medium to coarse-grained, grey and pink biotite granite, with numerous inclusions of migmatite. One outcrop of this granite is found to the northwest of Tzaneen. Another outcrop is found to the southwest.

The **Mashishimale Suite (Vi)** consists of fine, medium and coarse-grained biotite granite. Where medium-grained, it tends to be amphibole bearing and where fine-grained it is also leucocratic. It outcrops to the southwest of Phalaborwa.

The **Schiel Complex (Vs)** comprises gabbro, hornblende granite, and syenite. The syenite that constitutes about two-thirds of the complex at surface is generally a

medium-grained, grey to brownish grey rock displaying weakly-developed foliations (Brandl, 1987). Two areas of outcrop are found in the northwest of the study area.

The **Entabeni Granite (Ven)** is muscovite-biotite granite, found in the northwest of the study area. The extent of the outcrop is limited.

### **Transvaal Supergroup**

The rocks of the **Wolkberg Group (Vw)** outcrop in a thin band in the southwest of the study area as a prominent part of the Drakensberg, where they dip regionally inwards towards the base of the Transvaal basin. These rocks have been extensively folded and are responsible for some of the magnificent scenery that is observed in the Blydepoort area and around Abel Erasmus Pass in the Mpumalanga. The Wolkberg Group comprises of shale, quartzite and basalt. The **Black Reef Formation (Vbl)** overlies the Wolkberg Group and consists of fine to medium-grained quartzite, basic lava, tuff, agglomerate and shale. It outcrops from south of Tzaneen to Graskop. The **Chuniespoort Group (Vh)** is further sub-divided in two subgroups, the Malmani and the Penge Subgroup. The Malmani Subgroup consists of grey to pink dense and poorly bedded dolomite and limestone with chert layers. The Penge Subgroup consists of banded ferruginous quartzite and shale with interbedded asbestos at various levels. It is found in the southwest of the map area, and forms a prominent part of the Drakensberg. Composed of sedimentary and volcanic rocks, the **Pretoria Group (Vp)** has a maximum thickness of 10.5 km. Shale, quartzite, andesitic lava, mudstone, basic lava, tuff, hornfels are present. A broad band of Pretoria Group rocks occur to the northwest of Graskop in the southwest of the study area.



*Table 4Plate 3Plate 3: View of the cliffs at Abel Erasmus pass presenting a clear impression of the various strata constituting the Wolkberg Group and the Black Reef Formation of the Transvaal Supergroup (Photograph: T Maluleke)*

**Diabase (N-Zd)** dykes occur throughout most of the map. The dykes in the southern half of the study area are mainly of the Jurassic period and the northern half are mostly of Namibian age.

The **Unnamed Vaalian Rocks (Vz)** comprise granite, pyroxenite, granodiorite, and are found outcropping in a large area around Tzaneen and continuing northeastwards.

### **Bushveld Complex**

The **Rustenburg Suite (Vr)** comprises norite, pyroxenite, anorthosite, gabbro, magnetite, gabbro, and diallage pegmatoid. It is characterised by a well-developed

igneous layering, with rocks units that are uniform in composition and may be traced over considerable distances. A broad expanse of Rustenberg rocks is found in the southwest of the map area.



*Plate 4: Layers of chromite in anorthosite of the Rustenburg Layered Suite exposed in the riverbed of the Dwars River, Mpumalanga. This site was declared a national monument (Photograph: W.H. du Toit)*

## 2.6.4 Mokolian

### Bushveld Complex

The **Lebowa Suite** comprises coarse-grained, pink, hornblende granite. Two small spots of this rock can be found in the southwest corner of the study area.

The **Phalaborwa Complex (Mh)** comprises pyroxenite, dunite, pegmatoid, foskorite, carbonatite, and syenite. An isolated outcrop of this rock type is found immediately south of Phalaborwa. This complex, which expresses itself on the surface primarily as Loolekop, was the target of copper-mining activities by ancient people, probably for as long as 1 200 years. The complex is a pipe-like structure and has an age close to 2 050 Ma (Walraven, 1989).

### Plate 5: Phalaborwa Mining History



The original outcrop was a large hill known as Loolekop. The surface of the hill was once littered with primitive workings excavated by local tribesmen. Primitive smelting was carried out in the surrounding hills.

In 1934 the first modern mining started with the extraction of apatite. The remoteness of the area led to the termination of the first mining ventures. Interest however remained and in 1946 Dr. Hans Merensky started an intensive prospecting on Loolekop. In the process of this prospecting a very large low grade copper sulphide ore body was discovered which proved to be potentially exploitable. A joint venture between Rio Tinto Zinc and Newmont Mining followed and resulted in the formation of the Phalaborwa Mining Company in 1956. During 1957 to 1962 the ore body was proved and a pilot plant operation was built. In 1966 production commenced in one of the largest open pit copper mines of the world. It is here that most of South Africa's copper is mined. The open pit is 450 m deep and measures nearly 2 km in diameter. Due to the vast size of the open pit it has become a unique tourist attraction. (Photograph: T Maluleke)

The **Sabiesand Granophyre (Msa)** is a fine to medium-grained, micrographic quartz gabbro. A small outcrop of this granophyre is found close to the southern limits of the map area to the northwest of Skukuza.

The **Soutpansberg Group (Ms)** comprises primarily basalt, but also quartzite, quartzitic sandstone, shale, tuff, greywacke and conglomerate. It is found in the northwest of the map area, to the west of Manamane and to the north of Levhubu. These rocks have been affected by oblique slip faulting and two major trends exist i.e. one east-northeast and the other west-northwest to northwest.

### 2.6.5 Namibian

The **Timbavati Gabbro (Nti)** is a mafic to ultra-mafic rock that is intrusive in the Goudplaats and Makhutswi Gneisses. It outcrops as irregular sill like bodies dipping between 20° and 30° towards the east (Schutte, 1986 and Venter, 1990). In the more northern areas, the intrusion is characterised by a series of prominent hills whereas in the south it tends to be less resistant to weathering than the surrounding granitic rocks resulting in only a few isolated hills (Venter, 1990). Irregular patches of Timbavati Gabbro can be found scattered throughout the east of the map area between Skukuza and Shingwedzi as dykes and sills.

### 2.6.6 Permian – Cretaceous

#### Karoo Supergroup

Most of the eastern part of the National Kruger Park is underlain by a succession of sedimentary and volcanic rocks resting discordant on the underlying basement complex. The succession dips between 4° and 17° towards the east (Schutte, 1974) except in the far north where it dips towards the north (Venter, 1990).

The **Undifferentiated Karoo (Pe)** rocks, which form the basis of the Karoo Super Group, unconformably overlie the basement complex and consist of mudstone and shale with inter-layered conglomerate, grit sandstone and thin inter-layered coal layers (Venter, 1990). Between Crocodile Bridge and the Olifants River prominent outcrops of Ecca shale and sandstone, occur but further north outcrops occur only sporadically or are completely absent (Schutte, 1986 and Venter, 1990). It is thought that the aquifer potential of these rocks will be relatively poor occurring predominantly in secondary aquifers.

According to Schutte (1986), the **Clarens Formation (Trc)** can in the northern parts of the Kruger Park be divided into two units namely the lower Red Rocks Member and upper Tshipise Member. The former consists of a fine-grained, mottled red and white, shaly sandstone representing sediments of fluvial origin that were deposited on alluvial plains in a climate that was becoming progressively dryer (Truswell, 1977). Tshipise Member consists of fine-grained, cream-coloured massive sandstone and forms numerous low hills and prominent ridges characterised by caves and vertical rock faces (Schutte, 1986 and Venter, 1990). This formation was mainly deposited in an aeolian environment.

The **Lebombo Group (Jl)** constitutes the volcanic portion of the Karoo Supergroup and comprises extrusive mafic volcanic rock, which concordantly overlies the Clarens Formation. The basalt probably represents flood basalts, which poured out along faults or fractures associated with the break-up of Gondwanaland ("Hot spots" theory). The

basalt can be porphyritic or amygdaloidal in places. Outcrops are scarce and generally covered by black clay soil. The basalt is overlain by pale-pink to red and purple rhyolitic to dacitic lavas, which is weathering and erosion resistant and consequently has a strong topographic expression, forming the backbone of the Lebombo range. The basalt and rhyolite appear interfingered along the contact. The rhyolite reaches its maximum thickness of approximately 2.5 km in the most southern part of the Kruger Park (Bristow & Venter, 1986). The Lebombo Group is found in a broad band adjacent to the Mozambique border throughout the map area.

The **Tshokwane Granophyre (Jts)** intruded the Lebombo Group as irregular bodies and sills (Schutte, 1986). The rocks, which vary between light grey and pink and medium to coarse grained, consist largely of quartz, feldspar and clinopyroxene (Brandl, 1987). It is very resistant to weathering and subsequently forms prominent ridges and hills in a long belt close to the Mozambique border to the north of the Olifants River (Bristow & Venter, 1986). Granophyre dykes with a north/south orientation occur in the southern parts of the Kruger Park.

### **2.6.7 Quaternary**

The most important occurrences of **alluvium (Q)** are along the Tsende River north of Letaba, the Shingwidzi River and its tributaries in the northeast of the area, and sporadic occurrences in the southwest of the map area. It consists mostly of alternating layers of clay and poor to well sorted sand and gravel deposits.

## **2.7 Structural Geology**

Faults, shear zones, dykes and linear features identified by remote sensing are depicted in Figure 8. The structural history of specifically the Archaean rocks in the map area is extremely complex as they covered a time span of almost 1 000 Ma and is reflected by the variety of trends of these features. The north-west to southeast trend does, however, seem to be the most prevalent.

The gneisses and migmatites in the northern part of the Lowveld were intensely folded and strongly metamorphosed. Further to the south, the biotite gneiss has a strong regional foliation but show fewer periods of deformation than the gneiss and migmatite.

The granites of the Nelspruit Suite underwent relative little deformation, except for their marginal zones where intense interaction between these granites and the gneiss and migmatites resulted in highly deformed rocks (Walraven, 1989).

Faulting is observed in the Transvaal Sequence rocks and also in the younger Karoo rocks of the Lebombo Range. The prominent northeast-southwest oriented faults in the southwestern corner of the map area are considered to have played an important role in the intrusion history of the Bushveld Complex. It acted as channels for the movement of magma as well as terminators of moving blocks of crust and overlying strata (Walraven, 1989).

## **3. HYDROGEOLOGY OF THE DIFFERENT GEOLOGICAL UNITS**

### **3.1 Aquifers**

An aquifer can be defined as “a stratum which contains intergranular interstices, or a fissure/fracture or a system of interconnected fissures /fractures capable of transmitting groundwater rapidly enough to directly supply a borehole or a spring” (Vegter, 2001).

For the purposes of the 1:500 000 map series aquifers are divided into four types namely:

- Intergranular
- Fractured
- Fractured and intergranular
- Karst

Relatively small areas of Karst and Intergranular aquifers are present. The intergranular aquifers primarily comprise alluvium. The most prevalent aquifer type is the Intergranular and Fractured type, as a result of extensive chemical weathering of the relatively flat areas of Pre-Cambrian rocks. It is therefore not surprising that much of the Fractured only aquifer type is found in the Drakensberg and Lebombo Mountains, whose higher relief is related to its resistance to weathering.

It should be borne in mind that the conditions regarding yields and type of aquifers depict the general conditions over a wide area. As such, the information cannot be used to specify the exact conditions at any given point and does not contain the detail information necessary for the siting of boreholes.

## **3.2 Hydrochemistry**

### **3.2.1 Introduction**

“Water quality” is a term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for an intended purpose ([www.dwaf.gov.za](http://www.dwaf.gov.za)). These characteristics are controlled or influenced by substances, which are either dissolved or suspended in water. Water that looks clean and tastes good does not necessarily mean it is safe to drink. In the analyses of water, a number of variables are taken into account to determine the suitability of the water for any given use, be it for domestic, farming, mining or industrial purposes, or its suitability to maintain a healthy ecosystem.

Interaction of infiltrating rainwater with the soils and rocks ultimately gives rise to the quality of the groundwater. Factors such as the chemical composition of the host rocks, rate of flow, time in a specific environment, evapotranspiration rates and recharge patterns has an influence on the final chemical composition of the groundwater. Some substances occur naturally in variable quantities in groundwater. Some substances occur rarely and some are mostly the result of pollution by human activity.

This brochure aims to give an indication of the natural groundwater quality in this area. For this reason, and the difficulty and cost involved in analysing for organic compounds, metals and microbiological quality, only the chemical analyses of inorganic compounds most commonly occurring in natural groundwater are discussed. Concentrations are given in mg/l.

Figure 9 shows the groundwater quality as depicted on the published hydrogeological map, but at a reduced scale. The most obvious correlation with the electrical conductivity map is the rainfall map - regions of higher rainfall having better quality water than areas of lower rainfall. This would imply that poorer quality groundwater is stagnant and

gradually increases in salinity, while areas with better quality groundwater are more regularly recharged.

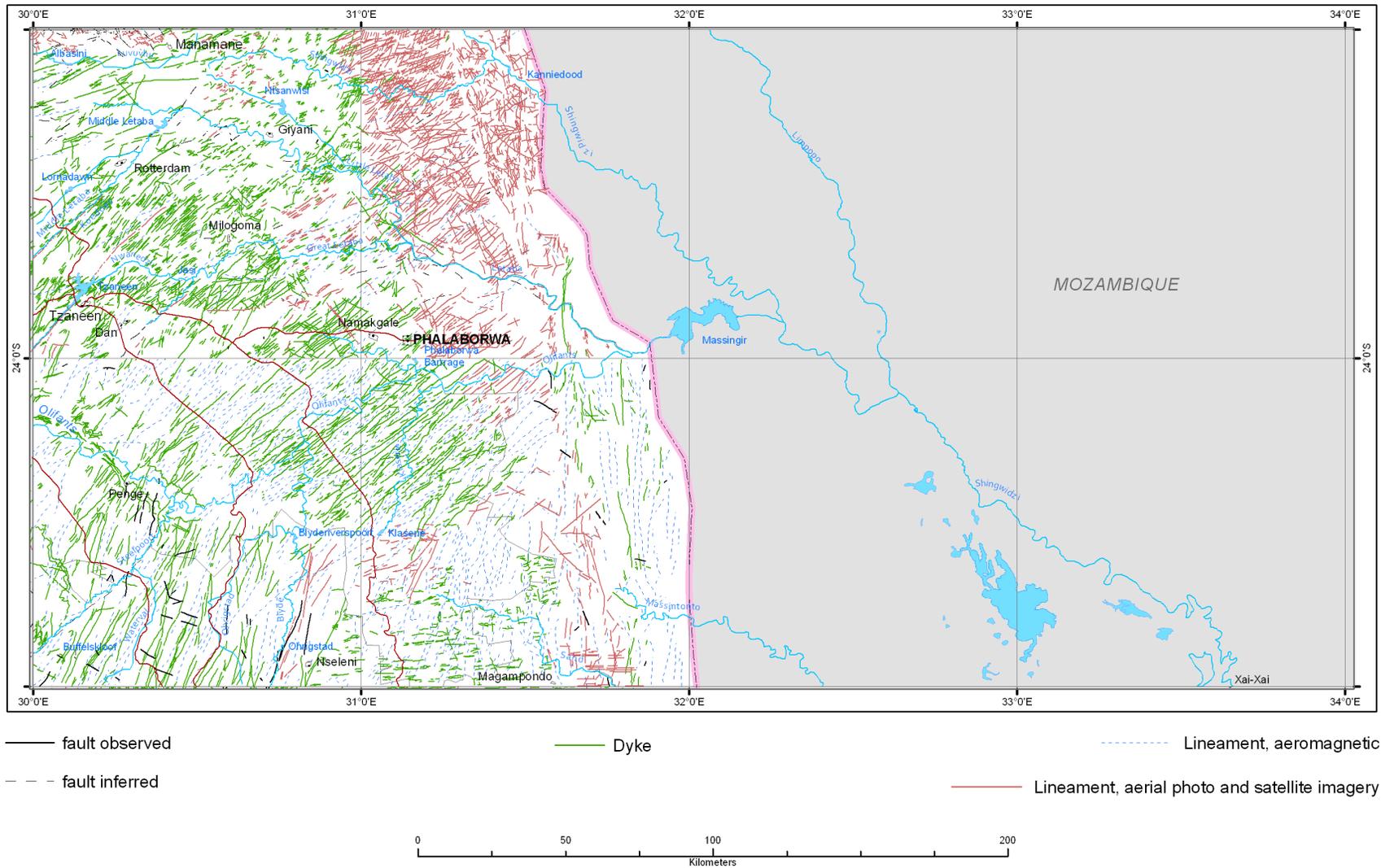


Figure 8: Structural geology of the area

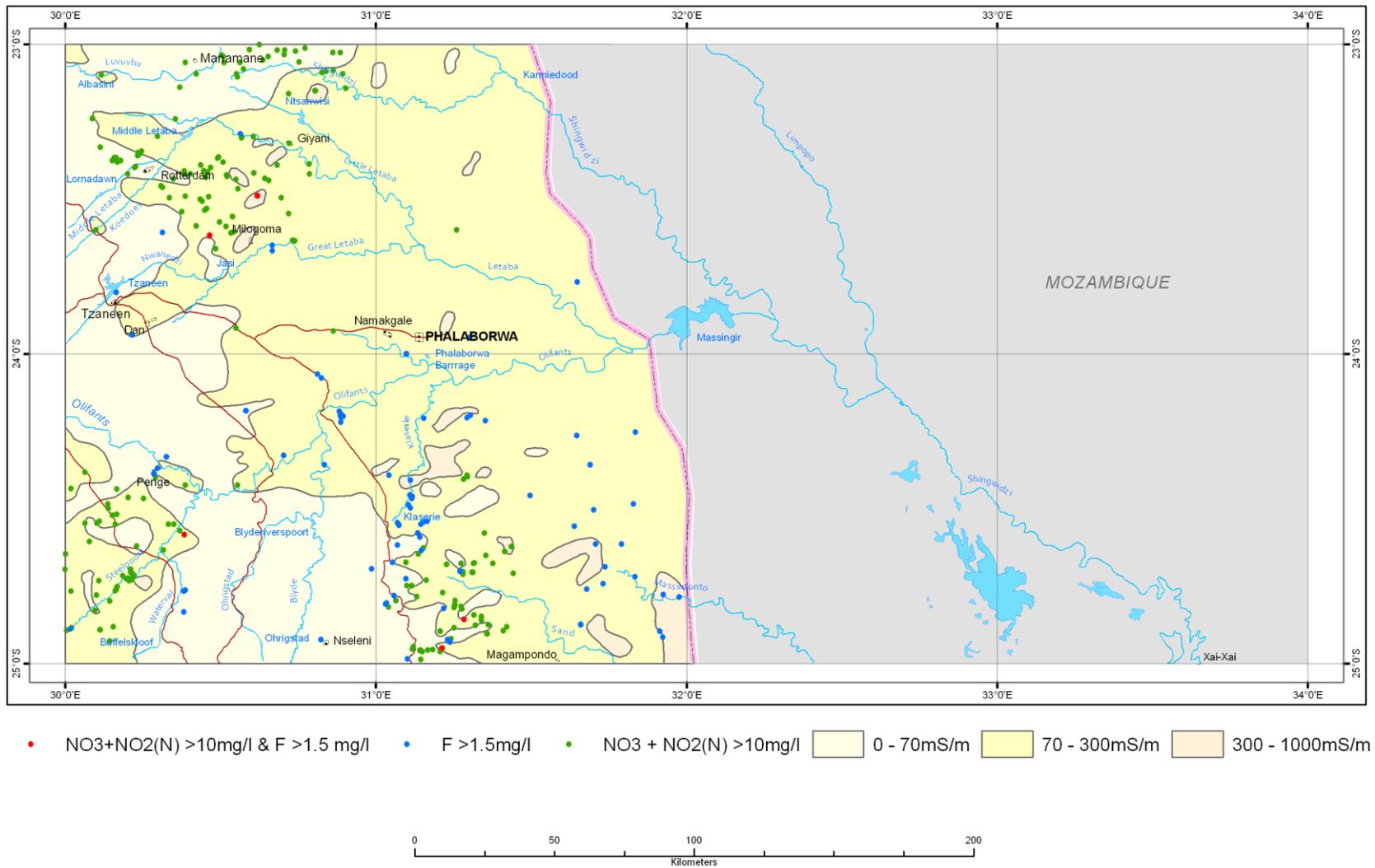


Figure 9: Groundwater quality

Care needs to be taken when interpreting the distribution of high fluoride and high nitrate values on the published sheet. A comprehensive nitrate and fluoride survey of the area was not done. Thus high nitrates and fluoride values are only shown where data is available. The absence of high values shown on the map therefore does not indicate that high fluoride and nitrate values are not a problem. The lack of depicted high nitrate and fluoride values could be due to there being no data available rather than there being no fluoride or nitrate problems.

None the less, the extent of known high values of nitrate and fluoride is considerable. The most probable source of high nitrates is from pit latrines in informal settlements as well as agricultural activities although the natural occurrences of high nitrates have not yet been investigated.

### 3.2.2 Aquifer Hydrochemistry

The National Water Quality Database (WMS) was utilised for hydrochemical data analysis and interpretation. Table 4 shows the average derived from each of the aquifer units. The DWAF Target Water Quality Range (TWQR) for domestic use has been used for comparison. Seven of the units did not have any chemistry data for analysis. They are Jts, Rsa, Vtu, Ven, Mle, Mh, and Msa.

Where the concentration displayed in Table 4 exceeds TWQR, they are shown in bold red.

Table 5: Hydrochemistry of the Phalaborwa Map Area

Symbol	pH	EC	NO <sub>3</sub>	F	TAL (as CaCO <sub>3</sub> )	Na	Mg	SO <sub>4</sub>	Cl	K	Ca
Units		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
DWAF TWQR	6.0-9.0	70	6	1	20-300	100	70	200	250	200	150
Q	8.37	<b>169.3</b>	4.94	0.66	<b>420.16</b>	<b>140.21</b>	49.06	33.65	94.79	2.11	37.15
Jl	8.67	<b>177.39</b>	2.57	1	<b>498.94</b>	<b>187.39</b>	<b>71.92</b>	26.78	214.96	1.62	50.4
Trc	8.73	<b>256</b>		0.8	<b>735.9</b>	<b>403.3</b>	<b>85.9</b>	59.8	<b>378.2</b>	3.14	43.6
Pe	8.76	<b>205</b>	0.29	<b>1.42</b>	<b>657.73</b>	<b>384.67</b>	<b>38.67</b>	16.7	<b>294.17</b>	5.92	39.37
Nti	8.39	<b>131.34</b>	5.38	0.57	<b>453.29</b>	<b>154.91</b>	67.45	13.36	166.78	3.14	41.67
Ms	7.64	11.32	1.12	0.2	42.13	4.24	4.83	11	3.93	0.5	7.77
Vr	8.25	<b>106.9</b>	<b>18.89</b>	0.23	<b>356.22</b>	49.76	<b>93.55</b>	45.19	93.53	3.28	46.21
Vz	7.71	66.87	5.04	0.62	190.35	65.14	24.01	12.22	79.14	2.51	34.36
n-zd	8.02	<b>107.74</b>	<b>18.64</b>	0.78	<b>316.79</b>	87.68	57.89	45.74	98.12	2.61	58.27
Vp	7.83	<b>77.53</b>	<b>7.22</b>	0.53	255.27	59.87	44.57	38.81	74.23	4.55	37.89
Vh	7.82	54.68	2.62	0.45	184.57	27.23	26.79	31.56	45.29	3.65	41.99
Vbl	7.26	9	0.9	0.18	40.4	2.1	4.5	0	3.8	2.08	9
Vw	8.22	<b>116.05</b>	<b>23.95</b>	0.55	<b>370.23</b>	<b>107.17</b>	62.22	33.66	104.5	2.62	60.23
Vs	8.32	58.16	3.38	0.43	248.51	47.56	28.43	10.1	31.74	3.14	38.1
Vi	8.35	<b>214.22</b>	<b>13.73</b>	<b>1.64</b>	<b>621.8</b>	<b>309.38</b>	<b>74.37</b>	53.13	<b>290.25</b>	3.86	64.92
Vha	8.07	<b>101.67</b>	<b>7.78</b>	0.73	<b>329.79</b>	<b>112.09</b>	37.67	24.05	115.14	4.09	52.34
Vcu	7.85	<b>82.48</b>	5.87	0.7	240.48	98.64	26.12	14.9	101.44	2.92	39.24
Rv	8.31	<b>85.11</b>	3.79	0.43	<b>322.22</b>	84.14	37.44	20.29	81.38	3.95	50.06
Rsh	7.33	67.6	<b>15.64</b>	0.24	202.5	43.7	35.2	6	56.2	2.6	33.1
Rr	7.9	48.9	3.96	0.3	210.19	20.52	23.26	6.9	17.87	1.08	45.64
Ze	7.78	66.13	4.22	0.66	191.52	88.21	20.83	12.75	89.74	2.42	23.88
Zz	8.19	<b>95.02</b>	3.48	0.9	299.45	<b>146.28</b>	25.9	14.66	127.96	2.33	31.29
Zg	7.89	58	2.66	0.31	245.91	33.76	29.42	9.49	18.17	1.96	37.61
Zy	8.24	<b>117.85</b>	<b>10.13</b>	0.78	<b>434.73</b>	<b>102.31</b>	<b>73.29</b>	28.48	107.31	4.38	47.76
Zp	7.37	17.05	1.55	0.54	70.95	16	5.13	5.8	6	1.94	10.58
Zma	8.34	<b>146.38</b>	<b>9.48</b>	0.75	<b>427.14</b>	<b>198.44</b>	54.74	34.52	216.75	5.29	48.89
Zgo	8.13	<b>124</b>	<b>12.19</b>	0.5	<b>338.85</b>	<b>121.35</b>	55.72	20.68	172.28	5.34	59.72

### **3.2.3 Intergranular Aquifers**

Intergranular describes aquifers in which groundwater occurs in openings between granules and grains of unconsolidated material such as sand and gravel. Such openings can either be of a primary or secondary nature. Primary openings refer to the voids left during the deposition of the material. The “intergranular” aquifers on the map refer to this type. The capacity of intergranular aquifers to store or yield water is influenced by factors such as grain size, roundness of grains, ratio of different grain sizes, clay content and the density of compaction. The greatest restricting factors on intergranular aquifers within the map area are considerable clay content and limited recharge. The areal distribution of the intergranular aquifers is shown in Figure 10.

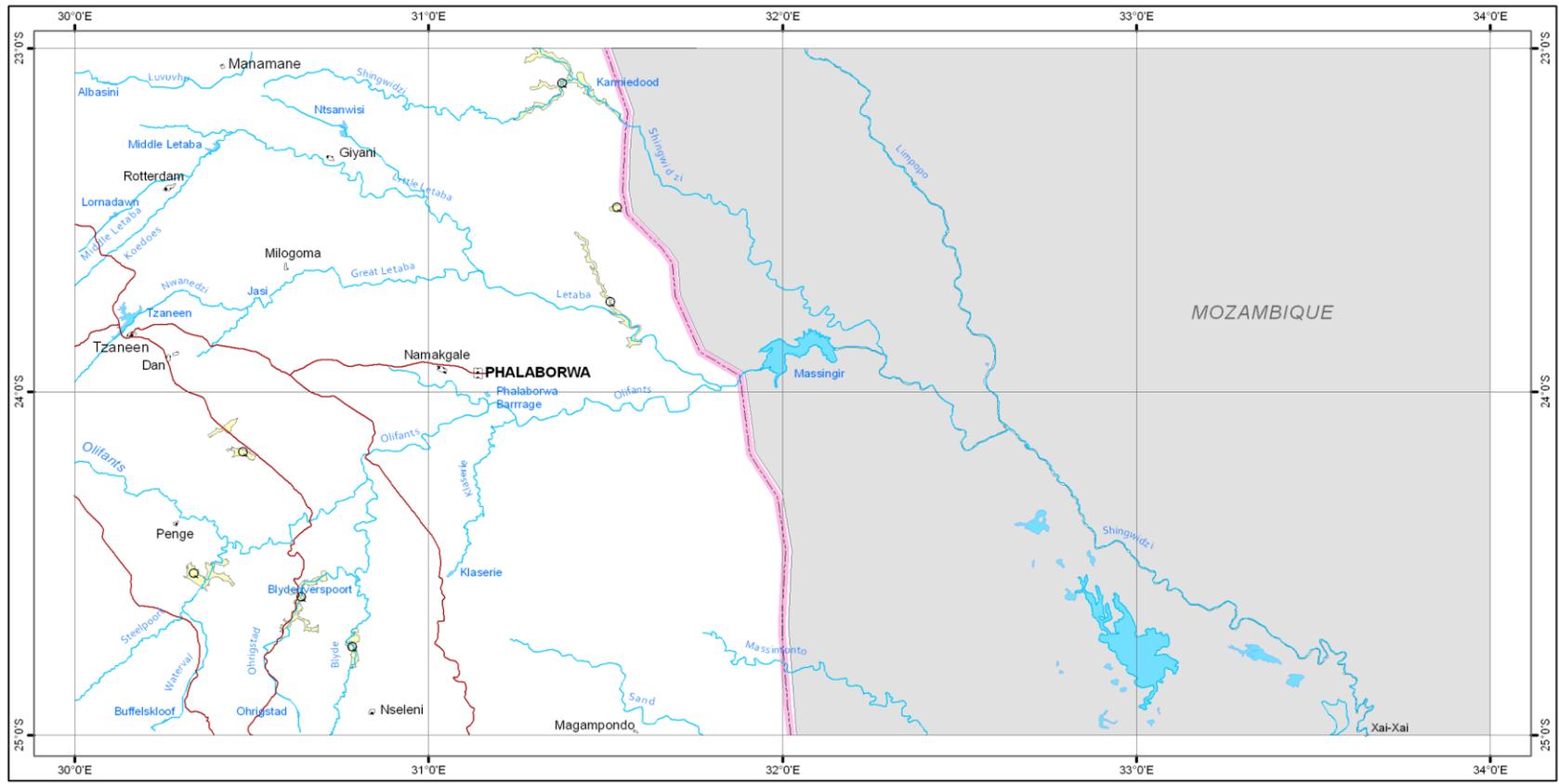
#### **3.2.3.1 Alluvial deposits (Q)**

Groundwater occurs in Tertiary-Quaternary alluvial deposits of limited lateral extent and thickness along many river terraces in the map area. It varies in thickness from a few centimetres to tens of meters. Accumulatively the alluvium only covers a small percentage of the total map area and in general consists of alternating layers of clay and poorly to well-sorted sand and gravel layers. The alluvial aquifers in the map area are in many cases utilized in conjunction with the underlying weathered and fractured bedrock aquifers. Water-levels respond quickly during flood events. Due to its limited extent laterally and in depth, the aquifers are also vulnerable to over-abstraction during periods of drought when there is little or no recharge. The highest percentage (40%) of boreholes drilled in this unit is observed with the yield frequency of 0.5 to 2.0 ℓ/s as seen in Figure 11. Borehole yields range from 0.15 to 15.6 ℓ/s with a median yield of 1.3 ℓ/s.

The 15 available chemical analyses (Figure 12) show that groundwater in the Alluvial Deposits are not acceptable for domestic use. Approximately 73% of boreholes have EC values above the recommended limit for drinking water (70 mS/m), but only 1 borehole had an EC value above 300 mS/m (the maximum allowable limit). This value (1020 mS/m) might be due to local contamination. It is also possible that some of these boreholes will have penetrated and intercepted poorer quality water in the underlying hard rock formations drilled and thus not representative of the groundwater quality in the Alluvial Deposits. The EC values of only three sampling points do not exceed the limit for domestic use. The average EC value is 169.30 mS/m (Table 4). The water type displayed by this aquifer is sodium–magnesium–bicarbonate–chloride (Figure 13).

#### **Pilgrim’s Rest**

Pilgrim’s Rest Town is a living museum of the early gold mining town and the birthplace of South Africa’s gold industry. Alec Patterson first discovered alluvial Gold in 1873 on a farm named Ponieskrantz, but he kept his new found fortune quiet. Shortly afterwards another prospector, William Trafford also made a gold discovery lower down in the stream and register his claim with the Gold commissioner at Mac Mac. On 22nd September 1873, Pilgrim's Rest was officially proclaimed a gold field. The news sparked of the biggest gold rush of that time and hundreds of diggers as far afield as America, England, and Australia flocked to the Gold fields to seek their fortune. More or less 1500 diggers were working in and around the area and some 4000 claims were made. In 1876, most of the tents were replaced with structures that are more permanent and various businessmen started to trade in Pilgrims Rest, supplying the diggers with the necessary equipment and provisions. The largest recorded nugget found in the area is the “Brenda” Nugget, weighing in at about 214 oz. ([www.pilgrims-rest.co.za](http://www.pilgrims-rest.co.za))



Q Alluvium

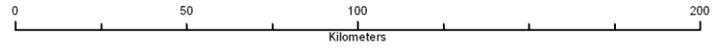


Figure 10: Distribution of the Intergranular Aquifers

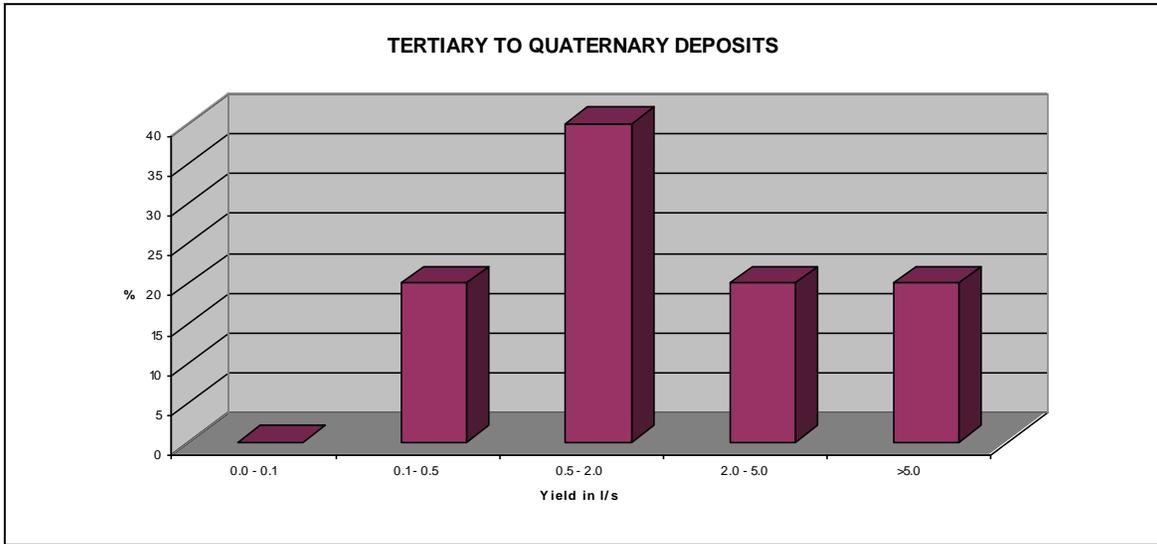


Figure 11: Yield frequency of boreholes in the intergranular Tertiary to Quaternary Deposits (40 boreholes analysed, 5 dry boreholes)

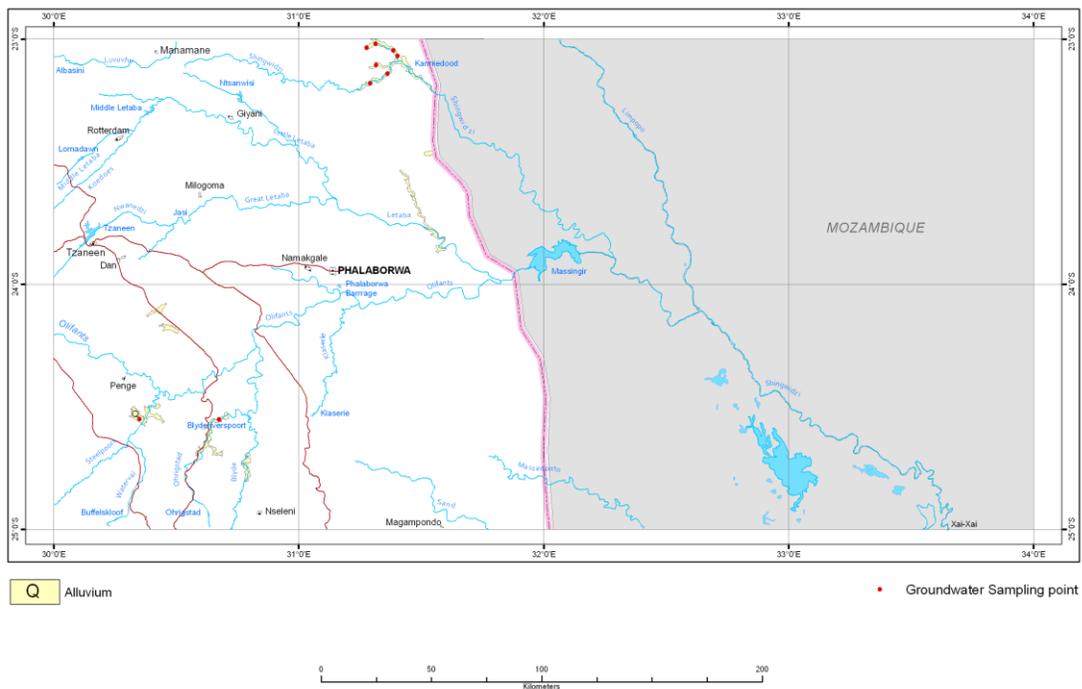


Figure 12: Distribution of the Alluvial Deposits and associated groundwater sampling points.

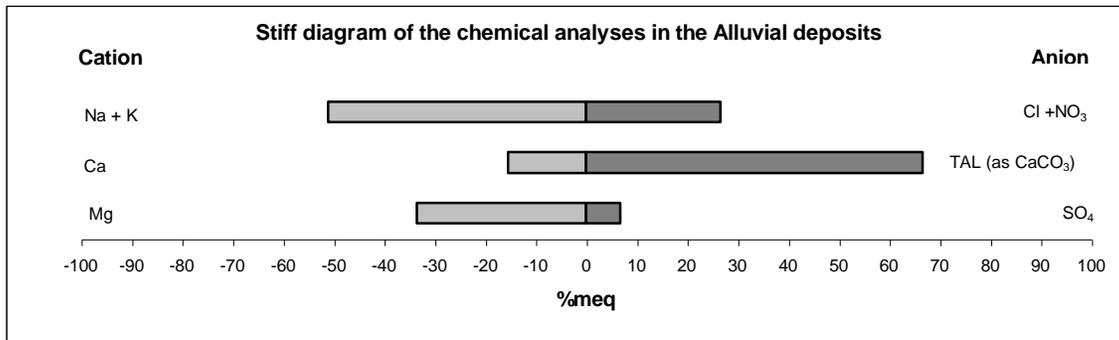


Figure 13: Stiff diagram of the chemical analyses (Alluvial Deposits)

### 3.2.4 Fractured Aquifers

Fractured or secondary aquifers refer to conditions where groundwater moves through a variety of joints, cracks, fractures and faults. In fractured aquifers, groundwater is contained mainly in the fractures, joints, and fissures including the important jointed transitional zone between the weathered and solid rock components and on bedding planes. The aerial distribution of the fractured aquifers is shown in Figure 14.

#### 3.2.4.1 Wolkberg Group

Water in the Wolkberg Group, which rests unconformably on the basement rocks, is more commonly found in fractures related to various stresses, such as tension, compression, or off-loading. It occurs mostly in mountainous areas and is sometimes inaccessible to drilling rigs. Owing to its inaccessibility and limited and restricted occurrence, the groundwater resources of the Wolkberg Group are regarded as insignificant. Its groundwater potential is not well known in this area, but is expected to be low to moderate. The median borehole yield is 2.47 l/s and the maximum is 5.1 l/s. Greater than 40% of the boreholes drilled into this group had a yield frequency of 2.0 to 5.0 l/s (Figure 15).

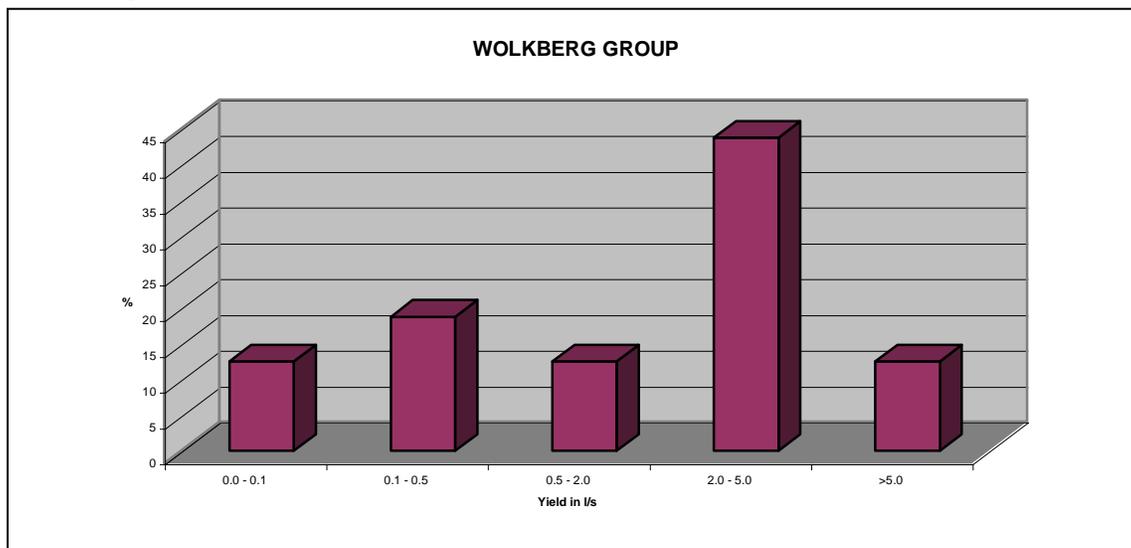


Figure 14: Yield frequency of boreholes in the Wolkberg Group (16 boreholes analysed, no dry boreholes)

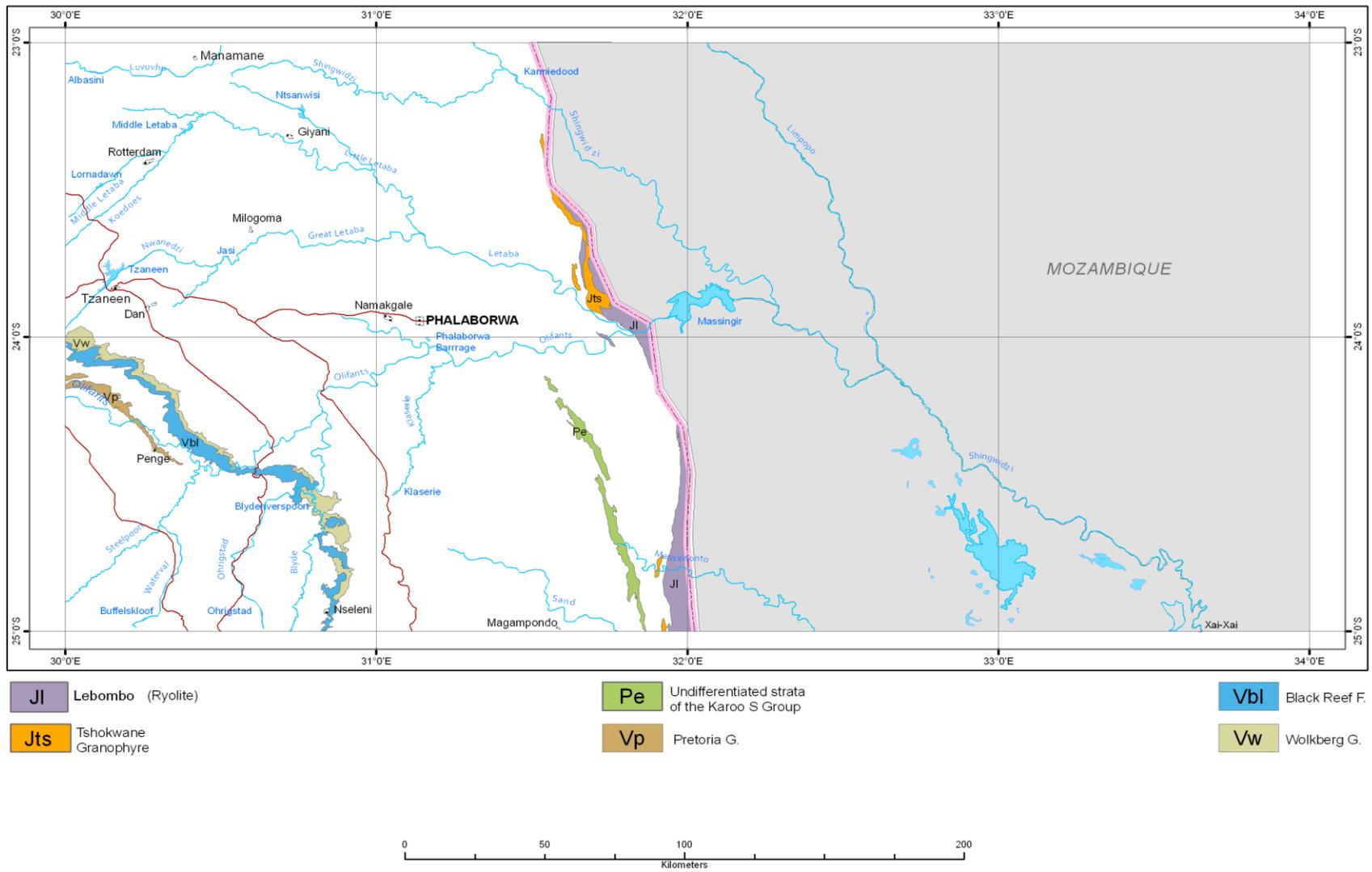


Figure 15: Distribution of the Fractured Aquifers

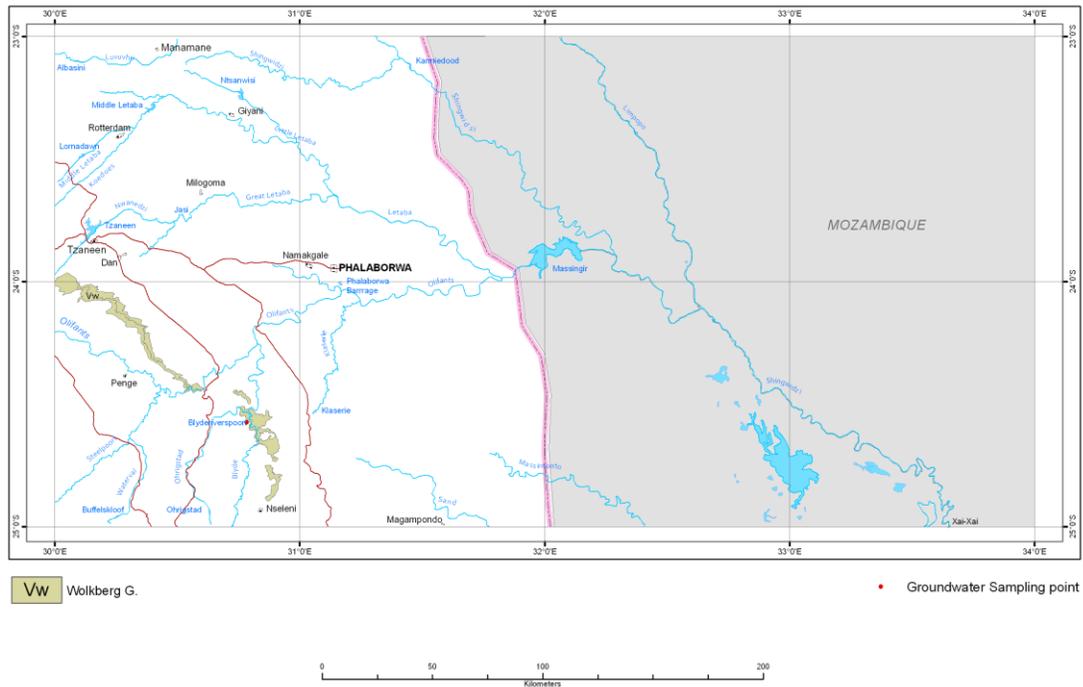


Figure 16: Distribution of the Wolkberg Group and associated groundwater sampling points.

Only 2 sampling points have EC values below the 70 mS/m and 3 sampling points have EC values below 300 mS/m. One of the sampling points has sodium and magnesium values above the maximum allowable limit for domestic use, which increased the electrical conductivity of the water. These conclusions might not be statistically valid because only 6 borehole water analyses (Figure 16) were available. The water found in this aquifer is of slightly alkaline nature and displays a magnesium–sodium–calcium–bicarbonate–chloride character (Figure 17).

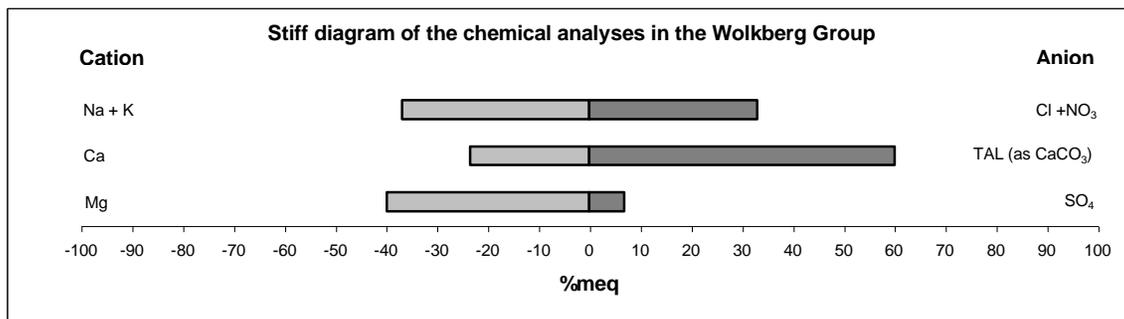


Figure 17: Stiff diagram of the chemical analyses (Wolkberg Group)

### 3.2.4.2 Black Reef Formation

The Formation is composed almost entirely of quartzite, with lenticular beds of grit and conglomerate. Dips are shallow and everywhere towards the inside of the Transvaal

basin. It rests paraconformably on the Wolkberg Group. Although the Formation occurs in mountainous areas, being part of the escarp and thus a major tourist attraction, made it accessible for groundwater development. Although little information is available on the occurrence of groundwater, water in the Black Reef Formation may be intercepted at the contact zones of dykes and sills, along faults and shear zones, and in fractures related to tensional, compressional and/or off-loading stresses. The median yield of 4.5 l/s might not be representative as data from only 7 water-bearing boreholes are available. The maximum borehole yield recorded is 9.5 l/s and the highest frequency class is 2.0 to 5.0 l/s. Despite this positive yield statistics, the groundwater potential of the Black Reef Formation is expected to be low to moderate with possible recharge from the overlying dolomites. The groundwater resources of the Black Reef Formation are therefore regarded as insignificant.

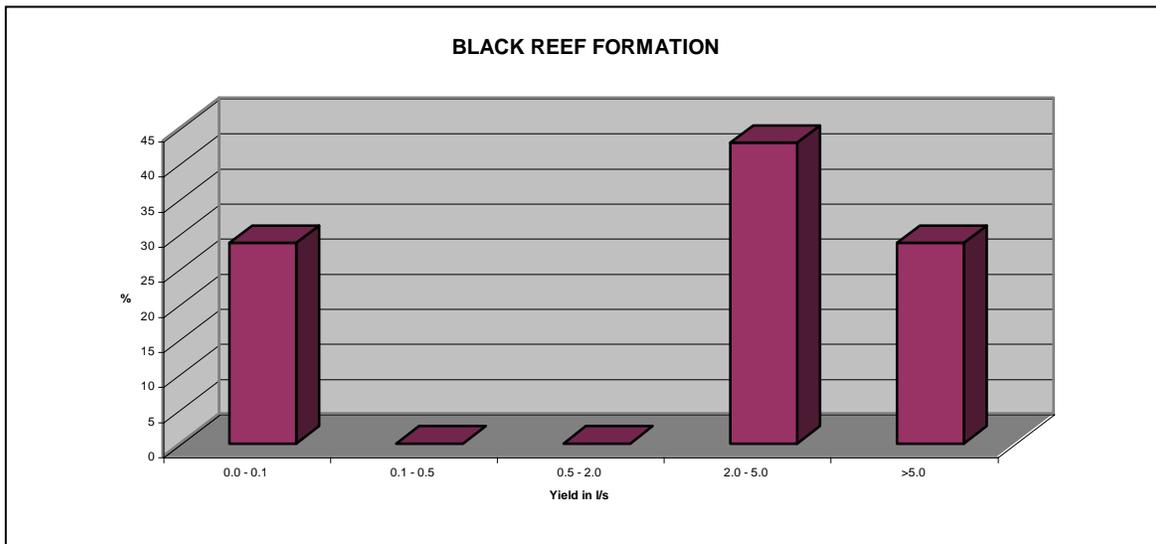


Figure 18: Yield frequency of boreholes in the Black Reef Formation (7 boreholes analysed, no dry boreholes)

Only one chemical analysis was available (Figure 19). It reveals calcium–magnesium–bicarbonate water and in general is fit for human consumption (Figure 20).

*Plate 6: Bourke's Luck Potholes*



Where the Blyde River and the Treur River meet, water erosion has formed one of the most remarkable geological phenomena in the country, known as the Bourke's Luck Potholes. Through the centuries, the whirling action of the water caused waterborne sand and rock to grind huge, cylindrical potholes into the Black Reef Quartzite Formation. The Potholes were named after a gold digger, Tom Burke, who staked a claim nearby. Although his claim did not produce a single ounce of gold, he correctly predicted that large gold deposits would be found in the area. The Potholes is located 35km north of Graskop town. ([www.sabie.co.za](http://www.sabie.co.za)) (Photograph: T Maluleke)

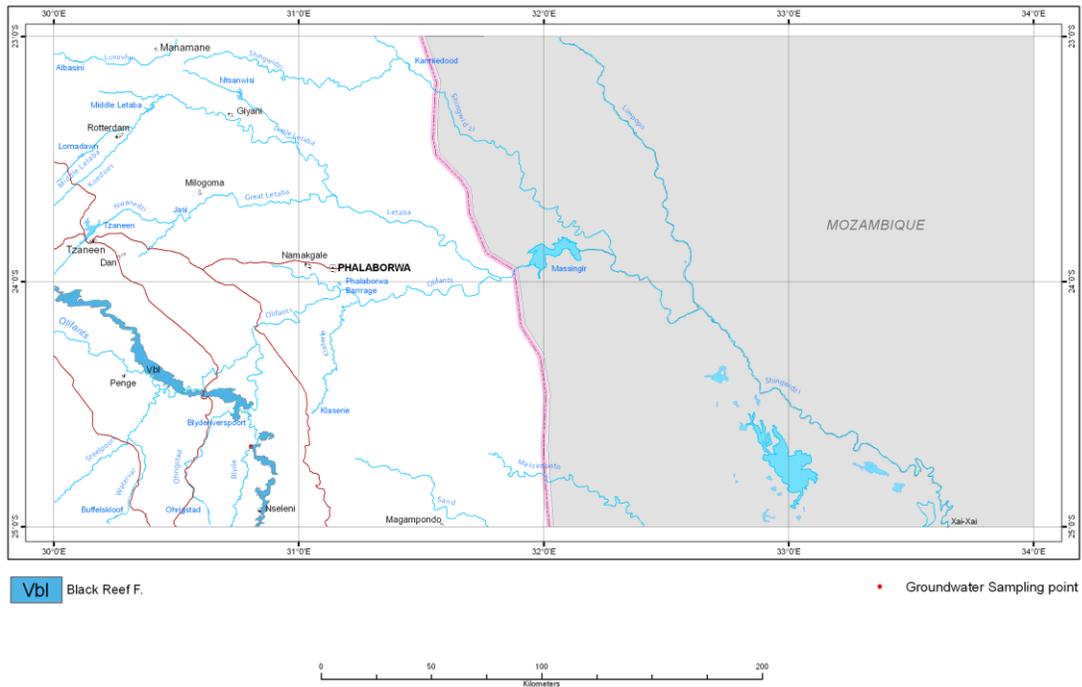


Figure 19: Distribution of the Black Reef Formation and associated groundwater sampling points.

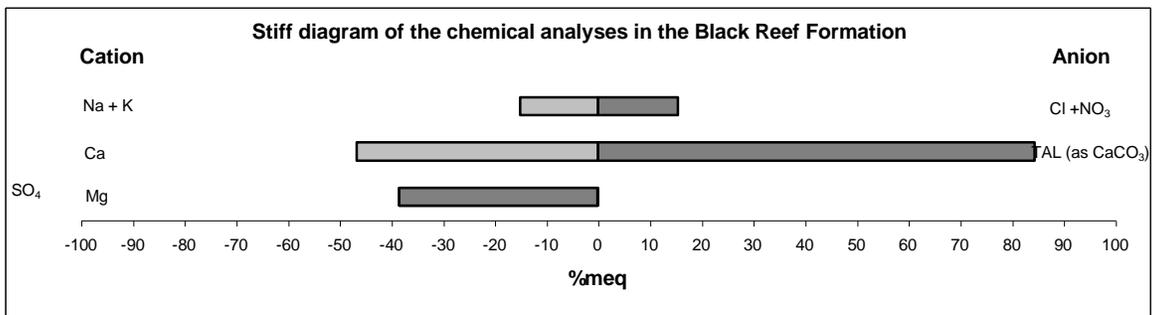


Figure 20: Stiff diagram of the chemical analyses (Black Reef Formation)

### 3.2.4.3 Pretoria Group

A broad band of Pretoria Group rocks occur to the northwest of Graskop in the southwest of the map area. However, only a tiny proportion of these rocks have fractured aquifer characteristics - the bulk of the rocks being classified as fractured and intergranular. The overall geohydrological characteristics of the Pretoria Group are therefore discussed under Intergranular and Fractured Aquifers. It is worth noting that the yields of the fractured aquifers (in the 0.1-0.5 l/s median yield class) of the Pretoria Group are generally lower than the yields of the Intergranular and Fractured Aquifers.

### 3.2.4.4 Undifferentiated strata of the Karoo Supergroup

According to Burger (1949) almost all of the water intercepted in the Undifferentiated Strata of the Karoo Supergroup is reasonable brackish. Yield data were obtained from 6 boreholes. Yields range from 0.18  $\ell/s$  to 0.5  $\ell/s$  with a median of 0.26  $\ell/s$ . All the boreholes analysed falls into the 0.1 to 0.5  $\ell/s$  frequency class (Figure 21). The aquifer potential of these rocks can be regarded as relatively poor. Burger (1949) concluded that chances of obtaining adequate supplies are more favourable where interlayered coal layers occur in the sediments than where only sandstone and ordinary shale layers occur. A few boreholes drilled next to dolerites dykes intrusive in sediments of the Eccca Group, indicated that yields get progressively smaller the closer boreholes are drilled to the contact (Burger, 1949). The poor yields generally obtained in the Undifferentiated Strata can be ascribed to the fact that small potential water bearing fractures are filled up with secondary material. This was observed in dry riverbeds where the different layers are exposed. Dolerite intrusions as well as fractured sediments occurring at depth are the better targets for successful groundwater development in this geohydrological unit. The distribution of the Undifferentiated Karoo Supergroup is displayed in Figure 22.

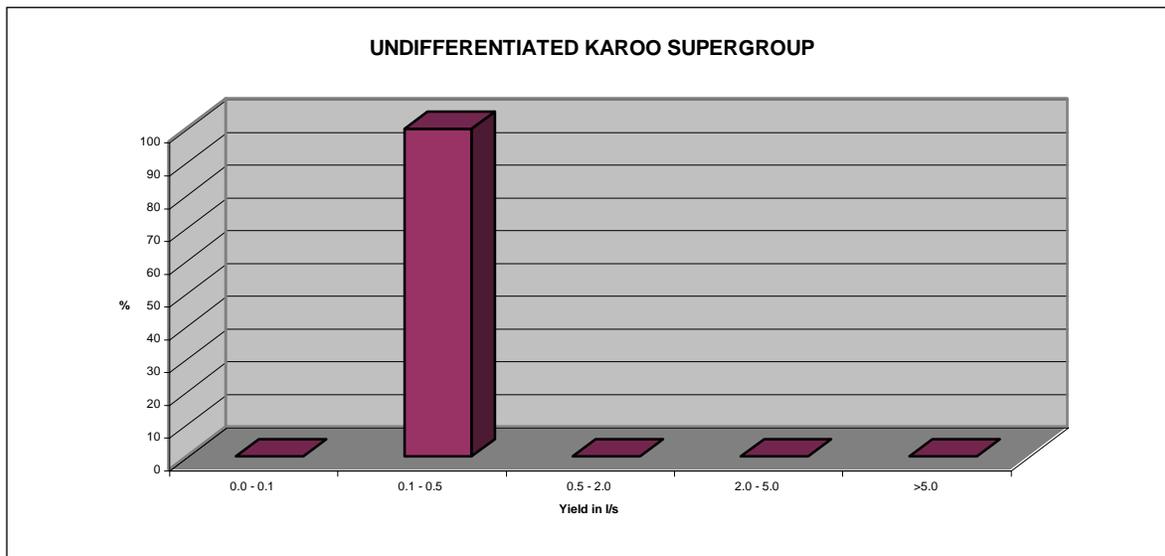


Figure 21: Yield frequency of boreholes in the Undifferentiated Strata of the Karoo Supergroup (6 boreholes analysed, no dry boreholes)

A chemical analysis of borehole water (3 samples) indicates the water to be of alkaline nature with an average total alkalinity (657.73  $\text{mg}/\ell$ ) exceeding the maximum allowable limit for domestic use (650  $\text{mg}/\ell$ ). The water displays a sodium-bicarbonate-chloride nature (Figure 23). All the EC measurements were above 70  $\text{mS}/\text{m}$  (recommended limit for domestic use) and below the maximum allowable limit (300  $\text{mS}/\text{m}$ ) with an average of 205  $\text{mS}/\text{m}$ . Elevated fluoride, chloride and sodium levels were encountered. These conclusions might not be statistically valid because only 3 borehole water analyses were available (Figure 22).

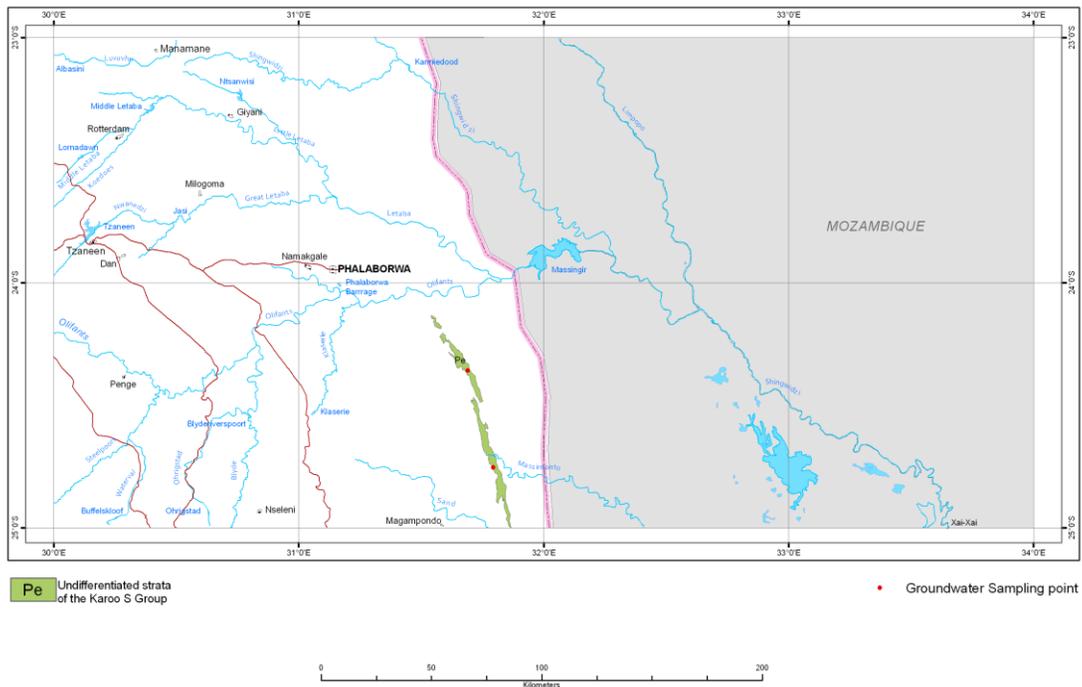


Figure 22: Distribution of the Undifferentiated Strata of the Karoo Supergroup and associated groundwater sampling points.

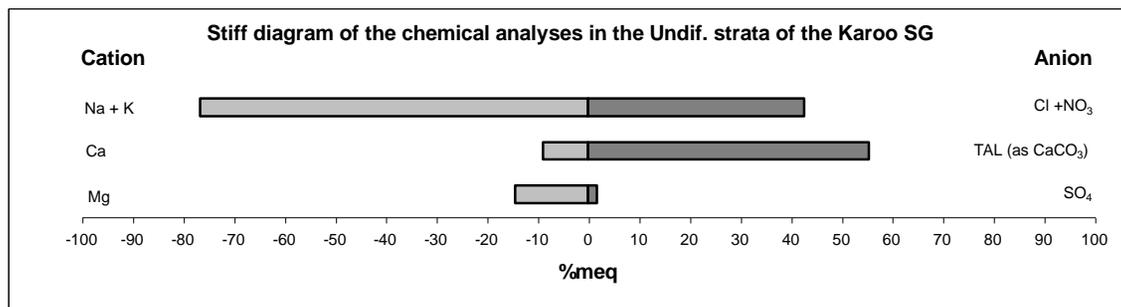


Figure 23: Stiff diagram of the chemical analyses (Undifferentiated Strata of the Karoo Supergroup)

### 3.2.4.5 Lebombo Group: Rhyolite

The median yield of boreholes in the rhyolite is only 0.03 l/s and is generally regarded as having a very low development potential (Du Toit, 1998). This is confirmed by the fact that 64% of the boreholes fall within the 0.0 to 0.1 l/s frequency class (Figure 24). Most of the water, which is generally intercepted within the first 30m, occurs in fractured rhyolite and to a lesser extent in fractured dolerite intrusions or on the contact with the host rock (Du Toit, 1998). The distribution of the Lebombo Group comprising rhyolite is displayed in Figure 25.

According to Hem's (1970) classification groundwater from the rhyolites is moderate brackish and based on the dominant ion relations a sodium-chloride water type. The water is high in Cl, which has built up with time and could it thus be classified as old water according to the Davis & DeWiest (1966) classification. The Stiff diagram (Figure

26) below also indicates the water to be of sodium-chloride character. The only analysis available for the rhyolite indicates an EC value of 404 mS/m whilst the fluoride and sulphate exceed maximum recommended limits for domestic use.

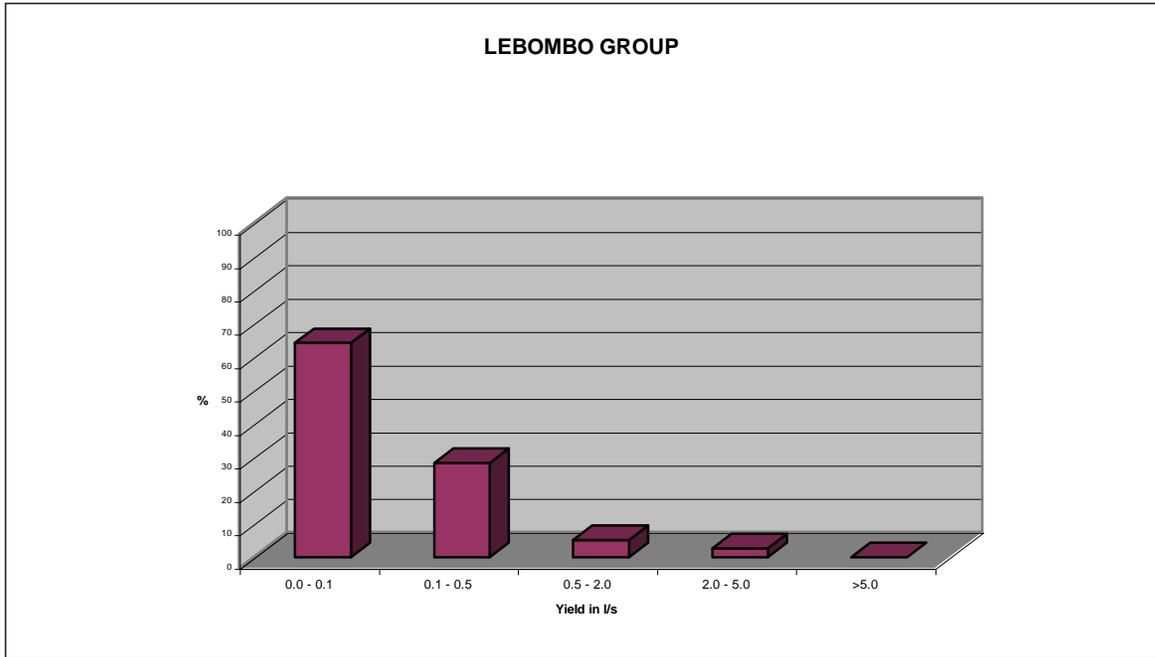


Figure 24: Yield frequency of boreholes in the Lebombo Group: Rhyolite (39 boreholes analysed, 18 dry boreholes)

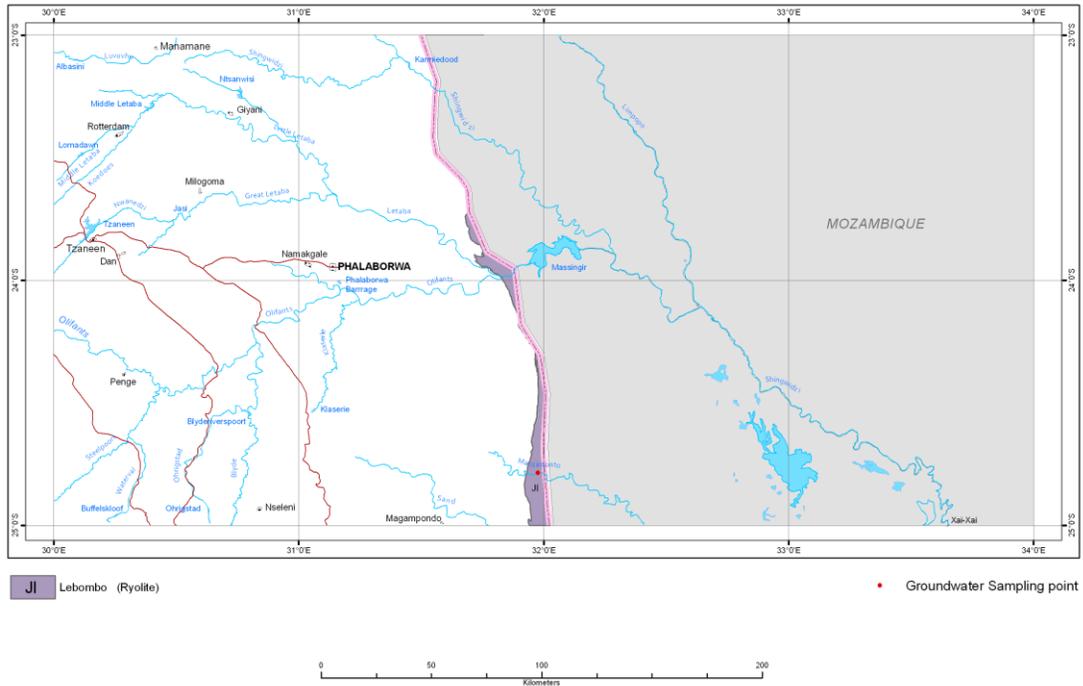


Figure 25: Distribution of the Lebombo Group: Rhyolite and associated groundwater sampling points.

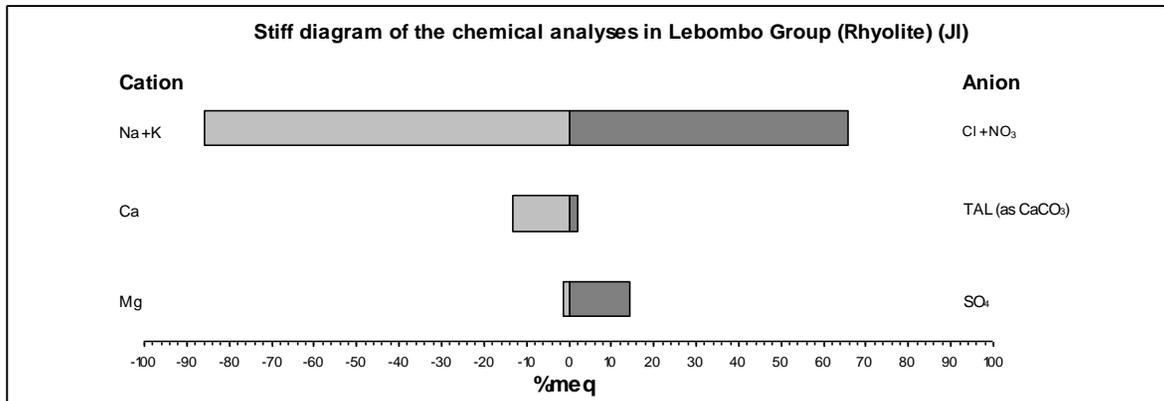


Figure 26: Stiff diagram of the chemical analyses (Lebombo Group: Rhyolite)

### 3.2.4.6 Tshokwane Granophyre

Yield data are only available from 2 boreholes within the map area. However, considering yield data of boreholes drilled in Tshokwane Granophyre outside of the map area —permitted characterization of this hydrogeological unit. Water is generally intercepted within the first 50m where it occurs in either fractured granophyre or along dolerite dyke contacts. Drilling results indicated that fractured granophyre and fractures associated with dyke intrusions are equally important targets for successful groundwater development. The median yield of boreholes in the Tshokwane Granophyre is 0.45 l/s thus having a moderate development potential (Du Toit, 1998). This is confirmed by the fact that 43% of the boreholes fall within the 0.5 to 2.0 l/s frequency class (Figure 27). The distribution of the Tshokwane granophyre is displayed in Figure 28.

According to Hem's (1970) classification groundwater from the Tshokwane Granophyre is moderate brackish and based on the dominant ion relations a sodium-magnesium-calcium-chloride-bicarbonate water type. The water is high in Cl, which has built up with time and could it thus be classified according to the Davis & DeWiest (1966) classification, as old water. The Stiff diagram (Figure 29) below confirms the sodium-chloride character of the water. The only analyses available for the Tshokwane Granophyre indicates an EC value of 249 mS/m whilst the fluoride and sulphate exceed maximum recommended limits for domestic use. The water is also of alkaline nature with total alkalinity exceeding the maximum limit.

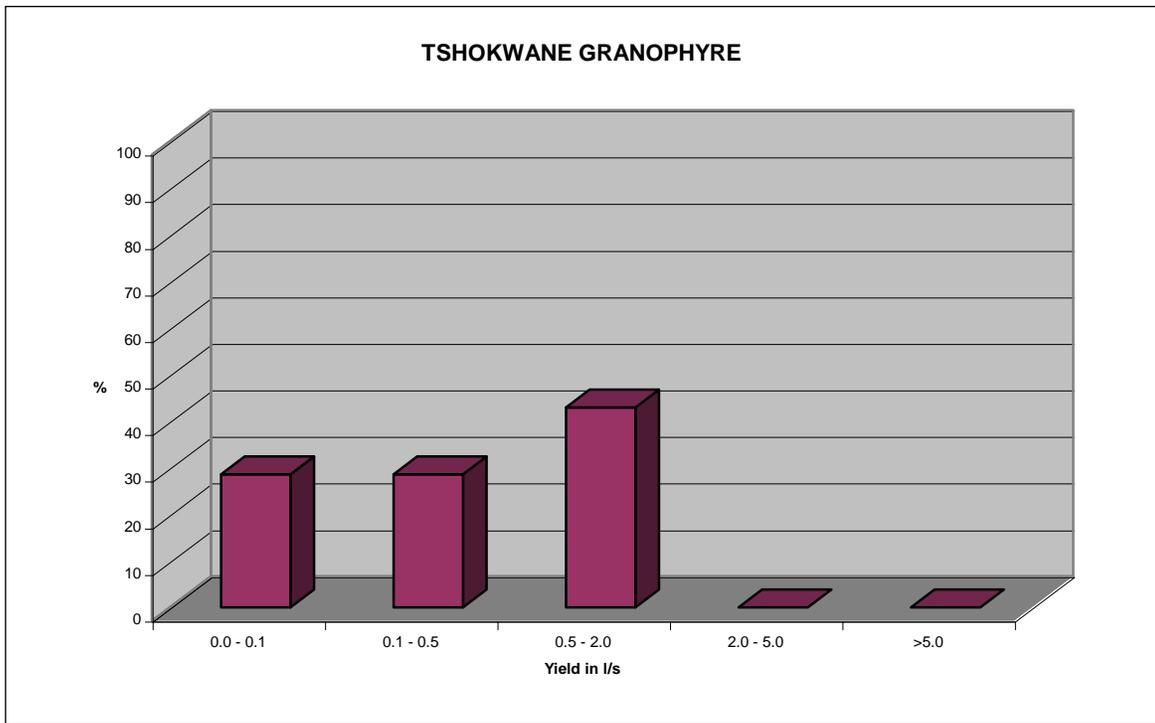


Figure 27: Yield frequency of boreholes in the Tshokwane Granophyre (7 boreholes analysed, 2 dry boreholes)

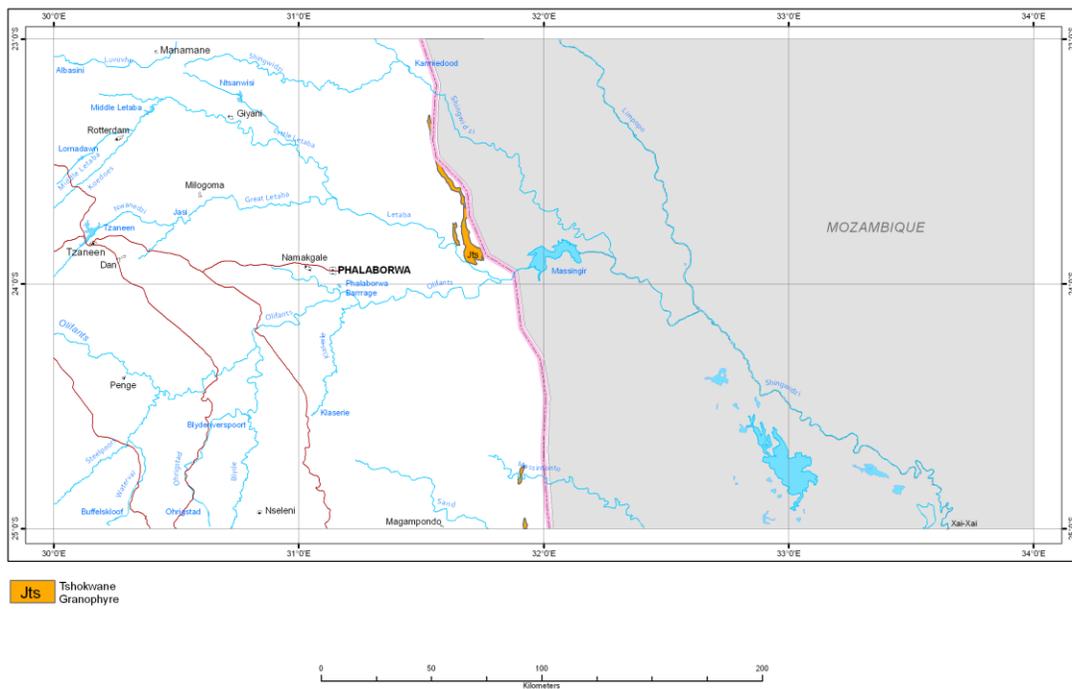


Figure 28: Distribution of the Tshokwane Granophyre

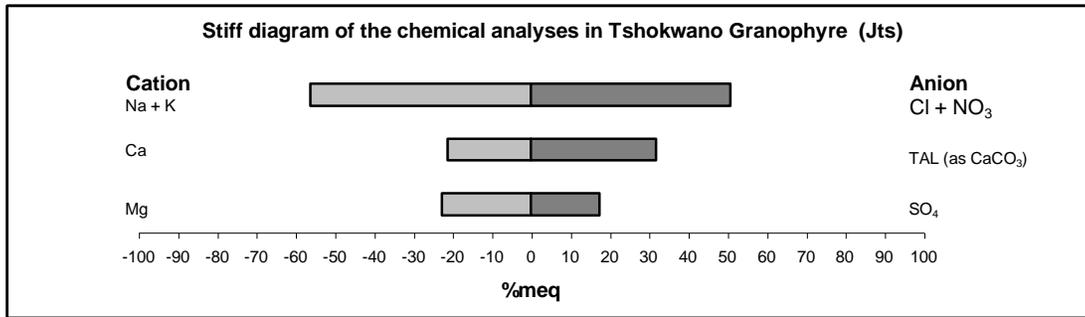


Figure 29: Stiff diagram of the chemical analyses (Tshokwane Granophyre)

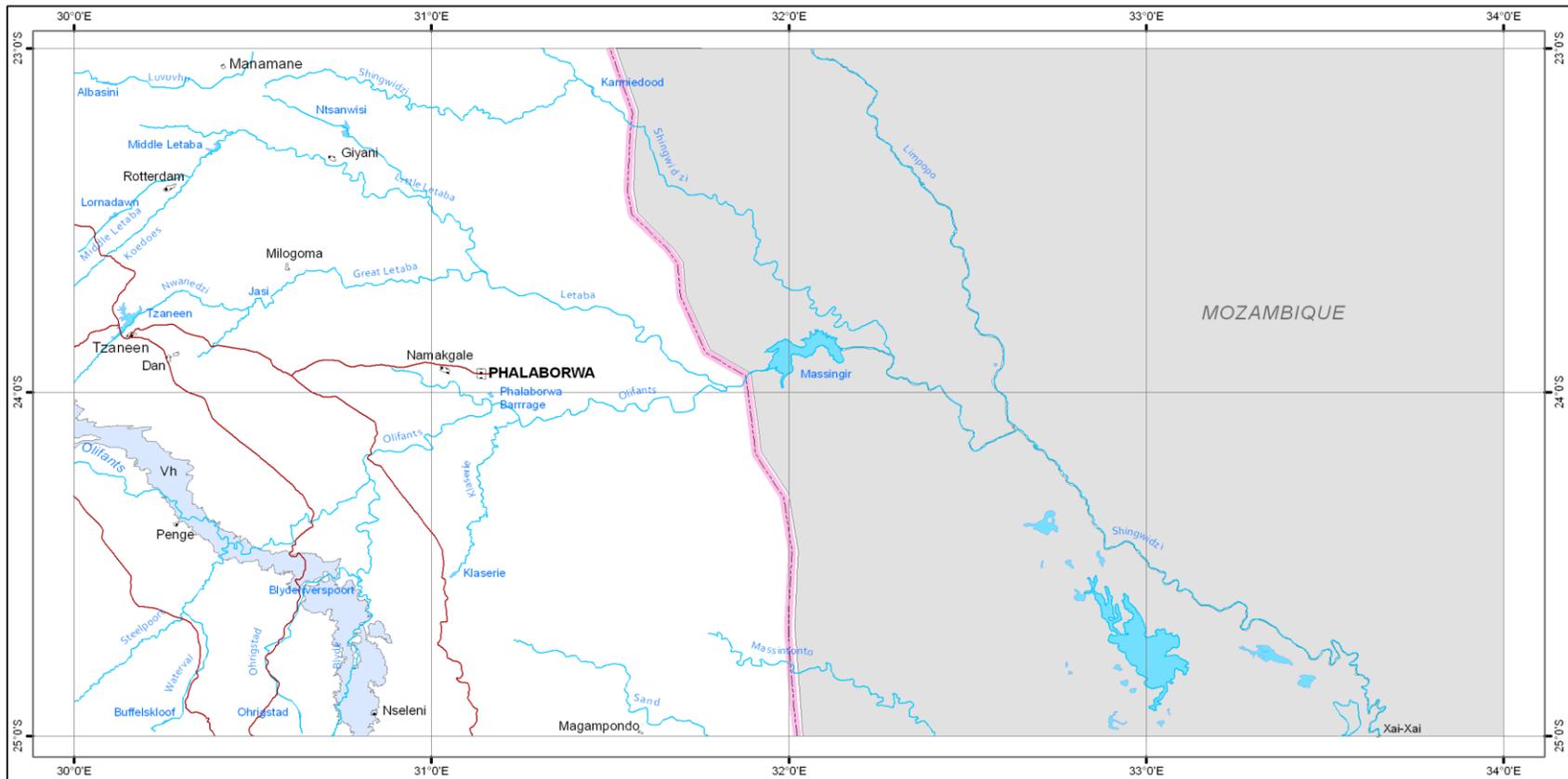
### 3.2.5 Karst Aquifers

Karst aquifers are water-bearing, soluble rock layers at or near the earth's surface in which groundwater flow is concentrated along secondarily enlarged fractures, fissures, conduits, and other interconnected openings. They are formed by the chemical dissolving action of slightly acidic water on highly soluble rocks, most notably limestone and dolomite, and to a lesser degree, gypsum, anhydrite, and halite. For the processes of karst to be active, water must dynamically circulate through these soluble rocks - exposing the rock to interaction with water and enabling transport of solutes, and the water must be under-saturated with respect to the chemical constituents of the rock - enabling dissolution to occur. This interplay of flow (hydrology) and dissolution (geochemistry) removes rock creating increasingly larger voids along the pathways.

Figure 30 shows the distribution of the Karst aquifers in the map area.



Plate 7: Water flowing from a cavity in the dolomites of the Malmani Subgroup viewed from the Abel Erasmus pass near the J.G. Strydom Tunnel; These cavities are connected to the Echo Cave system located about 10km to the south of this site (Photograph: T Maluleke)



Vh Chuniespoort G.

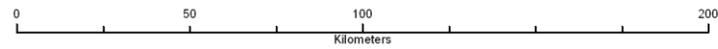


Figure 30: Distribution of the Karst Aquifer

### 3.2.5.1 Chuniespoort Group

Groundwater occurs along fault and shear zones associated with intense deformation resulting in the occurrence of fractures, joints, and cavities subsequently enlarged by dissolution processes in the dolomites. Groundwater is also found at the contact zones of dykes and sills, and in fractures of diverse origin. Access to these dolomitic areas is hampered by the mountainous terrain, which contributes to groundwater being under-utilized. The latter is probably a blessing in disguise as the numerous springs (not mapped) occurring in the Malmani sub-group, contribute extensively to base flow of many of the rivers in the area. Some of these rivers flow through the Kruger National Park, which biodiversity is for obvious reasons, very vulnerable to any development impacting negatively on flow in these rivers.

The highest yield frequency 2.0 to 5.0 l/s accounts for greater than 35% of the borehole analysed and only 3 dry boreholes were listed in the database (Figure 31). The median yield is 2.3 l/s and its maximum yield is 16.0 l/s.

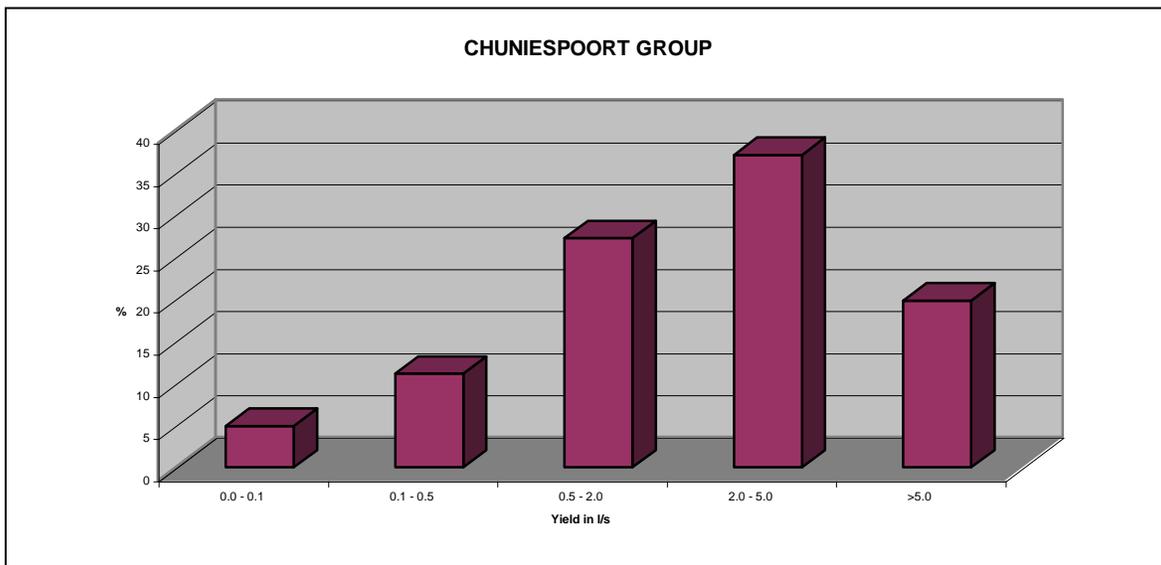


Figure 31: Yield frequency of boreholes in the Chuniespoort Group (84 boreholes analysed, 3 dry boreholes)

The 29 available chemical analyses (Figure 32) show that groundwater in the Chuniespoort are acceptable for domestic use and display a magnesium-calcium-sodium-bicarbonate-chloride character (Figure 33). Only one fluoride and nitrate exceeded the maximum allowable limit. The average EC value is 54.68 mS/m (Table 4) with a maximum value of 166.10 mS/m.

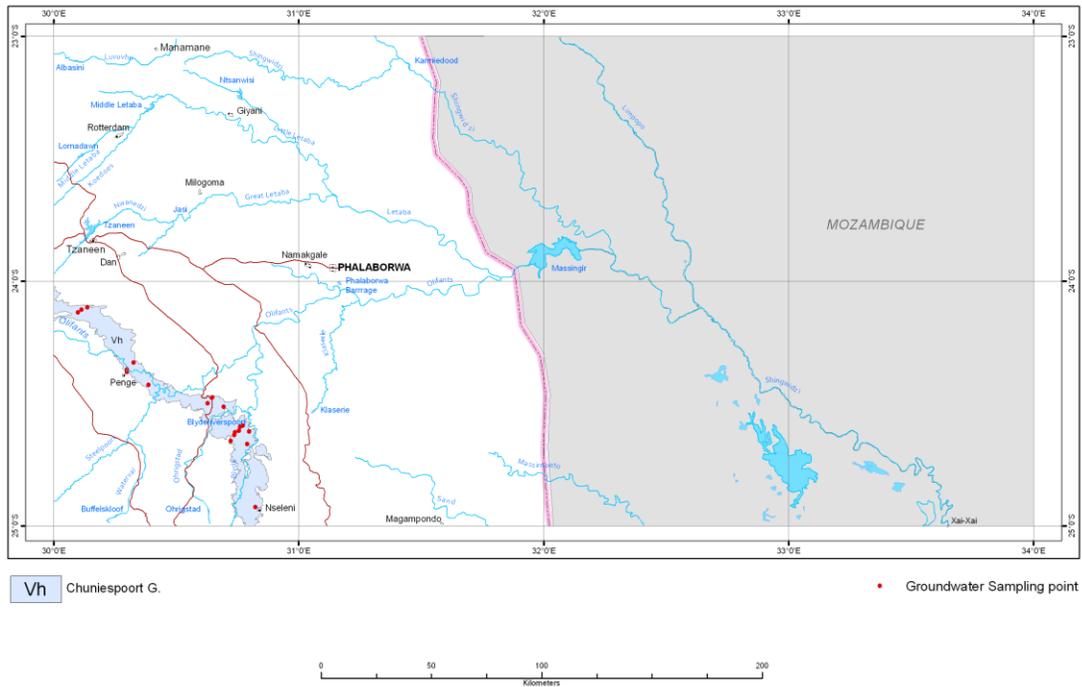


Figure 32: Distribution of the Chuniespoort Group and associated groundwater sampling points.

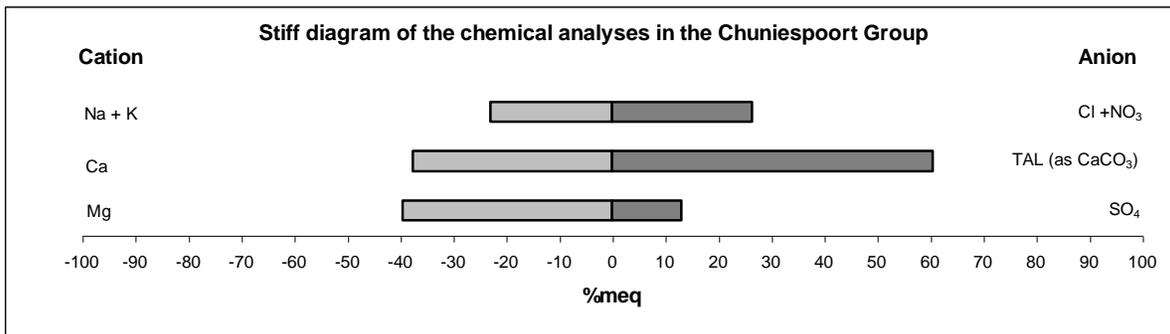


Figure 33: Stiff diagram of the chemical analyses (Chuniespoort Group)

### 3.2.6 Intergranular and fractured aquifers

“Intergranular and fractured”, as used on this map, describe aquifers within the same lithology, in which groundwater occur in both the above modes with the exception that the intergranular interstices are secondary of nature. Secondary intergranular interstices normally result where the less resistant material in a medium to coarse-grained hard rock lithology, such as granite and gneiss, is removed by weathering, leaving intergranular interstices between the remaining more resistant granules. The same restricting factors as mentioned above are valid for this type of aquifer within the map area. Limited information regarding water levels and depth of weathering rendered it impossible to accurately delineate aquifers of this type within the map area. This type, as indicated on the map, rather refers to the property of the lithology to contain groundwater

in both modes than to the actual condition at any given locality. The distribution of the intergranular and fractured aquifers is shown in Figure 34.

### **3.2.6.1 Goudplaats Gneiss**

The Goudplaats Gneiss, which forms the floor on which the Bandelierskop Complex and Murchison Sequence have been deposited, covers an extensive portion of the total map area. The gneiss has been intruded by various granites and numerous dykes with a predominantly northeast/southwest strike. In some areas these intrusions even reach dyke swarm status. The groundwater potential of the gneiss is in general moderate to good with more than 35% of these boreholes occurring in the yield class 0.5 to 2.0 l/s. In total 1053 boreholes were analysed of which 16% of the boreholes are dry (Figure 35). The median yield is 2.0 l/s and the highest encountered was 30.0 l/s.

Some of the high yielding boreholes appear to be related to the occurrence of pegmatites in the area whose origin, composition and its relation to the occurrence of groundwater is not yet known. Drilling in the Goudplaats Gneiss in Limpopo revealed that the presence of these pegmatites can make a considerable difference in the yield over very short distances. Water is also obtained in deep basins of weathering and in the transitional zone between weathered and solid gneiss as well as in fracture zones occurring at various depths. A study done in the Kruger National Park by Du Toit (1998) indicated that in 77% of the cases water, was intercepted in the Goudplaats Gneiss within the first 30m. Many of the fractures intercepted at depth are thought to be related to off-loading. Water occurs also in fault and shear zones and to a lesser extent along dyke contacts. Current stress fields play an important role in the success rate of boreholes drilled along these structures. Northeast to southwest trending structures tend to be less successful than the northerly trending ones due to the presence of compressional and extensional stresses respectively. Some of the broader dykes are sometimes more fractured, fissured or decomposed than the surrounding host rock and thus carry the water themselves. As the broader dykes cooled slower than the narrow ones they are coarser grained and therefore more susceptible to weathering and fracturing (Du Toit, 1986).

Groundwater is mostly used for stock watering and domestic purposes and to a lesser extend for irrigation.

The water quality evaluation based on 611 analyses (Figure 36) reveals a large fluctuation in EC. Approximately 63% of boreholes have EC values above the recommended limit for drinking water (70 mS/m) but only 5% have values higher than 300 mS/m (The maximum allowable limit). The mean EC value is 124.13 mS/m.

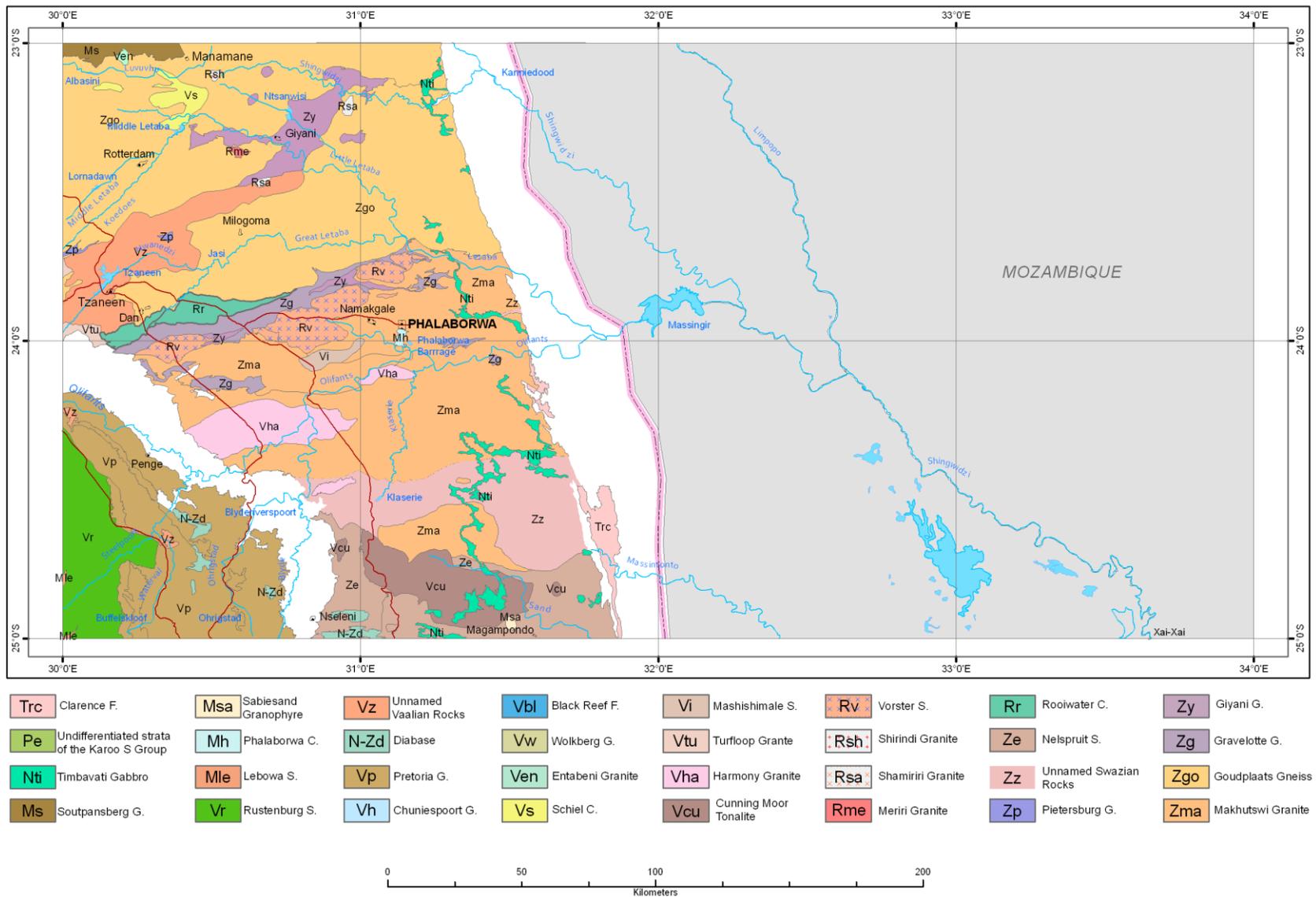


Figure 34: Distribution of the Intergranular and Fractured Aquifers

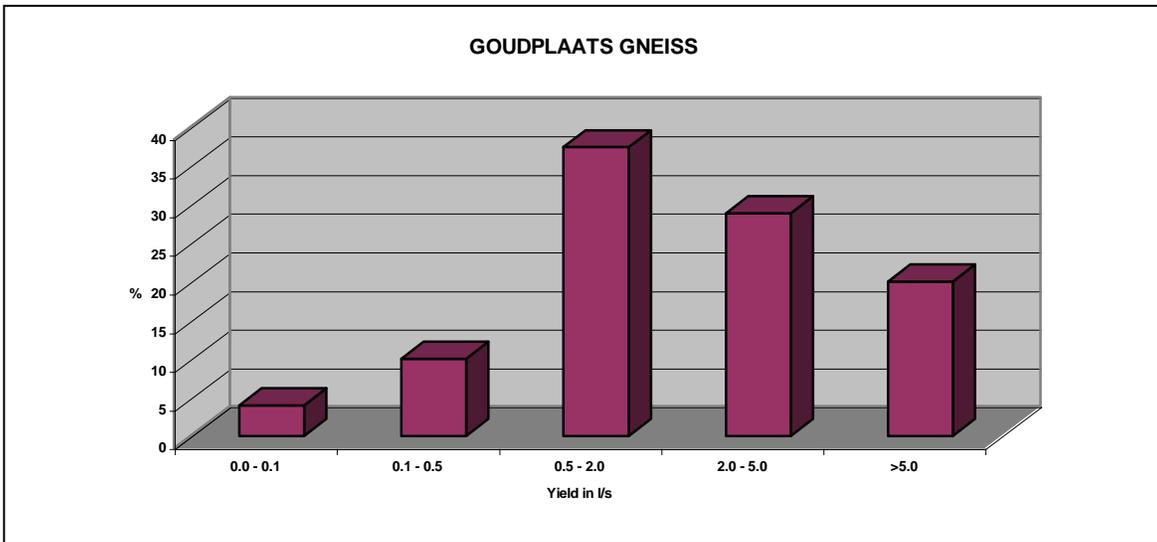


Figure 35: Yield frequency of boreholes in the Goudplaats Gneiss (1053 boreholes analysed, 171 dry boreholes)

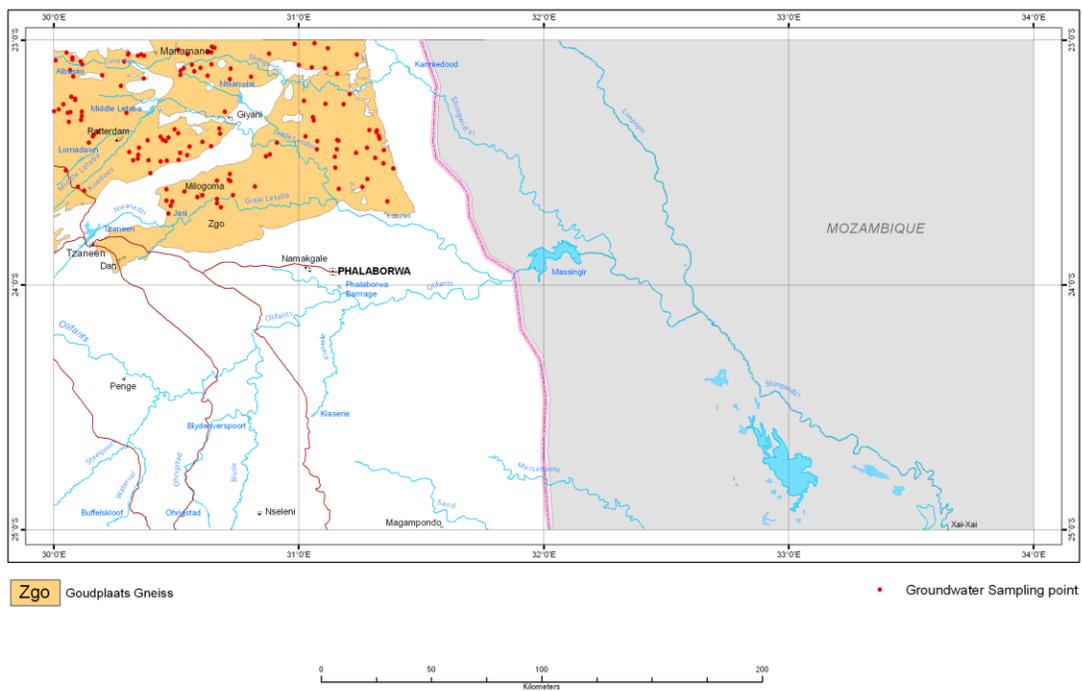


Figure 36: Distribution of the Goudplaats Gneiss and associated groundwater sampling points.

According to the Stiff diagram (Figure 37), groundwater in the Goudplaats Gneiss is of sodium–magnesium–calcium–bicarbonate–chloride character. The average nitrate value exceeds the maximum allowable limit for domestic use (Table 4).

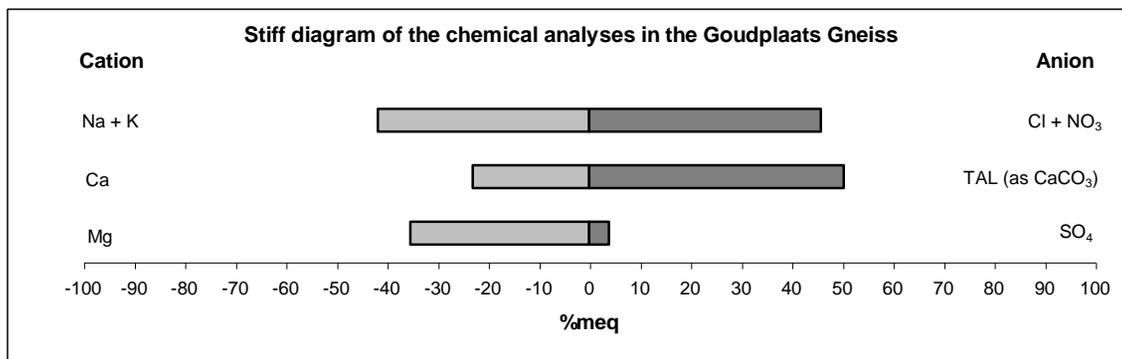


Figure 37: Stiff diagram of the chemical analyses (Goudplaats Gneiss)

### 3.2.6.2 Makhutswi Gneiss

A comparison of drilling results between the Goudplaats and Makhutswi Gneiss (Du Toit, 1998) indicated the latter to possess over a slightly better groundwater potential than the former with more than 37% of the boreholes occurring in the yield class 0.5 to 2.0 l/s. This is related to deeper weathering and a higher frequency of fracturing occurring at depth in the Makhutswi Gneiss. 741 Borehole yield frequency analyses were available for interpretation of which less than 10% of these boreholes were dry (Figure 38). The median yield is 1.2 l/s and the highest 40.0 l/s.

In terms of groundwater occurrence, basins of weathering and fractured zones at depth will yield the best results. Many of the fractures intercepted at depth are thought to be related to off-loading. As in case of the Goudplaats Gneiss, some of the high yielding boreholes in the Makhutswi Gneiss also appear to be related to the occurrence of pegmatites in the area. According to Du Toit (1998) in 68% of the cases water will be intercepted within the first 30m. Water occurs also in fault and shear zones and to a lesser extent along dyke contacts. Current stress fields play an important role in the success rate of boreholes drilled along these structures. Like the Goudplaats Gneiss, the Makhutswi Gneiss was extensively intruded by dykes with a dominating northeast/southwest orientation.

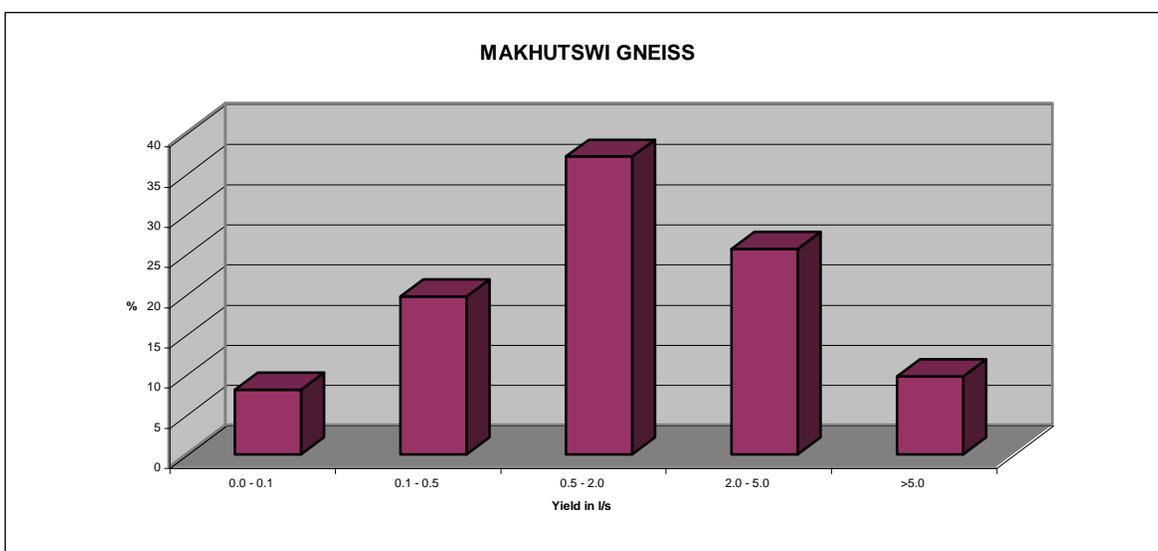


Figure 38: Yield frequency of boreholes in the Makhutswi Gneiss (741 boreholes analysed, 69 dry boreholes)

Chemical analyses of borehole water (462 samples – Figure 39) indicate that fresher water is associated with the western and southern map areas. It appears that a positive correlation exists between the rainfall and the concentration of dissolved solids or its electrical conductivity.

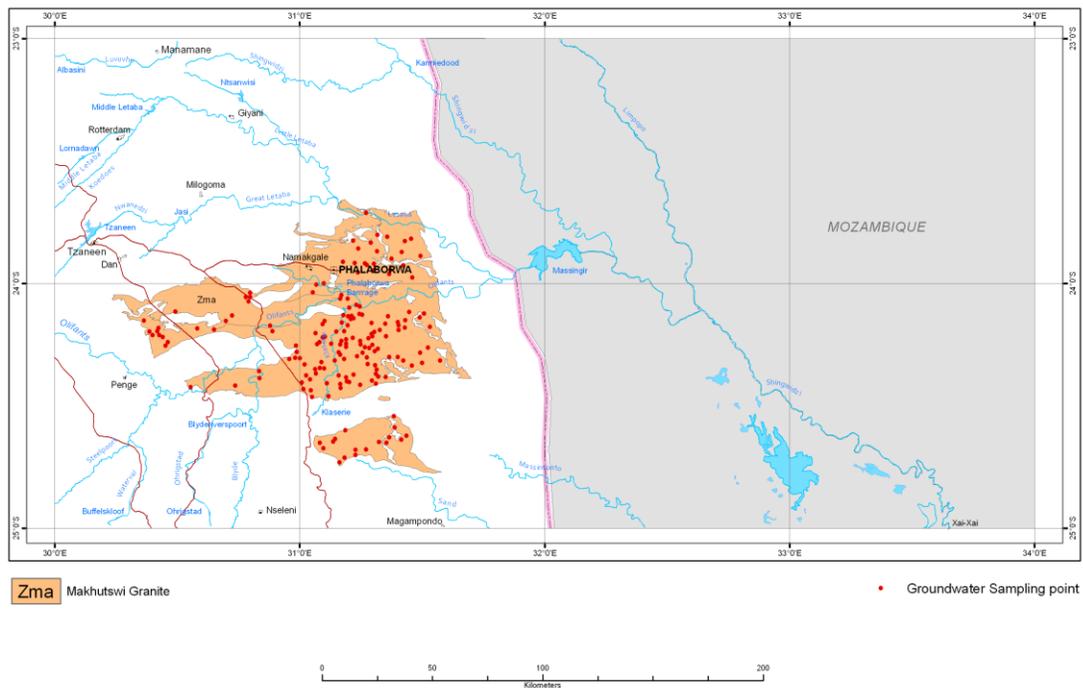


Figure 39: Distribution of the Makhutswi Gneiss and associated groundwater sampling points.

According to the Stiff diagram (Figure 40), groundwater in the Makhutswi Gneiss is of sodium–magnesium–bicarbonate–chloride character. The average nitrate and sodium values exceed the maximum allowable limit for domestic use (Table 4).

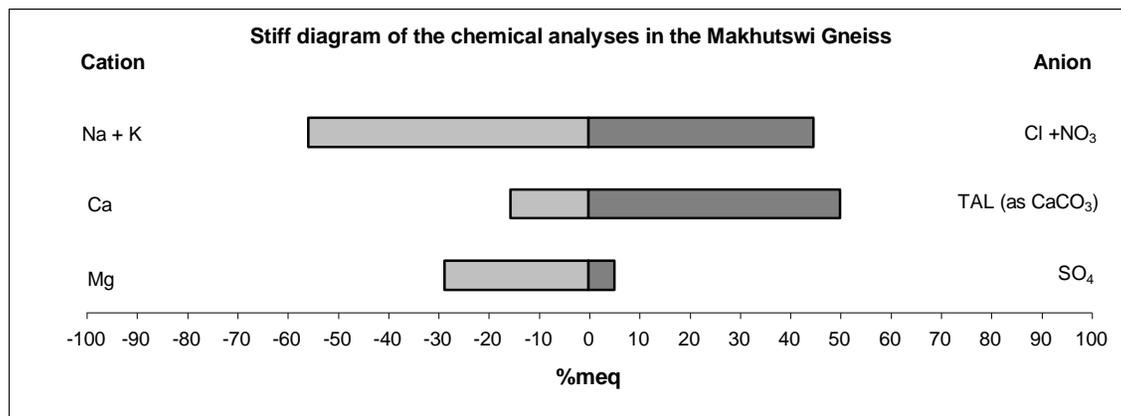


Figure 40: Stiff diagram of the chemical analyses (Makhutswi Gneiss)

### 3.2.6.3 Pietersburg Group

This Group, which is a typical Archaean greenstone belt, only covers a limited area. No borehole yield data were available. Of the six formations distinguished within the Group, only the Mothiba Formations occurs in the map area comprising talc-chlorite and amphibole-chlorite schist, amphibolite and serpentinite.

Deep weathering of between 18 and 48m is not uncommon in the Mothiba Formation. However, a very low permeability, possibly due to excessive clay produced through the weathering processes, renders its basins of weathering extremely poor aquifers. Water is exclusively obtained in fissures and fractures below the weathering zone. Groundwater also occurs in faults and associated shear zones, lithological contacts, and also dyke contacts.

Only four chemical analyses were found (Figure 41). The water quality does not pose any problem for domestic use with all the EC values below 70 mS/m and reveals a sodium-calcium-magnesium-bicarbonate character (Figure 42). The median EC value is 17.05 mS/m (Table 4). Only one fluoride value exceeded the recommended limit but may be due to local contamination.

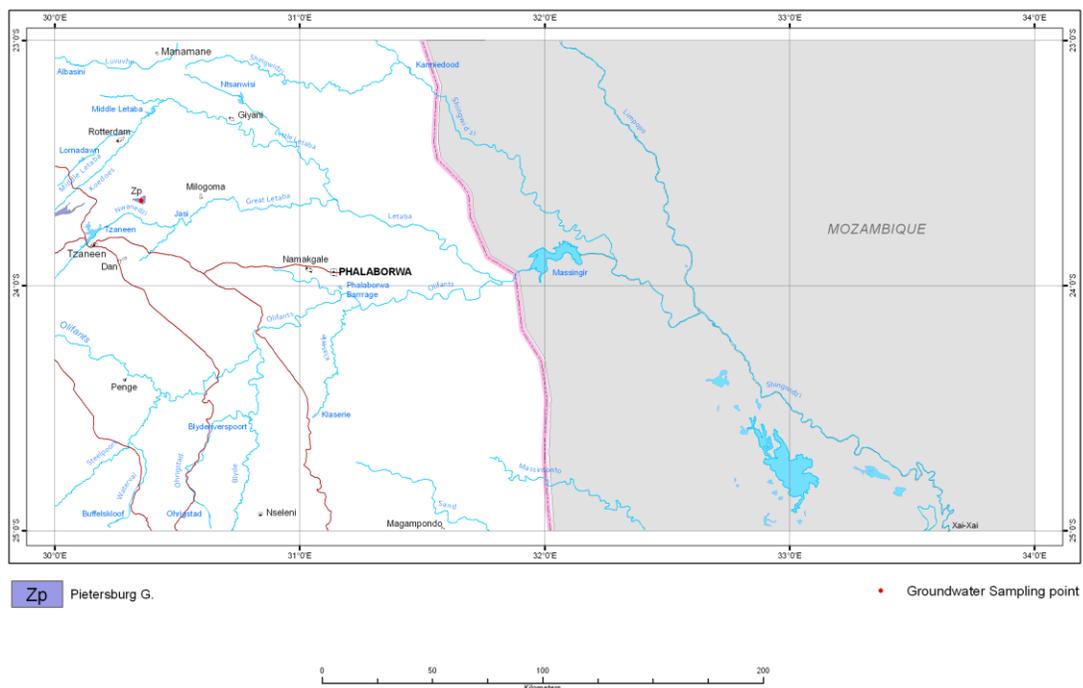


Figure 41: Distribution of the Pietersburg Group and associated groundwater sampling points.

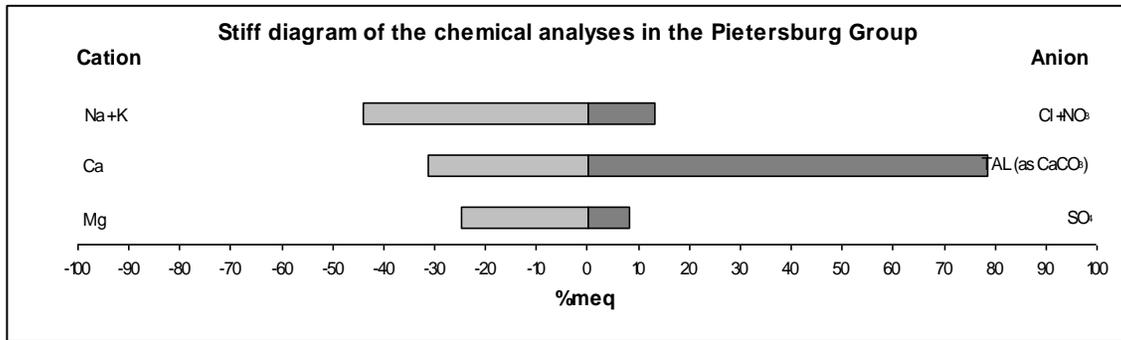


Figure 42: Stiff diagram of the chemical analyses (Pietersburg Group)

### 3.2.6.4 Gravelotte Group

The Gravelotte Group comprising quartz-mica schist, talc-schist and actinolite-chlorite schist, amphibolite with banded ironstone, quartzite, serpentinite and marble possess similar geohydrological characteristics as the Pietersburg and Giyani Groups (Schutte, 1986). Water is mostly obtained in fracture zones, faults and along dyke contacts. 50 Boreholes were available for interpretation of which 20% of these boreholes were dry (Figure 43). 40% of these boreholes fall into the 0.5 to 2.0  $\ell/s$  yield frequency class. The median borehole yield is 1.01  $\ell/s$  and the highest is 8.2  $\ell/s$ .

The 49 available chemical analyses (Figure 44) show water to be unsuited for domestic use due to an average of 10.13 mg/ $\ell$  for nitrate (Table 4), which exceeds the recommended limit. 94% of the EC values are below 300 mS/m (Maximum allowable limit for domestic use) and the remainder below 70 mS/m (Recommended limit for domestic use). The water type displayed by this aquifer is magnesium-sodium-bicarbonate-chloride (Figure 45). Occasional high fluoride, magnesium and chloride values were encountered.

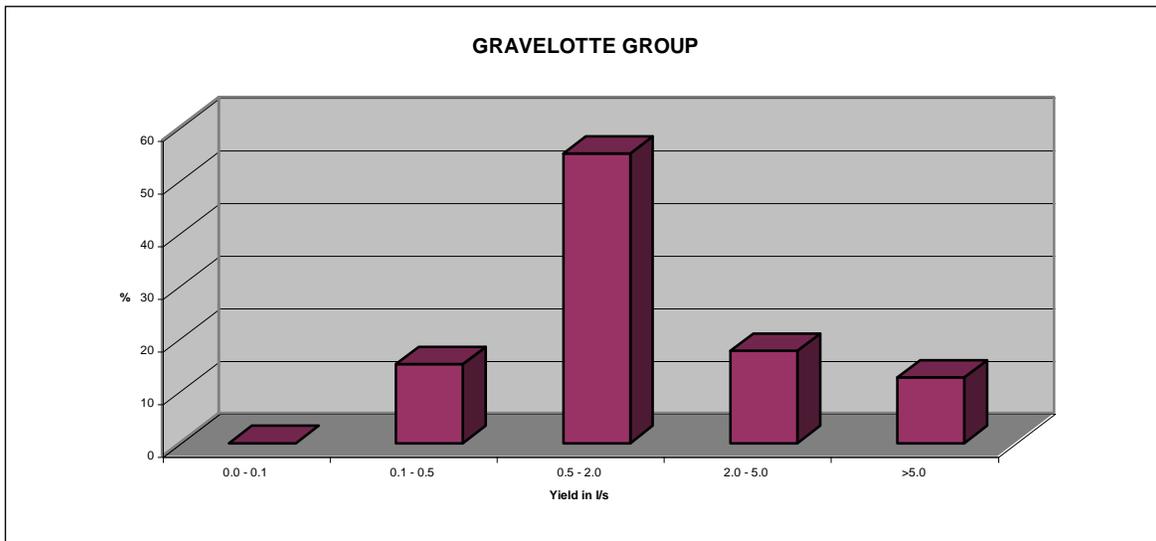


Figure 43: Yield frequency of boreholes in the Gravelotte Group (50 boreholes analysed, 10 dry boreholes)

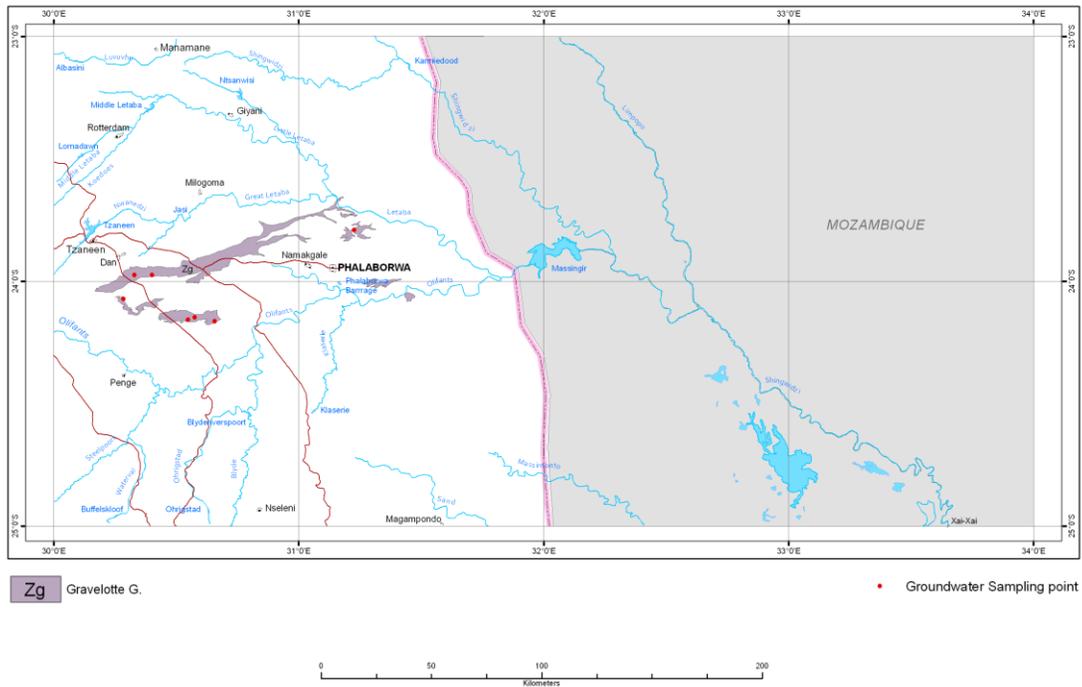


Figure 44: Distribution of the Gravelotte Group and associated groundwater sampling points.

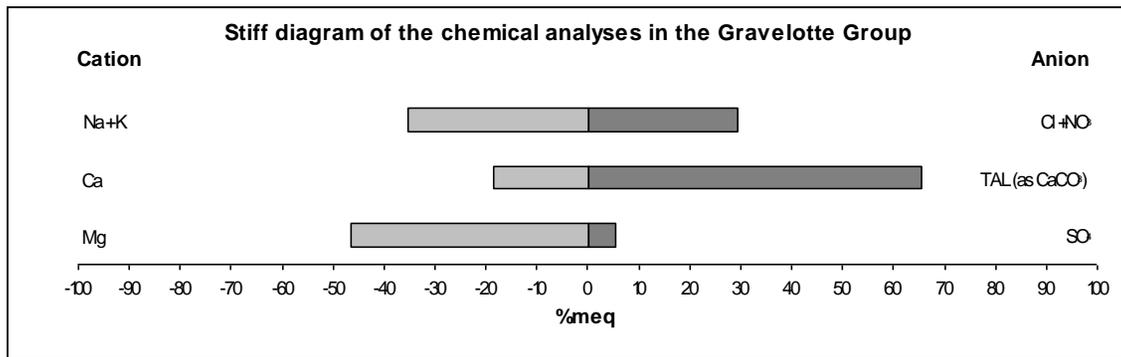


Figure 45: Stiff diagram of the chemical analyses (Gravelotte Group)

### 3.2.6.5 Giyani Group

The Giyani Group, which comprises mostly ultramafic schist and amphibolite with interlayered banded ironstone, show many similarities with the Pietersburg and Gravelotte Groups in terms of groundwater occurrence. Drilling results, however, indicated that fractures are more frequently intercepted at depths up to 80m in the Giyani Group than in the other Groups. Dykes are also good targets for successful boreholes. Of the 80 boreholes analysed only 14 boreholes were dry (Figure 46). Greater than 30% of the boreholes analysed had a yield frequency of 0.5 to 2.0  $\ell/s$ . The highest borehole yield found in this group is 21.0  $\ell/s$  and the median yield is 2.5  $\ell/s$ .

In total chemistry data from 62 boreholes were analysed (Figure 47). Some elevated nitrate and magnesium values were encountered but the average of these variables are below the recommended limit for domestic use (Table 4). These points might be anomalies and due to local contamination. The average EC value is 58 mS/m with 82% below 70 mS/m, 16% below 300 mS/m and only one point above the maximum allowable limit (300 mS/m). This point is an anomaly and might be due to local pollution.

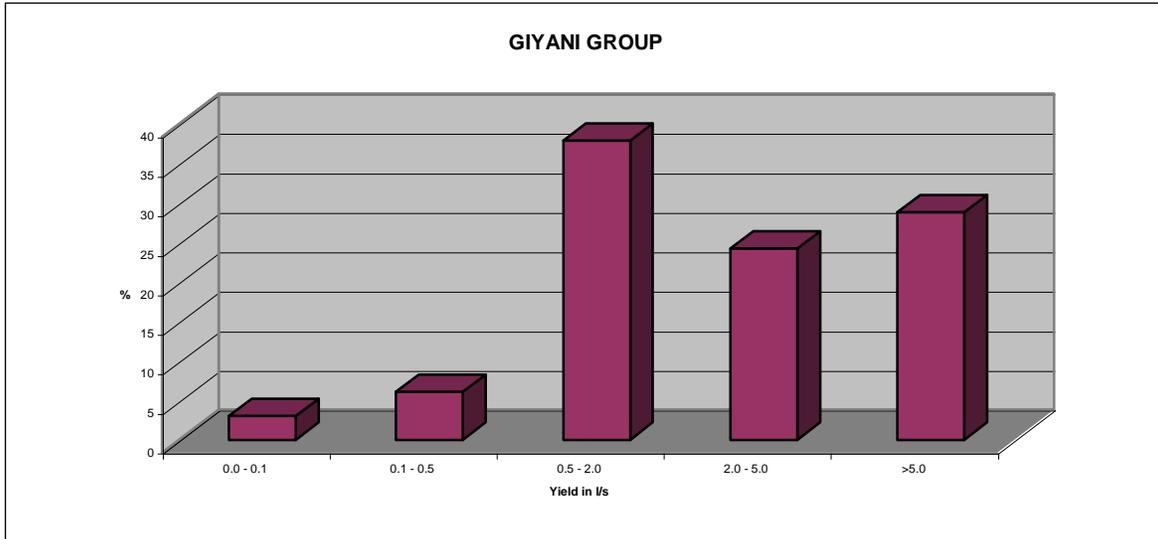


Figure 46: Yield frequency of boreholes in the Giyani Group (80 boreholes analysed, 14 dry boreholes)

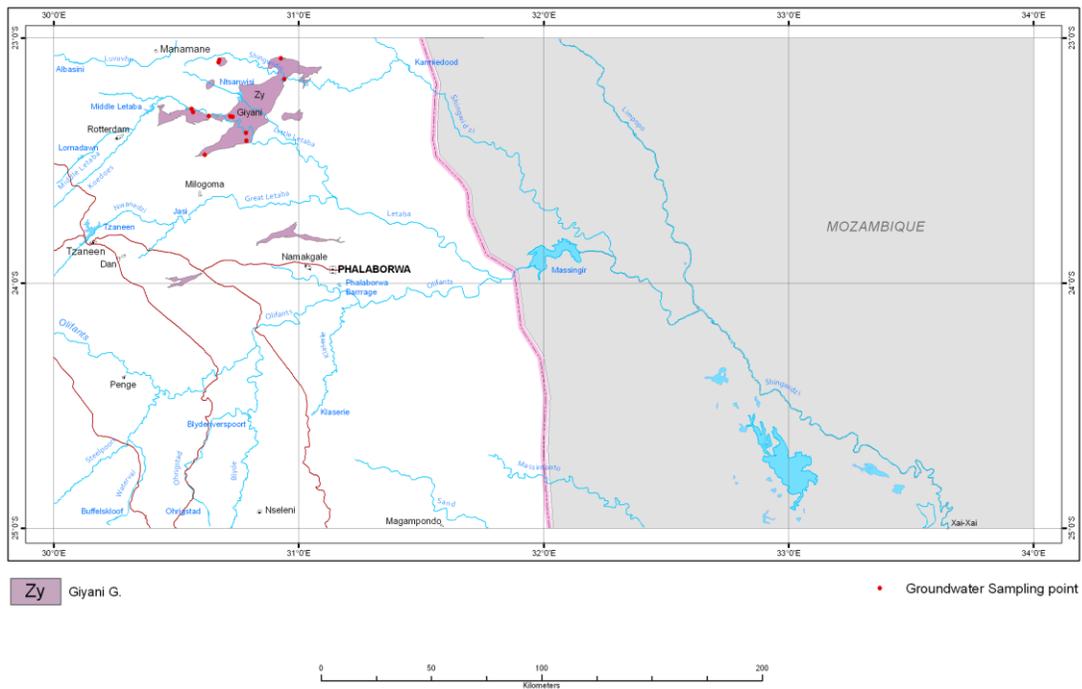


Figure 47: Distribution of the Giyani Group and associated groundwater sampling points.

In general the water encountered in this aquifer is acceptable for domestic use and display a magnesium–calcium–sodium–bicarbonate character (Figure 48).

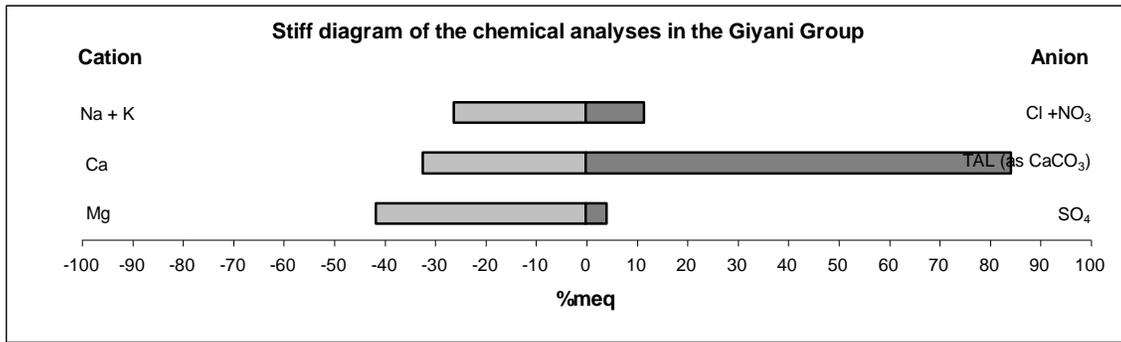


Figure 48: Stiff diagram of the chemical analyses (Giyani Group)

### 3.2.6.6 Unnamed Swazian Rocks

These Unnamed Swazian Rocks comprise mostly migmatite and fine grained grey to dark grey homogenous gneiss. It is cut by some fine to coarse grained pegmatite veins, which could be targeted for successful groundwater development. Statistics indicated that in about 79% of the cases water is intercepted within the first 40m. The Unnamed Swazian Rocks have shown strong similarities with the Makhutswi Gneiss in terms of the frequency of fracture zones occurring at depth. In total 251 borehole analyses were available for interpretation of which only 15 boreholes were dry (Figure 49). The highest yield frequency class (0.5 to 2.0 l/s) accounts for greater than 40% of the boreholes with the second highest yield frequency 0.1 to 0.5 l/s class 28%. The average yield for these rocks is 1.55 l/s with a median of 0.93 l/s. The highest yield encountered was 15.0 l/s.

Du Toit (1998) who assessed the occurrence of groundwater in the National Kruger Park has, however, found that yields of boreholes drilled in the Unnamed Swazian Rocks have shown a tendency to decline over time. It was concluded that the most probable cause was lack of recharge and subsequent continuous pumping from storage. The occurrence of groundwater in this geohydrological unit is in most cases associated with weathered and fractured basins and to a lesser extent with dyke intrusions.

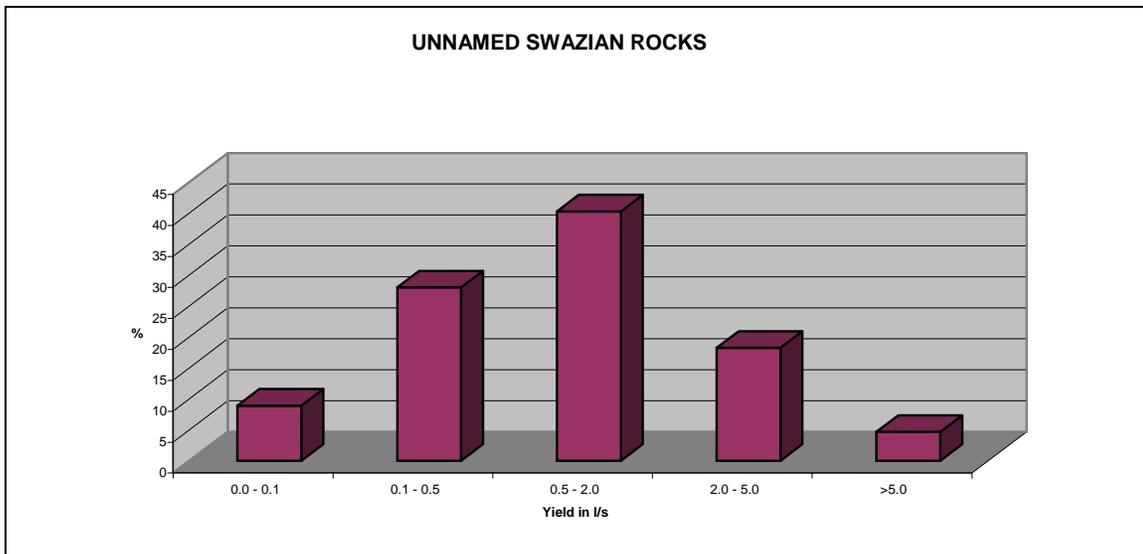


Figure 49: Yield frequency of boreholes in the Unnamed Swazian Rocks (251 boreholes analysed, 15 dry boreholes)

The 137 available chemical analyses (Figure 50) show that groundwater encountered in the Unnamed Swazian Rocks is of sodium–magnesium–bicarbonate–chloride character (Figure 51). The average sodium value encountered for this unit were above the recommended limit for domestic use (100 mg/ℓ) and gave rise to an elevated average EC value as well. Isolated values of nitrate, fluoride, magnesium, and chloride also occasionally exceed the recommended limit for domestic use but the average values are below these limits.

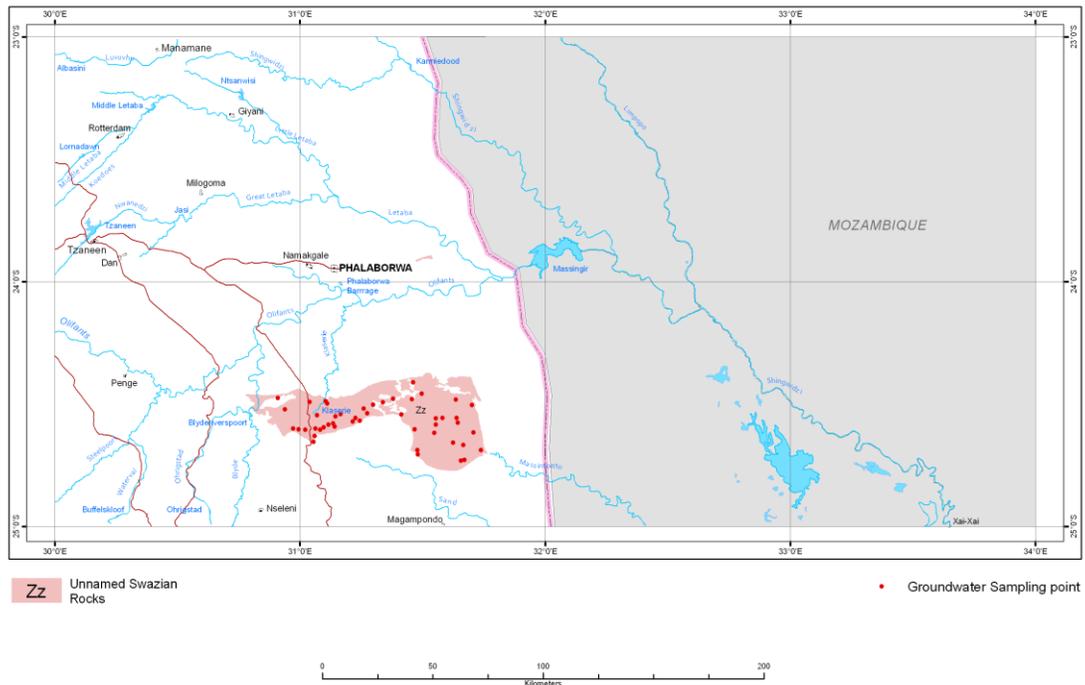


Figure 50: Distribution of the Unnamed Swazian Rocks and associated groundwater sampling points.

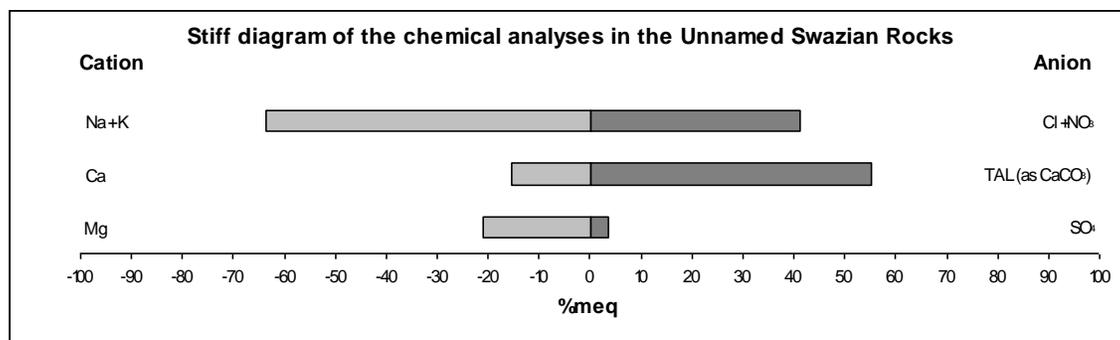


Figure 51: Stiff diagram of the chemical analyses (Unnamed Swazian Rocks)

### 3.2.6.7 Nelspruit Suite

It was found that in more than 80% of the cases water was intercepted within the first 30 m although fracture zones can generally be expected up to 80 m (Du Toit, 1998). The Nelspruit Suite has shown some similarities with the Goudplaats Gneiss and Unnamed Swazian Rocks. The groundwater development potential can generally be regarded as low to moderate. Water is mostly intercepted in weathered and fractured basins and, provided

the boreholes are correctly placed, dyke contacts are also good targets for groundwater development.

Of the 119 boreholes that were analysed, only 1 borehole was dry. The highest yield frequency class (0.5 to 2.0 l/s) accounts for more than 35% of the boreholes analysed (Figure 52). The highest borehole yield encountered was 12.2 l/s and the median yield was 1.0 l/s.

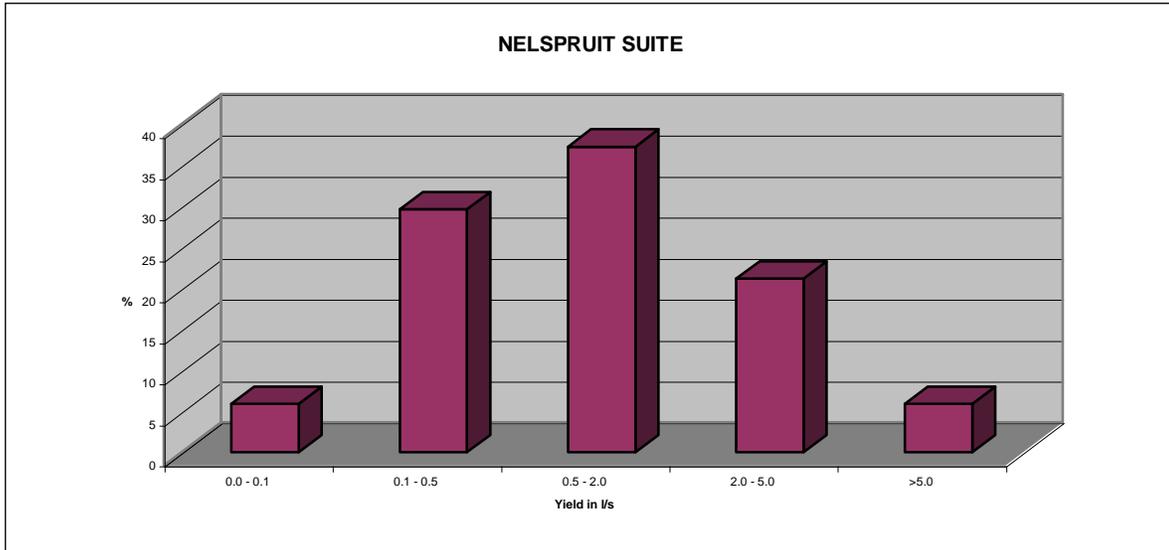


Figure 52: Yield frequency of boreholes in the Nelspruit Suite (119 boreholes analysed, 1 dry borehole)

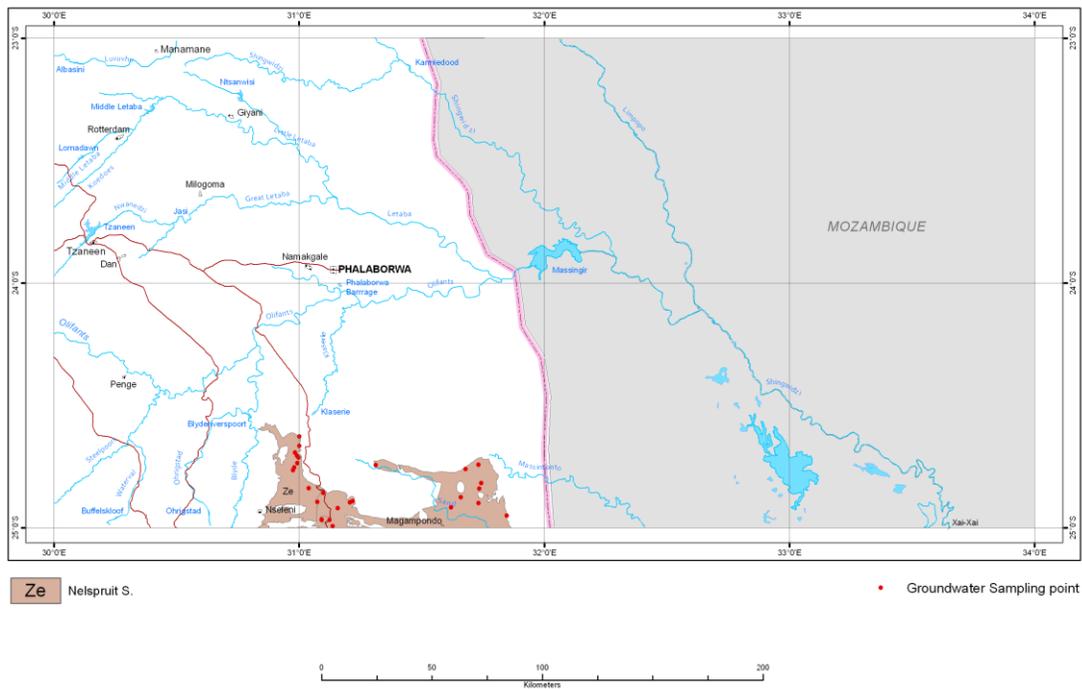


Figure 53: Distribution of the Nelspruit Suite and associated groundwater sampling points

101 Borehole analyses were made available for chemical interpretation (Figure 53). The averages of the variables analysed were all below the recommended levels for domestic use. Isolated high values (above maximum allowable limit for domestic use) of nitrate, fluoride, sodium, magnesium and chloride were encountered. The average EC value is 66.13 mS/m with less than 10% of the measurements above the recommended limit and only 3 points above the maximum allowable limit.

Groundwater encountered in the Nelspruit Suite display sodium–magnesium–bicarbonate-chloride character on the stiff diagram (Figure 54)

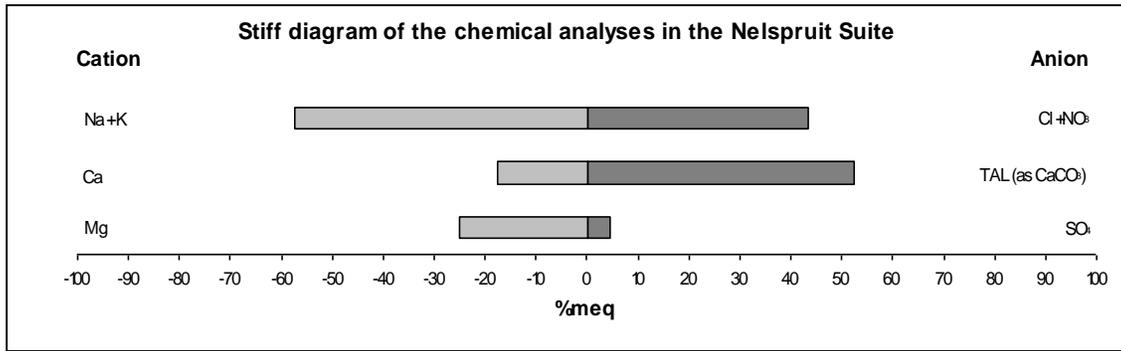


Figure 54: Stiff diagram of the chemical analyses (Nelspruit Suite)

### 3.2.6.8 Rooiwater Complex

A study done by Du Toit (1984) on the groundwater potential of the Rooiwater Complex indicated that groundwater is mainly intercepted in deep basins of weathering, the transitional zone between the weathered and fractured zone, and occasionally in fractures occurring in the more solid gabbros. Occasional high yielding boreholes are not uncommon in the Rooiwater Complex. Groundwater abstracted from the Rooiwater Complex is mostly used for irrigation, gardening and domestic purposes.

There were a total of 34 boreholes available for interpretation, seven of these boreholes were drilled dry and more than 70% encountered fall in the 0.5 to 2.0 l/s yield frequency class (Figure 55). The average yield is 1.8 l/s with a median of 1.51 l/s. The highest yield encountered was 26.0 l/s (Du Toit, 1984).

The 40 analyses available for interpretation indicate water quality to be acceptable for domestic use with only anomalies high values of nitrate and calcium. The average EC value is 48.90 mS/m and only two points were above 70 mS/m. The highest EC measurement encountered is 165.10 mS/m.

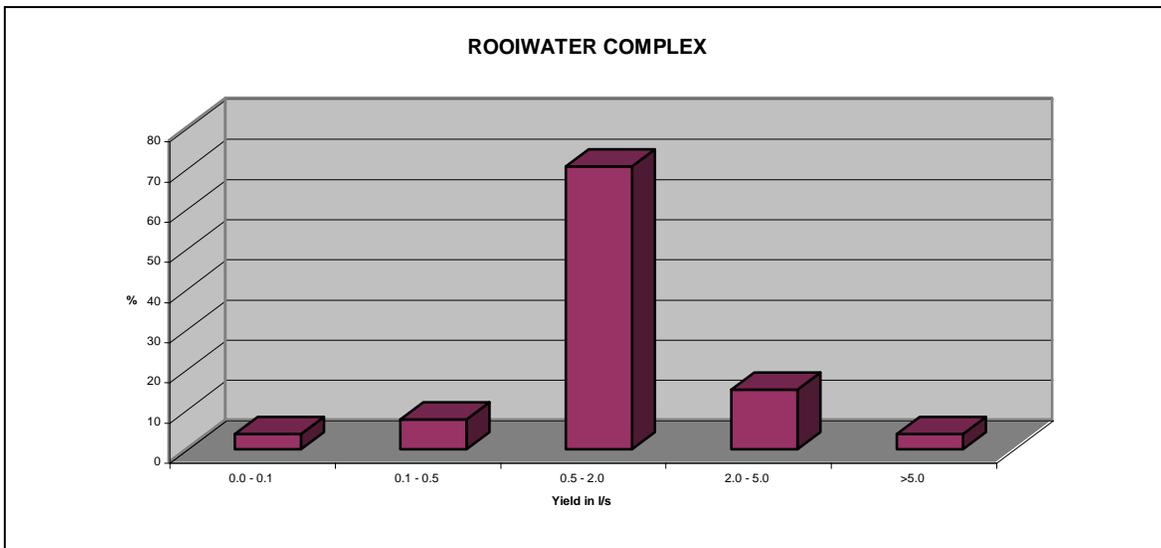


Figure 55: Yield frequency of boreholes in the Rooiwater Complex (34 boreholes analysed, 7 dry boreholes)

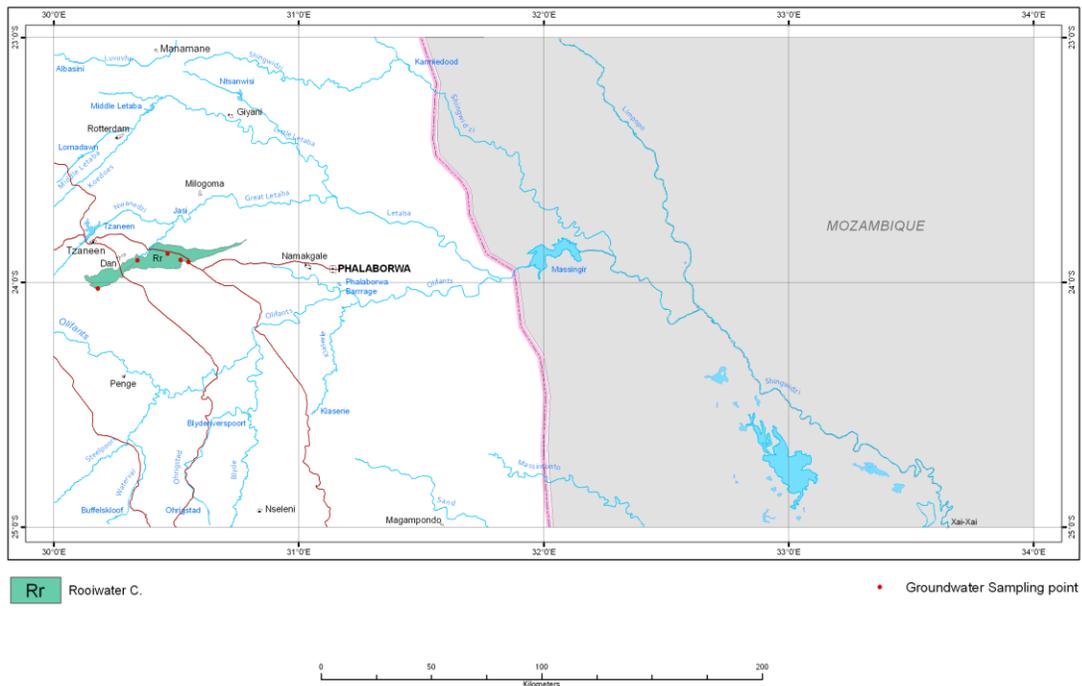


Figure 56: Distribution of the Rooiwater Complex and associated groundwater sampling points

In general the water encountered in this aquifer is acceptable for domestic use and display a calcium–magnesium–sodium-bicarbonate character (Figure 57).

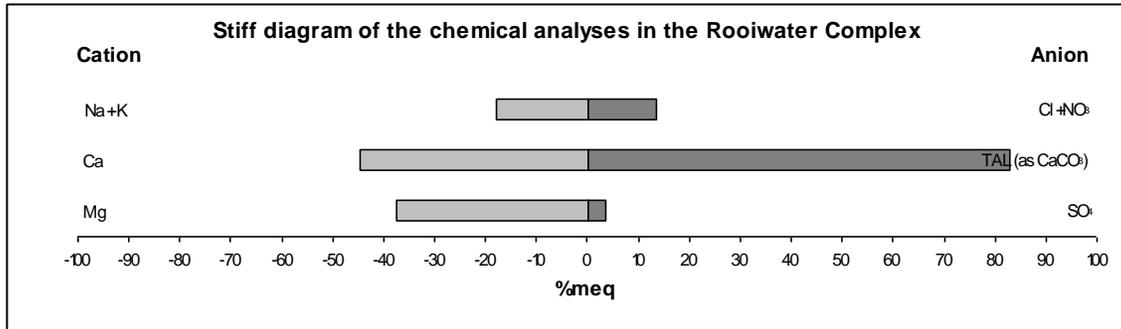


Figure 57: Stiff diagram of the chemical analyses (Rooiwater Complex)

### 3.2.6.9 Meriri Granite

Borehole data are available from only 3 boreholes and all these boreholes were dry. The groundwater potential of this Granite is generally low. Drilling results from many of these granite intrusions have shown that although they are weathered, groundwater is mostly found in fractures, quartz veins, pegmatites and contact zone with surrounding host rocks. Remnant roof-sections of the host rock close to the contact of these granite intrusions can also be successfully targeted for groundwater development. Water can also be found occasionally in minor fractures and fissures inflicted on surrounding rock by dyke intrusions.

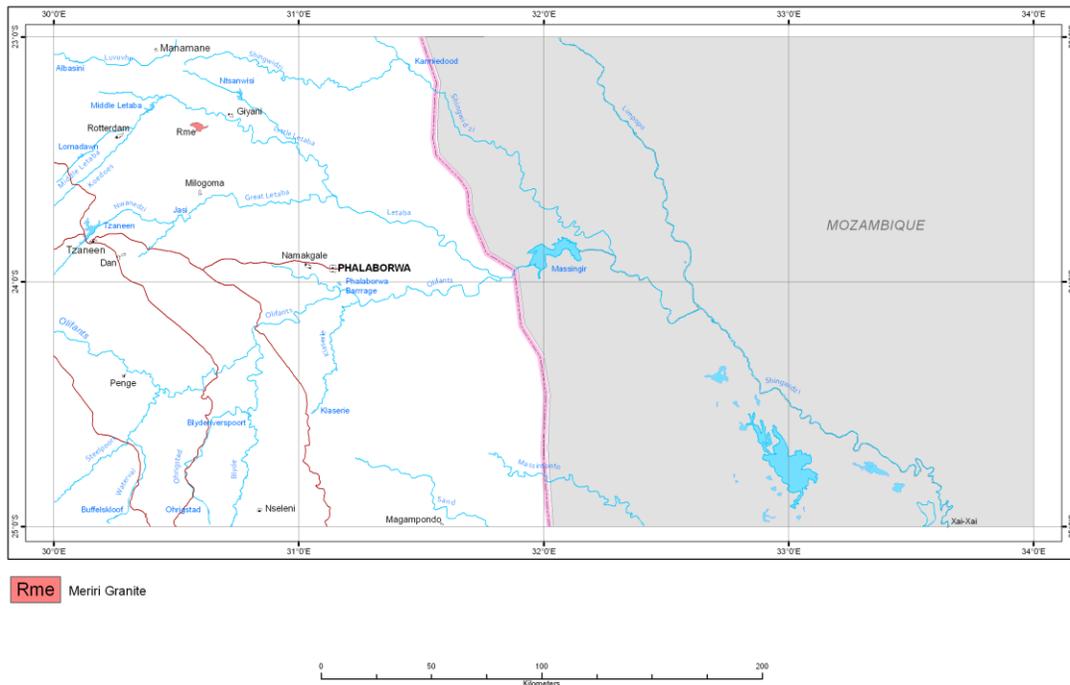


Figure 58: Distribution of the Meriri Granite and associated groundwater sampling points

Only two chemical analyses were found. It reveals sodium-magnesium-calcium-bicarbonate-chloride water. One nitrate value was above the maximum allowable limit for domestic use but could be an anomaly. Both the EC measurements were above the recommended limit for domestic use with an average of 180 mS/m. However, an extrapolation of this analyses result to the entire Meriri Granites should be avoided.

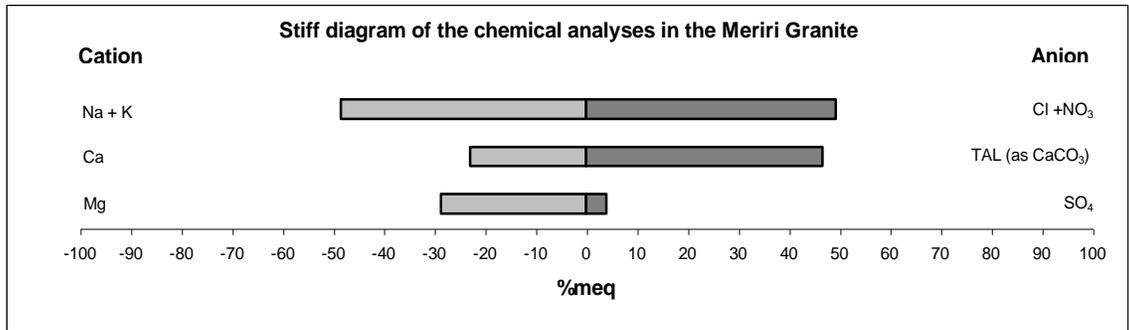


Figure 59: Stiff diagram of the chemical analyses (Meriri Granite)

### 3.2.6.10 Shamiriri Granite

No yield or chemistry data was available for the Shamiriri Granite. Similar to the Meriri Granite (chapter 3.2.6.9), the groundwater potential of the Shamiriri Granite is expected to be low. Drilling results from many of these granite intrusions have shown that although they are weathered, groundwater is mostly found in fractures, quartz veins, pegmatites and contact zone with surrounding host rocks. Remnant roof-sections of the host rock close to the contact of these granite intrusions can also be successfully targeted for groundwater development. Water can also be found occasionally in minor fractures and fissures inflicted on surrounding rock by dyke intrusions.

### 3.2.6.11 Shirindi Granite

No borehole data were available for the Shirindi Granites. The groundwater potential of the Shirindi Granite is expected to be low. As described above, the drilling results from many of these granite intrusions have shown that although they are weathered, groundwater is mostly found in fractures, quartz veins, pegmatites and contact zone with surrounding host rocks. Remnant roof-sections of the host rock close to the contact of these granite intrusions can also be successfully targeted for groundwater development. Water can also be found occasionally in minor fractures and fissures inflicted on surrounding rock by dyke intrusions.

All the chemical variables were below the recommended limit for domestic use except for the nitrate values. The water displays a magnesium-sodium-calcium-bicarbonate-chloride character. However, an extrapolation of this analyses result to the entire Shirindi Granites should be avoided due to the fact that only one borehole analysis was available. (Figure 60 and Table 4)



1.96 l/s with a median of 1.0 l/s. The highest yield is 8.0 l/s.

A total of 27 chemical analyses were available for interpretation (Figure 63). 63% of the EC values are below the recommended limit (70 mS/m) and the remainder below the maximum allowable limit (300 mS/m). The average EC measurement is 85.11 mS/m with the highest measurement encountered 189 mS/m. The water found in this aquifer is of slightly alkaline nature and displays a sodium-magnesium-calcium-bicarbonate-chloride character (Figure 64). Isolated high nitrate values were encountered.

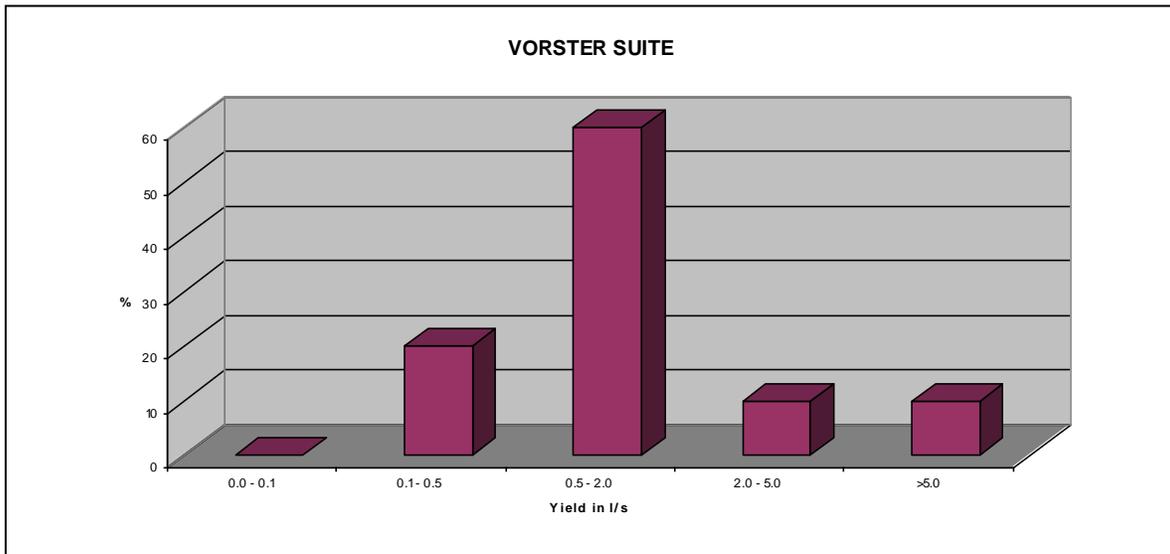


Figure 62: Yield frequency of boreholes in the Vorster Suite (17 boreholes analysed, 7 dry boreholes)

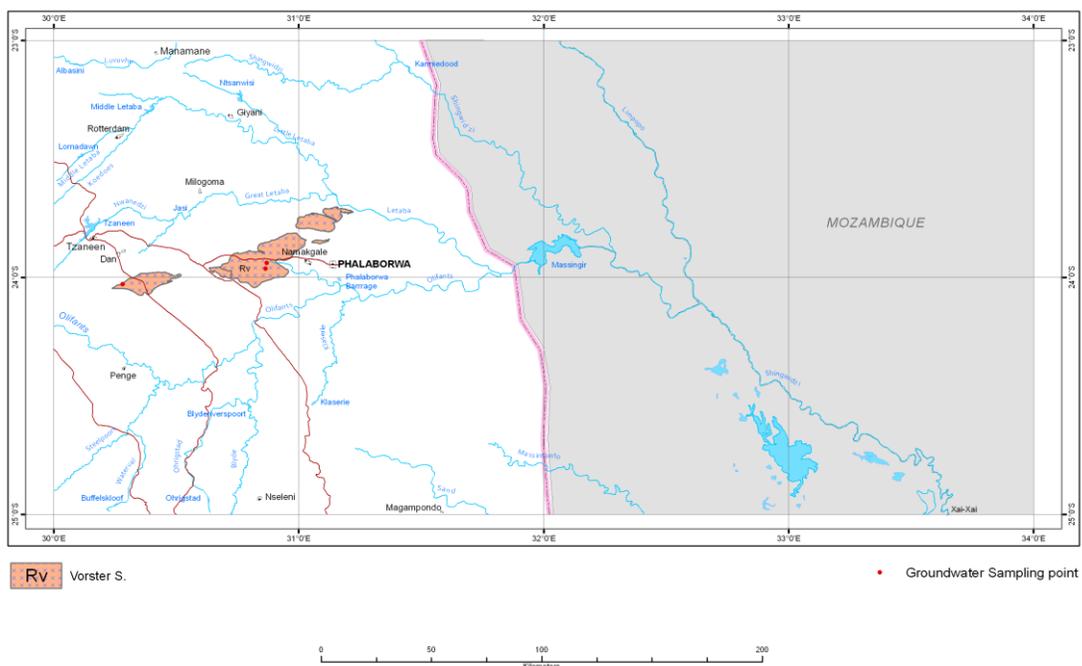


Figure 63: Distribution of the Vorster Suite and associated groundwater sampling points

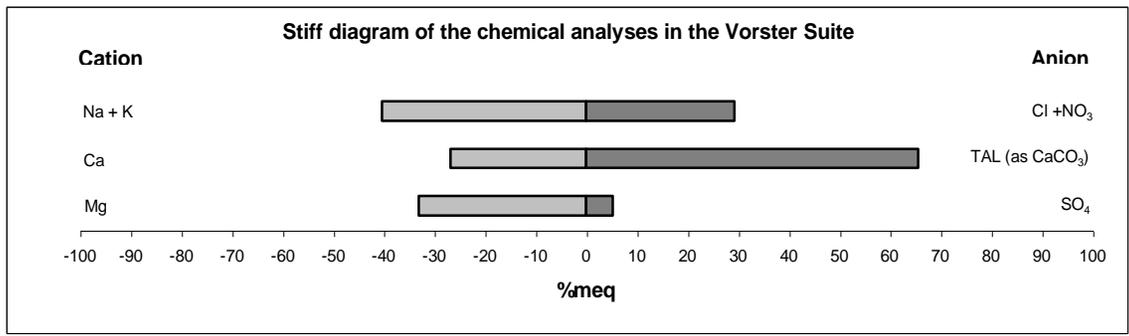


Figure 64: Stiff diagram of the chemical analyses (Vorster Suite)

### 3.2.6.13 Cuning Moor Tonalite

The Cuning Moore Tonalite comprises a light grey medium to coarse grained sphene bearing tonalite or diorite with a low to moderate groundwater development potential. Water can be found in the weathered zone, in the fractured transitional zone between the weathered and unweathered material, at contacts with dykes and sills, and in fractures related to tensional or compressional stresses and/or offloading.

In total 153 borehole records were available for interpretation of which only 9 boreholes were dry (Figure 65). More than 48% of the boreholes are between 0.1 to 0.5 l/s frequency and the 0.5 to 2.0 l/s yield frequency accounts for 33% of the boreholes. The median borehole yield is 0.4 l/s, while the highest yield encountered was 6.0 l/s.

The water quality evaluation based on 161 analyses (Figure 66) reveals a sodium-magnesium-calcium-bicarbonate-chloride character (Figure 67). EC values range from 8.5 mS/m to 346 mS/m with an average of 82.48 mS/m and indicate that fresher water is associated with the western and southern map areas. It appears that a positive correlation exists between the rainfall and the concentration of dissolved solids or its electrical conductivity. Total alkalinity, sodium and magnesium occasionally exceed maximum recommended limits, while fluoride and nitrate are the only anions to exceed maximum allowable limits in some instances.

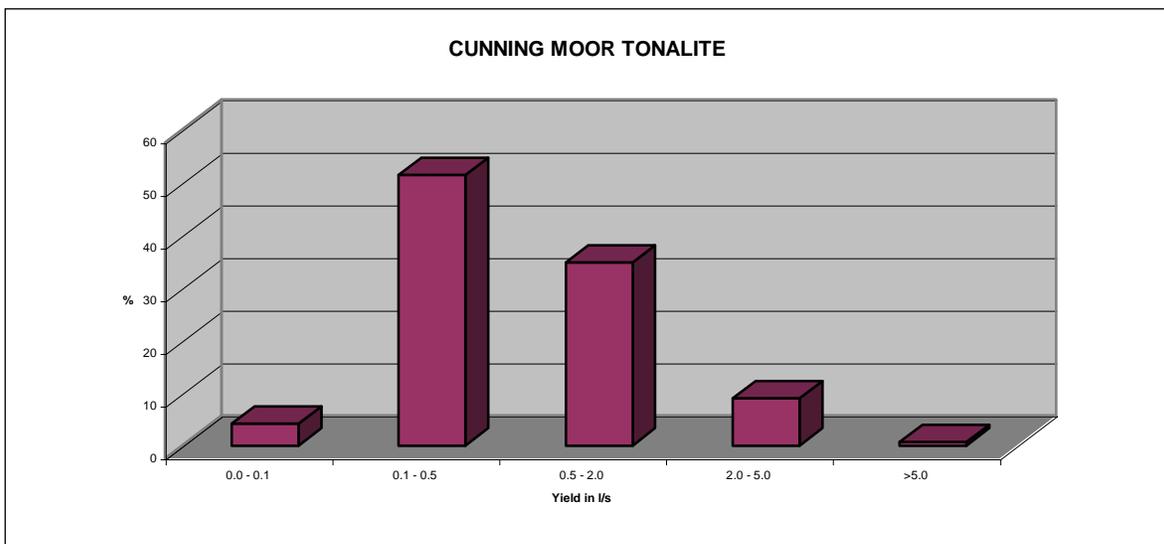


Figure 65: Yield frequency of boreholes in the Cuning Moore Tonalite (153 boreholes analysed, 9 dry boreholes)

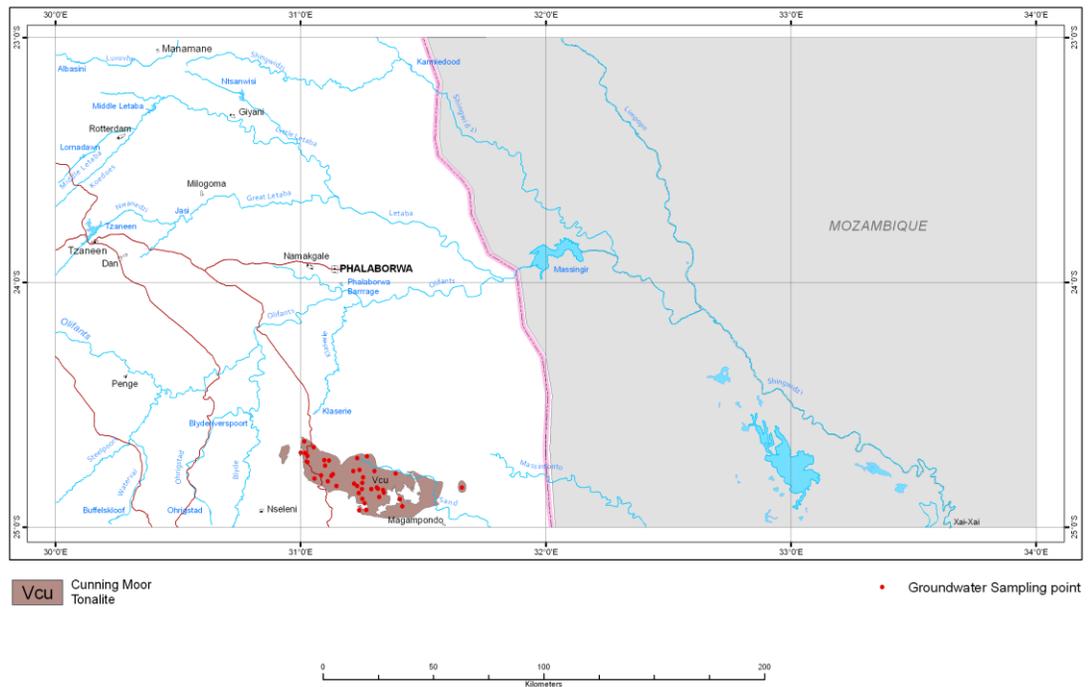


Figure 66: Distribution of the Cuning Moore Tonalite and associated groundwater sampling points

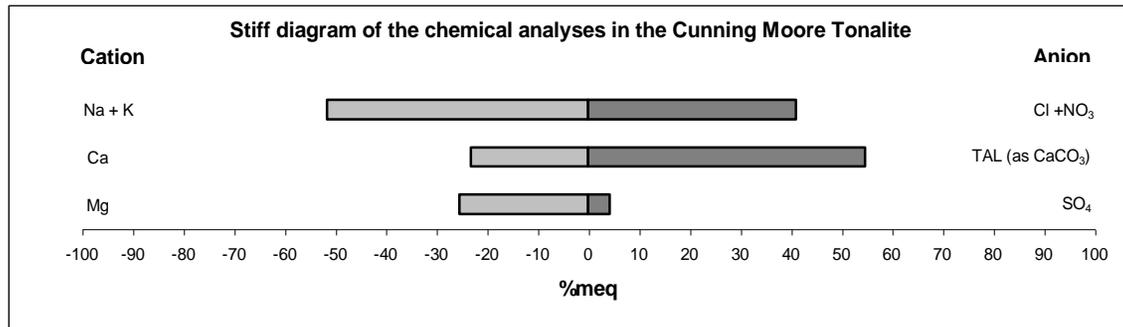


Figure 67: Stiff diagram of the chemical analyses (Cuning Moore Tonalite)

### 3.2.6.14 Harmony Granite

The groundwater potential of this Granite is generally moderate. Groundwater occurs mostly in fractures at the base of the weathered zone, quartz veins, pegmatites and contact zone with surrounding host rocks and occasionally in fractures at depth. Water can also be found occasionally in minor fractures and fissures inflicted on surrounding rock by dyke intrusions. Of the 103-borehole records available for interpretation, 24 were dry (Figure 68). The average yield of the boreholes analysed is 2.15 l/s and the median borehole yield is 1.1 l/s. The highest yield found is 10.0 l/s.

The water quality evaluation based on 78 analyses (Figure 69) reveals a large fluctuation in EC. Approximately 62% of boreholes have EC values above the recommended limit for drinking water (70 mS/m) but only 1 point has a value higher than 300 mS/m (The maximum allowable limit). The mean EC measurement is 101.67 mS/m with a median of

103.90 mS/m. Isolated high values of nitrate, fluoride, magnesium, sodium and chloride were encountered

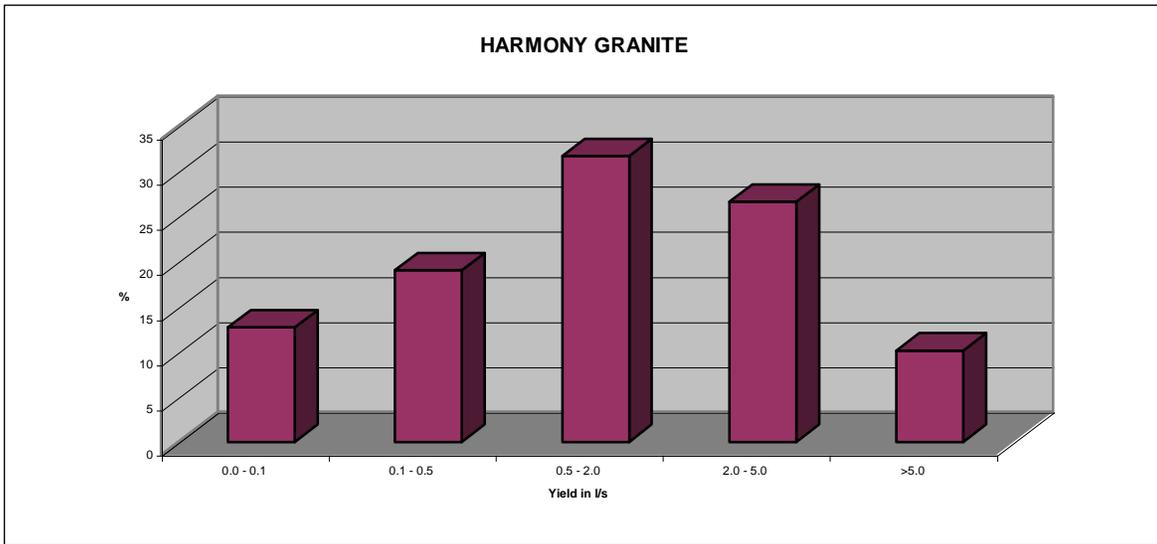


Figure 68: Yield frequency of boreholes in the Harmony Granite (103 boreholes analysed, 24 dry boreholes)

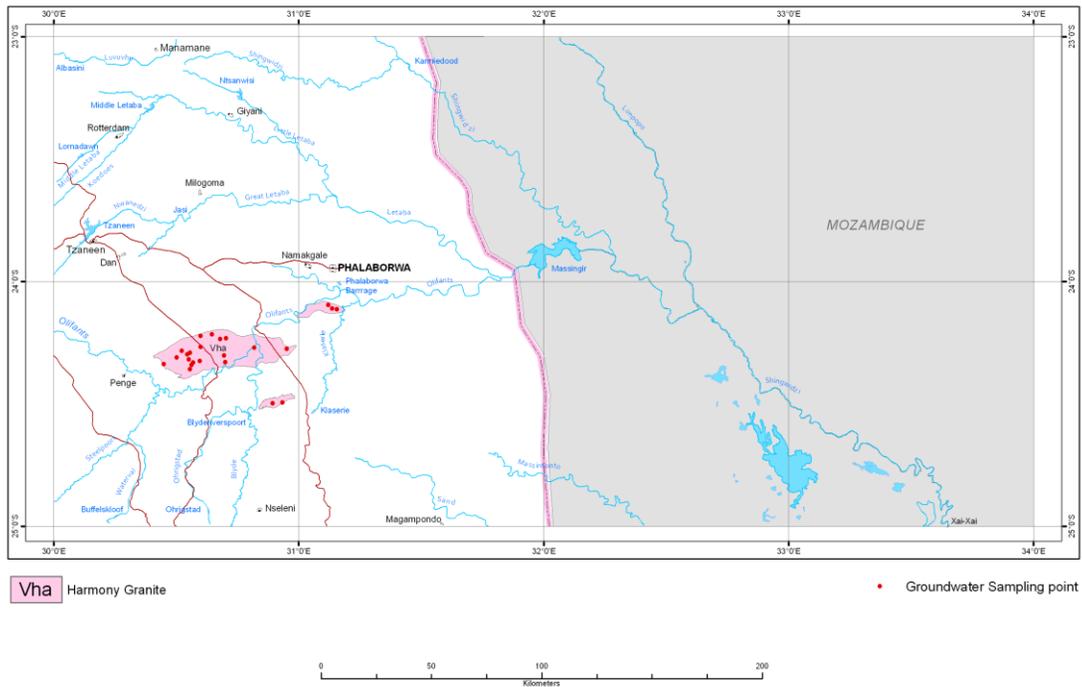


Figure 69: Distribution of the Harmony Granite and associated groundwater sampling points

The water found in this aquifer is of slightly alkaline nature and displays a sodium-magnesium-calcium-bicarbonate-chloride character (Figure 70).

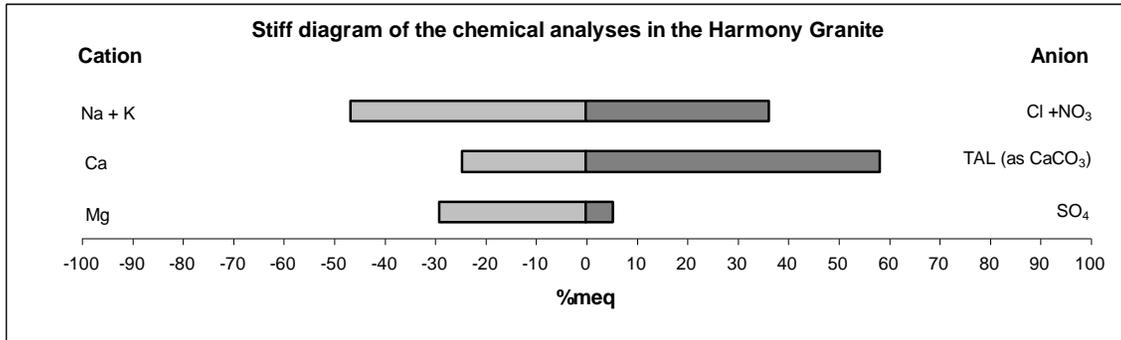


Figure 70: Stiff diagram of the chemical analyses (Harmony Granite)

### 3.2.6.15 Turfloop Granite

Borehole yield data was obtained from only one borehole. This borehole had a yield > 5 l/s. No borehole chemistry was available for interpretation. Based on the characteristics of the Turfloop Granite as described in the Polokwane Brochure, the depth of weathering is generally shallow with outcrops appearing as numerous scattered hills as seen between Polokwane and Tzaneen. The groundwater potential of this Granite is generally low. Water occurs mainly in fracture zones, quartz veins, pegmatites and contact zone with surrounding host rocks. Water also occurs occasionally in minor fractures and fissures inflicted on surrounding rock by dyke intrusions

### 3.2.6.16 Mashishimale Suite

The Mashishimale Suite comprising the Transport, Lillie and Hoed Granites has geohydrological characteristics similar to most of the other granite intrusions in the map area.

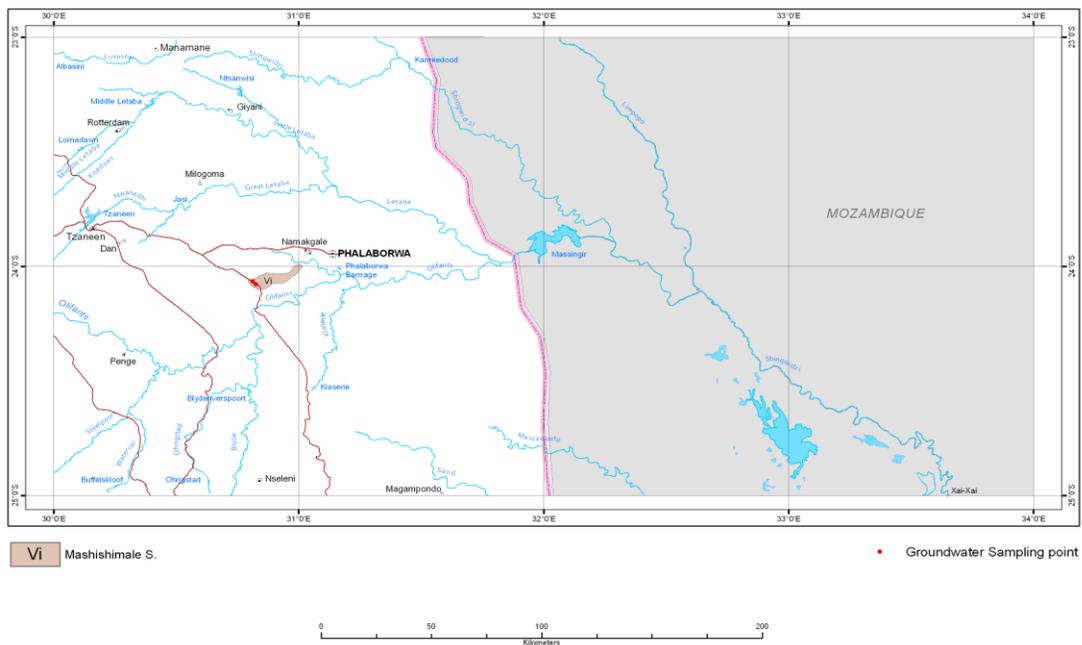


Figure 71: Distribution of the Mashishimale Suite and associated groundwater sampling points

The groundwater potential of this Suite is generally low with water occurring mainly in fracture zones, quartz veins, pegmatites and contact zone with surrounding host rocks. Water can also be intercepted in minor fractures and fissures inflicted on surrounding rock by dyke intrusions. Only two boreholes yield data were available for interpretation. The median borehole yield is 0.47 l/s and the highest 0.82 l/s.

The water was of alkaline nature and displays a sodium-magnesium-bicarbonate-chloride character (Figure 72). The average nitrate and fluoride values exceed the maximum allowable limit for domestic use and the average sodium, magnesium, and chloride values exceed the recommended limit for domestic use (Table 4). EC measurements range from 113 to 296 mS/m with an average of 214.22 mS/m, which is above the recommended limit for drinking purpose (70 mS/m). In total 10 chemical analyses were available.

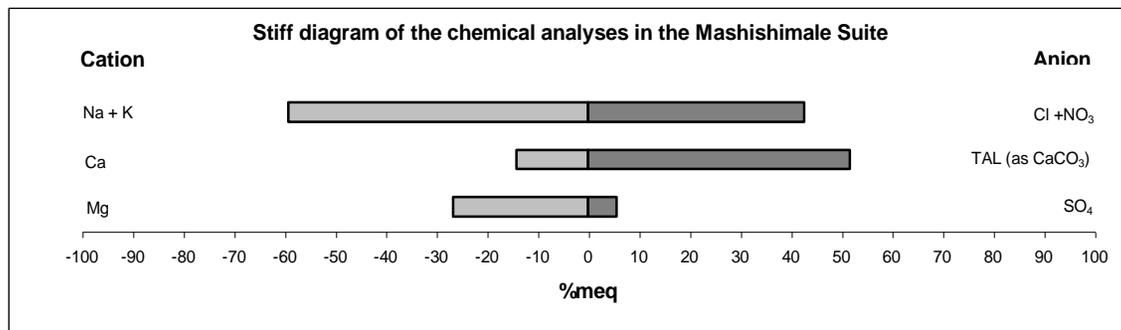


Figure 72: Stiff diagram of the chemical analyses (Mashishimale Suite)

### 3.2.6.17 Schiel Complex

The Schiel Complex is situated in the northwestern part of the map area and comprises mostly hornblende granite and syenite. Water is found in basins of weathering, the fracture zone between the weathered and solid rock, and also in occasional fractures occurring at depth. Water is sometimes intercepted in minor fractures and fissures inflicted on surrounding rock by dyke intrusions. The highest borehole yield intersected in these rocks was 8.0 l/s and the median yield was 1.21 l/s. The highest borehole yield frequency class is 2 to 5 l/s and accounts for more than 26% of the boreholes encountered in the Schiel Complex (Figure 73).

The 7 available chemical analyses show that groundwater encountered in the Schiel Complex is suitable for domestic use (Figure 74). The groundwater tends to be slightly alkaline with roughly equal proportions for sodium, calcium and magnesium. The water found in this aquifer displays a magnesium-sodium-calcium-bicarbonate character (Figure 75). One sample was encountered with a nitrate value (13.11 mg/l) above the maximum allowable limit (10 mg/l). EC values range from 32 to 102 mS/m with a mean of 58.16 mS/m.

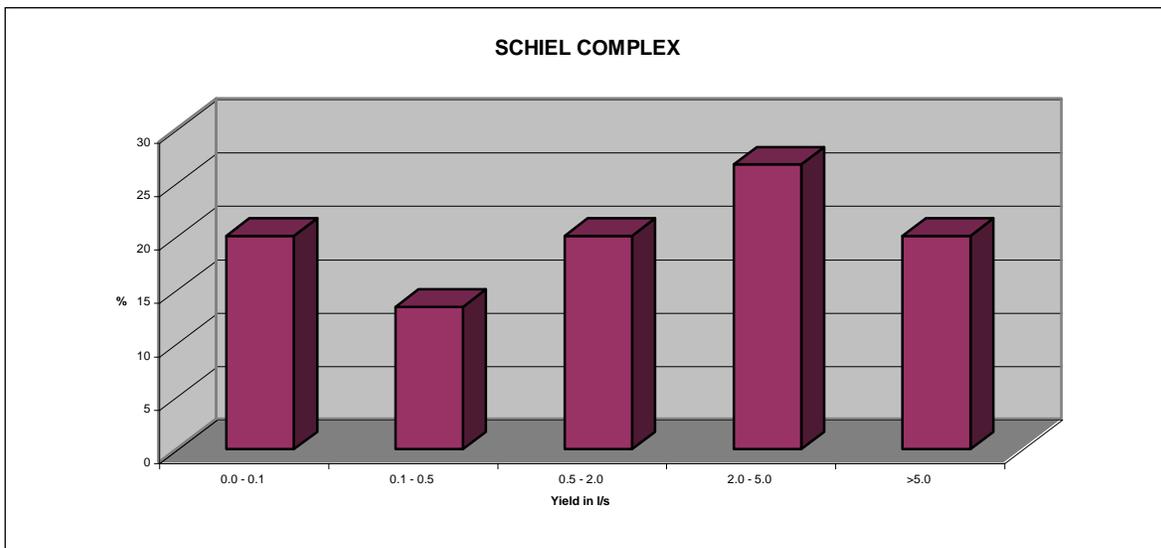


Figure 73: Yield frequency of boreholes in the Schiel Complex (21 boreholes analysed, 6 dry boreholes)

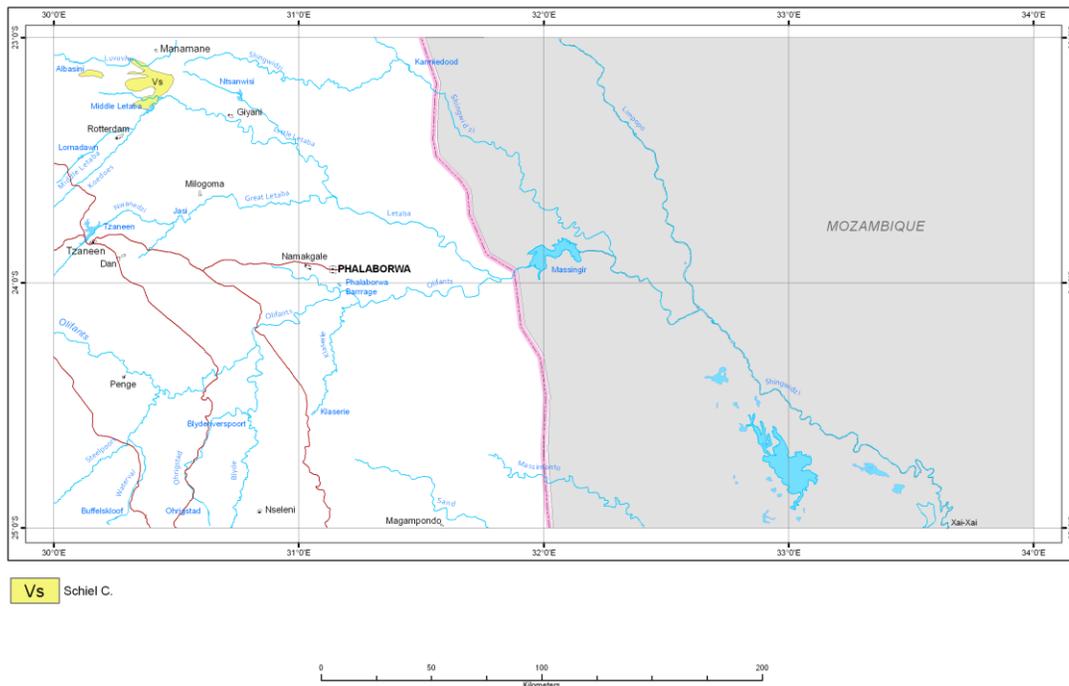


Figure 74: Distribution of the Schiel Complex and associated groundwater sampling points

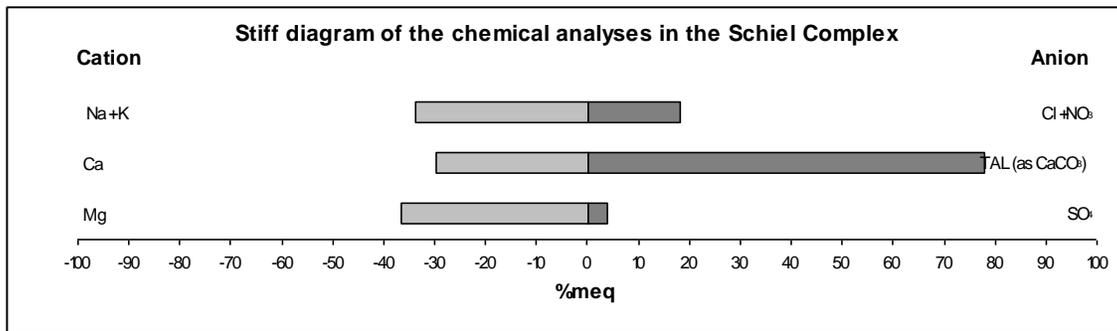


Figure 75: Stiff diagram of the chemical analyses (Schiel Complex)

### 3.2.6.18 Entabeni Granite

The Entabeni Granite has geohydrological characteristics similar to most of the other granite intrusions in the map area. The groundwater potential of this Granite is generally low with water occurring mainly in fracture zones, quartz veins, pegmatites and contact zone with surrounding host rocks. Water can also be intercepted in minor fractures and fissures inflicted on surrounding rock by dyke intrusions. The depth of weathering is generally shallow. Yield data are only available for one borehole with a value of 1.3 l/s. The lack of borehole data is probably due to the small areal extent of this geological unit. No borehole chemistry data was available for the Entabeni Granites.

### 3.2.6.19 Pretoria Group

Due to similar hydrogeological characteristics and also because of cartographic reasons, the different Formations of the Pretoria Group have been grouped together. It is mainly composed of shales and clastic rocks including quartzite, conglomerate and sandstone. The Pretoria Group in particular were intruded on a large scale by diabase in the form of sills and dykes especially the Silverton Formation, as a result of the Bushveld Igneous Complex. The diabase intrusions play a significant role in the occurrence of groundwater in the Pretoria Group. In general the shaly groups with the associated diabase tend to occupy the lower ground while the quartzites stand out as ridges. The water-bearing properties of the quartzite and shale are dependent on fracturing. The shale is in general far more favourable than the quartzites although the quartzites constitute good aquifers where fractured. Where the shales have been metamorphosed and converted to hornfels by the heat of the Bushveld Complex (contact metamorphism), its water bearing properties diminished. The hornfels usually are very hard rocks with few joints. Water also occurs in fault and associated shear zones, upper and lower contact zones between diabase and overlying and underlying shale and quartzite as well as dyke contacts. Water is also obtained in the diabase sills where these are weathered to below the groundwater level. Water may also be obtained in fractures caused by offloading and a variety of tectonic stresses. The median borehole yield in the Pretoria Group is 0.81 l/s and the maximum is 20.0 l/s.

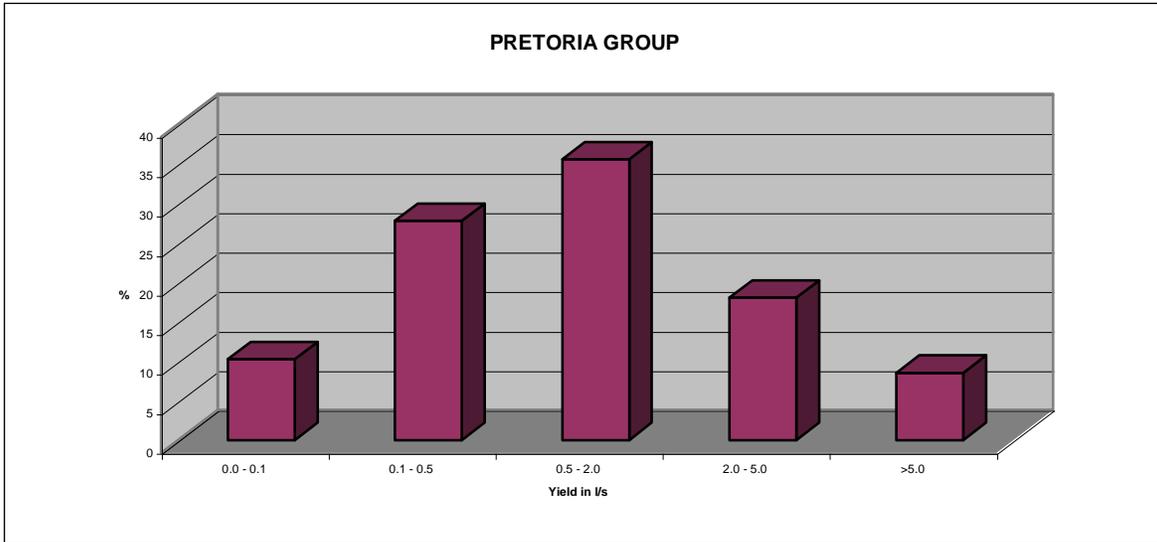


Figure 76: Yield frequency of boreholes in the Pretoria Group (424 boreholes analysed, 13 dry boreholes)

The water quality evaluation based on 56 analyses (Figure 77) reveals a mixture of water with 50% of the boreholes below 70 mS/m (recommended limit for drinking water) and 50% of the boreholes below 300 mS/m (the maximum allowable limit). The average EC value is 77.53 mS/m (Table 4) and the highest measurement encountered is 270 mS/m.

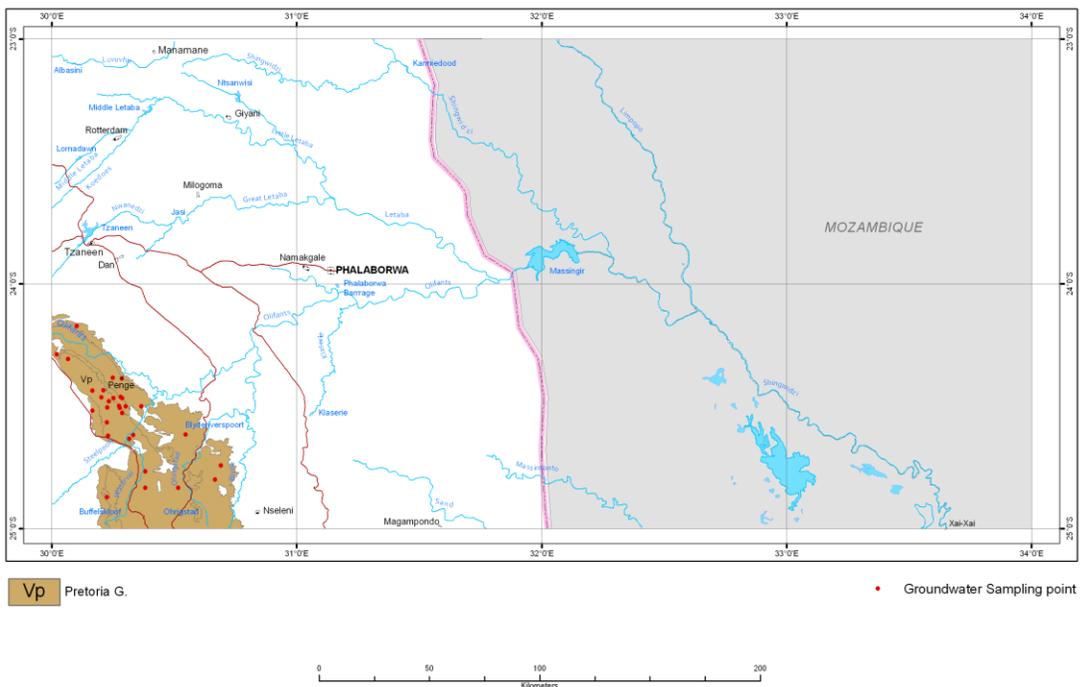


Figure 77: Distribution of the Pretoria Group and associated groundwater sampling points

The water type displayed by this aquifer is magnesium-sodium–calcium-bicarbonate–chloride (Figure 78). Total alkalinity and magnesium occasionally exceed maximum recommended limits, while fluoride and nitrate are the only anions to exceed maximum allowable limits in some instances.

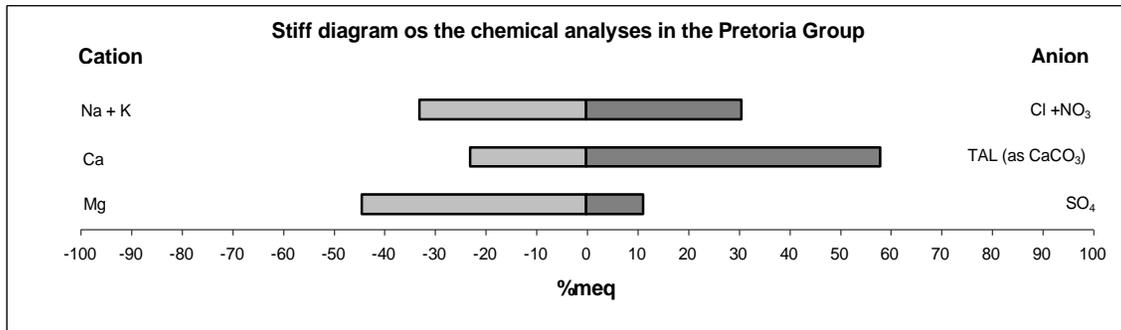


Figure 78: Stiff diagram of the chemical analyses (Pretoria Group)

### 3.2.6.20 Unnamed Vaalian Rocks

The Unnamed Vaalian Rocks (Vz) comprise granite, pyroxenite, granodiorite, and are found outcropping in a large area around Tzaneen. Water may be found in basins of weathering, at the fractured contact between zone between weathered and un-weathered rocks, at the contact zones of dykes, and in fractures related to tensional or compressional stresses and/or off-loading. The analysis of 139 borehole records (Figure 79) indicates that borehole yields can be classified as ‘moderately high’ as 38% of the yields are between 0.5 to 2.0 l/s. The highest borehole yield found is 75 l/s and the median yield is 1.0 l/s.

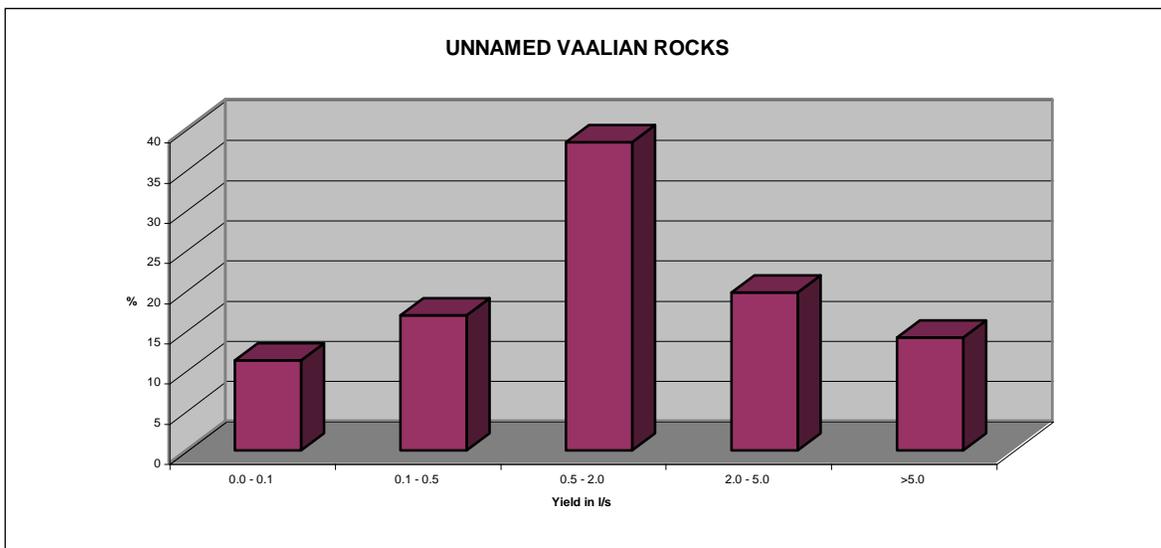


Figure 79: Yield frequency of boreholes in the Unnamed Vaalian Rocks (139 boreholes analysed, 32 dry boreholes)

The 188 analyses (Figure 81) indicated the water quality of the Unnamed Vaalian Rocks to be of potable quality but isolated high values of nitrate, fluoride, sodium, magnesium, chloride and calcium were encountered. The average EC measurement is 66.87 mS/m with only 2 chemical analyses above the maximum allowable limit for domestic use (300 mS/m).

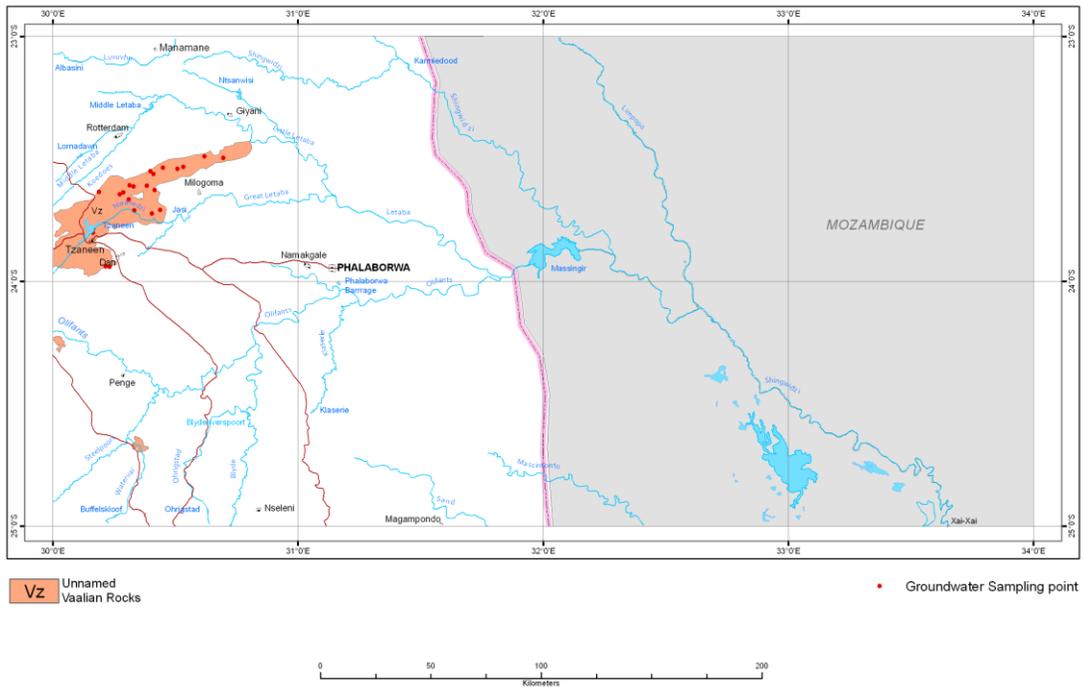


Figure 80: Distribution of the Unnamed Vaalian Rocks and associated groundwater sampling points

The Stiff Diagram (Figure 81) displays sodium-magnesium-calcium-bicarbonate-chloride water character.

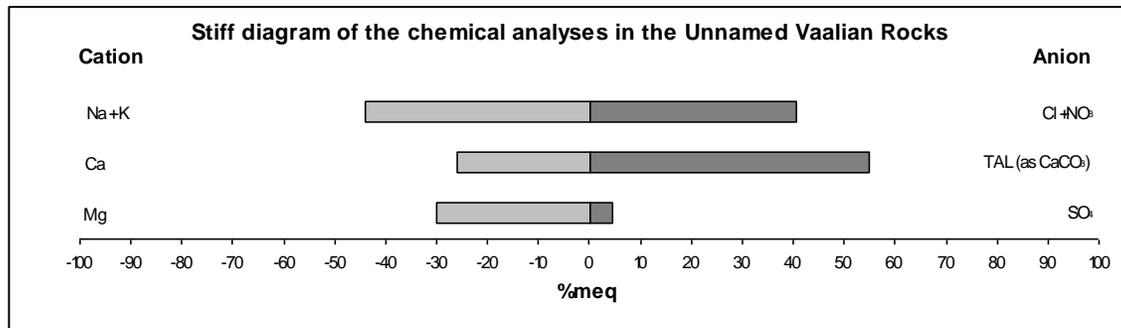


Figure 81: Stiff diagram of the chemical analyses (Unnamed Vaalian Rocks)

### 3.2.6.21 Rustenburg Suite

Rocks belonging to this Suite are characterised by a well-developed igneous layering and various rock units which form part of it, have a fairly uniform composition and may be traced over appreciable distances. The Suite consists mainly of mafic rocks including norite, gabbro, magnetite gabbro, anorthosite, pyroxenite and others. The groundwater potential is generally good with 42% (Figure 82) of the successful boreholes yielding >2 l/s. Water occurs mainly in deeply weathered and fractured mafic rocks. Due to the relative high permeability of the weathered and fractured rock, these basins can be extremely good aquifers. Problems have been experienced in some of the mines outside the map area where large volumes of water are intercepted in fractured anorthosite at

depths of 300m. Water is also obtained in fault and associated shear or fracture zones, contact zones and dyke contacts. The borehole yield analysis reveals that approximately 27% of 119 boreholes documented yield between 2 – 5 ℓ/s, 26% yield between 0.5 – 2 ℓ/s, 23% between 0.1 – 0.5 ℓ/s, and 15% are stronger than 5 ℓ/s (Figure 82). The median borehole yield is 1.0 ℓ/s and the maximum encountered was 25 ℓ/s.

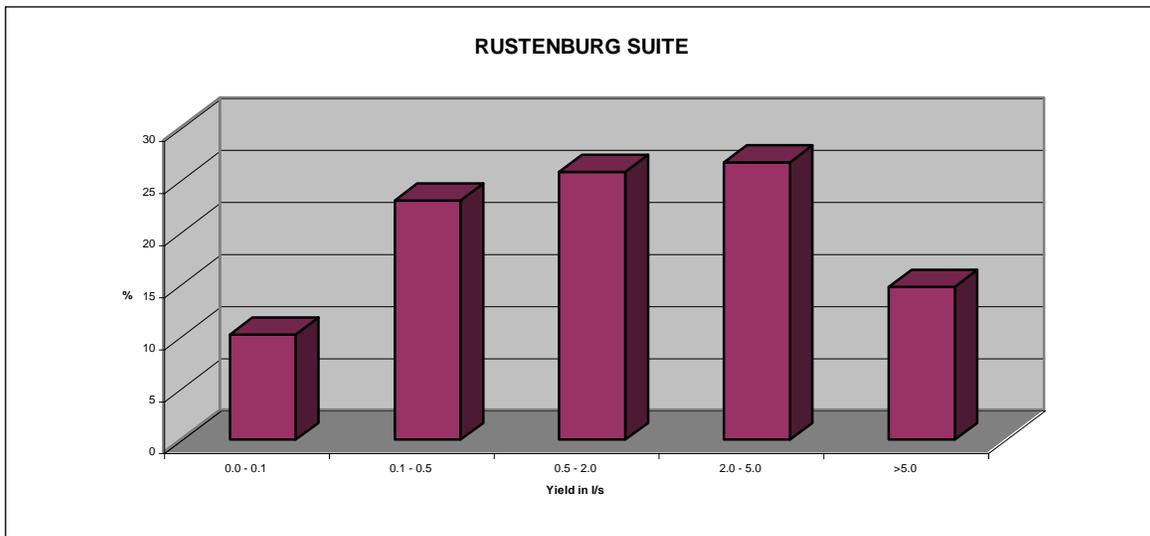


Figure 82: Yield frequency of boreholes in the Rustenburg Suite (119 boreholes analysed, 10 dry boreholes)

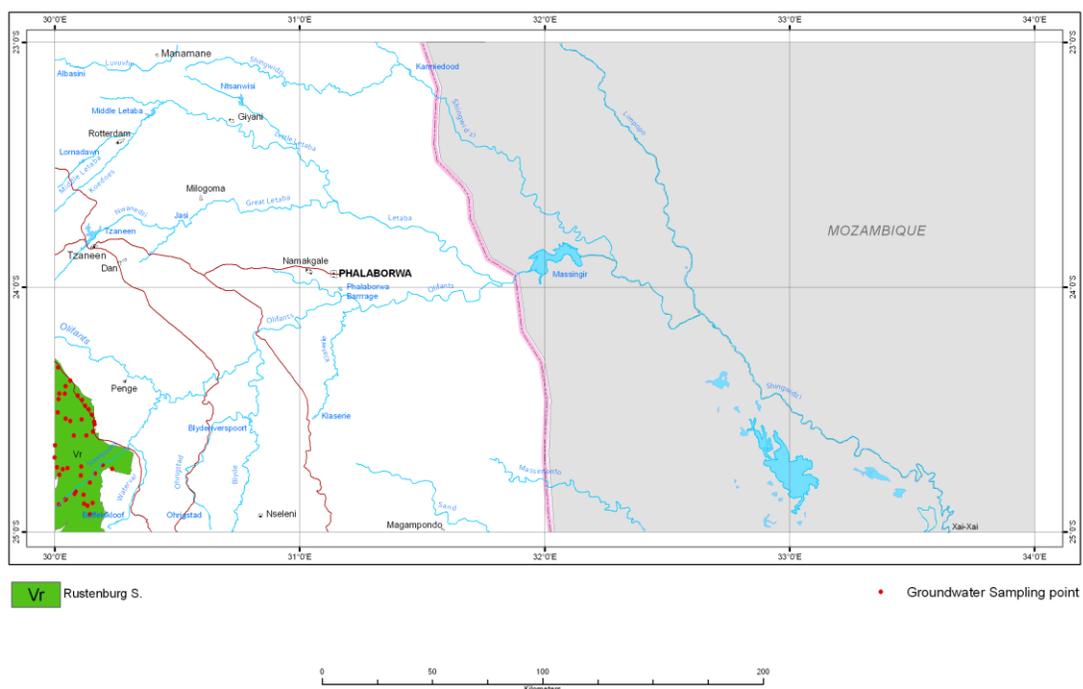


Figure 83: Distribution of the Rustenburg Suite and associated groundwater sampling points

The water within this unit is not suitable for domestic use due to the average nitrate level being above the maximum allowable limit for potable water (Table 4). One EC measurement was also above the maximum allowable limit with corresponding high chloride and magnesium values. This point is, however, an anomaly and may be due to local contamination. A total of 105 chemical analyses were available for interpretation (Figure 83). The water displays a magnesium-bicarbonate-chloride character (Figure 84) and appears to be slightly alkaline.

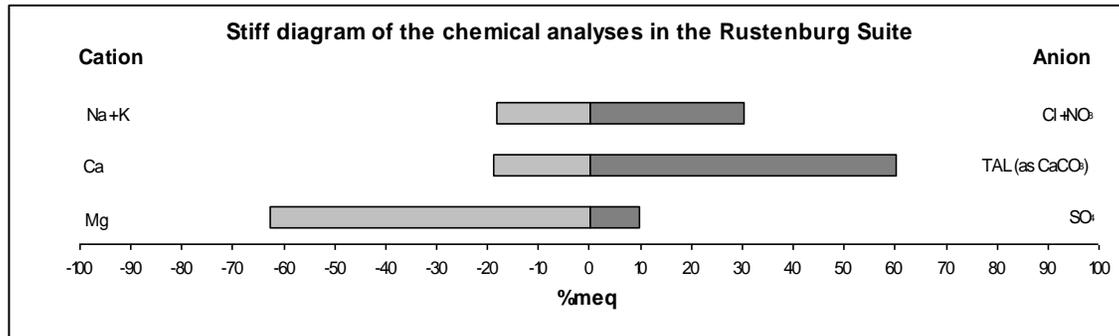


Figure 84: Stiff diagram of the chemical analyses (Rustenburg Suite)

### 3.2.6.22 Lebowa Suite

This Suite includes all the granite rocks of the Bushveld Complex. Several types of granite ranging from very coarse-grained to fine-grained may be distinguished but have not been separated on the map. No borehole yield or groundwater quality data are available for this unit. The lack of borehole data is probably because only two small areas are covered by this geohydrological unit. Based on information on the Lebowa Suite outside of the map area indications are that the groundwater potential of these granites is in general poor but the occasional good supply (>3 ℓ/s) does occur. Drought relief action (1992/93 and 1995) statistics indicated that only one out of every five boreholes drilled were successful. The storage capacity of the granites is very low. Water is obtained in faults, fracture zones and dyke contacts.

### 3.2.6.23 Phalaborwa Complex

These rocks, although extremely important for their mineral wealth, are insignificant as far as groundwater is concern. No borehole yield or groundwater quality data are available for the Phalaborwa Complex.

### 3.2.6.24 Sabiesand Granophyre

No information is available for borehole yields or groundwater quality for this geohydrological unit. However, it is expected that it will have the same characteristics as the Tshokwane Granophyre. Water is therefore generally expected to occur in either fractured granophyre or along dyke contacts. Drilling results indicated that fractured granophyre and fractures associated with dyke intrusions are equally important targets for successful groundwater development. The Sabiesand Granophyre is expected to have a moderate development potential.

### 3.2.6.25 Soutpansberg Group

Groundwater will tend to be channelled along lines of weakness and along interconnecting fissure systems. The occurrence of unconsolidated alluvium overlying

these rocks represents areas of shallow seated water supply. The data from 24 identified boreholes drilled into the Soutpansberg group indicated that 40% have a yield of between 2.0 to 5.0 l/s and the yield can be characterised as 'moderately high'. Boreholes yields from this group have a median of 2.5 l/s and a maximum of 8.75 l/s.

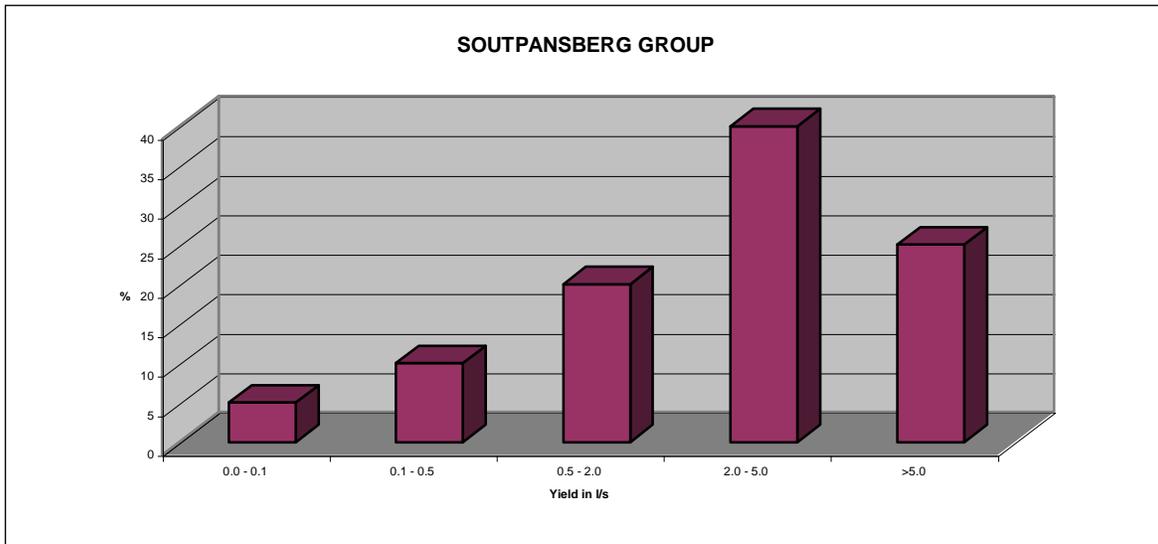


Figure 85: Yield frequency of boreholes in the Soutpansberg Group (24 boreholes analysed, 4 dry boreholes)

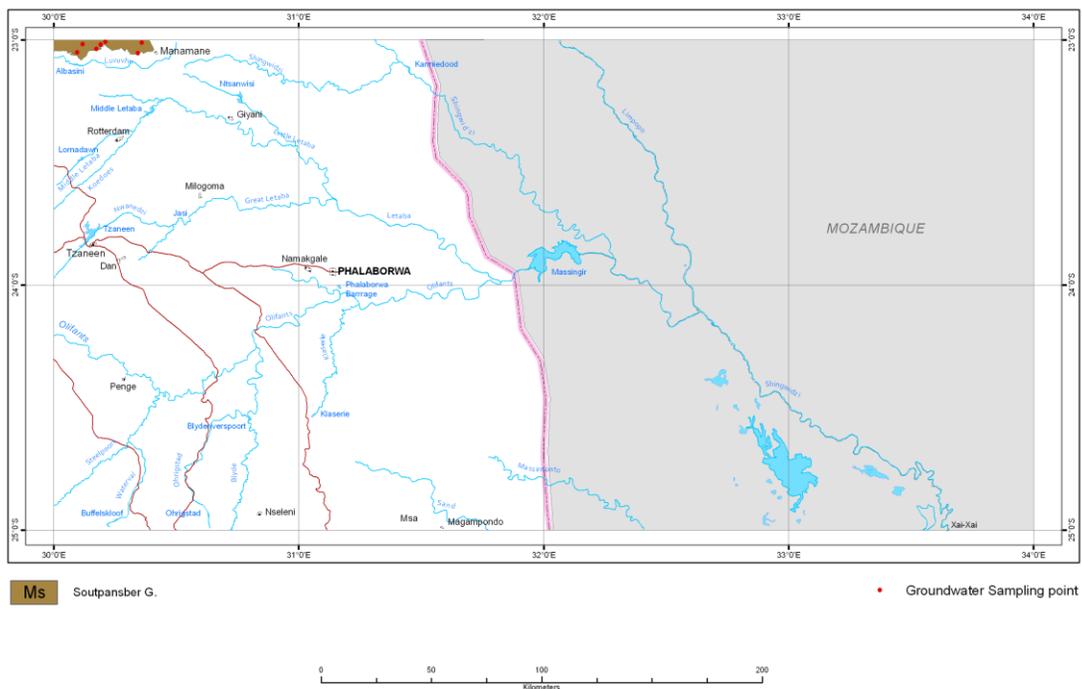


Figure 86: Distribution of the Soutpansberg Group and associated groundwater sampling points

Only 6 analyses were available for interpretation and reveal the water to be of potable quality (Figure 86). The water displays a magnesium-calcium-bicarbonate-sulphate character with an average EC measurement of only 11.32 mS/m. These conclusions might not be statistically valid because only 6 borehole water analyses were available.

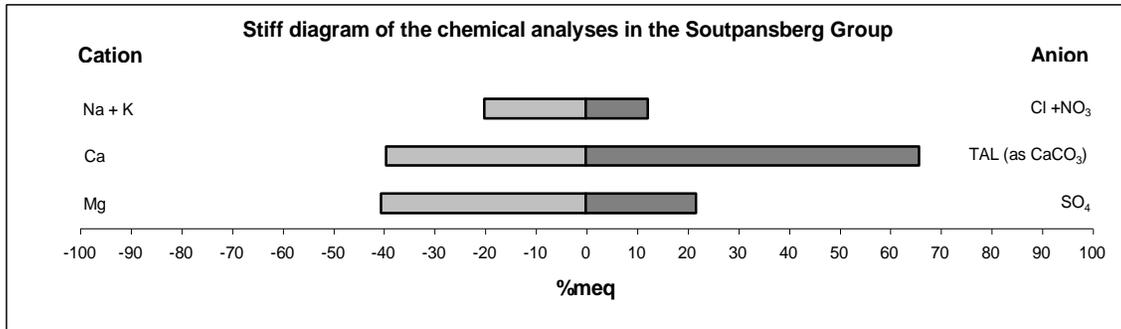


Figure 87: Stiff diagram of the chemical analyses (Soutpansberg Group)

### 3.2.6.26 Timbavati Gabbro

The Timbavati Gabbro is a mafic to ultramafic rock that intruded the older granites and gneisses of the Basement Complex. It outcrops as irregular sill-like bodies dipping between 20° and 30° to the east (Schutte, 1986 and Venter, 1990). In the Tshange and Phonda areas in the Kruger Park, the intrusion is characterized by a series of prominent hills. Further to the south they tend to weather more easier than the surrounding granitic rocks as only a few isolated hills such as Shilawuri, Shitlhave, and Skipberg appears (Venter, 1990). The median borehole yield for the gabbro is 0.5 l/s and the maximum yield 6.0 l/s (Figure 88). Water is in most cases found in weathered and fractured gabbro as well as in deeper-seated fracture zones. Water is also found at the contacts of these intrusions with the host rock. In 84% of the cases analysed most of the water was intercepted within the first 30m and in 16% of the cases between 30 and 60m. The Timbavati Gabbro can be regarded as having an average groundwater development potential.

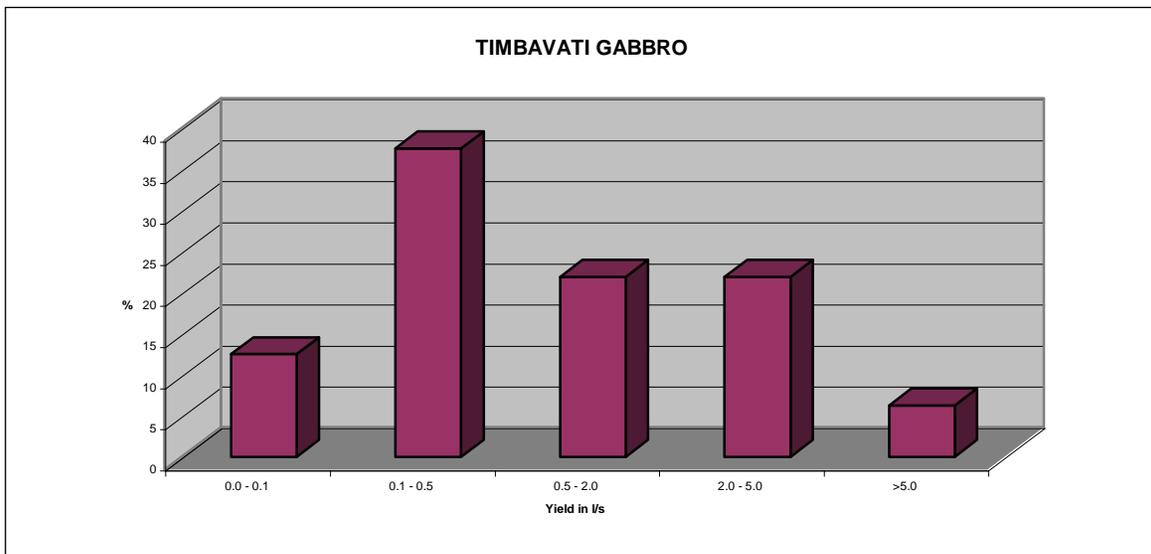


Figure 88: Yield frequency of boreholes in the Timbavati Gabbro (36 boreholes analysed, 4 dry boreholes)

The water quality evaluation based on 22 analyses (Figure 89) reveals that the water located within this unit is not suitable for drinking purposes. The average EC measurement is 131.43 mS/m and the water encountered is of a slightly alkaline to alkaline nature. Isolated nitrate, sodium, magnesium and chloride were encountered. The water displays a sodium-magnesium-bicarbonate-chloride character (Figure 89).

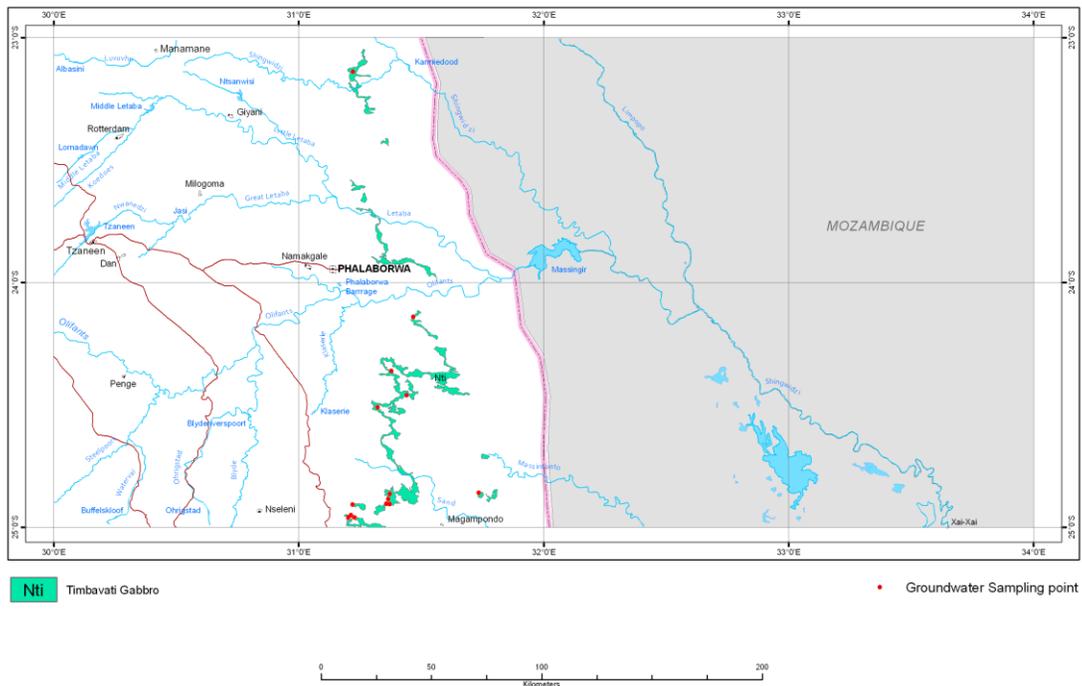


Figure 89: Distribution of the Timbavati Gabbro and associated groundwater sampling points

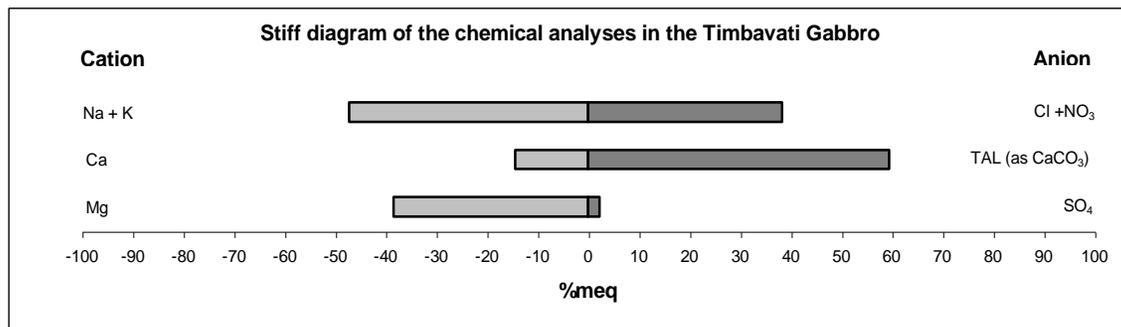


Figure 90: Stiff diagram of the chemical analyses (Timbavati Gabbro)

### 3.2.6.27 Diabase Intrusions

Diabase dykes occur throughout the map area. Boreholes drilled on contacts between diabase and the host rock has a median yield of 1.67 l/s and a highest yield of 7.65 l/s, based on data from 18 boreholes (Figure 91).

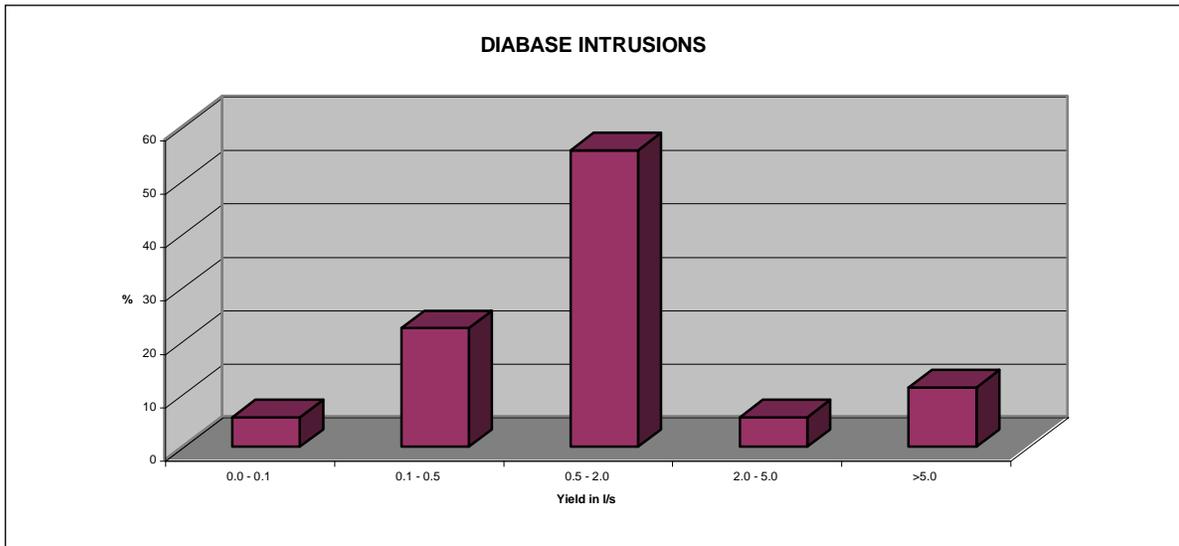


Figure 91: Yield frequency of boreholes in the Diabase Intrusions (18 boreholes analysed, no dry boreholes)

Although only 9 analyses (Figure 92) results were available for interpretation, it reveals water to be unsuitable for drinking purposes. Only 4 Nitrate values were below the maximum allowable limit for domestic use with an average value of 18.64 mg/l. The EC measurements, with an average of 107.74 mS/m, also display water to be unsuitable for human consumption. High values of fluoride were also encountered. The Stiff diagram below display water to be of magnesium-sodium-calcium-bicarbonate-chloride character (Figure 93).

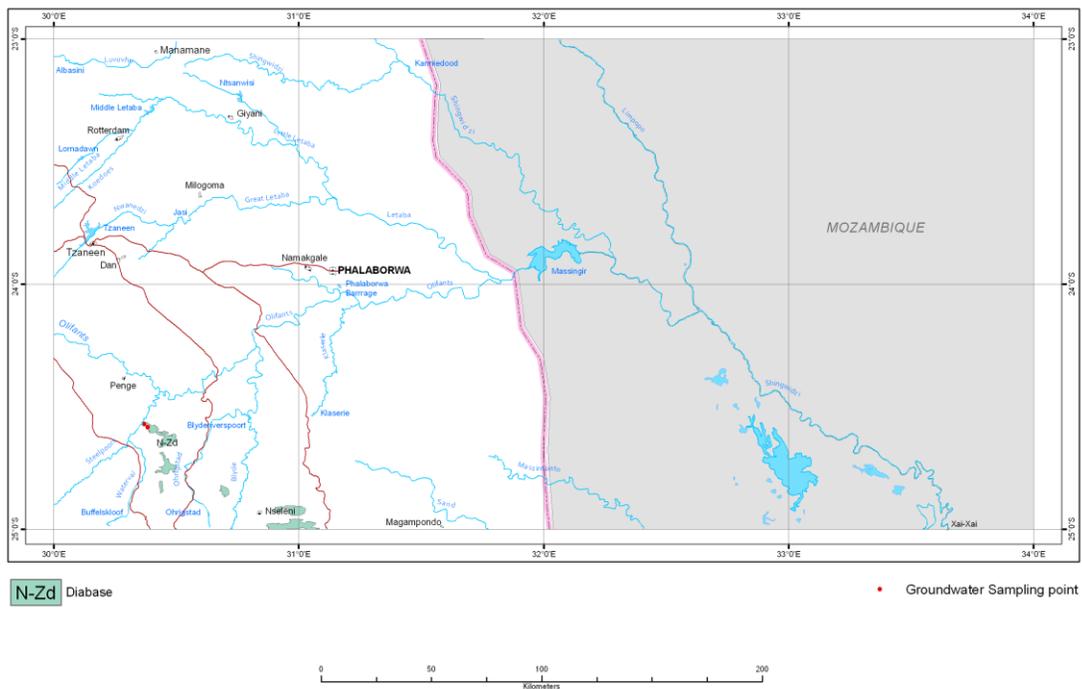


Figure 92: Distribution of the Diabase Intrusions and associated groundwater sampling points

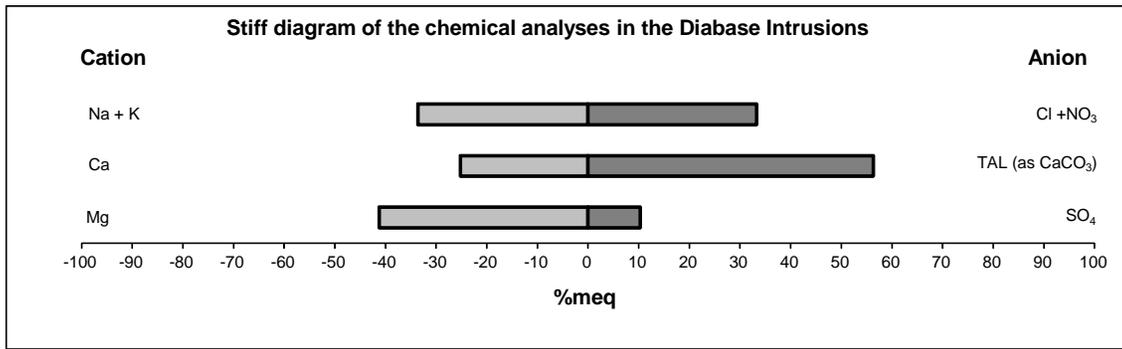


Figure 93: Stiff diagram of the chemical analyses (Diabase Intrusions)

### 3.2.6.28 Clarens Formation

According to Schutte (1986) the Clarens Formation can in the northern parts of the Kruger Park be sub-divided into two units namely the underlying Red Rocks Member and overlying Tshipise Member. The former comprises fine grained red and white-stained shaly sandstone representing sediments of fluvial origin deposited on alluvial plains during a period when the climate was progressively becoming dryer and dryer (Truswell, 1977 and Venter, 1990). The Tshipise Member comprises fine grained creamy coloured sandstone. It forms numerous low hills and prominent ridges characterized by caves and vertical rock-faces and mainly deposited in an Eolithic environment (Schutte, 1986 and Venter, 1990). The Clarence Formation had a median yield of 0.64 l/s and a maximum of 1.55 l/s. Almost 70% of the boreholes fall in the 0.5 to 2.0 l/s frequency class (Figure 94). These yields are based on data from 10 boreholes. Du Toit (1998) concluded that 67% of the boreholes intercepted water within the first 40m and that the Clarens Formation displayed a considerable residual primary water bearing character. This characteristic was also found in the Tshipise Sandstone south of Alldays in a recent study. Groundwater is generally obtained in fractured sandstone as well as on the contact with overlying basaltic rock and underlying sediments. Dolerite intrusions in the form of dykes and sills also created secondary fractures and joints at the contact with the host rock. Water also occurs in fault zones transecting through the sandstone. The residual primary porosity is expected to make a considerable contribution as well. The Clarens Formation can be regarded as having a moderate to high groundwater development potential. Figure 96 displays the distribution of the Clarens Formation.

Only one borehole was available for water quality interpretation and thus is not representative. Nevertheless, the water has a sodium-magnesium-bicarbonate-chloride character. The latter is more or less in agreement with the findings of Du Toit (1998) who further classified the water as fresh to moderately brackish based on electric conductivity measurements taken during his study.

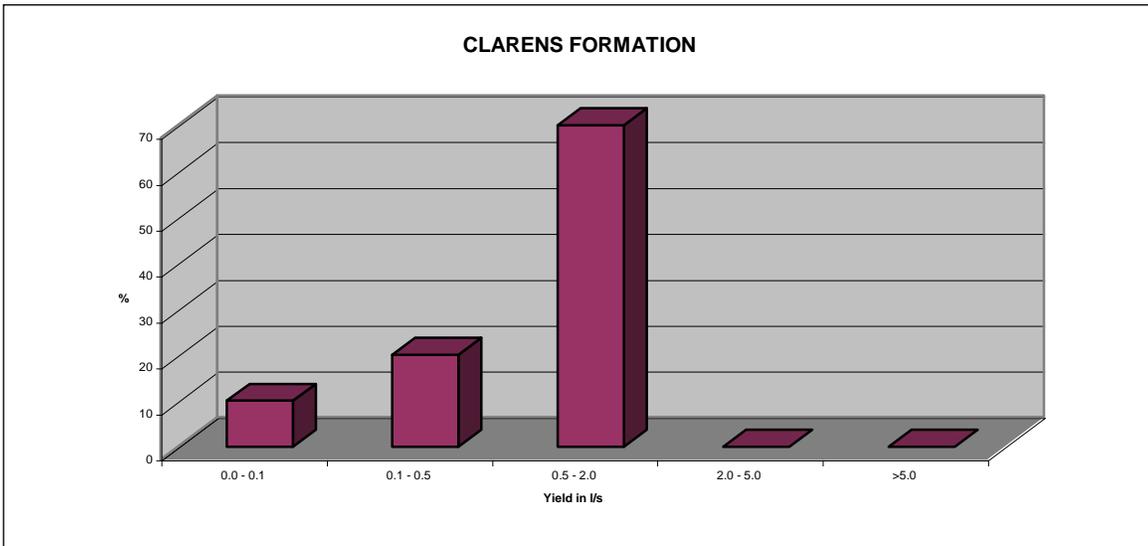


Figure 94: Yield frequency of boreholes in the Clarens Formation (10 boreholes analysed, no dry boreholes)

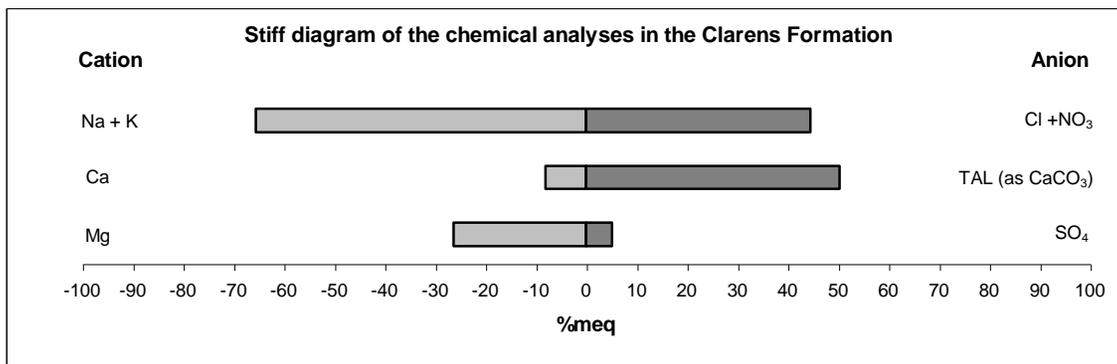


Figure 95: Stiff diagram of the chemical analyses (Clarens Formation)

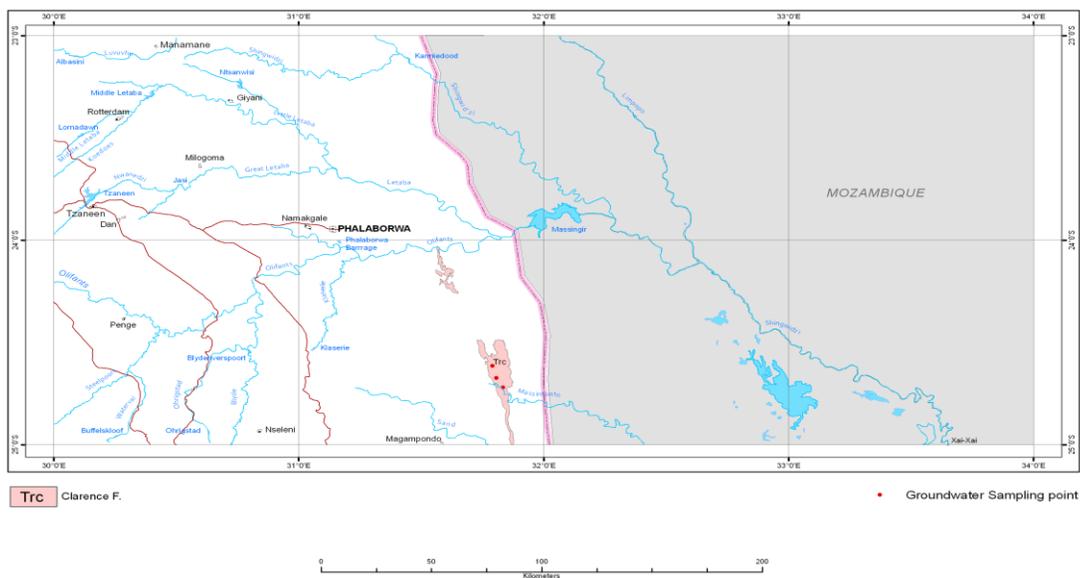


Figure 96: Distribution of the Clarens Formation and associated groundwater sampling points

### 3.2.6.29 Lebombo Group (Basalt)

The Lebombo Group (Basalt) comprises extrusive mafic volcanic rocks resting concordantly on the Clarens Formation. The basalt probably represents flood basalts which poured from fractures and cracks associated with the breakup of Gondwanaland (Schutte, 1986) ("Hot spots" theory). Outcrops are generally scarce and mostly covered by black turf. The Lebombo Group (Basalt) can be regarded as having a low to moderate groundwater development potential. Almost 50% of the water is found within the first 20m but water has on occasions been intercepted at 100m and deeper. Groundwater can be found in the fractured transitional zone between weathered and unweathered rock and fractured basalt at depth. To a lesser extent, water can also be found at the contact zone with underlying rocks or dykes and along faults. Although yields as high as 14.4 l/s are reported, the median yield is 1.1 l/s. More than 85% of the boreholes analysed falls in the 0.5 to 2.0 l/s frequency class (Figure 97). Only 8 boreholes were dry.

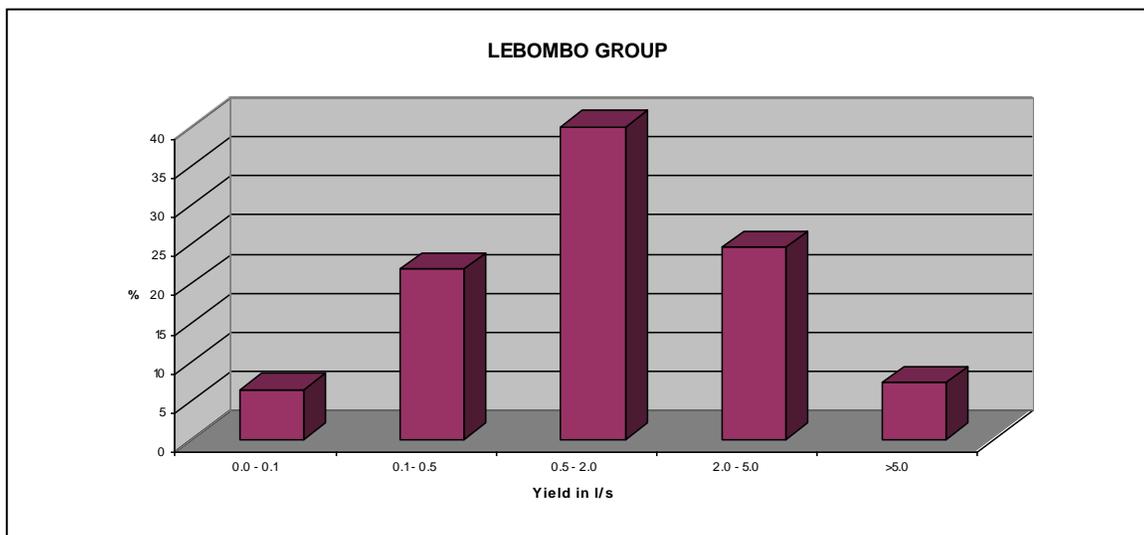


Figure 97: Yield frequency of boreholes in the Lebombo Group (Basalt) (229 boreholes analysed, 8 dry boreholes)

90 Borehole water analyses (Figure 98) indicate the water to be of alkaline nature with total alkalinity above the recommended limit. The Stiff diagram (Figure 99) below indicates water to be of sodium-magnesium-bicarbonate-chloride character. The average EC measurement was 177.39 mS/m (Table 4), the median 136.50 mS/m and the highest measurement encountered 1280 mS/m. Sodium, magnesium, calcium, fluoride and chloride occasionally exceed maximum recommended limits.

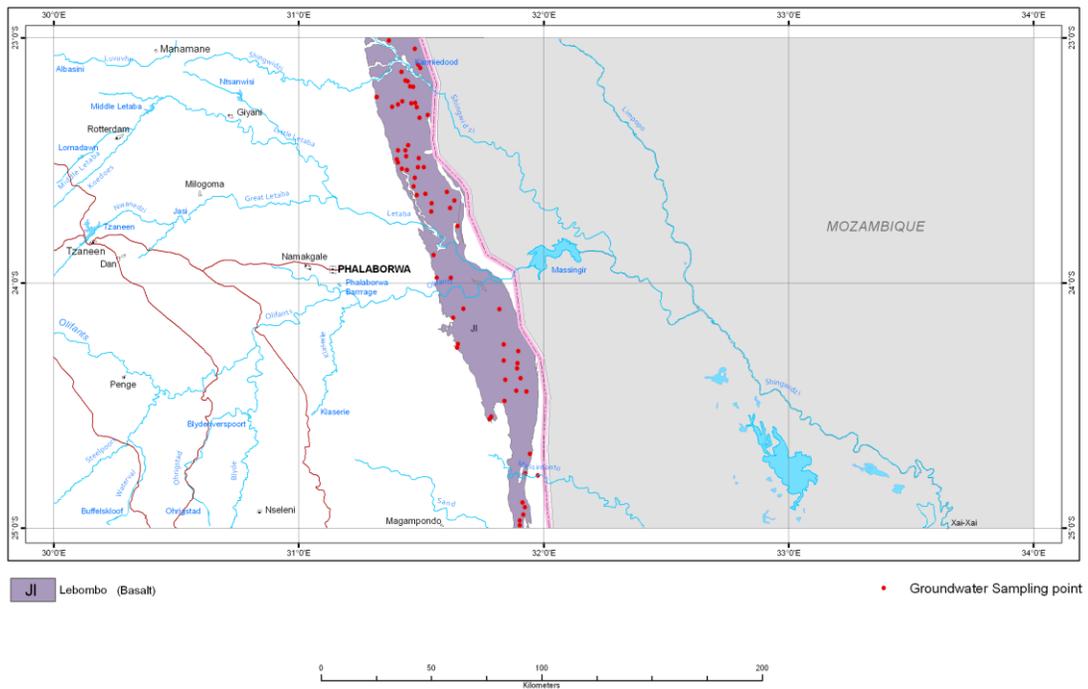


Figure 98: Distribution of the Lebombo Group (basalt) and associated groundwater sampling points.

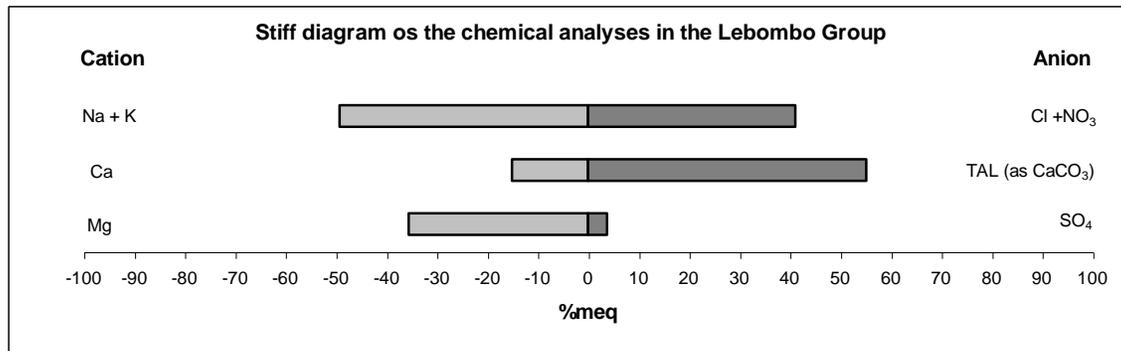


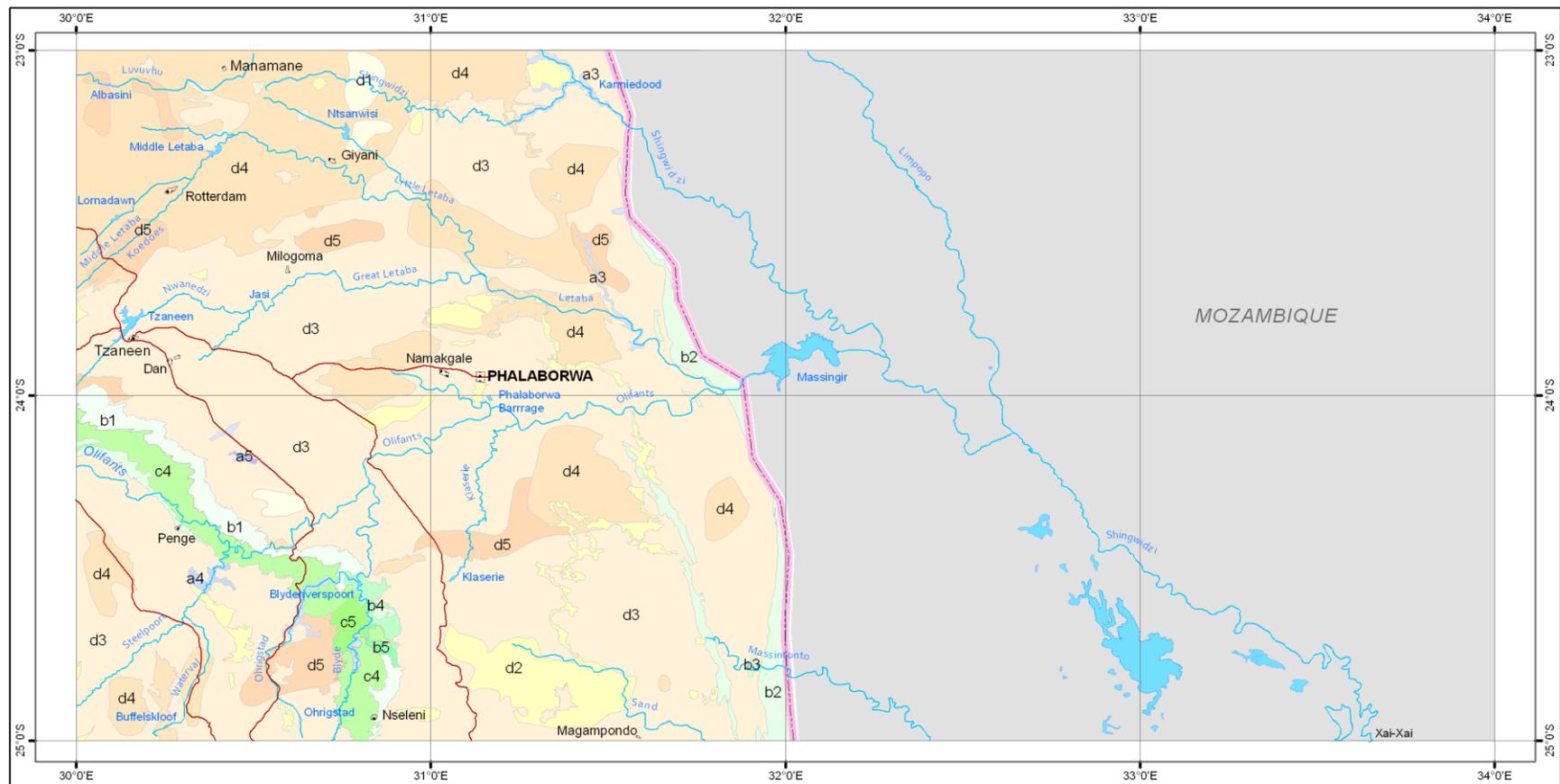
Figure 99: Stiff diagram of the chemical analyses (Lebombo Group) (basalt)

### 3.3 Borehole yield distribution

Figure 100 shows the median borehole yields. The most noticeable feature is the large area of high median yields (>2 and ≤ 5) in the northwest of the map area.

On a broad regional scale, the only feature that can be directly related to yields is the area of Chuniespoort Group rocks. Here high median yields of 2-5 l/s correlate with predominately dolomite and limestone rocks (karstification).

For the rest of the map area there appear to be no obvious one-to-one relationship between the yields and lithology, structural features, climate, or topography.



**Groundwater Occurrence**

**Intergranular**

- a3 Intergranular 0.5 - 2.0 l/s
- a4 Intergranular 2.0 - 5.0 l/s
- a5 Intergranular > 5.0 l/s

**Fractured**

- b1 Fractured 0.0 - 0.1 l/s
- b2 Fractured 0.1 - 0.5 l/s
- b3 Fractured 0.5 - 2.0 l/s
- b4 Fractured 2.0 - 5.0 l/s
- b5 Fractured > 5.0 l/s

**Karst**

- c4 Karst 2.0 - 5.0 l/s
- c5 Karst > 5.0 l/s

**Intergranular and Fractured**

- d1 Intergranular and Fractured 0.0 - 0.1 l/s
- d2 Intergranular and Fractured 0.1 - 0.5 l/s
- d3 Intergranular and Fractured 0.5 - 2.0 l/s
- d4 Intergranular and Fractured 2.0 - 5.0 l/s
- d5 Intergranular and Fractured > 5.0 l/s

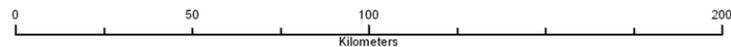


Figure 100: Median borehole yield across the map area

### 3.4 Springs

The main springs and thermal springs are shown in Figure 101.

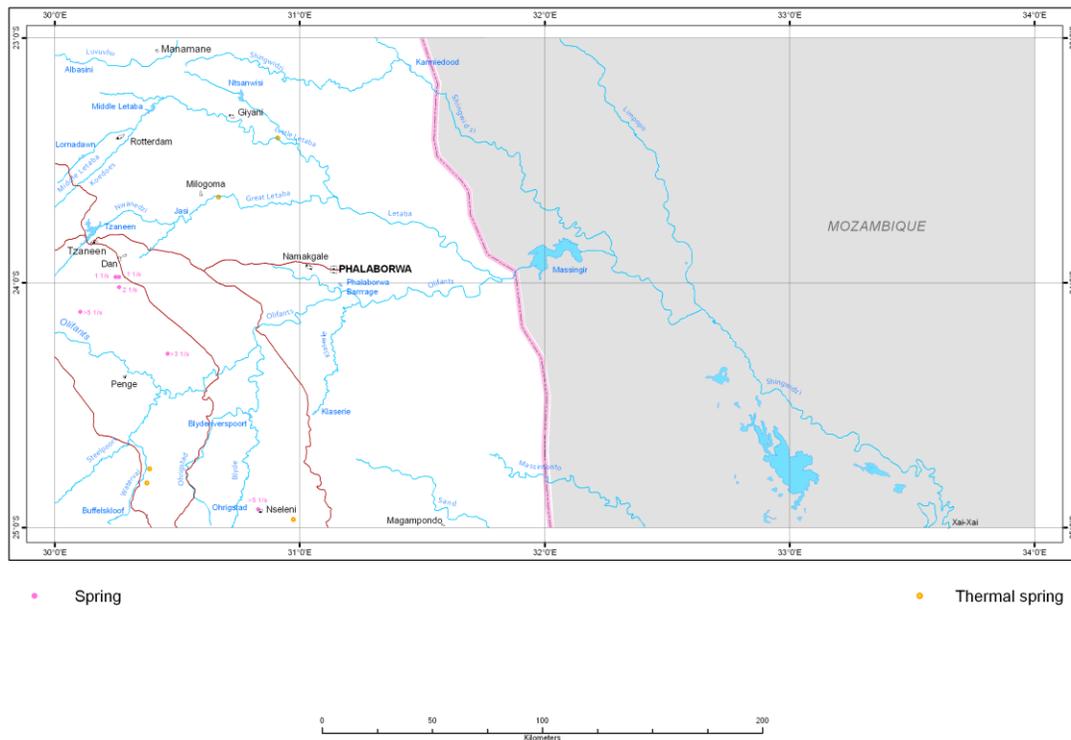


Figure 101: Springs

#### 3.4.1. Non-thermal Springs

Most of the non-thermal springs are found to the southeast of Graskop in the Rooiwater Complex, the Gravelotte Group, the Chuniespoort Group, and the Harmony Granite. A spring is also found at Graskop in the Chuniespoort Group, which is also the main source of supply to the town. The springs in the carbonate rocks of the Chuniespoort Group are the most high-yielding, both having yields of greater than 5 l/s.

#### 3.4.2 Thermal Springs

According to Kent (1969) the origin of the thermal springs is attributed to the presence of deep structures, principally fault-zones, which provide continuously circulating convection or artesian systems by means of which rain and surface run-off water descends to depth, takes up heat of the rocks and returns to the surface sufficiently rapidly for losses of heat to be relatively small. Virtually all of the rocks concerned have no primary permeability – the aquifers are secondary and the permeability thus due to fracturing. Impermeable sections of the fault-zones may play a part by restricting direct percolation from the intake areas to the springs. In general, the heat is attributed to the normal geothermal gradient, but in some instances where there has been late Tertiary to Recent movements along the fault-zones a proportion may be due to this tectonism.

Five thermal springs are depicted on the Phalaborwa map. One is found east of Graskop in Timbavati Gabbro. Two are found between Lydenburg and Burgersfort in the Pretoria Group and two are found along the Great and Little Letaba Rivers respectively.

The spring along the Great Letaba River and referred to by Kent (1950) as the Letaba Hot Spring, is located on the farm Eiland where a fault in the Goudplaats Gneiss was intruded by a dolerite dyke. The temperature is around 40.6°C with an estimated flow of 4,78 l/s. Kent (1941) described it as a sulphur spring as there is always a sulphurous odour in the vicinity of the spring.

The spring along the Little Letaba River is named Souting and according to Kent (1968) due to a fault in the Goudplaats Gneiss. The temperature is around 43°C with an estimated flow of 1.57 l/s. Two thermal springs, De Bad and Voortrekkerbad, occur midway between Lydenburg and Burgersfort a few kilometres east of the Waterval River on the farms Winterhoek en Fraaiuitzicht respectively. They are regarded as warm springs with temperatures ranging between 25°C and 37 °C. No information is available on the flow rates or on the reasons why they occur here. The last of the five thermal springs occurs at the Sabie Mineral Resort next to the Sabie River in Hazyview. As in case of the previous two springs this is also regarded a warm spring falling in the same 25°C to 37 °C temperature range. Timbavati Gabbro underlies the site but no further information is available.

#### **4. GROUNDWATER RELATED MATTERS**

##### **4.1 Groundwater Movement and storage**

Groundwater levels in this area almost invariably mimic the surface topography, with groundwater divides commonly coinciding with surface water divides.

The stagnant groundwater chemistry type, and the broadly flat terrain of much of the Lowveld, suggests that very little lateral groundwater movement occurs in these flat-lying areas.

Vegter (1995) states that groundwater recharge is dependent in the first instance on rainfall. He considers recharge to be involved in the absorption and addition of water to the zone of saturation. Recharge to groundwater resources on the Phalaborwa map sheet is dependent on effective rainfall defined as the fraction of rainfall that will infiltrate to the saturated zone after evaporation, transpiration, run off and inception loss. Recharge may also occur from rivers or dams with controlling factors such as open fracture zones and type of bedding material underlying the surface water bodies.

Surface water percolates through the unsaturated weathered zone to the saturated zone where all openings are filled with water. Storage related to structural features such as fault zones, fracture zones, joints and bedding planes can be major depending on the ratio of the openings to the solid rock. These structural features are usually the preferential pathways for water movement where they act as conduits rather than to contribute to storage.

Unconfined aquifer storage occurs in unconsolidated alluvial deposits along rivers and in the weathered zone in certain areas. Specific yield (indication of storage capacity) can be expressed as the volume of water that will drain under gravity from a saturated rock of unit volume. It is usually quoted as a percentage of the total volume. Storage capacity decreases rapidly as the depth of weathering and/or alluvial thickness decreases.

Storage in the rock matrix is in micro pores and fractures. In igneous and metamorphic rocks this storage can be very small while it is usually much more in sedimentary rocks.

It is important to note that the rate at which an aquifer can yield water (borehole yield) is merely a function of its permeability. It is not a measure of the volume of water in storage or sustainability of the yield. Fresh dolomite has a very low primary porosity but as openings are formed by solution secondary porosity can be very high.

## 4.2 Borehole Positioning

Table 5 depicts the different geophysical techniques for successful borehole siting recommended for the different hydrogeological units. Siting targets are described for most of the hydrogeological units in Chapter 3.

Essential aids to use during the siting of boreholes together with field observations of the geology are aerial photographs, satellite images, and aero magnetics.

*Table 6: Recommended geophysical siting techniques*

GROUP/FORMATION	HYDROGEOLOGICAL UNIT	CLASS	1a	1b	2a	2b	3	4	5
Alluvial deposits	Q	A	***		**			*	**
Wolkberg Group	Vw	B		**	***		***		
Black Reef Formation	Vbl	B		**	***		***		
Pretoria Group	Vp	B	**	*	***		***		
Undifferentiated strata of the Karoo Super Group	Pe	B	**	**	***	***	***		
Lebombo Group	Jl	B	**	***	***	*	**		
Tshokwane Granophyre	Jts	B	***	*	***	**	**		
Chuniespoort Group	Vh	C				**	***	***	
Goudplaats Gneiss	Zgo	D	***	**	***	**	**		
Makhutswi Gneiss	Zma	D	***	**	***	**	**		
Pietersburg Group	Zp	D	***	*	***	**	**		
Gravelotte Group	Zg	D	***	**	***	**	**		
Giyani Group	Zy	D	***	**	***	**	**		
Unnamed Swazian Rocks	Zz	D	***	**	***	**	**		
Nelspruit Suite	Ze	D	***	**	***	**	**		
Rooiwater Complex	Rr	D	***	**	***	**	***		
Cunning Moore Tonalite	Vcu	D	***	**	***	*	**		
Harmony Granite	Vha	D	***	*	***	**	**		
Turfloop Granite	Vtu	D	***	*	***	**	**		
Mashishimale Suite	Vi	D	***	**	***	*	**		
Schiel Complex	Vs	D	**	**	***	*	**		

Entabeni Granite	Ven	D	***	*	***	**	**		
Pretoria Group	Vp	D	**	*	***	**	***		
Unnamed Vaalian Group	Vz	D	***	**	***	*	***		
Rustenburg Suite	Vr	D	***	**	***	**	**		
Lebowa Suite	Mle	D	***	**	***	***	**		
Phalaborwa Complex	Mh	D	**	**	***	**	**		
Sabiesand Granophyre	Msa	D	***	*	***	**	**		
Soutpansberg Group	Ms	D		**	***		***		
Timbavati Gabbro	Nti	D	***	**	**	**	**		
Diabase Intrusions	N-Zd	D	*	***	***	**	***		
Clarens Formation	Trc	D		**	***	**	***		
Lebombo Group	Jl	D	**	**	***	**	**		

**Geophysical Method**

- 1a Electrical Resistivity – soundings
- 1b Electrical Resistivity – profiling
- 2a Electromagnetic - EM-34
- 2b Electromagnetic - Genie SE
- 3 Magnetic
- 4 Gravity
- 5 Seismic

**Rating**

- \*\*\* Essential
- \*\* Useful
- \* Not essential

**4.2.1 Information on the use of geophysical methods (from existing reports)**

**Electrical Resistivity Soundings:** Schlumberger and Wenner vertical electrical soundings (VES) were extensively and successfully used in the past in granitoid, gneissic and sedimentary environments. Cost and time implications limit the current use in groundwater development. The Wenner configuration was used with moderate success in areas with shallow weathering i.e. <36 metres. Although the empirical method of interpretation is a quick method, the estimated depth to bedrock can be grossly incorrect because of the higher than normal susceptibility to lateral effects. Despite being costly, the accuracy and high resolution of data obtained with the Schlumberger configuration makes this a highly recommended method. The interpretation of the data must be done by qualified and experienced personnel.

**Electrical Resistivity Profiling:** Older instruments limit the user to a single theoretical depth of investigation making the method time consuming and expensive. The geological environments investigated are the same as with the resistivity soundings. This method was usually used as a relatively fast way to cover vast distances before conducting soundings. The development of electromagnetic methods replaced the single spacing profiling method in groundwater surveys. The development of resistivity profiling instruments that can measure apparent resistivity at multiple theoretical depths (such as the Lund) reinstated the resistivity method as a highly recommended tool. The method should be used in a combination with other instruments and, as with all methods, the surveyor should have an understanding of the hydrogeological conditions.

**Electromagnetic EM-34:** Can be successfully used in most of the units to locate geological lineaments related to dykes and faults as well as deep weathered and fracture zones. Shallow highly conductive layers must be taken in consideration during

interpretation. The theoretical depth of applicability is approximately 60m, reducing use in deep water table environments. The interpreted dip and width of structures is usually extrapolated in such cases.

**Electromagnetic Genie:** An electromagnetic system developed to obtain data at depths up to 150m. The Stratagem is similar but much more advanced. The Genie has distinguished itself as a reliable and useful instrument in detecting water bearing zones located in a conductive environment. Its effectiveness, from a groundwater exploration point of view diminishes tremendously in higher resistive environments (Du Toit, 1989). As with the Stratagem, an experienced geophysicist should do interpretation of data. Due to time and cost implications, the use of the Genie is limited. Surveys with the Stratagem are expensive and are mostly used for mine exploration.

**Magnetic:** Still the most widely used method due to cost and time effectiveness. It is a highly recommended method to use in combination with all the other available methods in all the units on the map sheet. In the Quaternary alluvial deposits it is used to locate secondary targets associated with lineaments overlain by the deposits while in the other units it will be used to locate lineaments such as dykes when using it as a single geophysical method or to confirm and to identify the type of lineament when using the method in conjunction with other methods. Case studies reported that not all fault zones show magnetic response but when using it with other methods the smaller anomalies could be interpreted. When interpreting data one should be aware of responses related to amphibolite, or the presence of magnetite in the rocks of the Bushveld Complex.

**Gravity:** Preferable method in dolomitic rocks or where sufficient rock density contrasts exist. It is known from verbal conversations with various surveyors that the method can be successfully applied to locate drilling targets in schist, gneiss and granitoid. In dolomitic environments, the use of this method together with the magnetic method is highly effective. No reports were available where the gravity method was used on other geological environments within the map area.

**Seismic:** Due to cost, time and logistical implication this method is not widely used in the map area.

### 4.3 Groundwater Availability - Harvest Potential

The National Harvest Potential Map (Seward, Baron and Seymour, 1996) shows the maximum amount of groundwater that can theoretically be abstracted on a sustainable basis. Usually there are factors such as legal, economic, and environmental considerations that prevent this maximum being exploited.

The highest Harvest Potential for the Phalaborwa map area is the >25 000 m<sup>3</sup>/km<sup>2</sup>/annum range, and the lowest is the 6000 - 10 000 m<sup>3</sup>/km<sup>2</sup>/annum range.

The variation in Harvest Potential shows some resemblance to the relief and rainfall maps. Very broadly speaking, the Harvest Potential is higher where the rainfall and elevation are higher. However, there are many exceptions to this rule. Since the Phalaborwa map area falls under the Harvest Potential classification of areas where there is insufficient storage to absorb the recharge from one rainy season to the next, the variation in Harvest Potential is more likely to reflect changes in the storage potential of the rocks, with the thickness of the saturated weathered zone an important controlling factor.

What is clear, however, is that the Harvest Potential map shows little correlation with the median yield map. This clearly points out the dangers of assuming that the areas with the highest borehole yields will have the highest sustainable yields. Only the carbonate rocks of the Chuniespoort Group have both a high Harvest Potential and high borehole yields.

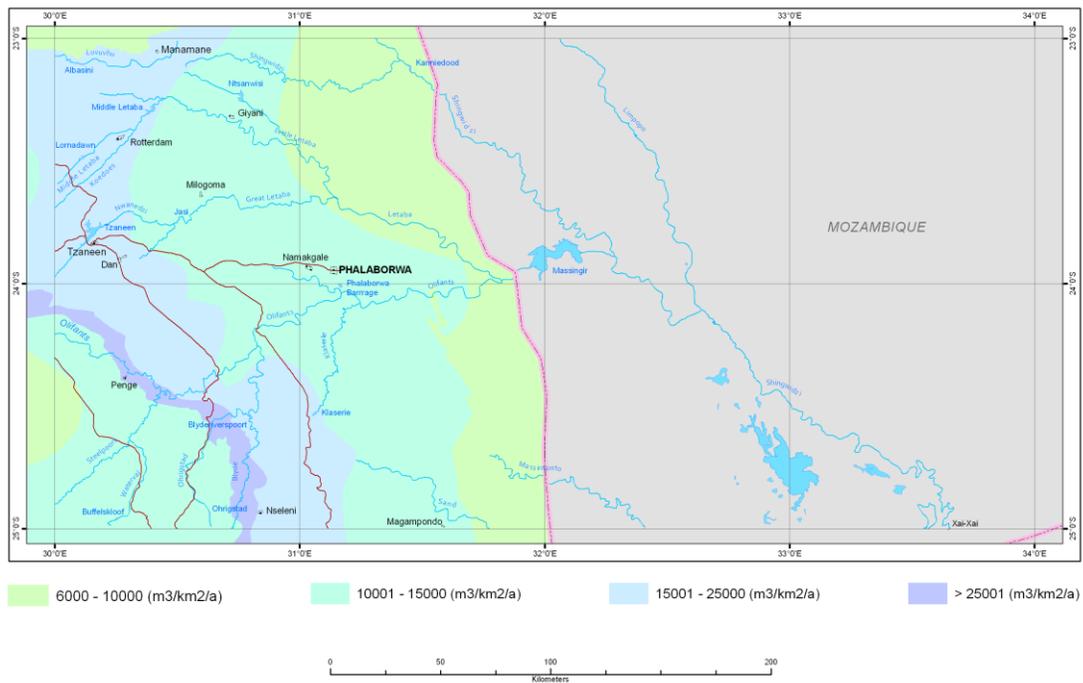


Figure 102: Harvest potential (After Seward, Baron, & Seymour, 1996)

#### 4.4 Groundwater Management

Under the new Water Act (Chapter 4.7), the **Minister of the Department of Water Affairs is the custodian** (trustee) of water resources on behalf of the National Government, with the responsibility to provide a framework for the protection, use, development, conservation and management of water resources for the country as a whole. It must be managed in an integrated manner according to the principles of the Act (sustainability, equity and efficiency).

To manage water resources on a local level, Catchment Managing Agencies (CMAs) and Water User Associations (WUAs) must be established that operate under the framework of the NWS and DWA guidelines. The CMA is responsible for a water allocation plan within their catchments and a Catchment Water Strategy (CWS) that is similar to the NWS. The WUA is responsible for a few functions such as the protection of water resources and to prevent water wastage.

At present the **Department of Water Affairs is responsible** for administering all aspects of the Act on the Minister's behalf as no CMA's or WUA are yet in operation within the map area.

Over-exploitation of groundwater resources is a general problem especially where extensive irrigation is practised such as in the Mooketsi and Orighstadt areas, or poorly managed well fields utilized for large scale town supplies. This can be prevented and controlled through sound groundwater management. Management can be simplified to:

- 1) PLANNING: setting targets or objectives
- 2) IMPLEMENTATION: taking steps to realise those targets
- 3) CONTROL: reviewing and revising steps 1) and 2) in the light of whether or not the set targets were met

Groundwater management is, when viewed with this broad perspective, no different from any other form of management. Targets might include:

- Limiting abstraction to what is sustainable on a long-term basis
- Limiting the impact of groundwater abstraction on other aspects of the environment - e.g. the effect of groundwater abstraction on base-flow. This could mean groundwater being abstracted at less than the sustainable rate
- Maintaining a certain level of groundwater quality

Achieving these targets basically revolves around setting limits on the amount of groundwater that may be abstracted, and setting limits on the amount of pollutants that may enter the groundwater system.

Control entails monitoring groundwater levels and groundwater quality to see if the targets are being met. Other components of the hydrological cycle such as rainfall and abstraction also need to be monitored to check that the targets themselves are realistic, and whether they need to be modified.

It is essential that groundwater be managed at all levels from local authorities such as Graskop down to individual farmers. Regular or continuous measurements of groundwater-level fluctuations together with accurate abstraction and rainfall measurements all displayed on one graph will provide sufficient aquifer status information to ensure a sustainable supply. Over-pumping can be detected in advance and the necessary precautionary measurements (reduction in abstraction, water restrictions etc.) taken to prevent borehole failure at critical times. Long-term measurements of groundwater-levels, abstraction, and rainfall are also essential in the accurate assessment of recharge and aquifer storage and subsequent compilation and/or refining of a groundwater management model.

It is equally important to monitor the quality of the groundwater on a regular basis in order to detect any deterioration in the water quality in advance. The frequency of sampling for chemical analysis depends on the water usage (domestic, stock watering, agricultural, industrial) and aquifer vulnerability but should at least be analysed once or twice a year for macro, tracer and microbiological constituents. Further information on these can be obtained from the Department of Water Affairs.

Where applicable the conjunctive use of surface and groundwater is recommended. During summertime when losses due to evaporation are at their highest surface water should be utilized extensively with groundwater only supplementing any shortages. During wintertime when evaporation losses are generally at their lowest groundwater should be utilized extensively, which could be recharged again during summertime. Surface water could thus only supplement shortages during this period.

Effective groundwater management was made possible by the 1998 National Water Act (Chapter 4.7), which draws no legal distinction between surface water and groundwater. A variety of legal instruments are now available to set limits to abstraction. Before 1998 groundwater was classified as private water by the 1956 Water Act, and management could only be enforced in proclaimed Control Areas.

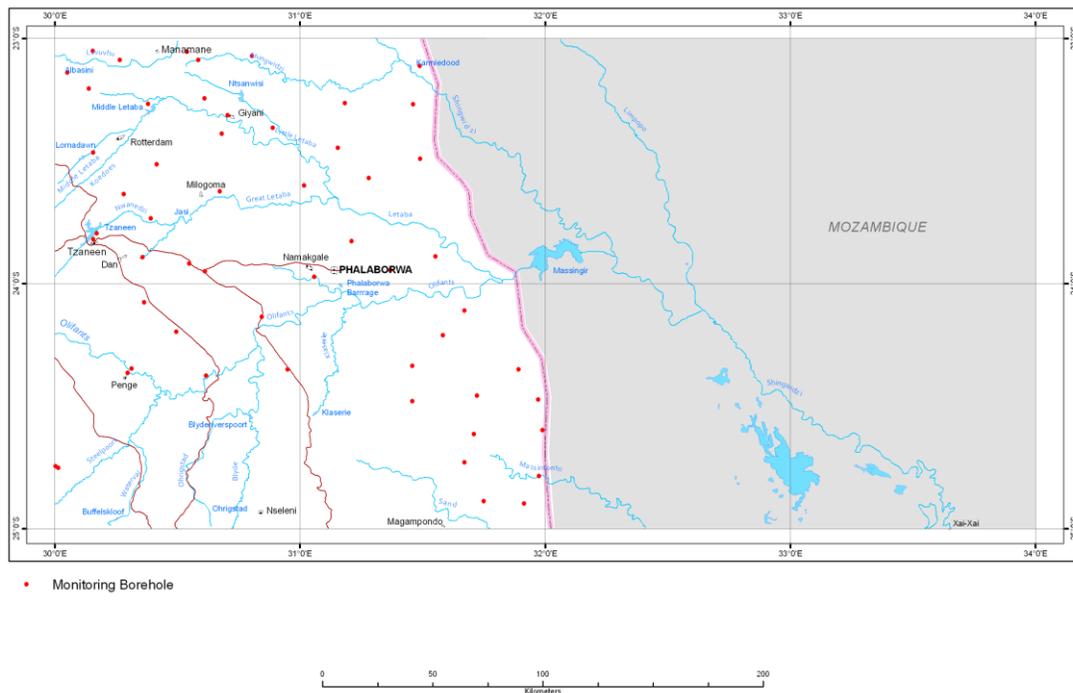


Figure 103: Distribution of water level monitoring boreholes

The Department of Water Affairs currently has dedicated monitoring boreholes equipped with electronic data loggers in the mapping area measuring water levels and water temperature. The locations of the monitoring boreholes, which are not displayed on the map sheet, are depicted in Figure 103. Quarterly water level status reports are produced from the collected data, which are available on request from the Department's regional office in Polokwane. The status reports are also available on the Department's website ([www.dwa.gov.za](http://www.dwa.gov.za))

#### 4.5 Groundwater Utilisation

Apart from drinking purposes, groundwater in terms of large-scale abstraction is mainly used for irrigation in the mapping area. This creates pressure on groundwater resources with return flows containing fertiliser and pesticide residues. In areas such as Levhuvu, Letsitele, Giyani, Burgersfort and Orighstadt surface and groundwater are used conjunctively. The large-scale groundwater use is listed in Table 6.

Table 7: Large-scale groundwater abstraction

Locality/Area	Geological Unit	Abstraction Volume (Million mm <sup>3</sup> /a)	Main Use
Giyani	Giyani Group and the Goudplaats Gneiss	0.9	Domestic
Graskop	Chuniespoort Group	1.5	Domestic
Levhuvu	Goudplaats Gneiss	2.0	Irrigation
Letsitele	Goudplaats Gneiss	2.0	Irrigation
Orighstadt	Pretoria Group and Alluvial deposits	4.5	Irrigation
Burgersfort	Pretoria Group and Alluvial deposits	1.7	Irrigation
Mooketsi	Goudplaats Gneiss	5.0	Irrigation

#### 4.6 Recommended future studies

The growing population and development in South Africa are bound to put the country's scarce water resources under tremendous pressure in years to come. To be able to absorb this anticipated pressure the country should invest in groundwater exploration and research in order to maintain and manage existing resources and develop new resources. The following possible subjects are suggested:

- Research the occurrence, development and management of groundwater in the crystalline rocks, which largely underlie the mapping area. The rural areas situated between the Kruger National Park and the Drakensberg mountain range in particular depend largely on groundwater from these rock formations.
- The determination of the orientation and origin of water-bearing fractures occurring in the gneisses and granites in the mapping area. It is in particular the relationship between horizontally orientated fractures and off-loading that is of interest. It is likely that thick layers of sedimentary rock overlay the gneiss in the Lowveld area and that decompressional fractures developed during removal of the sedimentary rocks. Considering the large number of dykes in the area it is possible that most of the vertically orientated fractures / structural features were intruded by dykes leaving only the horizontal features to target for groundwater development
- The occurrence and origin of high nitrate concentrations in borehole water within or close to villages with special reference to sanitation (pit latrines) and agriculture practices and the removal of vegetation.
- The mapping area is transected by a large concentration of dykes (dyke swarms) with a mostly northeast orientation. Determine the influence of these dyke swarms on groundwater in general such as for instance the relationship between success rate of boreholes and dyke orientations. The shear zones (which also have a northeast orientation) in the mapping area could be included in such a study. The latter could depend very much on the current stress fields in the area but this need to be confirmed.
- An investigation into and the determination of current stress fields in the mapping area would enhance the overall success rate of boreholes in the area. The identification of structural features more or less parallel orientated to the current compressional stress field would not only have a greater chance of success but would (if properly managed) also be more sustainable in the long term.
- The Drakensberg mountain range where the highest average annual rainfall occurs bound the map area on the western side. The EC insert map shows the groundwater quality to increase in salinity from west to east, which raise a few questions: In terms of the apparent better quality along the escarpment to what

extent is the Drakensberg range acting as a recharge area? In terms of the apparent poorer water quality present what is the rate of recharge from direct rainfall in the Lowveld area or is there no recharge at all? Using isotopes to investigate recharge along a west / east line starting from the Drakensberg up to the Mozambique border could enhance current knowledge and a better understanding of groundwater recharge in the mapping area

- The management and maintenance of local water sources (boreholes) is almost non-existing. The development of a low-maintenance pump with a build-in easy-to-read abstraction and water-level measuring device would make a tremendous contribution to sustainable borehole water supply in the rural areas.
- Exploration into the occurrence and utilization of deeply (> 200m) seated aquifers.

#### **4.7 National Water Act (Act 108 of 1998)**

The **National Water Act** (Act 108 of 1998) replaces the old Water Act (Act 56 of 1956). The most important implications to groundwater users is that groundwater is now considered as part of the larger **hydrologic cycle** and that **ownership** thereof is not private but belonging to all South Africans. The meaning of this is that landowners with strong groundwater sources or with a river occurring on his or her property do not have the right to use the water without authorization.

The Act makes provision for the separation of power between different spheres of government. The **Minister of the Department of Water Affairs is the custodian** (trustee) of water resources on behalf of the National Government, with the responsibility to provide a framework for the protection, use, development, conservation and management of water resources for the country as a whole. It must be managed in an integrated manner according to the principles of the Act (sustainability, equity and efficiency).

The Act allows the Minister to delegate most of his or her powers and duties to departmental officials, water management institutions, advisory committees, and water boards. The framework to achieve the principles and purpose of the Act is the National Water Strategy (NWS). To manage water resources on local level Catchment Managing Agencies (CMAs) and Water User Associations (WUA) must be established. These institutions must operate under the framework of the NWS and DWA guidelines. The CMA is responsible for a water allocation plan within their catchments and a Catchment Water Strategy (CWS), which is similar to the NWS. The WUA is responsible for a few functions such as the protection of water resources and to prevent water wastage. All South Africans should be able to participate in water management and participate meaningfully in decisions on water matters that affect them. These new institutions will be representative of and facilitate the involvement of communities and other stakeholders in decision-making.

At present, the Department of Water Affairs is responsible for administering all aspects of the Act on the Minister's behalf. As regional CMA's (19 CMA's are planned) and other local water management institutions are established the Department will over time delegate or assign water resource management responsibilities to these institutions. In the longer term, the Department's role will mainly be to develop national policy and a regulatory framework to govern the way other institutions manage the water resources. The Department will maintain general oversight of these institutions' activities and how well they perform.

The National Water Act is important because it provides a framework to protect water resources against over exploitation and pollution as demand and stress on the environment is increasing. The Act must ensure that there is water for social and economic development for the present and the future. It is also important because it recognises that water belongs to the whole nation for the benefit of all people. The only right to water ensured by the National Water Act is referred to as the reserve. All users, except the users falling under Schedule 1, must register their use or apply for a licence. Aspects that will be considered before allocating water to users in a catchment will be water needed for strategic purposes such as Eskom, inter catchment water transfers and international obligations.

#### **4.7.1 Water user registration and licences**

Licensing of water use is compulsory reserving the right to the minister of DWA to publish a notice in the Government Gazette requiring all existing and potential water users except Schedule 1 users to apply for licences. The application for a Water User's Licence does not differentiate between users of surface or groundwater.

**Schedule 1** users are relatively low water users such as domestic household supplies, non-commercial small gardens, livestock watering for subsistence use, (not feeding pens), storing and using run-off water from a roof. The use is not excessive in relation to the available source and needs of other users.

**Continuation of existing lawful use:** Existing users who were already using water legally before the National Water Act came into operation must register that use and may continue using the water without having to apply for a licence. This is a transitional measure until the water use needs to be formally licensed. The window period was between September 1996 and October 1998. These users must inform DWA of their usage and DWA will verify if the use is legal.

**General Authorization:** General permission has been granted by the Minister for other slightly larger uses from certain less-stressed sources. This permission has been given by means of general authorisations published in the Government Gazette. A general authorisation is only applicable to specific rivers or catchments and is not applicable to the whole country. The users must report their water use but due to the small volumes they are not required to be licensed, this includes users such as small-scale farmers in low stressed areas.

**Users who need to be licensed:** Section 21 of the Act lists water use that must be licensed. Existing and potential water users must ensure that they comply and are familiar with the requirements of the Act. The different water uses are summarised below:

- 21 (a) Taking water from a water resource (Abstraction),
- 21 (b) Storing of water,
- 21 (c) Impending or diverting the flow of water in a water course,
- 21 (d) Engaging in a stream flow reduction activity,
- 21 (e) Engaging in a controlled activity identified as such in section 37 or declared under section 38(l),
- 21 (f) Discharging waste or water containing waste into a water resource,
- 21 (g) Disposing of waste in a manner which may detrimentally impact on a water resource,

- 21 (h) Disposing in any manner of water which contains waste from, or which has been heated in any industrial power generation process,
- 21 (i) Altering the bed, banks, course or characteristics of a watercourse
- 21 (j) Removing, discharging or disposing of water found underground,
- 21 (k) Using water for recreational purposes

If the user receives water from a local government or any other bulk supplier there is no need to register. The local government or any other bulk supplier must register. All licences will be issued with conditions to ensure that the water use authorized by the licence does not have a negative impact on the water resource or other water users. These conditions will be negotiated with the water user wherever possible. Conditions can include a time period and the monitoring of quantity and quality.

#### **4.7.2 The Reserve**

The only right to water ensured by the National Water Act is referred to as the reserve. The Minister is required to determine the RESERVE for all, or part of any significant water resource unit. A water resource unit is usually a catchment area or it can be smaller to differentiate between different hydrological settings or it can be “hotspots”. Hotspots are regions within a catchment area that are completely different due to pollution or usage that can be related to industry or mining.

The reserve must be “set aside” before water is allocated for other uses. The reserve includes basic human needs (currently 25lt/person/day) and the ecological reserve needed to sustain ecosystems within the water resource unit such as the aquatic, riparian and their associated biological diversity ecosystems.

#### **4.7.3 Resource Directed Measures**

Resource Directed Measures (RDM) is a strategy developed by The Department of Water Affairs to ensure the protection of water resources as outlined in the NWA. A series of measures falling under the RDM that must be addressed includes a classification system, classification of each major resource unit, determination of resource quality objectives and setting the reserve. The objective is to balance protection and development by assessing as accurately as possible how much water can be abstracted from a system before the reserve is affected.

A class is allocated to each resource unit representing the level of protection required for the water resource and to state the extent to which the water can be used. The classification is used to define the present status of the resource unit and to define the state towards which the water resource needs to be managed sustainable (future state). The classification process involves stakeholder participation and consultation as users must know the current state and to decide how the future state must look as development and usage must be balanced against the degradation of the environment. During the **resource quality objectives** future quality and quantity of the source and conditions of the aquatic and riparian ecosystems are provided as an **environmental statement**. The minister of DWA is responsible to set the reserve. Basic human needs are set at 25lt/person/day and the ecological reserve is determined by investigation groundwater/surface interactions. Management of the resource units will be an on-going process with emphasis on pollution prevention, emergency spillage and rehabilitation, monitoring quality and quantity, monitoring abstraction and compliance of licensed water users. Availability and demand must be managed in an integrated manner to maintain the resource quality objectives.

#### **4.7.4 Monitoring**

Monitoring, recording, assessing and dissemination of information on water resources are critically important for achieving the objectives of the act. The DWA is responsible to set up National water monitoring systems that will facilitate the continued and co-ordinated monitoring of various aspects of water resources by collection relevant information and data through established procedure and mechanisms, from a variety of sources including organs of state, water management institutions and water users. Monitoring of aspects such as quantity, quality, the use and rehabilitation are some of the aspects. As part of the water user licence, users can be required to supply information on abstraction, water levels and quality on a time frequency negotiated between DWA and the licence holder. The NWA is not the only Act requiring monitoring, as it is also part of the environmental requirements for various other industrial, mining, sewerage and landfill management. No information was available or could be obtained on any monitoring boreholes by government or private institutions.

#### **4.8 Groundwater contamination and pollution**

Groundwater contamination is defined as the introduction of any substance into groundwater by the action of man. Pollution is defined as the direct or indirect alteration of the physical, chemical or biological properties of a water resource to make it-

- a) less fit for any beneficial purpose for which it may reasonable expected to be use.
- b) harmful or potentially harmful to-
  - the welfare, health of safety human beings,
  - any aquatic or non-aquatic organisms,
  - the resource quality, or to property,

(Source: National water Act, Act No 36 of 1998)

Pollution is one of the greatest threats of our time. Groundwater is, like surface water, very vulnerable to pollution. It is very difficult and expensive to rehabilitate an aquifer once it is polluted. In the environmental Act, the principle of "polluter pays for the rehabilitation" is followed. Managers of companies responsible for the degradation of the environment can be held responsible.

In the modelling of pollution mitigation sources, pollution sources are classified at first according to its geometry. Point sources are sources such as waste disposal, underground storage tanks, septic tanks and sewage works. These sites should be selected with utmost care, continuously monitored and reported on by groundwater pollution specialists in order to protect vulnerable aquifers. The establishment or closure of such sites is strictly controlled by the Department of Water Affairs in order to protect the water resources of the country. Selling and storage points for petrol, diesel, chemicals and fertilizers are widespread with waste disposal and sewerage works mostly confined to the bigger towns and cities within the map area. In the rural areas of the map, a common problem is high concentrations of nitrates that have been introduced into the water through pit-latrines and cattle-kraals. Other occurrences are displayed on the map sheet.

Line sources are possible pollution sites such as sewage pipelines and railway lines (use of weed killing chemicals). Aerial sources are industrial, mining and irrigation areas with a big aerial discharge of contaminants. These sources are also widespread throughout the area. Mining activities such as the coal mines are all potential sources of pollution if not properly managed.

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