

**AN EXPLANATION OF THE  
1:250 000 HYDROGEOLOGICAL MAP SERIES, MAP SHEET 2328  
POLOKWANE**



**By**

**W.H. Du Toit & C.J. Sonnekus**

**June 2025**

## FOREWORD

Groundwater in South Africa is under-utilised, although some local over-exploitation does occur. Groundwater schemes can be implemented quickly and cheaply and are 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, 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. To rectify this situation, groundwater information locked away in expert's minds and computer databases, is being made available on maps. The second step in this program at the regional level is, the upgrading of the original "General Hydrogeological Maps" at the scale of 1: 500 000 to 4 x 1:250 000 scale hydrogeological maps i.e. Modimolle, Polokwane, Lephalale, and Thabazimbi.

The main purpose of these 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 geohydrologists' 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.

BY MASWUMA ZACHARIA  
DIRECTOR: NATIONAL HYDROLOGICAL SERVICES (2025)  
DEPARTMENT OF WATER AND SANITATION  
PRETORIA

**Cover page:** View of the Utrecht batholith from the northeast. The Utrecht Granite crops out in the background with Hout River Gneiss making up the foreground. Granite of the Bushveld Complex forms the hill behind the Utrecht batholith in the top left-hand corner of the photograph. (Photograph by WH du Toit).

---

## PREFACE

Except for 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 while 97% occurs underground (Johnson Division, 1975). Owing to the lack of perennial streams in the arid to semi-arid areas, two-thirds of South Africa's surface area are 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 to comprehend how and where groundwater occurs.

The Polokwane 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 be varied. 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 median borehole yield per aquifer unit, 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 be informative to planners and developers, especially in the light of the Reconstruction and Development Programme, and it will play a constructive role in general groundwater education, groundwater awareness building and groundwater protection.

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.

---

## **BACKGROUND TO THE PROJECT**

The Southern African Development Community (SADC) is a regional grouping of 16 sovereign countries, comprising Angola, Botswana, Comoros, Eswatini, Democratic Republic of Congo (DRC), Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Tanzania, Zambia, and Zimbabwe. As articulated in the amended Treaty of 1992, SADC's main objective is to foster co-operation and mutual benefit by all Member Countries from the resources in the region.' (Revised Sub-Grand Manual 2022).

To counter meteorological changes experienced in the region that influence water supply, the SADC-GMI (Southern African Development Community Groundwater Management Institute) was established as a Centre of Excellence in groundwater. The mandate is to build capacity in the region through targeted training and funding of groundwater related projects. To fulfil this mandate, the SADC-GMI started awarding sub-grants to Member Countries in 2017 for the implementation of groundwater related pilot projects using a grant from the World Bank through the SADC Secretariat.

After the successful completion of one of these projects, (The Sustainable Groundwater Management in SADC Member Countries, Phase 1 project), the SADC-GMI implemented phase 2 of the same project under the strategic guidance of the SADC Secretariat. Phase 2 entails the updating of the Polokwane 2326 hydrogeological map sheet and brochure. VSA Rebotile Metsi Consulting was appointed 15 January 2024 as consultant for the project on a lump-sum contract format. The Prime Partner for SADC-GMI on this project is the Department of Water and Sanitation (DWS), Republic South Africa (RSA). The function of DWS is to monitor, assist, guide, and to assess progress, deliverables, and invoices on behalf of SADC- GMI. This is done through engagement on monthly DWS internal progress meetings as well as monthly SADC-GMI Sub-Grant Project Management Progress Meetings.

## ACKNOWLEDGEMENTS

W.H. du Toit, VSA Rebotile Metsi Consulting (Mapping team)  
C.J. Sonnekus, VSA Rebotile Metsi Consulting (Mapping team)  
Dr ZA. Botes, VSA Rebotile Metsi Consulting (Mapping team)  
A.J.I. du Toit, VSA Rebotile Metsi Consulting (GIS team)  
B. Saunders, VSA Rebotile Metsi Consulting Graphic (Designer)  
A.M. Cronje, VSA Rebotile Metsi Consulting, Admin, (Data capture team)

### Project Management team

L.Z. Maswuma, DWS (Director: National Hydrological Services, (NHS)  
Dr L. Lalumbe, DWS (Scientist Manager: Directorate: NHS, Geohydrological Information Services, project Manager)  
F. Ramusiya, DWS (Scientist Manager: Directorate: NHS, Geohydrological Monitoring and Assessment)  
O.V. de Beer, DWS (Scientist Production: Directorate: NHS, Geohydrological Information Services)  
T. Chetty, DWS (Scientist Production: Directorate: Spatial Information (SI), Geographic Information & Archiving)

### SADC-GMI

J. Sauramba (Executive Director)  
T. Dlamini (Communication and documentation)  
B. Gwangwawa (ESS Compliance oversight)  
S. Luveta (Logistical Coordinator)  
K. Mulenga (Infrastructure Consultant)  
M. Ntsekhe (Subgrant Compliance oversight)  
T. Poo (Finance)

### DWS: National Office

Q. Boshomane  
D. Jacobs  
A. Kuiper  
K. Majola  
L. Mathume  
S. Mndaweni  
Dr P. Mokoena-Fuku  
M.C. Pule  
H.M. Visagie

## DATA AND REPORTS

**DWS (Pretoria)** National groundwater and water quality databases  
**DWS (Pretoria)** Geohydrological Reports  
**Council for Geoscience (Pretoria)** Geological information  
**Municipalities for the map area**  
**VSA Rebotile Metsi Consulting**

## TABLE OF CONTENTS

<b>1. INTRODUCTION</b> .....	<b>1</b>
1.1 General.....	1
<b>2. MAP COMPILATION</b> .....	<b>2</b>
2.1 Data sources:.....	2
2.2 Main map: Polokwane hydrogeological map scale 1: 250 000 .....	2
2.2.1 : Inset maps: <b>4</b>	
2.2.2 : Brochure: <b>4</b>	
<b>3. HYDROGEOLOGICAL CLASSIFICATION</b> .....	<b>4</b>
<b>4. PHYSICAL ENVIRONMENT</b> .....	<b>7</b>
4.1 General.....	7
4.2 Terrain Morphology .....	15
4.3 Elevation.....	17
4.4 Climate .....	18
4.5 Surface Hydrology .....	20
<b>5. GEOLOGY</b> .....	<b>24</b>
5.1 Regional geology .....	24
5.2 Structural geology .....	29
<b>6. GENERAL: HYDROCHEMISTRY AND AQUIFER UNITS</b> .....	<b>32</b>
6.1 Aquifer Hydrochemistry.....	35
6.2 Aquifer Units .....	59
<b>7. HYDROGEOLOGY OF THE VARIOUS GEOLOGICAL GROUPS AND FORMATIONS</b> .....	<b>64</b>
7.1 PRIMARY AQUIFERS .....	66
7.1.1 <b>CATEGORY A: INTERGRANULAR AQUIFERS</b> .....	<b>66</b>
7.1.1.1 TERTIARY-QUATERNARY ALLUVIUM DEPOSITS (Q).....	66
7.2 SECONDARY AQUIFERS .....	72
7.2.1 <b>CATEGORY B: FRACTURED AQUIFERS</b> .....	<b>73</b>
7.2.1.1 UNDIFFERENTIATED KAROO SEDIMENTS (C-Tr).....	74
7.2.1.2 SWARTRANT FORMATION (Psr) .....	76
7.2.1.3 WELLINGTON FORMATION (C-Pwe).....	80
7.2.1.4 VAALWATER FORMATION (Mva) .....	82
7.2.1.5 CLEREMONT FORMATION (Mcl) .....	87
7.2.1.6 KRANSBERG SUBGROUP (Mkr).....	91
7.2.1.7 BLOUBERG FORMATION (Mbb) .....	96
7.2.1.8 MAKGABENG FORMATION (Mma).....	100
7.2.1.9 SETLAOLE FORMATION (Mse).....	104
7.2.1.10 KOEDOESRAND FORMATION (Mko).....	108
7.2.1.11 WYLLIESPOORT FORMATION (SOUTPANSBERG SUPERGROUP) (Mwp).....	111
7.2.1.12 UNDIFFERENTIATED ROOIBERG GROUP (Vrb) .....	114
7.2.1.13 WOLKBERG GROUP (Vwo).....	117
7.2.2 <b>CATEGORY C: KARST AQUIFERS</b> .....	<b>118</b>
7.2.2.1 MALMANI SUBGROUP (Vma) .....	118
7.2.3 <b>CATEGORY D: INTERGRANULAR AND FRACTURED AQUIFERS</b> .....	<b>122</b>
7.2.3.1 LETABA FORMATION (Jle).....	124
7.2.3.2 DIABASE (N-Za).....	127
7.2.3.3 PALALA GRANITE (Mpa) .....	132
7.2.3.4 SIBASA FORMATION (SOUTPANSBERG GROUP (Msi) .....	137
7.2.3.5 NEBO GRANITE (Mn) .....	141
7.2.3.6 VILLA NORA GABBRO-ANORTHOSITE (Vv) .....	147
7.2.3.7 UNDIFFERENTIATED RUSTENBURG LAYERED SUITE (Vrs) .....	151
7.2.3.8 UNDIFFERENTIATED PRETORIA GROUP (Vpg).....	155
7.2.3.9 MATLALA GRANITE (Vml) .....	158
7.2.3.10 SMITSKRAAL GRANITE (Vs).....	162
7.2.3.11 PALMIETFONTEIN GRANITE (Vpf) .....	162
7.2.3.12 UNNAMED GRANITE ROCKS (Vz).....	165
7.2.3.13 UTRECHT GRANITE (Vut) .....	168
7.2.3.14 TURFLOOP GRANITE (Rt-Vt).....	172
7.2.3.15 UITLOOP GRANITE (Ru-Vu).....	175

7.2.3.16	LUNSKLIP GRANITE (RI-VI) .....	176
7.2.3.17	MOLETSI GRANITE (Rmo) .....	181
7.2.3.18	MATOK GRANITE (Rma) .....	185
7.2.3.19	HUGOMOND GRANITE (Rhu) .....	188
7.2.3.20	HOUT RIVER GNEISS (Rho) .....	189
7.2.3.21	HOUT RIVER GNEISS WITH XENOLITHS (Rhx).....	194
7.2.3.22	UNDIFFERENTIATED MESSINA SUITE (BEIT BRIDGE COMPLEX), (Zms)198	
7.2.3.23	UNDIFFERENTIATED BEIT BRIDGE COMPLEX (Zbc) .....	202
7.2.3.24	UNDIFFERENTIATED MALALA DRIFT GROUP (Zma).....	206
7.2.3.25	MOUNT DOWE GROUP (Zmd).....	210
7.2.3.26	UNDIFFERENTIATED BANDELIERKOP COMPLEX (Zbk) .....	213
7.2.3.27	UNDIFFERENTIATED PIETERSBURG GROUP (MOSTLY MOTHIBA FORMATION) (Zpg) .....	217
7.2.3.28	GOUDPLAATS GNEISS (Zgo) .....	222
7.2.2.29	GOUDPLAATS GNEISS WITH XENOLITHS (Zgx).....	226
<b>8.</b>	<b>SPRINGS AND ARTESIAN BOREHOLES .....</b>	<b>230</b>
8.1	Hot Springs .....	230
8.2	Cold Springs .....	230
8.3	Artesian boreholes .....	231
<b>9.</b>	<b>GROUNDWATER RELATED MATTERS.....</b>	<b>232</b>
9.1	The National Water Act (Act 108 1998) .....	232
9.1.1	<b>Water user registration and licenses .....</b>	<b>233</b>
9.1.2	<b>The Reserve .....</b>	<b>235</b>
9.1.3	<b>Resource Directed Measures .....</b>	<b>235</b>
9.1.4	<b>Monitoring .....</b>	<b>236</b>
9.2	Groundwater recharge, storage, and movement .....	238
9.3	Borehole siting .....	240
9.4	Groundwater management.....	243
9.4.1	<b>Groundwater contamination and pollution.....</b>	<b>244</b>
9.4.2	<b>Groundwater utilization .....</b>	<b>244</b>
9.4.2.1	Harvest potential .....	246
9.5	Future groundwater and associated projects .....	247
<b>10.</b>	<b>REFERENCES .....</b>	<b>249</b>

## LIST OF FIGURES

FIGURE 1: TERRAIN MORPHOLOGY (KRUGER, 1983) .....	16
FIGURE 2: ELEVATION .....	18
FIGURE 3: MEAN ANNUAL PRECIPITATION .....	19
FIGURE 4: MEAN ANNUAL EVAPORATION .....	20
FIGURE 5: DRAINAGE REGIONS AND MAJOR DAMS (HRU, 1981) .....	23
FIGURE 6: SIMPLIFIED REGIONAL GEOLOGY OF THE MAP AREA .....	28
FIGURE 7: INFERRED AND OBSERVED GEOLOGICAL LINEAMENTS .....	31
FIGURE 8: DISTRIBUTION OF ELECTRICAL CONDUCTIVITY (EC) AND BOREHOLES WITH NITRATE AND FLUORIDE VALUES EXCEEDING THE ACCEPTABLE LEVELS FOR HUMAN CONSUMPTION .....	63
FIGURE 9: GEOGRAPHICAL DISTRIBUTION OF THE INTERGRANULAR AQUIFERS (TERTIARY-QUATERNARY ALLUVIUM DEPOSITS) .....	66
FIGURE 10: YIELD FREQUENCY FOR TERTIARY-QUATERNARY ALLUVIAL (Q) AQUIFERS .....	69
FIGURE 11: TRILINEAR DIAGRAMS, PIPER AND DUROV FOR THE TERTIARY-QUATERNARY ALLUVIAL DEPOSITS (Q) .....	70
FIGURE 12: GEOGRAPHICAL DISTRIBUTION OF THE FRACTURED ROCK AQUIFERS .....	73
FIGURE 13: GEOGRAPHICAL DISTRIBUTION OF THE UNDIFFERENTIATED KAROO SEDIMENTS (C-TR) AND THE ASSOCIATED GROUNDWATER SAMPLING POINTS .....	75
FIGURE 14: YIELD FREQUENCY FOR THE FRACTURED AQUIFERS OF THE UNDIFFERENTIATED KAROO SEDIMENTS (C-TR) .....	75
FIGURE 15: GEOGRAPHICAL DISTRIBUTION OF THE SWARTRANT FORMATION (PSR.) .....	78
FIGURE 16: YIELD FREQUENCY FOR THE FRACTURED AQUIFERS OF THE SWARTRANT FORMATION (PSR) .....	78
FIGURE 17: TRILINEAR DIAGRAMS, PIPER AND DUROV FOR THE SWARTRANT FORMATION (PSR) .....	79
FIGURE 18: GEOGRAPHICAL DISTRIBUTION OF THE WELLINGTON FORMATION (C-PWE) .....	81
FIGURE 19: YIELD FREQUENCY FOR THE FRACTURED AQUIFERS OF THE WELLINGTON FORMATION (C-PWE) .....	82
FIGURE 20: GEOGRAPHICAL DISTRIBUTION OF THE VAALWATER FORMATION (MVA.) .....	83
FIGURE 21: YIELD FREQUENCY FOR THE FRACTURED AQUIFERS OF THE VAALWATER FORMATION (MVA), ONLY POLOKWANE DATA USED .....	84

FIGURE 22: YIELD FREQUENCY FOR THE FRACTURED AQUIFERS OF THE VAALWATER FORMATION (MVA), DATA USED FROM 3 MAP SHEET AREAS, (CROSS-BOUNDARY OCCURRENCE)	84
FIGURE 23: TRILINEAR DIAGRAMS, PIPER AND DUROV FOR THE VAALWATER FORMATION (MVA)	85
FIGURE 24: GEOGRAPHICAL DISTRIBUTION OF THE CLEREMONT FORMATION (MCL)	88
FIGURE 25: YIELD FREQUENCY FOR FRACTURED AQUIFERS OF THE CLEREMONT FORMATION (MCL)	88
FIGURE 26: TRILINEAR DIAGRAMS, PIPER AND DUROV FOR THE CLEREMONT FORMATION (MCL)	89
FIGURE 27: GEOGRAPHICAL DISTRIBUTION OF THE KRANSBERG SUBGROUP (MKR) AND ASSOCIATED GROUNDWATER DATA POINTS	92
FIGURE 28: YIELD FREQUENCY FOR FRACTURED AQUIFERS OF THE KRANSBERG SUBGROUP (MKR)	93
FIGURE 29: TRILINEAR DIAGRAMS, PIPER AND DUROV FOR THE KRANSBERG SUBGROUP (MKB) FIRST GROUP OF 80 SAMPLES	94
FIGURE 30: TRILINEAR DIAGRAMS, PIPER AND DUROV FOR THE KRANSBERG SUBGROUP (MKB) SECOND GROUP OF 82 SAMPLES	94
FIGURE 31: GEOGRAPHICAL DISTRIBUTION OF THE BLOUBERG FORMATION (Mbb) AND THE ASSOCIATED GROUNDWATER DATA POINTS.	97
FIGURE 32: YIELD FREQUENCY FOR FRACTURED AQUIFERS OF THE BLOUBERG FORMATION (Mbb)	97
FIGURE 33: TRILINEAR DIAGRAMS, PIPER AND DUROV FOR THE BLOUBERG FORMATION (Mbb)	98
FIGURE 34: GEOGRAPHICAL DISTRIBUTION OF THE MAKGABENG FORMATION (MMA) AND THE ASSOCIATED GROUNDWATER DATA POINTS	100
FIGURE 35: YIELD FREQUENCY FOR THE FRACTURED AQUIFERS OF THE MAKGABENG FORMATION (MMA)	101
FIGURE 36: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE MAKGABENG FORMATION (MMA), FIRST GROUP OF 61 SAMPLES	102
FIGURE 37: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE MAKGABENG FORMATION (MMA), SECOND GROUP OF 115 SAMPLES	102
FIGURE 38: GEOGRAPHICAL DISTRIBUTION OF THE SETLAOLE FORMATION (Mse) AND THE ASSOCIATED GROUNDWATER DATA POINTS	104
FIGURE 39: YIELD FREQUENCY FOR THE FRACTURED AQUIFERS OF THE SETLAOLE FORMATION (Mse)	105
FIGURE 40: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE SETLAOLE FORMATION (Mse).	106
FIGURE 41: GEOGRAPHICAL DISTRIBUTION OF THE KOEDOESRAND FORMATION (Mko) AND THE ASSOCIATED GROUNDWATER DATA POINTS	108
FIGURE 42: YIELD FREQUENCY FOR THE FRACTURED AQUIFERS OF THE KOEDOESRAND FORMATION (Mko).	109
FIGURE 43: TRILINEAR DIAGRAMS, PIPER AND DUROV FOR THE KOEDOESRAND FORMATION (Mko)	109
FIGURE 44: GEOGRAPHICAL DISTRIBUTION OF THE WYLLIESPOORT FORMATION (MWP) AND THE ASSOCIATED GROUNDWATER DATA POINTS	112
FIGURE 45: YIELD FREQUENCY FOR THE FRACTURED AQUIFERS OF THE WYLLIESPOORT FORMATION (MWP)	112
FIGURE 46: TRILINEAR DIAGRAMS, PIPER AND DUROV FOR THE WYLLIESPOORT FORMATION (MWP)	113
FIGURE 47: GEOGRAPHICAL DISTRIBUTION OF THE UNDIFFERENTIATED ROOIBERG GROUP (VRb) AND THE ASSOCIATED GROUNDWATER DATA POINTS	115
FIGURE 48: YIELD FREQUENCY FOR FRACTURED AQUIFERS OF THE UNDIFFERENTIATED ROOIBERG GROUP (VRb)	116
FIGURE 49: GEOGRAPHICAL DISTRIBUTION OF THE WOLKBERG GROUP (Vwo).	117
FIGURE 50: GEOGRAPHICAL DISTRIBUTION OF THE KARST AQUIFERS ROCK AQUIFERS	118
FIGURE 51: GEOGRAPHICAL DISTRIBUTION OF THE MALMANI SUBGROUP (VMA) AND THE ASSOCIATED GROUNDWATER DATA POINTS	119
FIGURE 52: YIELD FREQUENCY FOR FRACTURED AQUIFERS OF THE MALMANI SUBGROUP (VMA)	120
FIGURE 53: TRILINEAR DIAGRAMS, PIPER AND DUROV FOR THE MALMANI SUBGROUP (VMA)	120
FIGURE 54: GEOGRAPHICAL DISTRIBUTION OF THE INTERGRANULAR AND FRACTURED AQUIFERS	123
FIGURE 55: GEOGRAPHICAL DISTRIBUTION FOR THE INTERGRANULAR AND FRACTURED AQUIFERS OF THE LETABA FORMATION (Jle) AND ASSOCIATED GROUNDWATER DATA POINTS	124
FIGURE 56: YIELD FREQUENCY FOR THE INTERGRANULAR AND FRACTURED AQUIFERS OF THE LETABA FORMATION (Jle)	125
FIGURE 57: TRILINEAR DIAGRAMS, PIPER AND DUROV FOR THE LETABA FORMATION (Jle)	125
FIGURE 58: GEOGRAPHICAL DISTRIBUTION OF THE DIABASE INTRUSIONS (N-ZA) AND THE ASSOCIATED GROUNDWATER DATA POINTS.	129
FIGURE 59: YIELD FREQUENCY FOR THE INTERGRANULAR AND FRACTURED AQUIFERS OF THE DIABASE INTRUSIONS (N-ZA)	130
FIGURE 60: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR DIABASE (N-ZA).	131
FIGURE 61: GEOGRAPHICAL DISTRIBUTION OF THE PALALA GRANITE (MPa) AND THE ASSOCIATED GROUNDWATER DATA POINTS	133
FIGURE 62: YIELD FREQUENCY FOR FRACTURED AQUIFERS OF THE PALALA GRANITE (MPa)	134
FIGURE 63: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE PALALA GRANITE (MPa) DATA POINTS	135
FIGURE 64: GEOGRAPHICAL DISTRIBUTION OF THE SIBASA FORMATION (SOUTPANSBERG GROUP) (MSI) AND THE ASSOCIATED GROUNDWATER DATA POINTS	137
FIGURE 65: YIELD FREQUENCY FOR THE INTERGRANULAR AND FRACTURED AQUIFERS OF THE SIBASA FORMATION (MSI)	138
FIGURE 66: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE SIBASA FORMATION (MSI), CROSS-BOUNDARY SECTION	139
FIGURE 67: GEOGRAPHICAL DISTRIBUTION OF THE NEBO GRANITE (MN) AND THE ASSOCIATED GROUNDWATER DATA POINTS	142
FIGURE 68: YIELD FREQUENCY FOR THE INTERGRANULAR AND FRACTURED AQUIFERS OF THE NEBO GRANITE (MN), CROSS-BOUNDARY SECTION.	142
FIGURE 69: YIELD FREQUENCY FOR THE INTERGRANULAR AND FRACTURED AQUIFERS OF THE NEBO GRANITE (MN), CENTRAL OUTCROP	143
FIGURE 70: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE NEBO GRANITE (MN), CROSS-BOUNDARY SECTION	144
FIGURE 71: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE NEBO GRANITE (MN), CENTRAL SECTION	145
FIGURE 72: GEOGRAPHICAL DISTRIBUTION OF THE VILLA NORA GABBRO-ANORTHOSITE (Vv) AND THE ASSOCIATED GROUNDWATER DATA POINTS	148
FIGURE 73: YIELD FREQUENCY FOR THE INTERGRANULAR AND FRACTURED AQUIFERS OF THE VILLA NORA GABBRO-ANORTHOSITE (Vv)	148
FIGURE 74: TRILINEAR DIAGRAMS, PIPER AND DUROV FOR THE VILLA NORA GABBRO-ANORTHOSITE (Vv).	149
FIGURE 75: GEOGRAPHICAL DISTRIBUTION OF THE UNDIFFERENTIATED RUSTENBURG LAYERED SUITE (Vrs) AND THE ASSOCIATED GROUNDWATER DATA POINTS	152
FIGURE 76: YIELD FREQUENCY FOR THE INTERGRANULAR AND FRACTURED AQUIFERS OF THE UNDIFFERENTIATED RUSTENBURG LAYERED SUITE (Vrs).	153
FIGURE 77: TRILINEAR DIAGRAMS, PIPER AND DUROV FOR THE UNDIFFERENTIATED RUSTENBURG LAYERED SUITE (Vrs)	154
FIGURE 78: GEOGRAPHICAL DISTRIBUTION OF THE UNDIFFERENTIATED PRETORIA GROUP (Vpg)	157
FIGURE 79: YIELD FREQUENCY FOR THE FRACTURED AQUIFERS OF THE UNDIFFERENTIATED PRETORIA GROUP (Vpg)	157

FIGURE 80: GEOGRAPHICAL DISTRIBUTION OF THE MATLALA GRANITE (VML) AND THE ASSOCIATED GROUNDWATER DATA POINTS.	159
FIGURE 81: YIELD FREQUENCY FOR FRACTURED AQUIFERS OF THE MATLALA GRANITE (VML)	159
FIGURE 82: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE MATLALA GRANITE (VML) DATA POINTS.	160
FIGURE 83: GEOGRAPHICAL DISTRIBUTION OF THE SMITSKRAAL GRANITE (VS)	162
FIGURE 84: GEOGRAPHICAL DISTRIBUTION OF THE PALMIETFONTEIN GRANITE (VPF) AND THE ASSOCIATED GROUNDWATER SAMPLING POINT	163
FIGURE 85: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE PALMIETFONTEIN GRANITE (VPF) DATA POINTS	163
FIGURE 86: GEOGRAPHICAL DISTRIBUTION OF THE UNNAMED GRANITE ROCKS (Vz) AND ASSOCIATED GROUNDWATER DATA POINTS	166
FIGURE 87: YIELD FREQUENCY FOR FRACTURED AQUIFERS OF THE UNNAMED GRANITE ROCKS (Vz)	166
FIGURE 88: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE UNNAMED GRANITE ROCKS (Vz)	167
FIGURE 89: GEOGRAPHICAL DISTRIBUTION OF THE UTRECHT GRANITE (VUT) AND THE ASSOCIATED GROUNDWATER DATA POINTS	169
FIGURE 90: YIELD FREQUENCY FOR FRACTURED AQUIFERS OF THE UTRECHT GRANITE (VUT)	170
FIGURE 91: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE UTRECHT GRANITE (VUT) DATA POINTS	170
FIGURE 92: YIELD FREQUENCY FOR FRACTURED AQUIFERS OF THE TURFLOOP GRANITE (RT-Vt)	173
FIGURE 93: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE TURFLOOP GRANITE (RT-Vt) DATA POINTS	174
FIGURE 94: GEOGRAPHICAL DISTRIBUTION OF THE UITLOOP GRANITE (RU-VU)	176
FIGURE 95: GEOGRAPHICAL DISTRIBUTION OF THE LUNSKLIP GRANITE (RL-VL) AND THE ASSOCIATED GROUNDWATER DATA POINTS	177
FIGURE 96: YIELD FREQUENCY FOR FRACTURED AQUIFERS OF THE LUNSKLIP GRANITE (RI-VI)	178
FIGURE 97: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE LUNSKLIP GRANITE (RL-VL) DATA POINTS	179
FIGURE 98: GEOGRAPHICAL DISTRIBUTION OF THE MOLETSI GRANITE (RMO) AND THE ASSOCIATED GROUNDWATER DATA POINTS	182
FIGURE 99: YIELD FREQUENCY FOR FRACTURED AQUIFERS OF THE MOLETSI GRANITE (RMO)	182
FIGURE 100: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE MOLETSI GRANITE (RMO) DATA POINTS	183
FIGURE 101: GEOGRAPHICAL DISTRIBUTION OF THE MATOK GRANITE (RMA) AND THE ASSOCIATED GROUNDWATER DATA POINTS.	185
FIGURE 102: YIELD FREQUENCY FOR FRACTURED AQUIFERS OF THE MATOK GRANITE (RMA)	186
FIGURE 103: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE MATOK GRANITE (RMA) DATA POINTS	186
FIGURE 104: GEOGRAPHICAL DISTRIBUTION OF THE HUGOMOND GRANITE (RHU) AND THE ASSOCIATED GROUNDWATER DATA POINTS	189
FIGURE 105: GEOGRAPHICAL DISTRIBUTION OF THE HOUT RIVER GNEISS (RHO) AND THE ASSOCIATED GROUNDWATER DATA POINTS	190
FIGURE 106: YIELD FREQUENCY FOR FRACTURED AQUIFERS OF THE HOUT RIVER GNEISS (RHO)	191
FIGURE 107: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE HOUT RIVER GNEISS (RHO), FIRST 237 DATA POINTS	192
FIGURE 108: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE HOUT RIVER GNEISS (RHO), SECOND BATCH OF 267 DATA POINTS	192
FIGURE 109: GEOGRAPHICAL DISTRIBUTION OF THE HOUT RIVER GNEISS WITH XENOLITHS (RHx) AND THE ASSOCIATED GROUNDWATER DATA POINTS.	195
FIGURE 110: YIELD FREQUENCY FOR FRACTURED AQUIFERS OF THE HOUT RIVER GNEISS WITH XENOLITHS (RHx)	195
FIGURE 111: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE HOUT RIVER GNEISS WITH XENOLITHS (RHx) FIRST BATCH OF 163 DATA POINTS.	196
FIGURE 112: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE HOUT RIVER GNEISS WITH XENOLITHS (RHx), SECOND BATCH OF 426 DATA POINTS.	196
FIGURE 113: GEOGRAPHICAL DISTRIBUTION OF THE UNDIFFERENTIATED MESSINA SUITE (BEIT BRIDGE COMPLEX), (ZMs) AND ASSOCIATED GROUNDWATER DATA POINTS	199
FIGURE 114: YIELD FREQUENCY FOR THE INTERGRANULAR AND FRACTURED AQUIFERS OF THE UNDIFFERENTIATED MESSINA SUITE (BEIT BRIDGE COMPLEX), (ZMs).	199
FIGURE 115: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE UNDIFFERENTIATED MESSINA SUITE (BEIT BRIDGE COMPLEX), (ZMs)	200
FIGURE 116: GEOGRAPHICAL DISTRIBUTION OF THE UNDIFFERENTIATED BEIT BRIDGE COMPLEX (Zbc) AND ASSOCIATED GROUNDWATER DATA POINTS.	203
FIGURE 117: YIELD FREQUENCY FOR THE INTERGRANULAR AND FRACTURED AQUIFERS OF THE UNDIFFERENTIATED BEIT BRIDGE COMPLEX (Zbc)	203
FIGURE 118: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE UNDIFFERENTIATED BEIT BRIDGE COMPLEX (Zbc)	204
FIGURE 119: GEOGRAPHICAL DISTRIBUTION OF THE MALALA DRIFT GROUP (ZMA) AND ASSOCIATED GROUNDWATER SAMPLING POINTS	206
FIGURE 120: YIELD FREQUENCY FOR THE INTERGRANULAR AND FRACTURED AQUIFERS OF THE UNDIFFERENTIATED MALALA DRIFT GROUP (ZMA)	207
FIGURE 121: TRILINEAR DIAGRAMS, PIPER AND DUROV FOR THE UNDIFFERENTIATED MALALA DRIFT GROUP (ZMA), 37 DATA POINTS.	208
FIGURE 122: GEOGRAPHICAL DISTRIBUTION OF THE MOUNT DOWE (ZMD) AND THE ASSOCIATED GROUNDWATER SAMPLING POINTS.	210
FIGURE 123: YIELD FREQUENCY FOR THE FRACTURED AQUIFERS OF THE MOUNT DOWE GROUP (ZMD)	211
FIGURE 124: TRILINEAR DIAGRAMS, PIPER AND DUROV FOR THE MOUNT DOWE GROUP (ZMD), 5 DATA POINTS	211
FIGURE 125: GEOGRAPHICAL DISTRIBUTION OF THE UNDIFFERENTIATED BANDELIERKOP COMPLEX (Zbk) AND THE ASSOCIATED GROUNDWATER DATA POINTS	213
FIGURE 126: YIELD FREQUENCY FOR THE FRACTURED AQUIFERS OF THE UNDIFFERENTIATED BANDELIERKOP COMPLEX (Zbk).	214
FIGURE 127: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE UNDIFFERENTIATED BANDELIERKOP COMPLEX (Zbk)	215
FIGURE 128: GEOGRAPHICAL DISTRIBUTION OF THE UNDIFFERENTIATED PIETERSBURG GROUP, (MOSTLY MOTHIBA FORMATION), (ZPG) AND THE ASSOCIATED GROUNDWATER DATA POINTS	218
FIGURE 129: YIELD FREQUENCY FOR THE INTERGRANULAR AND FRACTURED AQUIFERS OF THE UNDIFFERENTIATED PIETERSBURG GROUP, (MOSTLY MOTHIBA FORMATION), (ZPG).	219
FIGURE 130: TRILINEAR DIAGRAMS, PIPER AND DUROV FOR THE UNDIFFERENTIATED PIETERSBURG GROUP (ZPG)	220
FIGURE 131: GEOGRAPHICAL DISTRIBUTION OF THE GOUDPLAATS GNEISS (Zgo) AND THE ASSOCIATED GROUNDWATER DATA POINTS	222
FIGURE 132: YIELD FREQUENCY FOR FRACTURED AQUIFERS OF THE GOUDPLAATS GNEISS (Zgo)	223
FIGURE 133: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE GOUDPLAATS GNEISS (Zgo).	224
FIGURE 134: GEOGRAPHICAL DISTRIBUTION OF THE GOUDPLAATS GNEISS WITH XENOLITHS (ZGx) AND THE ASSOCIATED GROUNDWATER SAMPLING POINTS.	226
FIGURE 135: YIELD FREQUENCY FOR FRACTURED AQUIFERS OF THE GOUDPLAATS GNEISS WITH XENOLITHS (ZGx).	227

FIGURE 136: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE GOUDPLAATS GNEISS WITH XENOLITHS (ZGX), FIRST BATCH OF 127 DATA POINTS. _	227
FIGURE 137: TRILINEAR DIAGRAMS, PIPER, AND DUROV FOR THE GOUDPLAATS GNEISS WITH XENOLITHS (ZGX), SECOND BATCH OF 143 DATA POINTS.	228
FIGURE 138: DWS MONITORING BOREHOLES. _____	236
FIGURE 139: MEAN ANNUAL RECHARGE IN MM FOR THE FOUR, 1:250 000 MAPS THAT IS THE UPGRADE FOR THE _____	239
FIGURE 140: HARVEST POTENTIAL SHOWING VALUES IN M <sup>3</sup> /KM <sup>2</sup> /ANNUM (A. SEYMOUR AND P. SEWARD, 1995) _____	247

## LIST OF TABLES

TABLE 1: NUMBER OF BOREHOLE RECORDS EXTRACTED AND EVALUATED FROM THE NGA AND WMS _____	2
TABLE 2: HYDROGEOLOGICAL CLASSIFICATION OF GROUNDWATER OCCURRENCE AND BOREHOLE YIELDS IN THE MAP AREA. (AFTER ORPEN, 1994). _____	6
TABLE 3: WATER RESOURCES WITHIN THE WATERBERG DISTRICT, LEPHALALE LOCAL MUNICIPALITY _____	7
TABLE 4: WATER RESOURCES WITHIN WATERBERG DISTRICT, MOGALAKWENA LOCAL MUNICIPALITY _____	8
TABLE 5: WATER RESOURCES IN CAPRICORN DISTRICT, AGANANG LOCAL MUNICIPALITY. _____	9
TABLE 6: WATER RESOURCES IN CAPRICORN DISTRICT, NKUMPI LOCAL MUNICIPALITY _____	9
TABLE 7: WATER RESOURCES IN THE CAPRICORN DISTRICT, BLOUBERG LOCAL MUNICIPALITY. _____	10
TABLE 8: WATER RESOURCES IN THE CAPRICORN DISTRICT, MOLEMOLE LOCAL MUNICIPALITY _____	11
TABLE 9: WATER RESOURCES IN THE CAPRICORN DISTRICT, POLOKWANE LOCAL MUNICIPALITY _____	12
TABLE 10: WATER RESOURCES IN THE VHEMBE DISTRICT, MAKHADO LOCAL MUNICIPALITY. _____	14
TABLE 11: WATER RESOURCES IN MOPANI DISTRICT, GREATER LETABA LOCAL MUNICIPALITY _____	15
TABLE 12: WATER RESOURCES IN THE MOPANI DISTRICT, TZANEEN LOCAL MUNICIPALITY _____	15
TABLE 13: DETAILED EXPLANATION FOR FIGURE 1, TERRAIN MORPHOLOGY _____	16
TABLE 14: LIMPOPO ECOREGIONS AND COEFFICIENT OF VARIATION _____	18
TABLE 15: SURFACE HYDROLOGY, TABLE SHOWING THE UPPER TRIBUTARIES OF THE MOKOLO, LEPHALALA AND MOGALAKWENA THAT FLOW INTO THE LIMPOPO RIVER _____	21
TABLE 16: SURFACE HYDROLOGY, TABLE SHOWING THE UPPER TRIBUTARIES OF THE SAND, LEVUVHU, LETABA AND OLIFANTS THAT FLOW INTO THE LIMPOPO RIVER _____	22
TABLE 17: MAJOR DAMS, DRAINAGE BASIN, SUPPLYING RIVER AND STORAGE CAPACITY (HRU, 1981) _____	23
TABLE 18: CLASSIFICATION OF WATER BASED ON PIPER DIAGRAM (LANGGUTH, 1966), WATER TYPES _____	33
TABLE 19: CLASSIFICATION OF WATER TYPES BASED ON DUROV DIAGRAM (LLOYD AND HEATHCOTE, 1985) _____	34
TABLE 20: GUIDELINES FOR GROUNDWATER QUALITY AND SUITABILITY (DWA, 1996) _____	35
TABLE 21: INTERPRETATION OF THE HYDROCHEMICAL FACIES AS PERCENTAGES, WATER TYPE; FIRST PAGE _____	41
TABLE 22: INTERPRETATION OF THE HYDROCHEMICAL FACIES AS PERCENTAGES, WATER TYPE; SECOND PAGE _____	42
TABLE 23: INTERPRETATION OF THE HYDROCHEMICAL FACIES AS PERCENTAGES, WATER TYPE; THIRD PAGE _____	43
TABLE 24: HYDROCHEMISTRY OF THE POLOKWANE MAP AREA, 50 <sup>TH</sup> PERCENTILE (MEDIAN); FIRST PAGE _____	44
TABLE 25: HYDROCHEMISTRY OF THE POLOKWANE MAP AREA, 50 <sup>TH</sup> PERCENTILE (MEDIAN); SECOND PAGE _____	45
TABLE 26: HYDROCHEMISTRY OF THE POLOKWANE MAP AREA, 50 <sup>TH</sup> PERCENTILE (MEDIAN); THIRD PAGE _____	46
TABLE 27: HYDROCHEMISTRY OF THE POLOKWANE MAP AREA, 90 <sup>TH</sup> PERCENTILE (MEDIAN); FIRST PAGE _____	47
TABLE 28: HYDROCHEMISTRY OF THE POLOKWANE MAP AREA, 90 <sup>TH</sup> PERCENTILE (MEDIAN); SECOND PAGE _____	48
TABLE 29: HYDROCHEMISTRY OF THE POLOKWANE MAP AREA, 90 <sup>TH</sup> PERCENTILE (MEDIAN); THIRD PAGE _____	49
TABLE 30: SUMMARIZED MAJOR ANIONS: CHLORIDE, NITRATE AND SULPHATE CONCENTRATION RANGES WITHIN AQUIFER UNITS, FIRST PAGE _____	50
TABLE 31: SUMMARIZED MAJOR ANIONS: CHLORIDE, NITRATE AND SULPHATE CONCENTRATION RANGES WITHIN AQUIFER UNITS, SECOND PAGE _____	51
TABLE 32: SUMMARIZED MAJOR ANIONS: CHLORIDE, NITRATE AND SULPHATE CONCENTRATION RANGES WITHIN AQUIFER UNITS, THIRD PAGE _____	52
TABLE 33: SUMMARIZED MAJOR CATIONS: CALCIUM, POTASSIUM, MAGNESIUM AND SODIUM CONCENTRATION RANGES WITHIN AQUIFER UNITS, FIRST PAGE _____	53
TABLE 34: SUMMARIZED MAJOR CATIONS: CALCIUM, POTASSIUM, MAGNESIUM AND SODIUM CONCENTRATION RANGES WITHIN AQUIFER UNITS, SECOND PAGE _____	54
TABLE 35: SUMMARIZED MAJOR CATIONS: CALCIUM, POTASSIUM, MAGNESIUM AND SODIUM CONCENTRATION RANGES WITHIN AQUIFER UNITS, THIRD PAGE _____	55
TABLE 36: SUMMARIZED ELECTRICAL CONDUCTIVITY, pH, AND FLUORIDE CONCENTRATION RANGES WITHIN AQUIFER UNITS, FIRST PAGE _____	56
TABLE 37: SUMMARIZED ELECTRICAL CONDUCTIVITY, pH, AND FLUORIDE CONCENTRATION RANGES WITHIN AQUIFER UNITS, SECOND PAGE _____	57
TABLE 38: SUMMARIZED ELECTRICAL CONDUCTIVITY, pH, AND FLUORIDE CONCENTRATION RANGES WITHIN AQUIFER UNITS, THIRD PAGE _____	58
TABLE 39: BASIC INFORMATION FOR THE AQUIFER UNITS AND AREAL EXTENT, FIRST PAGE _____	60
TABLE 40: BASIC INFORMATION FOR THE AQUIFER UNITS AND AREAL EXTENT, SECOND PAGE _____	61
TABLE 41: BASIC INFORMATION FOR THE AQUIFER UNITS AND AREAL EXTENT, THIRD PAGE _____	62
TABLE 42: SUMMARY OF BOREHOLE YIELD DISTRIBUTIONS _____	65
TABLE 43: CHEMICAL STATISTICS FOR THE TERTIARY-QUATERNARY ALLUVIAL DEPOSITS (Q) _____	71
TABLE 44: CHEMICAL STATISTICS FOR THE SWARTRANT FORMATION (PSR) _____	80
TABLE 45: CHEMICAL STATISTICS FOR THE VAALWATER FORMATION (MVA) _____	86
TABLE 46: CHEMICAL STATISTICS FOR THE CLEREMONT FORMATION (MCL). _____	90
TABLE 47: CHEMICAL STATISTICS FOR THE KRANSBERG SUBGROUP (MKR) _____	95
TABLE 48: CHEMICAL STATISTICS FOR THE BLOUBERG FORMATION (MBB). _____	99

TABLE 49: CHEMICAL STATISTICS FOR THE MAKGABENG FORMATION (MMA)	103
TABLE 50: CHEMICAL STATISTICS FOR THE SETLAOLE FORMATION (Mse)	107
TABLE 51: CHEMICAL STATISTICS FOR THE KOEDOESRAND FORMATION (Mko)	110
TABLE 52: CHEMICAL STATISTICS FOR THE WYLLIESPOORT FORMATION (MWP)	114
TABLE 53: CHEMICAL STATISTICS FOR THE MALMANI SUBGROUP (VMA)	121
TABLE 54: CHEMICAL STATISTICS FOR THE LETABA FORMATION (Jle)	126
TABLE 55: CHEMICAL STATISTICS FOR THE DIABASE (N-ZA).	132
TABLE 56: CHEMICAL STATISTICS FOR THE PALALA GRANITE (MPA)	136
TABLE 57: CHEMICAL STATISTICS FOR THE SIBASA FORMATION (MSi)	140
TABLE 58: FLUORIDE AND NITRATE CONCENTRATIONS WITHIN THE ADJACENT 1:250 000 MAP SHEETS	141
TABLE 59: CHEMICAL STATISTICS FOR THE NEBO GRANITE (Mn), ALL UNITS POLOKWANE AND LEPHALALE MAP	146
TABLE 60: CHEMICAL STATISTICS FOR THE VILLA NORA GABBRO-ANORTHOSITE (Vv)	150
TABLE 61: CHEMICAL STATISTICS FOR THE UNDIFFERENTIATED RUSTENBURG LAYERED SUITE (Vrs).	155
TABLE 62: CHEMICAL STATISTICS FOR THE MATLALA GRANITE (Vml)	161
TABLE 63: CHEMICAL STATISTICS FOR THE PALMIETFONTEIN GRANITE (Vpf)	164
TABLE 64: CHEMICAL STATISTICS FOR THE UNNAMED GRANITE ROCKS (Vz)	168
TABLE 65: CHEMICAL STATISTICS FOR THE UTRECHT GRANITE (Vut)	171
TABLE 66: CHEMICAL STATISTICS FOR THE TURFLOOP GRANITE (Rt-Vt)	175
TABLE 67: CHEMICAL STATISTICS FOR THE LUNSKLIP GRANITE (Rl-Vl)	180
TABLE 68: CHEMICAL STATISTICS FOR THE MOLETSI GRANITE (Rmo)	184
TABLE 69: CHEMICAL STATISTICS FOR THE MATOK GRANITE (Rma)	187
TABLE 70: CHEMICAL STATISTICS FOR THE HOUT RIVER GNEISS (Rho)	193
TABLE 71: CHEMICAL STATISTICS FOR THE HOUT RIVER GNEISS WITH XENOLITHS (Rhx)	197
TABLE 72: CHEMICAL STATISTICS FOR THE UNDIFFERENTIATED MESSINA SUITE (BEIT BRIDGE COMPLEX), (Zms)	201
TABLE 73: CHEMICAL STATISTICS FOR THE UNDIFFERENTIATED BEIT BRIDGE COMPLEX (Zbc)	205
TABLE 74: CHEMICAL STATISTICS FOR THE UNDIFFERENTIATED MALALA DRIFT GROUP (Zma)	209
TABLE 75: CHEMICAL STATISTICS FOR THE MOUNT DOWE GROUP (Zma)	212
TABLE 76: CHEMICAL STATISTICS FOR THE UNDIFFERENTIATED BANDELIERKOP COMPLEX (Zbk)	216
TABLE 77: CHEMICAL STATISTICS FOR THE UNDIFFERENTIATED PIETERSBURG GROUP (MOSTLY MOTHIBA FORMATION) (Zpg)	221
TABLE 78: CHEMICAL STATISTICS FOR THE GOUDPLAATS GNEISS (Zgo).	225
TABLE 79: CHEMICAL STATISTICS FOR THE GOUDPLAATS GNEISS WITH XENOLITHS (Zgx)	229
TABLE 80: LIST OF SPRINGS WITHIN THE POLOKWANE MAP SHEET	231
TABLE 81: LIST OF ARTESIAN BOREHOLES WITHIN THE POLOKWANE MAP SHEET	232
TABLE 82: THE FOLLOWING ACTIVITIES CONSTITUTE WATER USES AND REQUIRE AUTHORIZATION IN TERMS OF SECTION 21 OF THE NWA	234
TABLE 83: ACTIVE DWS MONITORING BOREHOLES	237
TABLE 84: MEAN ANNUAL RECHARGE CALCULATED FOR THE 1:250 000 POLOKWANE MAP (AFTER VEGTER, 1995)	240
TABLE 85: GEOPHYSICAL SURVEY TECHNIQUES THAT CAN BE EMPLOYED IN EACH RESOURCE UNIT	241
TABLE 86: LOCALITIES WHERE LARGE-SCALE GROUNDWATER ABSTRACTION (>400 000 M <sup>3</sup> /A) ARE TAKING PLACE	246
TABLE 87: HARVEST POTENTIAL WITHIN THE POLOKWANE MAP SHEET	246

## LIST OF PLATES

PLATE 1: ALLUVIAL DEPOSITS ALONG THE DIEP RIVER (SANDSLOOT), THE REMOVAL OF SAND BY MINING AND THE LAYERED NATURE OF THE RIVER BANK, PHOTOS TAKEN 2023, C.J. SONNEKUS	69
PLATE 2: TAFELKOPPE, ONE OF THREE MESA-TYPE (FLAT-TOPPED HILLS), MADE UP OF WHITISH, FELDSPATHIC, COARSE-GRAINED, AND CROSS-BEDDED SANDSTONE OF THE SWARTRANT FORMATION. THE OTHER NEARBY HILLS ARE GA-MABULA AND TAMBOTIEPIEK WHICH IS ALONG THE R518 APPROXIMATELY 25KM EAST-SOUTH-EAST OF LEPHALALE. (PHOTOGRAPH: LOUWLARDUS SAFARIS, 18 NOVEMBER 2020).	77
PLATE 3: INTENSELY FRACTURED MOGALAKWENA FORMATION ON THE FARM KLIPFONTEIN 797 LR, WHICH CONSISTS OF PURPLISH BROWN, COARSE GRAINED SANDSTONE WITH INTERBEDDED CONGLOMERATE AND BOULDER CONGLOMERATE (PHOTOGRAPH: WH DU TOIT).	91
PLATE 4 & PLATE 5: WEATHERING OF THE SANDSTONE OF THE MOGALAKWENA FORMATION PRODUCES EXTRAORDINARY AND BEAUTIFUL SCENERY AND ROCK SHAPES AS ILLUSTRATED IN THE PHOTOGRAPHS (PHOTOGRAPH: WH DU TOIT).	91
PLATE 6: BUSHMAN PAINTINGS ENGRAVED IN SANDSTONE OF THE MOGALAKWENA FORMATION ON THE FARM WATERVAL 601 LQ SOUTH OF LEPHALALE (ELLISRAS) (PHOTOGRAPH: WH DU TOIT).	92
PLATE 7: IN THE BACKGROUND (SOUTH) IS THE CONCRETE WALL OF THE BLOUBERG DAM, THE CLIFF FACE IN THE FOREGROUND REPRESENTS AN EAST-WEST STRIKING FAULT ZONE, WYLLIESPOORT FORMATION, PHOTO 2014, C.J. SONNEKUS.	111
PLATE 8: IN THE FOREGROUND IS THE BLOUBERG DAM, IN THE BACKGROUND (EAST), ANOTHER EAST-WEST FAULT ZONE CAN BE SEEN IN THE CLIFF FACE, WYLLIESPOORT FORMATION, PHOTO 2014, C.J. SONNEKUS.	111
PLATE 9: GRABEN STRUCTURE IN RHYOLITE OF THE KWAGGASNEK FORMATION IN A ROAD CUTTING ALONG THE N1 ABOUT 10 KM SOUTH OF MOOKGOPHONG (NABOOMSPRUIT), PHOTOGRAPH WH DU TOIT.	115
PLATE 10: WESTERN VIEW OF THE NYL RIVER NEAR MOORDDRIFT 289 KR. THE MOUNTAINS IN THE BACKGROUND COMPRISE BUSHVELD GRANITE WITH GABBRO OF THE RUSTENBURG LAYERED SUITE IN THE FOREGROUND (PHOTOGRAPH: WH DU TOIT).	151

PLATE 11: CALCRETE VEINS CRISS-CROSSING THROUGH MAFIC ROCKS OF THE RUSTENBURG LAYERED SUITE IN A ROAD CUTTING BETWEEN CHUNIESPOORT AND BURGERSFORT (PHOTOGRAPH: WH DU TOIT) .....	151
PLATE 12: EASTERN VIEW OF THE CRITICAL ZONE OF THE RUSTENBURG LAYERED SUITE OUTCROPPING IN THE FOREGROUND WITH THE PRETORIA GROUP DOMINATING THE BACKGROUND (PHOTOGRAPH: WH DU TOIT) .....	151
PLATE 13: A BEAUTIFUL EXAMPLE OF A FAULT CUTTING THROUGH SEDIMENTS OF THE PRETORIA GROUP. FAULTS ARE GENERALLY GOOD TARGETS FOR GROUNDWATER EXPLORATION IN LIMPOPO, BUT CAN ALSO UNDER CERTAIN CIRCUMSTANCES ACT AS IMPERMEABLE BARRIERS TO GROUNDWATER FLOW (PHOTOGRAPH: WH DU TOIT) .....	156
PLATE 14: XENOLITHS OF GNEISS OCCURRING IN OUTCROPS OF THE MOLETSI GRANITE. STUDIES OF THE GROUNDWATER POTENTIAL OF THE MOLETSI AND OTHER LARGE GRANITE INTRUSIONS (BATHOLITHS) REVEALED THAT WEATHERED AND/OR FRACTURED REMNANT GNEISSIC ROOF SECTIONS ARE GOOD TARGETS FOR GROUNDWATER DEVELOPMENT AND CAN OCCASIONALLY PRODUCE YIELDS EXCEEDING 40ℓ/s. THESE HIGH YIELDS RELATE TO TENSIONAL FRACTURES, WHICH DEVELOPED IN THE ROOF DURING THE EMPLACEMENT OF THE MAGMA (PHOTOGRAPH: WH DU TOIT) .....	181
PLATE 15: VIEW OF YSTERBERG ON THE RIGHT COMPRISING BANDED IRONSTONE OF THE PIETERSBURG GROUP. THE MOUNTAIN ON THE LEFT CONSISTS OF SEDIMENTS OF THE TRANSVAAL SEQUENCE WITH THE YSTERBERG FAULT RUNNING ALONG THE VALLEY BETWEEN THEM. THE YSTERBERG FAULT, WHICH IS OF PRE-TRANSVAAL AGE, WAS RE-ACTIVATED ON VARIOUS OCCASIONS UNTIL AFTER DEPOSITION OF THE TRANSVAAL SEQUENCE. IT HAS A LATERAL DISPLACEMENT OF ABOUT 9KM (PHOTOGRAPH: WH DU TOIT) .....	218

---

## ABBREVIATIONS AND ACRONYMS

Abbreviation	Description
CMAs	Catchment Management Agencies (plural) single is CMA
CWS	Catchment Water Strategy
DWS	Department of Water and Sanitation
DWA	Department of Water Affairs
DWAF	Department of Water Affairs & Forestry
e.g.	Stands for the Latin phrase <i>exempli gratia</i> , meaning "for example."
ELU	Existing Lawful Water Use
Et al.	An abbreviation for the Latin phrase <i>et alia</i> , which means "and others".
GIS	Geographic Information System
GMI	Groundwater Management Institute
GRIP	Groundwater Resource Information Project (DWS project early 2000)
GRU	Groundwater Resource Units
GW	Groundwater
GRDM	Groundwater Resource Directed Measures
i.e.	Stands for <i>id est</i> , which is Latin for "that is."
IGS	Institute for Groundwater Studies
LGS	Lebowa Granite Suite
LSI	Langelier Saturation Index
MC	Management Class
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
mbgl	Meters Below Ground Level
magl	Meters Above Ground Level
mamsl	Meter Above Mean Sea Level
MCWAP	Mokolo Crocodile Water Augmentation Project
ND	Not detected (used in chemistry analysis)
NGA	National Groundwater Archive
NGDB	National Groundwater Data Base
NHS	National Hydrological Services
NWRS	National Water Resource Strategy
NWA	National Water Act of 1998
NWS	National Water Strategy
PSZ	Palala Shear Zone
RDM	Resource Directed Measures
RGS	Rashoop Granophyre Suite
RHP	River Health Programme
RLS	Rustenburg Layered Suite
RQOs	Resource Quality Objectives
SADC	South African Development Community
SADC-GMI	South African Development Community Groundwater Management Institute
SANS	South African National Standards
SAR	Sodium Absorption Rate
SDC	Source Directed Controls
SWD	Surface Water Dam
SW	Surface Water
TDS	Total Dissolved Solids
TOR	Terms of Reference

Abbreviation	Description
TWQR	Target Water Quality Range
UNESCO	United Nations Educational, Scientific and Cultural Organisation
Viz.	Stands for videlicet which is Latin for “namely”, “which is” or “as follows”
WARMS	The Water use Authorization & Registration Management System
WMA	Water Management Area
WMS	Water Management System
WRC	Water Research Commission
WRCS	Water Resource Classification System
WUAs	Water User Associations (plural), single WUA
WULA	Water Use License Application
e-WULAAS	Electronic Water Use License Application and Authorisation System

### SYMBOLS AND UNITS

Symbol or unit	Description
a	Annum
Ha	Hectare
HARMEAN	Harmonic mean
km	Kilometer
km <sup>2</sup>	Square kilometer
ℓ/s	Liters per second
m	Meter
M	Million
Mm <sup>3</sup>	Million cubic meters
meq	Milli-equivalents
mm	Millimeter
mm <sup>2</sup>	Square millimeter
mm/a	Millimeters per Annum
m <sup>2</sup>	Square meters
m <sup>3</sup>	Cubic meter
m <sup>3</sup> /annum	Cubic meters per annum
m <sup>3</sup> /d	Cubic meters per day
mg/ℓ	Milligram per Liter
mS/m	milliSiemens per meter
pH	Logarithm of the hydrogen ion concentration in moles per liter
s	Seconds

## 1. INTRODUCTION

### 1.1 General:

The **Polokwane Hydrogeological Map, sheet 2328**, scale 1:250 000, is a reconnaissance map and it is part of an upgrade of the first general synthesis of groundwater resources within this area i.e. the 1:500 000 Polokwane Hydrogeological Map. The latter comprises 4 x 1:250 000 geological maps namely Nylstroom (Modimolle), Pietersburg (Polokwane), Thabazimbi, and Ellisras (Lephalale).

The **objective** of the map and accompanying explanation brochure is to provide the public, the professional community, and planners with a general reference for planning, development, and management of groundwater resources. It is also to serve as an education tool to promote groundwater as an interesting and scientific subject.

**Deliverables:** 1:250 000 Hydrogeological map and explanation brochure; Methodology to create these maps and brochures.

**Groundwater occurrences** are very heterogeneous in South Africa while the mapping standards, legend, etc demand a high degree of conformity. Not all the important aspects of groundwater could be depicted on the map as conditions can vary dramatically from region to region. The explanatory brochure addresses some of the issues while the map portrays general hydrogeological conditions. The 1:250 000 scale might be regarded by some as relatively small. The map and brochure can thus not replace detailed site investigations needed, when, for example, boreholes must be sited or when site specific conditions must be determined. It can, however, to some extent, assist in identifying potential target areas for follow-up detailed ground investigations. Despite this, **site-specific detailed investigations** will always be recommended to determine local conditions. The map and accompanying explanation brochure will however provide general information and 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 median yield, aquifer type, groundwater quality, groundwater use and lithology. This brochure provides supplementary information for these topics and discusses other aspects of groundwater on an elementary level. Additional topics include recharge, storage, movement, the location of groundwater using geophysical methods, subterranean water control areas (this function is now part of the function of the Catchment Management Agencies, (CMA). management, pollution, utilization, and suggestions for future groundwater related projects or groundwater exploration.

A new **National Water Act (Act 36 of 1998)** was proclaimed in October 1998, (See section 9.1, p232). A brief discussion is included under management with the focus on the implication for water users and their obligations. The National Water Act is important as it provides a framework to protect water resources against over exploitation; to ensure water for social and economic development; and to ensure the availability of water for future generations.

Sustainability, equity, and efficiency are the **principles** of the National Water Act that provide the framework to guide the protection, use, development, conservation, management, and control of water resources.

## 2. MAP COMPILATION

### 2.1 Data sources:

Data sources for the compilation of the map include:

- The National Groundwater Archive (NGA) under the custody of the Department of Water Affairs (DWA), now the Department of Water and Sanitation (DWS),
- Water Management System (WMS), Department of Water and Sanitation (DWS),
- Borehole data and pumping tests executed during GRIP Project,
- Available Geohydrological reports from DWS,
- Consultant reports compiled for WULAs allocations,
- Existing information from various consultancies stationed in the Limpopo Province,
- Groundwater database of the consultancy,
- Reports and information from some of the municipalities.

Table 1: Number of borehole records extracted and evaluated from the NGA and WMS.

RECORDS EVALUATED POLOKWANE MAP SHEET					
NGA and GRIP-(Yield)		WMS and GRIP (chemistry)			
Total Number of Borehole Yields	Total Number of sources with Water-levels	Number of points after removal of duplicates	Number of time series data	Number of analyses used for evaluation-(tables)	Number of analyses used for Piper and Durov
(16841) of which 7059 is wet, 3845 dry and 6261 with no information	3792	14145	8700	5166	2246

### 2.2 Main map: Polokwane hydrogeological map scale 1: 250 000

The total map sheet covers an area of approximately 22 568.5km<sup>2</sup>. As one of four 1:250 000 hydrogeological map sheets, it represents a 31% portion of the upgrade of the first general synthesis of the groundwater resources of the area i.e. the 1:500 000 Polokwane Hydrogeological map that covered a total area of approximately 71 130km<sup>2</sup> (Botswana excluded).

The 1: 500 000 Polokwane map sheet is bordered by latitudes 23° and 25° south and longitudes 26° and 30° east whereas the 1: 250 000 Polokwane Hydrogeological map is bordered by latitudes 23° and 24° and longitudes 28° and 30°.

The methodology followed for the 1: 500 000 Polokwane Hydrogeological map series for the delineation of the aquifer units was to use the lithostratigraphy as depicted on the relevant 1: 250 000 geological map sheets viz. Ellisras 2326, Pietersburg 2328, Thabazimbi 2426 and Nylstroom 2428. Lithostratigraphy was used to sub-divide the map sheet area into hydrogeologically relevant lithological units (referenced as aquifer units), which possess some degree of lithological homogeneity and similarities in rock properties. However, lithological homogeneity and similarities in rock properties were not the only consideration. Where geological formations were large enough, they were regarded as separate units, despite lithological homogeneity and similarities in rock properties with adjacent formations or lithologies.

For the Polokwane 1: 250 000 Hydrogeological map sheet, a similar approach was followed but due to the smaller scale and a larger number of available data points with information it was possible to use the geological units as aquifer units even if these exhibited similar hydrogeological characteristics. Exceptions are the Aquifer Units i.e. Undifferentiated Karoo Sediments, Undifferentiated Rooiberg Group, Undifferentiated Pretoria Group and the Undifferentiated Messina Suite, Undifferentiated Beit Bridge Group, Undifferentiated Bandelier Complex and the Undifferentiated Pietersburg Group. The reasons are that the parts of the Polokwane map are extensively covered by Tertiary to Quaternary deposits hiding the

underlying geology and that some of the units are very narrow with a limited areal extent and with characteristics that are similar to the adjacent Formations.

In areas where the Undifferentiated Beit Bridge Complex had a larger areal extent and clear outcrop areas, it was divided into separate aquifer units that correspond to the relevant geological formations as depicted on the 1: 250 000 geological map sheet Polokwane 2426 viz. Malala Drift and Mount Dowe Groups.

The Aquifer Units are displayed as grey ornament on the map. A symbol/code in black representing the approximate age of the Formation, (first letter of the Erathem for example: 'M' for Mokolian or 'V' for Vaalian). Erathem was used up to the end of Namibian where after System was used. Hereafter the code/symbol is completed by the adding of two and/or three letters (author's choice) and displayed in black. The choice of the code/symbol to be used was also influenced by codes/symbols allocated to adjacent map sheets as these maps will form a unit.

It was found that the adjacent geological maps do not always match/line up, in terms of polygons, colour, or codes/symbols. This is due to the mapping being executed by many different authors and at different completion dates. This is especially true for the Thabazimbi (1973) and Ellisras (1996) geological map sheets. With the geohydrological map sheets however, the methodology followed was as such to avoid incompatible codes/symbols and polygons thus enabling a smooth fit when these maps are joined. These lithological units were then grouped together based on the expected groundwater occurrence viz. **Intergranular (a), Fractured (b), Karst (c), and Intergranular and Fractured (d).**

The borehole yield data available on the National Groundwater Archive represents data from different populations which are non-uniformly distributed in space and which are heavily skewed in a positive direction. Because of this, the median yield was recommended as a suitable measure of centrality rather than the average. The median was also found to be a reasonable discriminator between hydrogeological regions and was easy to compute and interpret as a "typical" yield of a region. To provide sufficient resolution of the data to permit visual portrayal in a distinguishable manner, the borehole yield data is classified according to six groupings for each of the four classes of mode of groundwater occurrence. The six borehole-yield-groupings have been selected in such a way as to provide physical meaning to the value of the borehole both in terms of the concomitant abstraction equipment and as a provider of water for a particular end water user.

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, 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.

If major existing and/or licensed groundwater abstraction points equal or higher than 100 000m<sup>3</sup>/annum occurs anywhere on the map it is shown as a filled red circle of various sizes that correspond to the estimated/reported annual volume of abstraction. Springs, thermal springs, artesian conditions, automatic water level recorders and monitoring points are shown in pink (filled circle), orange (empty circle), pink (empty circle), purple (open triangle), and purple (triangle with a dot) respectively.

Extensive use was made of the Geographic Information System (GIS), which allowed for cartographic compilation, data display, and manipulation.

### 2.2.1 : Inset maps:

The following inset maps have been included on the Polokwane Hydrogeological map sheet 2328:

An **east-west or north-south hydrogeological cross-section**, based on limited geological information and the author's own interpretation of the available information. The cross-section displays the third dimension and regional hydrogeological relationships discussed on the map. The static water level is included to show its relationship with surface topography.

**Distribution of borehole data:** A 1: 1 000 000 scale map to represent available groundwater source information distribution. The yellow colour represents no data points, light pink represents one data point, light blue 2-10 data points, violet 11-20 data points and the purple represent more than 20 data points.

**Elevation above sea level:** a 1: 1 000 000 scale, contour intervals relevant to the map at 200m. The elevation in the map area varies between 400-2000mamsl.

**Mean annual precipitation:** a 1: 1 000 000 scale, contour intervals at 100 to 200mm/a. The rainfall in the area varies from approximately 300 to just over a 1000mm/a.

**Groundwater quality map:** a 1:250 000 scale map has been compiled and depicted in the brochure. It represents contoured Electrical conductivity data, (a measure of salinity), the position of sampling points and an indication of problematic chemical species viz. Nitrate (concentration >10mg/l) and Fluoride (concentration >1.5mg/l). The EC intervals as well as the Nitrate and Fluoride values shown are based on the prescribed guidelines for human and livestock water consumption.

### 2.2.2 : Brochure:

The purpose of the explanatory brochure is to give information on the methodology followed in compiling the map, to highlight important groundwater topics, and to discuss groundwater occurrences in more detail as that could be depicted on the map. The objective is also to include relevant aspects for the aquifer units from the most recent research and/or findings from available groundwater reports. Groundwater occurrence is very heterogeneous in South Africa while the mapping standards, legend, etc. demanded a high degree of conformity. Aspects of groundwater that are important, which could not be shown on the map, will vary dramatically from area to area and the brochure provides opportunities to reflect this variability. Included in the brochure are frequency diagrams on borehole yields per aquifer and trilinear Piper and Durov diagrams giving information on groundwater chemistry for the various aquifer units appearing on the map. These should be considered as guideline values, especially for the groundwater resource units with low volumes of data available, as the accuracy of the findings is a function of available data and the quality of the data.

## 3. HYDROGEOLOGICAL CLASSIFICATION

The international UNESCO classification for hydrogeological maps (UNESCO 1983) was adapted to suit South African hydrogeological conditions and groundwater occurrences. The UNESCO classification distinguishes the occurrence of groundwater only according to the primary or secondary nature of interstices. Table 2 depicts the adapted hydrogeological classification used for the Polokwane map sheet according to the origin and nature of the saturated interstices combined with subdivisions based on existing known blow yields (after Orpen, 1994).

Four modes of groundwater occurrences based on the dominant porosity type are depicted on the 1:500 000 (original) and 1:250 000 (upgraded) hydrogeological map series.

- Intergranular (a),
- Fractured (b),
- Karst (c),
- Intergranular-and-Fractured (d)

Where two modes of groundwater occurrences occur at the same site such as along the Sand River, it is depicted as a two-layered aquifer (a/d) i.e. the upper aquifer being intergranular (a) and the bottom aquifer intergranular and fractured (d). Depending on the specifics it is portrayed in the colours of the occurrence.

The definition of the productivity ranges has been left by the UNESCO authors for the local map authors to define. Considering local conditions and equipment options for production boreholes, six sub-divisions were defined. On the Polokwane map sheet and in Table 2 of the brochure, the classes are represented by colours and the yield subdivisions by the tone of the respective colour. The subsurface lithology is presented by lithological ornaments and chronostratigraphy by alphabetical symbols. Production ranges are defined as follows:

- Very high borehole yields, generally greater than  $>10\ell/s$ . Can be used for large scale urban and rural water supply, industry, or large-scale irrigation, (568 boreholes on the map).
- High borehole yields, generally greater than  $5\ell/s$  to  $10\ell/s$ . Can be used for urban and rural water supply, industry, or large-scale irrigation, (745 boreholes on the map).
- Moderate borehole yields generally,  $2\ell/s$  to  $5\ell/s$ . It can be used for urban and rural water supply to small towns, industry, or small-scale irrigation, (1240 boreholes on the map).
- Low borehole yields generally,  $0.5\ell/s$  to  $2\ell/s$ . Can be used for domestic and livestock watering supply to rural settlements, hospitals and health centres or small-scale irrigation at community vegetable gardens, (1778 boreholes on the map).
- Very low borehole yields generally  $0.1\ell/s$  to  $0.5\ell/s$ . Can be used for domestic supply to single homesteads, schools, police stations, clinics, small rural villages (250 persons) or livestock watering. Boreholes in this group are mostly equipped with hand, submersible or wind pumps, (1279 boreholes on the map).
- Un-economical boreholes with yields generally  $< 0.1\ell/s$ . Non-reticulated water supply for isolated households or for monitoring in certain cases. Suitability depends on factors such as construction, objective of monitoring, location, and geological setting, (691 boreholes on the map).

Table 2: 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 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, vertically 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	5-10		b5	High	5-10		c5	High	5-10		d5	High	5-1					
a6	Very high	>10		b6	Very high	>10		c6	Very high	>10		d6	Very high	>10					
<p>Alluvial deposits of limited extent along river terraces consisting of transported material such as sand and gravel. Weathered crystalline rock with the principal 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 include dolomite and 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							

## 4. PHYSICAL ENVIRONMENT

### 4.1 General

The 1:250 000 Polokwane hydrogeological map sheet which is bounded by latitudes 23°S and 24°S and longitudes 28°E and 30°E, covers an area of approximately 22 568.51km<sup>2</sup>.

The map area covers sections of four District Municipalities with various Local Municipalities falling within the Districts viz. Waterberg District, (consisting of sections of the Lephalale and Mogalakwena Local Municipalities); Capricorn District, (consisting of Aganang and sections of Lepelle-Nkumpi, Blouberg, Molemole and Polokwane Local Municipalities); Vhembe District, (consisting of a section of the Louis Trichardt Local Municipality) and Mopani District, (consisting of a section of the Greater Tzaneen and Greater Letaba Local Municipalities).

A large number of formal, informal, rural settlements and towns are found within the map area. The population for 2025 was estimated at 1,89M using the population figures given by DWS in each of the Regional Water Schemes with a 1.8% yearly increase.

#### Waterberg District, Lephalale Local Municipality:

The section of the Lephalale Local Municipality is predominantly the rural villages and farming areas. Water supply is predominantly from boreholes but along the Lephalala River sand points are used to abstract surface water. High yielding boreholes related to fault zones supply some of the regional water schemes especially Tom Burke, Mmaletswai and Witpoort.

Table 3: Water Resources within the Waterberg District, Lephalale Local Municipality.

Water scheme Name	Water Scheme number	Settlement or settlements	Settlement type	Estimated population 2025	Scheme description	Water sources
Marnitz Supply	LEP0/1	Marnitz	Rural Scattered	243	Internal Bulk	Groundwater
Tom Burke Supply	LEP0/2	Tom Burke	Urban - Formal Town	296	Internal Bulk	Groundwater
Lephalale LM Farms Supply	LepFS	Farms Lephalale LM	Farming	22721	Internal Bulk	Groundwater
Mmaletswai RWS	NW100	Dipomponong, Ditaung, Ga-Maeteletsa, Ga-Mocheko, Hlagalakwena, Keletse le Mma, Kiti, Mmaletswai, Mokuruanyane Abbottspoor, Motswedding, Reabetswe, Mokuruanyane Martinique,	Rural - Small Village <= 5000	21060	Internal Bulk	Groundwater and surface water (sandpoints), Lephalala River
Witpoort RWS	NW114	Botsalanong, Kgobagodimo, Kopanong, Lepurupurung, Segale, Senoela, Thabo Mbeki, Tiapa le Borethe, Witpoort CBD, Mongalo,	Rural - Small Village <= 5000 & Urban - Former Township	16227	Internal Bulk	Groundwater and surface water (sandpoints), Lephalala River
Ga-Seleka RWS	NW115	Botshabelo, Madibaneng, Sefithlogo, Moong, Morwe,	Rural - Small Village <= 5000, Rural Scattered	9028	Internal Bulk	Groundwater and surface water (sandpoints), Lephalala River
				69575		

Note: The sources of information are the DWS water schemes shape file and the IDP 2024-2025 document of Lephalala Municipality; the population growth was estimated at 1.8% per year.

#### Waterberg District, Mogalakwena Local Municipality:

The Mogalakwena Municipality Quality of Life Study indicates that 79% of people in traditional areas and 18% of people in informal settlements have access only to basic pit latrines. Water supply includes surface water from Doordraai Dam (7-8MI/day), Uitloop groundwater resources (0.5MI/day), Weenen/Planknek dolomite aquifer (4MI/day), Moorddrift Borehole (0.5MI/day) and various rural boreholes (4-12MI/day), (IDP, 2024-2025 Mogalakwena Local Municipality).

The potential of 'rural boreholes' for the municipal area is more than stated in the IDP document as 4-12MI/day. This volume excludes the potential of the well fields at Uitloop, Weenen and Moorddrift. In 2011 WSM Leshika developed well fields and boreholes in the functional area (areas near Mokopane town) for the Mogalakwena Groundwater Master Plan and in 2014-2017 WSM Leshika and VSA Rebotile Metsi developed and verified groundwater sources. For the functional area a confirmed and potential yield of 13.5MI/day was reported and for the area north of the functional area a potential and confirmed yield of 21.4MI/day was reported. A large section of the Municipal area is underlain by farming and rural areas and rural villages. Platinum Group Minerals are mined in the municipal area which supports large industries and economic activities in Mokopane. Large stone quarries are found in the Granitic areas near Bakenberg.

Table 4: Water resources within Waterberg District, Mogalakwena Local Municipality.

Water scheme Name	Water Scheme number	Settlement or settlements	Settlement or settlements type	Estimated population 2025	Scheme description	Water sources
Glen Alpine RWS	CBGA/NC12	Mattanau, Galakwena, Ga-Tlhako, Breda, Duren, Lennes, Monte Christo, Preezberg, Rebone, Setuphulane, Sodoma, Sterkwater, Thabaleshoba, Tipeng, Uitzicht, Polen, Khala, Taueatswala,	Rural - Small Village <= 5000, Rural Scattered	27253	Internal Bulk	Along Mogalakwena River Groundwater and surface water (sandpoints) other only
Biesjeskraal WS	MOG01	Biesjeskraal	Rural Scattered	95	Internal Bulk	Groundwater
Daggakraal WS	MOG02	Daggakraal	Rural Scattered Low Density	89	Internal Bulk	Groundwater
Rebone RWS	NW1	Dipere, Ga-Chere, Galelia, Ga-Monare, Ga-Mushi, Ga-Nong, Grasvlei, Ham 1, Hlogoyanku, Lekhureng, Makobe, Mathekga, Moshuka, Nkidikitlana, Rapadi, Senita, Tennerif, Tiberius, Vergenoeg, Vianna, Matjijileng,	Rural - Small Village <= 5000	40569	Internal Bulk	Along Mogalakwena River Groundwater and surface water (sandpoints) other only groundwater
Bakenberg RWS	NW2	Masipa, Sepharane, Skilpadskraal, Skrikfontein A, Bakenberg Basogadi, Bakenberg Kwanaite, Bakenberg Matlaba, Bakenberg Mautjana, Bakenberg Mmotong, Bakenberg Mothwathwase, Claremont, Dikgokgopeng, Good Hope, Harmansdal, Jakkalskuil, Kabeane, Kaditshwene, Kgopeng, Kromkloof, Lesodi, Leyden, Lusaka Ngoru, Mabaladihlare 1, Makekeng, Malapila, Nelly, Paulos, Pudiyaagopa, Raadslid, Ramosesane, Rantlakane, Skrikfontein B, Taolome, Van Wykspan, Vlakfontein, Vlakfontein 2, Wydhoek, Good Hope East, Mphelelo, Mabula, Elensfontein, Mamatlakala, Marulaneng, Matebeleng,	Rural Scattered, Rural - Small Village <= 5000, Rural - Dense Village > 5000,	72829	Internal Bulk	Along Mogalakwena River Groundwater and surface water (sandpoints) other only groundwater
Ga-Pahladira RWS	NW5	Ga-Pahladira	Rural - Small Village <= 5000	3470	Internal Bulk	Groundwater
Mapela RWS	NW3	Ditlotswane, Mohlotlo Ga-Puka, Mohlotlo Ga-Sekhaolelo, Hans, Skimming, Ga-Molekana, Ga-Tshaba, Kwakwalata, Maala Parekisi, Mabuella, Mabusela, Masoge, Matopa, Mesopotania, Mmahlogo, Phafola, Ramorulane, Rooiwal, Sekuruwe, Witrivier,	Rural - Small Village <= 5000	49908	Internal Bulk	Along Mogalakwena River Groundwater and surface water (sandpoints) other only groundwater
Marken Supply	NW0/2	Marken	Urban - Formal Town	334	Internal Bulk	Groundwater
Uitspan Supply	NW0/3	Uitspan	Rural - Small Village <= 5000	893	Internal Bulk	Groundwater
				195440		

Note: The sources of information are the DWS water schemes shape file and the Mogalakwena Groundwater Master plan.

#### Capricorn District, Aganang Local Municipality:

The total area of the Aganang Local Municipality falls within the map sheet boundary; it is a rural area with 105 villages. Some of the regional water systems overlap with the Polokwane Local Municipality and are therefore managed by Polokwane Local Municipality. The economic activities that take place within the Municipality are mainly agriculture and Community based projects initiatives. Aganang Municipality is neither a water service authority nor a water provider. This task is managed by the Capricorn district municipality. Sanitation includes pit latrines, flush toilets connected to septic tanks or sewer systems. The District municipality is installing VIP latrines on a yearly basis. All the villages receive free basic water through provision of diesel and oil and payment of electricity bills for boreholes with electric pumps, (IDP 2116-2017, Aganang Local Municipality).

*Table 5: Water Resources in Capricorn District, Aganang Local Municipality.*

Water scheme Name	Water Scheme number	Settlement or settlements	Settlement or settlements type	Estimated population 2025	Scheme description	Water sources
Aganang LM Farms Supply	AgaFS	Farms	Rural-Farming	349	Rural	Groundwater
Ga Mokobodi GWS	CAGM/N C3	Mesehleng 2, Ga-Mabitsela, Leokaneng, Ga-Ramakadi-Kadi, Tibana, Hwibi, Goedgevonden, Moetagare, Ga-Phaka, Schoongelegen, Juno, Ga-Lepadima, Ga-Mokobodi, Ga-Ramotlokana, Mamehlabe, Pinkie, Ngwanallela, Rozenkranz,	Rural - Small Village <= 5000, Rural Scattered Very Low Density	35968	Internal Bulk	Groundwater
Aganang North GWS	CAGN/N C12	Ga-Moropa, Sekuruwe 2, Ga-Kolopo, Ga-Phagodi, Ga-Mankgodi B, Ga-Mankgodi A, Terbrugge A, Manyelo, Marowe, Modderput, Ga-Maribana, Ga-Mosehlong, Kanana, Mohlajeng, Ga-Mantlhodi, Ga-Motlakgomo, Uitkyk 1, Terbrugge B,	Rural Scattered Very Low Density, Rural - Small Village <= 5000	22425	Internal Bulk	Groundwater
				58742		

Note: The sources of information the DWS water schemes shape file and the Polokwane Groundwater Master plan; the population growth was estimated at 1.8% per year.

#### Capricorn District, Lepelle-Nkumpi Local Municipality:

*Table 6: Water Resources in Capricorn District, Nkumpi Local Municipality.*

Water scheme Name	Water Scheme number	Settlement or settlements	Settlement or settlements type	Estimated population 2025	Scheme description	Water sources
Lepelle-Nkumpi LM Farms Supply	LpNFS	Farms Lepelle Nkumpi LM	Farming	1275	Individual	Groundwater
				1275		

Note: The source of the information is the DWS water schemes shape file; the population growth was estimated at 1.8% per year.

#### Capricorn District, Blouberg Local Municipality:

Blouberg Municipality serves as a Water Services Provider (WSP) responsible for the function of operations and maintenance for water infrastructure with a budget allocated by the Water Services Authority (WSA) being the Capricorn District Municipality (CDM). The municipality is dependent on groundwater resources as there are no dams supplying bulk surface water. Currently 72% of the households within the Blouberg municipal area have access to water at the level of RDP standard. The municipality, together with the district municipality, provides free basic water and free water to its households in the form of free diesel supply and payment of electricity supply from ESKOM for the supply of connections to boreholes. There is a need to augment water supply from other sources such as the Glen-Alpine Dam. The WSA has indicated that there are positive prospects of securing supply from the Glen-Alpine Dam as the Department of Water Affairs (DWA) did a feasibility study, also aiming at securing a license transfer from agricultural to domestic use for the source. The bulk capacity at areas already supplied to RDP standard will be increased should the project be successful. Another source of supply is the Glenferness (Blouberg) Dam, which already has infrastructure that needs to be upgraded as it has now aged. The Glenferness (Blouberg) Dam previously supplied water to a reasonable portion of the Blouberg municipal area. About 65 percent of the population in Blouberg is without access to proper sanitation facilities. There are two types of sanitation services provided to the communities in the Municipality, namely dry sanitation (VIP toilets) and waterborne sewerage. The VIP toilets are provided in the rural communities and sewerage services are provided in towns such as Senwabarwana and Alldays. It will soon be provided in the new settlement at Tolwe, (IDP 2023-2024, Blouberg Local Municipality).

Table 7: Water resources in the Capricorn District, Blouberg Local Municipality.

Water scheme Name	Water Scheme number	Settlement or settlements	Settlement or settlements type	Estimated population 2025	Scheme description	Water sources
Vivo Supply	CAGV	Vivo	Rural Scattered Very Low Density	72	Internal bulk	Groundwater
Archibald GWS	CBARCH/NC12	Genua, Letswatla, Borwalathoto,	Rural - Small Village <= 5000 Rural - Small Village <= 5000	5997	Internal bulk	Groundwater
Avon GWS	CBAV	Puraspan, Avon, Dantzig 2, Bul Bul, Ga-Kibi, Innes, Indermark, Sewale North,	Rural - Small Village <= 5000, Rural - Dense Village > 5000, Rural Scattered Very Low Density,	31821	Internal bulk	Groundwater
Baltimore Supply	CBB0/1	Baltimore	Rural Scattered Very Low Density	63	Internal bulk	Groundwater
Dalmeny Local WS	CBDAL	Dalmeny	Rural Scattered Very Low Density	44	Internal bulk	Groundwater
Blouberg RWS	CBB/NC11	Ga-Rammutla 1, Schroelen, Tswatsane, Pickum 1, Ga-Mamolele, Schroelen 2, Ga-Motshemi, Ga-Mmatemana, Mophamamana, Ditatsu, Ga-Rammutla 2, Ga-Tefu, Matshira, Pickum 2, Ga-Mamohwibidu, Blouberg, Dantzig 1, Ga-Tshabalala, Sewale South,	Rural - Small Village <= 5000, Rural - Small Village <= 5000	26287	Internal bulk	Groundwater
Ga Hlako RWS	CBGH/NC12	Mokumuru, Ga-Mokopane, Ga-Maselela, Gamakgwata, Ga-Mabeba, Werden, Bodie, Manye, Dithabaneng, Mongalo, Udney 1, Ga-Maboth, Ga-Malokela, Kwaring, Sesalong, Ga-Mampote, Ga-Hlako, Miltonduff 1, Brodie Hill, Kobe, Kutumpa, Manye extension,	Rural - Small Village <= 5000 Rural Scattered Very Low Density	37448	Internal bulk	Groundwater
Gorkum GWS	CBGor/NC11/NC12	Berg-en-Dal, Ga-Mamoleka, Gorkum, Varedig, Sekhung, Morotsi,	Rural - Small Village <= 5001	49695	Internal bulk	Groundwater
Ga Rawesi GWS	CBGR/NC12	Uitkyk 2, Mesehleng 1, Aurora, Lekiting, Ga-Letswalo, Ga-Masekwa, Setlaole, Rotlokwa, Nonono, Murasie, Kgokonyane, Ga-Rawesi, Mokudung, Ga-Ngwepe, Schoongezicht,	Rural Scattered Very Low Density, Rural - Small Village <= 5000	11182	Internal bulk	Groundwater
Silwermyrn / Kirstenspruit GWS	CBS/K/NC12	Kirstenspruit, De La Roche, Non-Parella, De Villiersdale 1, Mons, Swarts, Thabanantlhana, De Villiersdale, De Villiersdale 2, Driekoppies, Nieuwe Jerusalem, Ga-Ntshireletsa, Silwermyrn, Papegaai, Ga-Mankgodi, Vergelegen, Grootdraai, Madibeng, Sebotlana,	Rural - Small Village <= 5000, Rural Scattered Very Low Density	17920	Internal bulk	Groundwater
Senwabarwana GWS	CBS/NC11	Bochem NorthWittenGa-MashalaneCumbrae (Senwabarwana)BorkumBochumBochem	Rural - Small Village <= 5000, Rural - Dense Village > 5000, Rural Scattered Very Low Density, Urban - Formal Town,	21491	Internal bulk	Groundwater
Taaiboschgroet GWS	CBT/NN17	BurgerregtThe GlenGlenfernessThe Grange	Rural - Small Village <= 5001	5769	Internal bulk	Groundwater
Thalahane GWS	CBTHA/NC11	Kgatalala, Thalahane,	Rural Scattered Very Low Density, Rural - Small Village <= 5000	3439	Internal bulk	Groundwater

211229

Note: The source of information is the DWS water schemes shape file; population growth was estimated at 1.8% per year.

### Capricorn District, Molemole Local Municipality:

Molemole municipality is a water services provider, and the Capricorn District Municipality is responsible for the provision of Sanitation services. Sanitation in this area is predominantly pit latrines; a small percentage is flush toilets installed by higher income individuals in the rural villages that connect to a seepage drain system. In Mogwadi 44% of the households have flush toilets. Water supply is from the District Municipality for some of the areas, but most of the water is from boreholes located within or around the villages. Shortages are experienced and between 5-10% of the people in the municipal area are supplied by water tankers, (IDP, 2024-2025, Molemole Local Municipality).

Table 8: Water resources in the Capricorn District, Molemole Local Municipality.

Water scheme Name	Water Scheme number	Settlement or settlements	Settlement or settlements type	Estimated population 2025	Scheme description	Water sources
Makgalong A & B GWS	CMMAKG	Makgalong A, Makgalong B,	Rural Scattered Very Low Density	554	Internal bulk	Groundwater
Botlokwa GWS	CMBOT	Ga-Phasha, St Brendans Mission School, Sekakene, Mangata, Mphakane, Ramatjowe, Ramatshowe, Matseke, Makgato,	Rural - Small Village <= 5000, Working Towns and Service Centres - Mines, Prisons etc, Rural - Small Village <= 5000, Rural - Dense Village > 5000,	53164	Internal bulk	Groundwater
Mogwadi / Wurthsdorp GWS	CMMW01	Wurthsdorp, Koniggratz, Fatima, Mohodi, Ga-Madikana, Mogwadi,	Rural - Dense Village > 5000, Rural - Small Village <= 5000, Urban - Formal Town,	33122	Internal bulk	Groundwater
Molemole West Individual GWS	CMMW02	Ga-Poopedi, Ga-Mokwele, Ga-Sako, Ga-Kgare, Koekoek, Ga-Mokgehle, Brussels, Sakoleng, Schoonveld 1, Reinland, Bouwlust, Schellenberg A, Schellenberg B, Ga-Broekmane, Ga-Moleele, Overdijk West, Brilliant, Schoonveld 2,	Rural Scattered Very Low Density, Rural - Small Village <= 5000	10947	Internal bulk	Groundwater
Nthabiseng GWS	CMN	Capricorn Park LCH, Nthabiseng, Morebeng,	Rural - Small Village <= 5000, Urban - Formal Town	97233	Internal bulk	Groundwater
Ramakgopa GWS	CMR	Ramakgopa, Eisleben, Mokganya,	Rural - Dense Village > 5000, Rural Scattered Very Low Density	30209	Internal bulk	Groundwater
Rietgat GWS	CMRIET	Rietgat (ZZZ)	Rural Scattered Very Low Density	295	Internal bulk	Groundwater
Molemole LM Farms Supply	MoLFS	Farms Molemole LM	Farming	8577	Internal bulk	Groundwater
				234101		

Note: The source of information is the DWS water schemes shape file; population growth was estimated at 1.8% per year.

### Capricorn District, Polokwane Local Municipality:

Polokwane Municipality is a Water Service Authority (WSA), and a Water Service Provider (WSP). Every Water Service Authority has a duty to all customers or potential customers in its area of jurisdiction to progressively ensure efficient, affordable, economical and sustainable access to Water Services [Water Services Act of 1997 Section 11]. Thus, a Water Service Authority has the duty to provide water services with the focus on: Ensure, Efficient, Affordable, Economical and Sustainable deliverables. The Polokwane Municipal area is divided into 16 Regional Water Supply Schemes of which 14 fall within the map area. The average daily supply is 99.6MI/day peaking at 163MI/day with a supply capacity of 122.33MI/day. In total 60% of the demand is met from sources outside the municipal boundary. Free basic water totaling 6kl/month is provided to all the rural water schemes and to registered indigent people within the city (IDP/document/2024-2025).

Table 9: Water resources in the Capricorn District, Polokwane Local Municipality.

Water scheme Name	Water Scheme number	Settlement or settlements	Settlement or settlements type	Estimated population 2025	Scheme description	Water sources
Badimong RWS	CPBAD	Unknown, Melkboom, Ga-Kgole, Badimong, Ga-Silwane, Mashongolile, Bergvley, Katzenstern, Ga-Mamphaka, Mongwaneng, Thune, Moshate, Kgatla, Thema, Ga-Mailula, Kgware, Masealama, Leswane, Tsware, Ga-Moropo, Thabakgone, Ga-Mahlanthe, Monywaneng, Viking, Komaneng, Matshela-Pata,	Rural - Small Village <= 5000, Rural Scattered Very Low Density, Rural - Dense Village > 5000,	48446	Internal bulk	Groundwater & surface water, (Ebenezer)
Boyne RWS	CPBOY	Makgopeng, Magokubung, Subiaco, Mankgaile, Makgeng, River View, Boyne, Zion City Moria, Mountain View, Tholongwe, Viking, St Engena's ZCC,	Rural Scattered Very Low Density Rural - Small Village <= 5000	9973	Internal bulk	Groundwater & surface water, (Ebenezer)
Houtrivier RWS	CPH/NP44	Komape 1, Mamadila, Ramagaphota, Komape 2, Moshate, Madikote, Komape 3, Mabuकेले, Koloti, Koloti Extension,	Rural Scattered Very Low Density, Rural - Small Village <= 5000	29304	Internal bulk	Groundwater & surface water, (Houtrivier Dam)
Houtrivier RWS (Aganang area)	CPH/NP44	Helena, Ga-Setshaba, Kalkspruit 1, Magongoa, Vlaklaagte, Christiana, Waschbank, Ga-Kgoroshi,	Rural - Small Village <= 5000, Rural Scattered Very Low Density	13037	Internal Bulk	Groundwater & surface water, (Houtrivier Dam)
Laaste Hoop RWS	CPLH	Maboi, Laaste Hoop Ward 7A, Manthorwane Extension, Manthorwane, Laaste Hoop Ward 7,	Rural - Small Village <= 5001	13473	Internal bulk	Groundwater & surface water, (Ebenezer Dam)
Mankweng RWS	CPMAN	Tsatsaneng, Moshate, Ga-Thoka, Mankweng B, Makgwareng, Mankweng B, Mankweng Unit F, Mankweng C, Mankweng D, Phomolong, Ga-Ramogale, Ga-Magowa, Ga-Makanye, University of the North, Mankweng Unit E, Mankweng A, Mankweng Unit G,	Rural - Small Village <= 5000, Rural - Dense Village > 5000, Urban - Formal Town, Urban - Former Township,	81554	Internal bulk	Groundwater & surface water, (Ebenezer Dam)
Moletje East GWS	CPME/NP110	Kobo, Chokoe, Setati, Mabitsela, Mashita, Matikireng, Mashita, Mabotsa 1, Ga-Mabotsa, Matamanyane, Hlahla, Makibelo, Semanya, Ramongwane 1, Makgodu Ext, Ramongwane 2, Mabotsa 2, Masobohlang,	Rural - Small Village <= 5000, Rural Scattered Low Density, Rural - Dense Village > 5000,	47734	Internal bulk	Groundwater
Moletje North GWS	CPMN/NPO44	Ditengteng, Mahwibitswane, Kgorosi (Thansa), Kgoroshi (Mphela), Manamela, Kgoroshi,	Rural - Small Village <= 5000	8315	Internal bulk	Groundwater
Molepo RWS	CPMOL	Ga-Molalemane, Leggadimane, Mamatsha, Ga-Ramphere,	Rural Scattered Very Low Density, Rural - Small Village <= 5000	8477	Internal bulk	Groundwater & surface water, (Molepo Dam)

260312

Water scheme Name	Water Scheme number	Settlement or settlements	Settlement or settlements type	Estimated population 2025	Scheme description	Water sources
Mothapo RWS	CPMOT	Makotopong 2, Makotopong 1, Cottage, Ntshichane, Ga-Mothiba, Nobody-Mothapo, Nobody-Mothiba,	Rural - Dense Village > 5000, Rural - Small Village <= 5000	41382	Internal bulk	Groundwater & surface water, (Ebenezer Dam)
Moletje South GWS	CPMS/NC8	Ga-Mapangula, Newlands, Ga-Mapangula, Doornspruit, Ga-Mapangula Ext, Setotlwane High School, Pax College, Vaalkop 1, Vaalkop 2, Lefahla, Doornspruit Ext, Sengatane, Makweya, Chebeng,	Rural - Small Village <= 5000, Working Towns and Service Centres - Mines, Prisons etc, Rural Scattered Very Low Density	15954	Internal bulk	Groundwater & surface water, [Mashashane (Ujiane) Dam]
Moletje South GWS (Aganang area)	CPMS/NC8	Ga-Matlapa, Segoahleng, Ga-Kgasha, Ngopane, Moshate, Sebor, Ujiane, Ga-Madiba, Glen Roy, Ga-Mangou, Mohlonong, Monotwane 2, Monotwane 1, Waterplaats, Diana, Jupiter, Sepanapudi, Sefahlane, Venus, Naledi, Mandela Park, Matlaleng, Maune, Boetse, Mapateng,	Rural - Small Village <= 5000, Rural Scattered Very Low Density	38988	Internal Bulk	Groundwater & surface water, [Mashashane (Ujiane) Dam]
Olifantspoort-Sand RWS	CPOS	New Pietersburg, Toska Mashini, Mokgokong, Mabotsa, Makgove, Kgohlwane, Perskebut Ext 2, Polokwane - Palmietfontein S/H C, Polokwane, New Pietersburg, Polokwane - Doornbult S/H, Blood River Extension, Perskebut, Polokwane - Mooifontein S/H, Polokwane - Palmietfontein S/H A, Blood River, Polokwane - Leeuikuil S/H, Polokwane - Elmadal S/H, Polokwane - Roodepoort S/H, Polokwane - SDA3, Polokwane - Myngenoegen S/H, Polokwane - Dalmada S/H, Polokwane - Geluk S/H, Polokwane - Ivydale Agricultural Holdings, Montinti Park, Seshego, Zone 6, Perskebut Ext 1, Polokwane - Palmietfontein S/H B, Makgove Extension, Thakgalang, Jansen Park/Sterkloop,	Urban - Former Township, Rural - Small Village <= 5000, Rural Scattered, Rural Scattered Very Low Density, Rural - Dense Village > 5000, Farming, Metropolitan Area, Rural Scattered Dense,	409021	Internal bulk	Groundwater (Seshego borehole field) & surface water, (Olifants sand) (Ebenezer, Seshego, Dab Naude Dams)
Sebayeng-Dikgale RWS	CPS/D	Mantheding, Ga-Mokgopo, Madiga, Moduwane, Sebayeng A, Sebayeng B, Kgwareng, Dikgale 1, Mphalong, Sefateng, Dikgale 2, Ga-Maphoto, Mankweng Hospital, Makgoba 1, Makgoba 2, Mehlakong, Masekwatse, Sentserere, Toronto Zondo, Mnashemong, Makgwareng, Lenyeny, Makengkeng, Dikgale 3, Dibibe, Ga-Kololo, Masekho, Ga-Mawashasha, Ga-Moswedi, Ga-Kama, Ga-Motholo, Mamotintane, Masekoleng, Mankweng Unit G Ext, Ga-Potse, Kgokong, Lebowa,	Rural - Small Village <= 5000, Rural Scattered Very Low Density, Rural - Dense Village > 5000, Urban - Former Township,	76908	Internal bulk	Groundwater & surface water, (Ebenezer, Olifants, Dab Naude Dams)
Segwasi RWS	CPSEG	Jack, Ga-Rakopi, Segwasi, Losmycherry, Mohlakeng,	Rural Scattered Very Low Density, Rural - Small Village <= 5000, Rural Scattered Dense,	4776	Internal bulk	Groundwater & surface water, (Ebenezer Dam)
Bakone GWS (Aganang area)	CAGBAK/NC3	Ga-Ramakara, Phetole, Madietane, Phofu, Dibeng, Semaneng, Ga-Selolo, Bakone, Manamela 2, Maineleng, Ntlotane 2, Mpone Ntlotane 1, Mpone Ntlotane 3, Boratapelo, Nokayamatlala, Ramalapa 1, Taung,	Rural - Small Village <= 5000	36054	Internal Bulk	groundwater
Aganang East GWS (Aganang area)	CAGE/NC3	Damplaats, Eerste geluk, Chloe A, Rampuru, Chloe B, Kgabo Park, Ga-Ramoshwane, Ga-Nonyane, Preezburg, Ramatlwane, Ga-Modikana, Ga-Piet, Ga-Rankhuwe, Wachtkraal, Kaalspruit 1, Vischkuil, Ga-Mmabasotho, Rapitsi, Ga-Phago, Lehlohlong,	Rural - Small Village <= 5000, Rural Scattered Very Low Density	35149	Internal Bulk	groundwater

658232

Note: The sources of information the DWS water schemes shape file and the Polokwane, IDP/document/2024=2025, the population growth was estimated at 1.8% per year.

### Vhembe District, Makhado Local Municipality:

Louis Trichardt is supplied by surface water from the Albasini Dam and various groundwater sources within the town. Water from the Nandoni Dam will be used in future to supply Louis Trichardt and surrounding villages with water. Currently most of the villages rely on groundwater. Spring is known to supply water to Buysdorp.

Table 10: Water resources in the Vhembe District, Makhado Local Municipality.

Water scheme Name	Water Scheme number	Settlement or settlements	Settlement or settlements type	Estimated population 2025	Scheme description	Water sources
Sinthumule / Kutama RWS	NN16	Ravele, Ramahantsha, Gogobole, Mutavhanoni, Raliphaswa, Ha-Magau, Zamenkom, Ha-Manavhela, Siyawoadza, Tshikwarani B, Raphulu, Vulabadzhi B, Thembaluvhilo, Dzumbathoho, Muduluni, Dzumbathoho, Tshikwarane, Tshikhodobo, Diiteleni, Midoroni, Maebane, Makhitha, Madaheni, Muraleni Block B, Muraleni Block C, Diiteleni, Lufukula, Ha-Madodonga, Ha-Mamburu, Madabani, Madombidza Zone 1, Rathidili, Madombidza Zone 2, Tshiozwi, Madombidza Zone 3,	Rural - Dense Village > 5000, Rural - Small Village <= 5000, Rural Scattered, Rural Scattered Very Low Density, Rural - Dense Village > 5000,	92148	Internal bulk	Groundwater
Alexandra Scheme	NN1	Alexandra	Rural Scattered Low Density	247	Internal bulk	Groundwater
Bandelierkop Supply	NN0/1	Bandelierkop	Urban - Former Township	93	Internal bulk	Groundwater
Tshitale RWS	NL10	Kwaaidraai, Donkerhoek, Mulima, Phelandavha, Mpofo, Thothololo, Vlakvillage, Sedzaufhire, Magobo, Ha-Matala, Ha-Mathule, Nthabalala, Masete, Mulima, Thembisa, Muila, Ha-Mamphagi, Madzedzeni, Tshifhefhe, Mulima Vuka, Muila,	Rural - Small Village <= 5000, Rural Scattered Very Low Density, Rural Scattered,	21586	Internal bulk	Groundwater
Makhado Air Force Base Supply	NN0/2	Makhado Air Force Base	Working Towns and Service Centres	1307	Internal bulk	Groundwater
Elim / Vleifontein RWS WS	NN22	Maila Ext, Vleifontein, Maila, Mundzhezdi,	Rural Scattered Very Low Density, Urban - Former Township, Rural - Dense Village > 5000, Rural - Small Village <= 5000,	16479	Internal bulk	Groundwater
Buysdorp Scheme	NN3	Buysdorp, Thalane	Rural - Small Village <= 5000, Rural Scattered Very Low Density,	1692	Internal bulk	Groundwater, fountain
Makhado RWS	NN5	MakhadoTshikotaTshikota Squatter	Urban - Formal Town, Urban - Former Township, Urban - Informal Settlements (Squatter Camp),	28440	Internal bulk	Groundwater
				161991		

Note: The sources of information the DWS water schemes shape file; the population growth was estimated at 1.8% per year.

### Mopani District, Greater Letaba Local Municipality:

The Mopani District Municipality (MDM) is the Water Services Authority (WSA) for the area. Water supply for the one settlement within the map area is from groundwater resources. The Greater Letaba Municipality (GLM) and Mopani District Municipality have signed a Water Services Provider (WSP) contract which allowed GLM to undertake operation and maintenance functions limited to the reticulation network. The threshold for provision of Free Basic Water (FBW) is a maximum of six (6) kilolitres per household. Within the larger municipal area, there are a total of 132 villages which receive unmetered free water supply and presumed to be above the FBW threshold. In areas where there are deficiencies in water availability, water supply is supplemented by water tankers without cost. According to Census 2011, about 75.6% of the households within the municipality are either without sanitation facilities or have sub-standard toilets like those without ventilation, or bucket system and chemical toilets, (IDP 2024-2025, Greater Letaba Local Municipality).

Table 11: Water resources in Mopani District, Greater Letaba Local Municipality.

Water scheme Name	Water Scheme number	Settlement or settlements	Settlement or settlements type	Estimated population 2025	Scheme description	Water sources
Sekgopo Local GWS	MLSEKG02	Sekgopo	Rural - Dense Village > 5000	30078	Internal bulk	Groundwater

Note: The sources of information the DWS water schemes shape file; the population growth was estimated at 1.8% per year.

#### Mopani District, Greater Tzaneen Local Municipality:

The Haenertsburg Water Scheme is supplied from Ebenezer Dam through the Water Treatment Works and conveyed by pumping mains to balancing reservoirs and then distributed through reticulation pipelines to the communities. The water treatment works are operated by Lepelle Northern Water. There is no waterborne sewer system in the Haenertsburg Water Scheme and residents rely on their own septic tanks, which are serviced by the municipal honey sucker. There are no boreholes supplying Haenertsburg town, (IDP 2024-2025, Greater Tzaneen Local Municipality).

Table 12: Water resources in the Mopani District, Tzaneen Local Municipality.

Water scheme Name	Water Scheme number	Settlement or settlements	Settlement or settlements type	Estimated population 2025	Scheme description	Water sources
Haenertsburg Individual Supply	MTTZ/1	Misty Crown, Clearwater Cove, Haenertsburg,	Rural - Small Village <= 5000, Urban - Formal Town,	2444	Internal bulk	Groundwater & springs, surface
Greater Tzaneen LM Farms Supply	TznFS	Farms Greater Tzaneen LM	farming	6194	Internal bulk	Groundwater & springs, surface
		Marima Thema	Rural - Small Village <= 5000	1755	Internal bulk	Groundwater & springs, surface
				10393		

Note: The sources of information are the DWS water schemes shape file and the IDP document of the local municipality. The population growth was estimated at 1.8% per year.

## 4.2 Terrain Morphology

The mapping area was divided by Kruger (1983) into nine terrain morphological units (Kruger, 1983) see Figure 1, viz.:

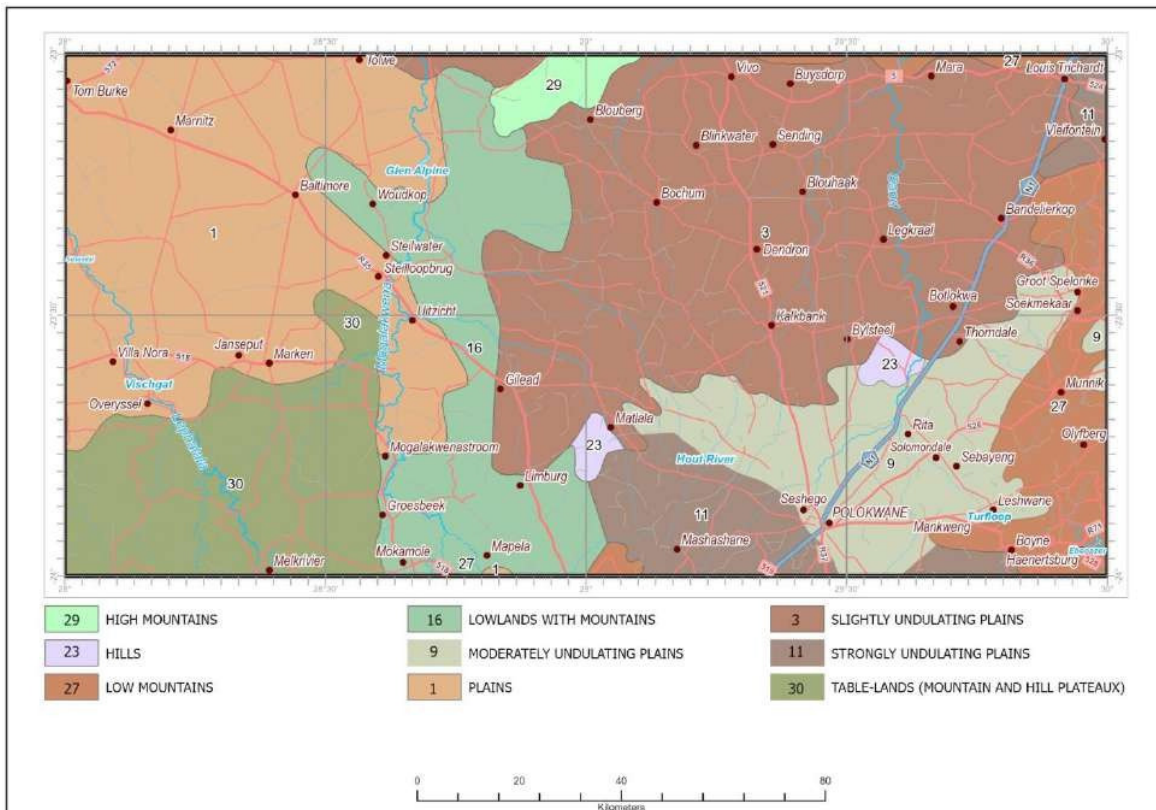


Figure 1: Terrain Morphology (Kruger, 1983)

Table 13: Detailed explanation for Figure 1, Terrain Morphology

BROAD DIVISION	MAP SYMBOL	DESCRIPTION	DRAINAGE DENSITY* (km/km <sup>2</sup> )	% OF AREA WITH SLOPES <5%
Plains with low relief	1	Plains	low - medium 0 - 2	> 80%
	3	Slightly undulating plains		
Plains with moderate relief	9	Moderately undulating plains	low - medium 0 - 2	
	11	Slightly undulating plains		
Lowlands, hills and mountains with moderate to high relief	12	Lowlands with hills	low - medium 0 - 2	50 - 80%
	13	Lowlands with parallel hills		

BROAD DIVISION	MAP SYMBOL	DESCRIPTION	DRAINAGE DENSITY* (km/km <sup>2</sup> )	% OF AREA WITH SLOPES <5%
	16	Lowlands with mountains		
Open hills, lowlands and mountains with moderate and high relief	18	Hills and lowlands	medium 0.5 - 2	20 - 50%
	19	Parallel hills and lowlands		
Closed hills and mountains with moderate and high relief	23	Hills	medium 0.5 - 2	< 20%
	27	Low mountains		
	29	High mountains		
Tablelands with moderate to high relief	30	Tablelands (mountain and hill plateau)	medium 0.5 - 2	< 80%

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

### 4.3 Elevation

The elevation within the map sheet is predominantly between 800 to 1200mamsl. The elevation is directly related to the regional as well as the structural geology of the area. The higher elevation, (1200- 1600mamsl), in the southern section of the map sheet consists of sediments of the Waterberg Supergroup that forms a plateau in the south-west. Buffelsberg / Mogoto Mountain south of Mokopane, consists primarily of dolomitic rocks whereas the Strydpoort Mountain Range between Zebediela and Lebowakgomo consists of quartzite and dolomitic rocks. The elevated hills and mountains with higher elevations predominantly east of the Boyne lineament consist of granitoid rocks. The Soutpansberg Mountain Range comprises a volcanic and sedimentary succession in the north-eastern part of the map sheet and the Blouberg is a sedimentary succession in the central northern section of the map sheet. Various granitoid batholiths and plutons occur within the map area that give rise to localized elevated hills.

Structurally the topography collectively represents a history of rifting, magmatism, compressional deformation and prolonged erosion.

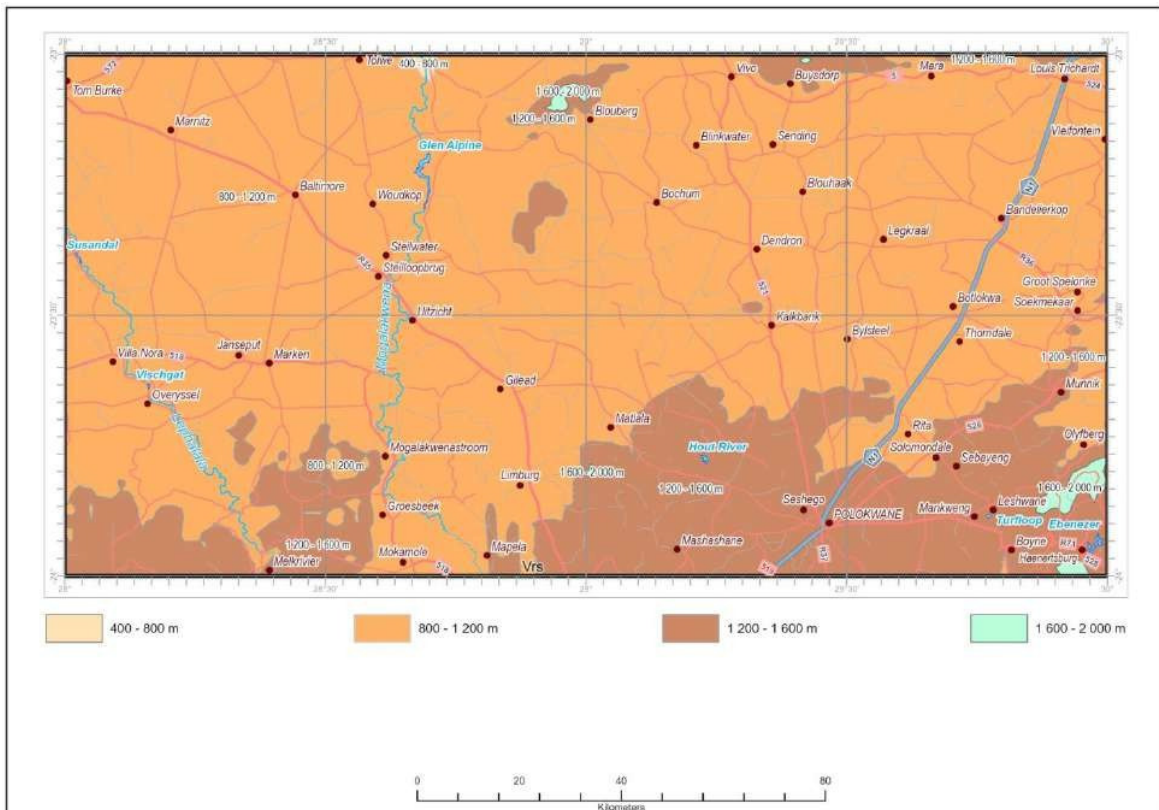


Figure 2: Elevation

#### 4.4 Climate

The climate is generally hot and dry in the plains, becoming more moist and cooler in the more mountainous and plateau areas. The area receives 90% of its annual rainfall between October and March, generally in the form of convection thunderstorms. Rainfall occurrence over the largest part of this area is very erratic and unreliable resulting in long dry periods. This is especially true for the north to north-western section of the map sheet i.e. Limpopo Plain Ecoregion (ER) where the Coefficient of Variation of annual precipitation is between 25-40%, while the rest of the area is predominantly between 20 to 35%, Refer to Table 14, page 18, (data obtained from A Level 1 River Ecoregional Classification System), Kleynhans et al., (2005).

Table 14: Limpopo Ecoregions and Coefficient of Variation

Ecoregion (ER)	Winter (July)		Summer (February)		Coefficient of Variation (% of annual precipitation)
	Mean daily Minimum Temperature	Mean daily Maximum Temperature	Mean daily Minimum Temperature	Mean daily Maximum Temperature	
(Limpopo Plain ER)	2 to >10°C	20 to >24°C	16 to >20°C	26 to 32°C	25 to 40%
(Waterberg plateau ER)	2 to 6°C	16 to 24°C	12 to 20°C	24 to 32°C	20 to 35%
(Soutpansberg ER)	4 to >10°C	16 to >24°C	14 to >20°C	22 to 32°C	<20 to 40%
(Northern Plateau)	2 to 5°C	18 to 24°C	14 to 20°C	24 to 30°C	25 to 35%
(Eastern Bankenveld)	0 to 8°C	12 to 24°C	8 to 20°C	18 to 30°C	20 to 34%
(North Eastern Highlands)	2 to 10°C	18 to >22°C	14 to 20°C	24 to 32°C	20 to 30%

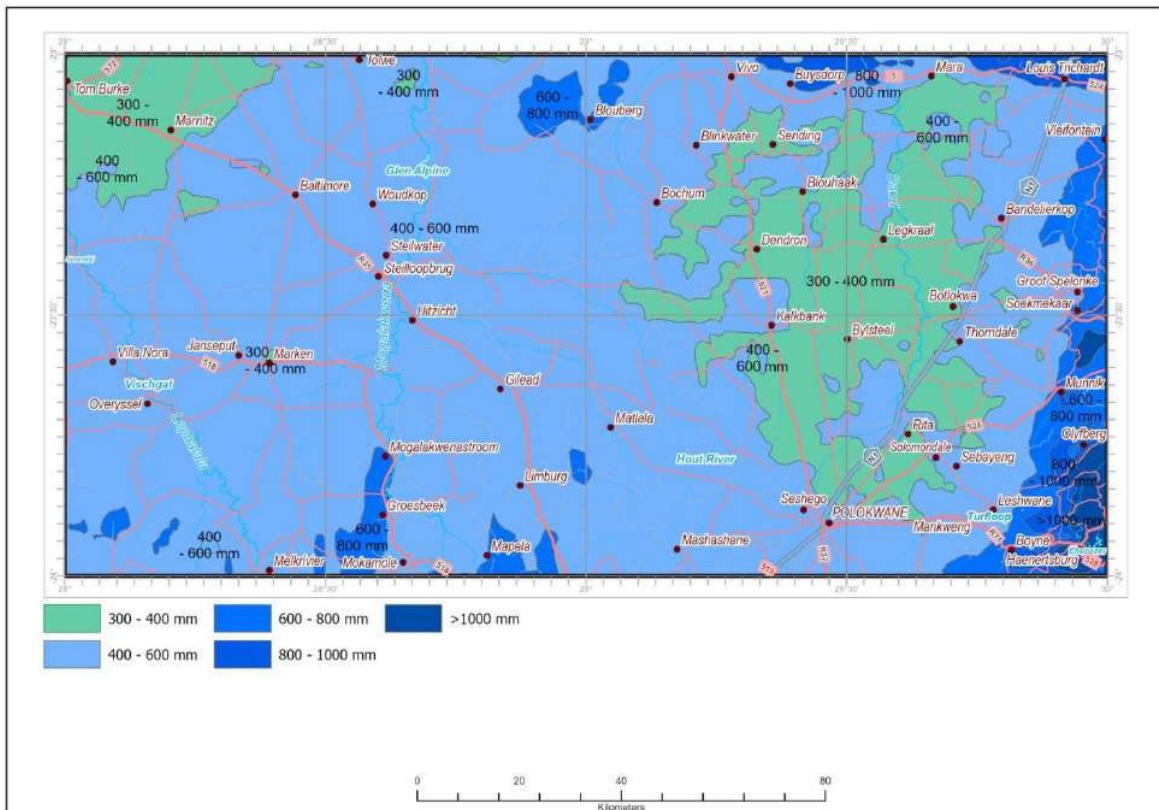


Figure 3: Mean Annual Precipitation

Mean Annual Precipitation (MAP) (Figure 3), varies from between 300 and >1000mm/annum over the map area. The lowest rainfall (green polygon) is in the north-west and centre-east (300-400mm/annum) and the highest (600->1000mm/annum) in the east and north-east in the mountainous area viz. Drakensberg Escarp and Soutpansberg. The scattered high precipitation in the rest of the map is along the Blouberg and other high areas in the Mokopane to the Molemole area and within the Waterberg Plateau. Rainfall occurrence over the largest part of this area is very erratic and unreliable resulting in long dry periods.

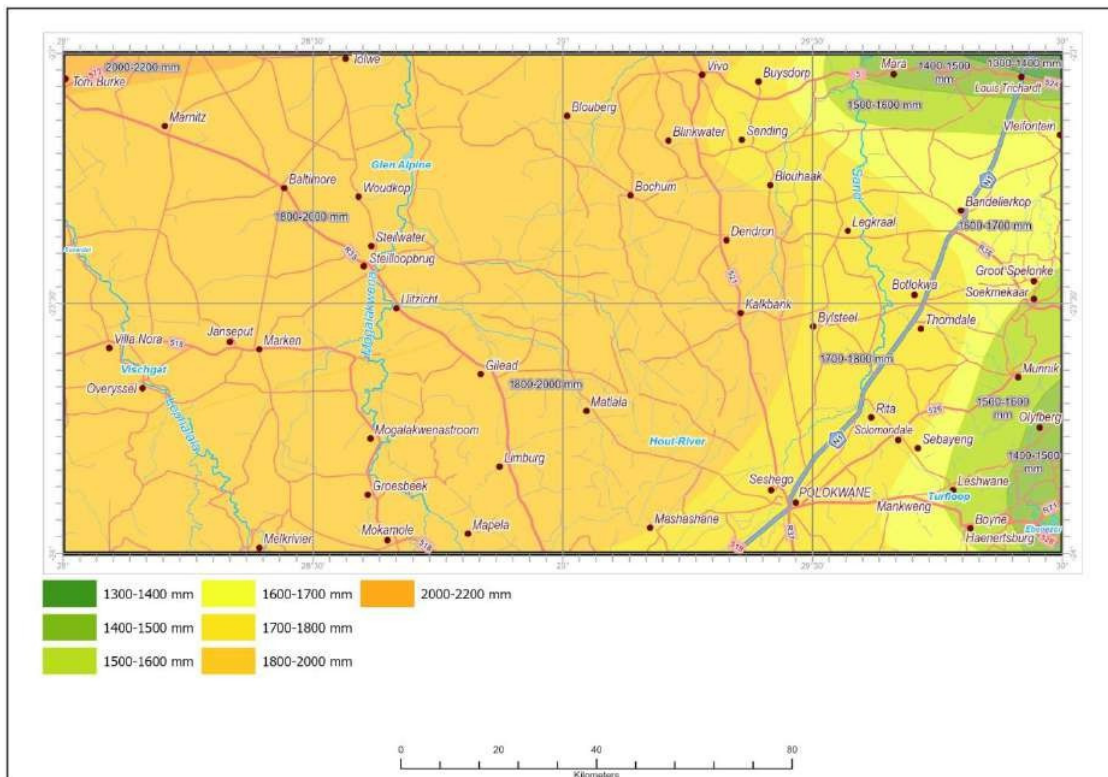


Figure 4: Mean annual evaporation

Mean Annual Evaporation (MAE) (Figure 4), varies between 1300-2000mm from east to west over the map area except in the north-west where it is the highest, (2000-2200mm).

#### 4.5 Surface Hydrology

The area can be divided into **two main drainage regions**, i.e. the Limpopo system (A), which drains approximately 94.8% of the area, and the Olifants system (B). Rivers of the Limpopo and Olifants systems flow mainly north- and east-wards respectively. Figure 5 shows the location of the two main surface water drainage basins as well as the major dams.

The **major dams** together with their storage capacities are depicted in Table 17. Smaller dams used for some of the Regional Water Schemes are listed but the information on those was limited. On a regional scale the larger rivers such as the Limpopo, Crocodile, Middel Letaba, Klein Letaba and Olifants Rivers are listed as perennial, although it is not unusual for these rivers to stop flowing in exceptionally dry periods. The deterioration of surface water flow in most if not all the rivers, due to over exploitation, resulted in periods with no surface flow, especially during dry periods. For example, the Limpopo River experienced no surface flow for approximately 8 months per year as reported at Beit Bridge well field.

Mode and irregular frequency of precipitation, combined with high evaporation rates, results in droughts and periodical flows in most, if not, all the smaller rivers and streams. Interaction between surface and groundwater in river systems is seasonal with rivers either gaining or losing water from and to groundwater. This interaction is dependent on factors such as the water level of the river, depth of erosion channel, type of riverbed material, structural geology, riparian vegetation, abstraction points near the river, and the static water level in the vicinity of the river.

Table 15: Surface Hydrology, table showing the upper tributaries of the Mokolo, Lephala and Mogalakwena that flow into the Limpopo River.

Arises (Ecoregion)	Outermost tributaries	Early Tributaries	Early to later Tributaries	Later Tributaries	Main Tributaries	Main River System	Comment
Waterberg Ecoregion:				Tamotie	Mokolo	Limpopo	<p>Only the tributaries of the Mokolo River are addressed that falls within the Polokwane map sheet. For the Lephala River tributaries outside the map area are also indicated. <b>The Waterberg Ecoregion:</b> The Waterberg is predominantly a tableland with moderate to high relief. The sandstones on the tableland are almost flat lying and are important escarpment shapers. Perennial rivers such as the Mogalakwena and Lephala have their sources in the Waterberg.</p> <p><b>Limpopo Plain:</b> Plains and lowlands characterize this ecoregion with low to moderate relief. The vegetation consists mostly of Bushveld types and Mopani veld. It is a dry to arid, hot region with virtually no perennial streams originating in the area itself. The Lephala and Mogalakwena Rivers are perennial rivers that traverse this region within the map area.</p> <p><b>Northern Plateau:</b> The plateau is dominated by plains with low to moderate relief. The vegetation consists mainly of Mixed Bushveld. North-Eastern Mountain Grassland is also prominent in limited areas. The major river is the seasonally flowing Sand River. No perennial streams arise in this region. The area is characterized by a low drainage density.</p> <p><b>Western Bankenveld:</b> This region has a complex topography that varies from lowlands, hills and mountains to closed hills and mountains with the relief varying from moderate to high. Although various Bushveld and Grassland types occur, Mixed Bushveld is the most definitive vegetation type of the region. Some of the up-stream perennial and non-perennial tributaries of the Mogalakwena River arise in this region. It is shown on the table but does not fall within the map boundary.</p> <p><b>Bushveld Basin:</b> This region consists predominantly of plains with a low relief with Mixed Bushveld being the dominant vegetation type. Some of the up-stream non perennial tributaries of the Mogalakwena River arise in this region of which the Nyl is the best known. Virtually no perennial tributaries arise in the region. The region occurs south of the map sheet boundary.</p> <p><b>Eastern Bankenveld:</b> The region is characterized by Closed hills and mountains with moderate and high relief. The vegetation cover consists of North-eastern Mountain Grassland and Mixed Bushveld veld types. For the map area this region is listed as some of the up-stream tributaries of the Sand, Olifants and Mogalakwena Rivers arise in this region.</p>
Waterberg Ecoregion:			Goudspruit Goudspruit unknown non perenial	Goudspruit Bloklandspruit Melkspruit unknown non perenial unknown non perenial Rietbokvleispruit Snyspruit	Lephala		
Limpopo Plain				Sonope Sethonoge Leokeng unknown non perenial			
Northern Plateau		Tshipu unknown non perenial	Natse unknown non perenial unknown non perenial	Seepabana			
		Matlala alias Nokayamatlala and Tlhapsana Seokeng	Matlala	Matlalane			
Waterberg Ecoregion:			Mothlakole alias Rietspruit	Klein Mogalakwena alias Motse			
Waterberg and Western Bankenveld Ecoregion:				Makomolo	Mogalakwena		
			Klein Sterk unknown non perenial unknown non perenial Unknown perenial	Sterk			
			Mmadikiri Dorp Tobiasspruit Andriesspruit	Nyl			
				unknown non perenial Dorp alias Ngwaditse Roosloot			
Bushveld Basin, Easterb Bankenveld and the Northern Plateau				unknown non perenial Groot Sand sloot alias Pholotsi			

Table 16: Surface Hydrology, table showing the upper tributaries of the Sand, Levuvhu, Letaba and Olifants that flow into the Limpopo River.

Arises (Ecoregion)	Outermost tributaries	Early Tributaries	Early to later Tributaries	Later Tributaries	Main Tributaries	Main River System	Comment
Limpopo Plain			unknown non perenial Ga-Mamasonya Brak (alias Senwabarwana or Hodiopong) Bosehla	unknown non perenial  Brak			<p><b>Limpopo Plain:</b> Plains and lowlands characterize this ecoregion with low to moderate relief. The vegetation consists mostly of Bushveld types and Mopani veld. It is a dry to arid, hot region with virtually no perennial streams originating in the area itself. The Lephalala and Mogalakwena Rivers are perennial rivers that traverse this region within the map area.</p> <p><b>Northern Plateau:</b> The plateau is dominated by plains with low to moderate relief. The vegetation consists mainly of Mixed Bushveld. North-Eastern Mountain Grassland is also prominent in limited areas. The major river is the seasonally flowing Sand River. No perennial streams arise in this region. The area is characterized by a low drainage density.</p>
				unknown non perenial Moleletsane			
Limpopo Plain and Northern Plateau		unknown non perenial	Mogwatsane alias Doringlaagte	Hout River	<b>Sand</b>		
			Strydomsloop alias Brakspruit				
Northern Plateau				Dwarsrivier alias Blinkwater		<b>Limpopo</b>	
				Koperspruit			
				Bloedrivier			
				Turfloop			
				Dieprivier alias Sandsloot			
Lowveld	Only one tributary within the map sheet boundary				<b>Luvuvhu</b>		
Lowveld and North Eastern Highlands	Koedoes	Lebjelebore	Khwali	Little Letaba alias Klein-Letaba			
		Mosukodutsi	Middle Letaba				
Eastern Bankenveld		unknown non perenial	Broederstroom	Groot Letaba	<b>Letaba</b>		
			unknown non perenial				
			Politsi				
Eastern Bankenveld			unknown non perenial	Mphogodima	<b>Olifants</b>		

Of the 4 dams listed in Table 17, that occurs within the map sheet boundary, one can be classed as large (> 60Mm<sup>3</sup>), one as intermediate (10-60Mm<sup>3</sup>) and the remaining two as small (0.5-10Mm<sup>3</sup>).

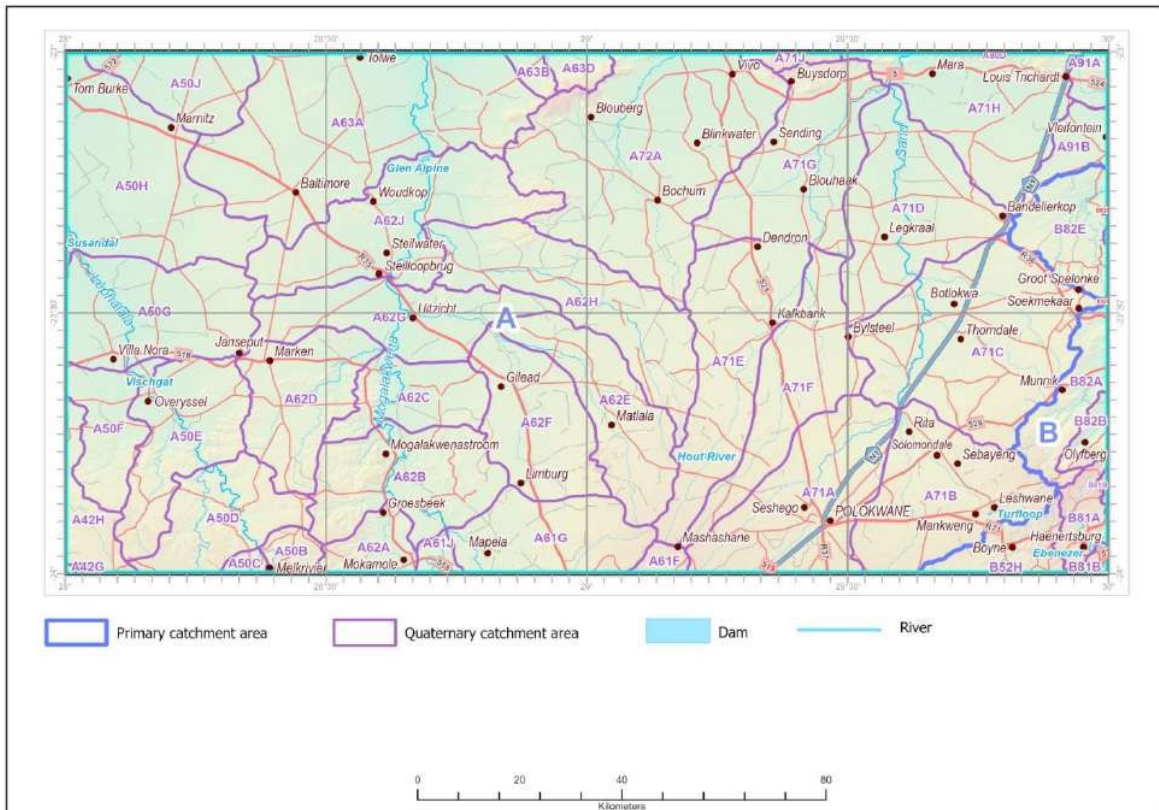


Figure 5: Drainage regions and major dams (HRU, 1981)

Table 17: Major dams, drainage basin, supplying river and storage capacity (HRU, 1981)

DAM NAME	DRAINAGE BASIN	RIVER	FSC STORAGE CAPACITY (Mm <sup>3</sup> )
Ebenezer	B8	Groot-Letaba River	69.2
Glen Alpine	A6	Mogalakwena River	18.9
Houtriver Dam / Matlala Dam	A7	Hout River	6.7
Dap Naude Dam	B8	Broederstroom River	2

Note: FSC is full storage capacity in million cubic meters.

Other very small dams in the area are the Turfloop dam (A7 drainage basin) built in 1987 in the Turfloop River, alias Pou River. The FSC is estimated to be less than 0.5Mm<sup>3</sup>. The Blouberg or Glenferness Dam is within the Blouberg Mountains. Due to a limited catchment area and capacity, the dam is currently not used for water supply. It was, however, used in the past for domestic water supply. Two small private earth dams within the Little Letaba River and north-east of Morebeng (Soekmekaar) are used for irrigation.

## 5. GEOLOGY

### 5.1 Regional geology

The geology occurring on the Polokwane Hydrogeological map sheet area, almost spans the length of the South African geological history and contains many of the major stratigraphic groups in the country. A simplified geological map, (Figure 6) was compiled from the 1: 250 000 Pietersburg (Polokwane) published geological map sheet and explanatory brochure (Council for Geoscience).

The major stratigraphic units formed the basis for the delineation of the hydrogeological aquifer units that were chosen according to geohydrological similarities. The boundaries of the hydrogeological aquifer units are in most cases similar to the geological boundaries. The major stratigraphic groups are as follows:

- The Basement Complex
- Granite intrusives
- Transvaal Supergroup
- Bushveld Complex
- Soutpansberg Group
- Waterberg Group
- Karoo Supergroup
- Quaternary deposits

#### The Basement Complex

The Basement Complex occurs in the area north of the Melinda Fault in the north-eastern section and in the centre-eastern part of the map sheet. It consists essentially of gneiss, banded gneiss, granite gneiss with infolded xenoliths of mafic to ultra-mafic material and migmatite associated with leucocratic granite [Goudplaats gneiss (Zgo)], greenstones [Bandelierskop Complex (Zba), Pietersburg Group (Zpg)], undifferentiated metamorphic rocks of the Beit Bridge Complex that includes the Mount Dowe (Zmd), Malala Drift (Zma) and Gumbu (Zbg) Groups, intrusive layers and lenses of ultramafic and anorthositic to gabbroic rocks [Messina Suite (Zms)], and migmatite gneiss [Hout River Gneiss (Rho)]. The Pietersburg Group (Zpg) occurs within the gneiss (Zgo and Rho) as a southwest striking belt of steeply folded material ranging from ultra-mafic to mafic lavas, acidic lavas, arenaceous sediments and chemical sediments such as banded iron formation and chert. The sequence was subjected to low-grade (green schist facies) metamorphism.

The Central Zone of the Limpopo Mobile Belt strike east-north-east across the northern part of the map sheet and it forms part of the Basement Complex. It is bounded in the north by major faults such as Abbottspoort, Melinda, and Vivo which have exposed deeper levels of the earth's crust, hence the high grade of metamorphism of the rocks that prevails within the belt.

#### Granite intrusives

The Basement Complex has been intruded by numerous younger granites such as, Matlala (Vml), Smitskraal (Vs), Palmietfontein (Vpf), Unnamed Granite Rocks (Vz) of Vaalian to Randian age, Utrecht (Vut), Turfloop Granite (Rt-Vt), Uitloop (Ru-Vu), Lunsklip (RI-VI), Moletsi (Rmo), Matok (Rma) and Hugomond (Rhu).

#### Transvaal Supergroup

The Transvaal Supergroup is not well presented on the Polokwane map sheet. The Wolkberg Group and Black Reef Formation are developed in the extreme south-eastern part of the map where they give rise to a prominent escarpment. Due to the small extent of the Black Reef Formation, it is not shown on the map sheet. Both the Chuniespoort and Pretoria Groups are present only as small metamorphosed xenoliths in the Bushveld Complex. The Chuniespoort Group is represented by serpentinized dolomite which occurs

near the floor contact of the Bushveld Complex. The Pretoria Group comprises quartzite, hornfels, and marble. A capping of acidic lava [Rooiberg Group (Vrb)] marks the end of Transvaal deposition and the beginning of the intrusion of the Bushveld Complex. It forms a major outcrop southeast of Villa Nora.

### **Bushveld Complex**

The emplacement of the complex was preceded by the intrusion of diabase sills that is largely confined to the Transvaal basin. The Bushveld Igneous Complex (BIC) is the largest layered igneous intrusion within the Earth's crust (Wikipedia, the free Encyclopedia). It has been tilted and eroded forming the outcrops around what appears to be the edge of a great geological basin: the Transvaal Basin. It is approximately two billion years old and is divided into four limbs or lobes i.e. northern, eastern, southern, and western. It comprises the mafic and ultramafic phase of the Rustenburg Layered suite (RLS), the felsic phase of the Rashedoep Granophyre Suite (RGS), and the Lebowa Granite Suite (LGS). The genetic relationship between the granites (LGS) and granophyres (RGS) and their relation to the underlying layered mafic-ultramafic intrusion (RLS), is not fully understood, (Earth-Science Reviews, Volume 250, id.104703, 2024). The RGS is generally more closely aligned with the pre-Bushveld Rooiberg Group, (Walraven, 1987a). Research suggests that the RGS was formed by melting of felsic volcanic rocks of the Rooiberg Group during the emplacement of the RLS, (Kinnaird, 2002). The granite intruded and formed a sill-like intrusive body over most of the complex. It has an estimated thickness of some 2.5km (MacCaskie, 1983).

The Bushveld Complex in the map area is represented by the Rustenburg Layered Suite in the centre of the map area and by the Villa Nora Gabbro-Anorthosite compartment that is seen as a separate intrusion to the main Complex. It is also represented by the Nebo Granite of the Lebowa Granite Suite and Palala Granite intrusion. The Palala Granite belongs to the Lebowa suite of granites as an ultimate fractionation of the Bushveld Igneous Complex magma (Journal of African Earth Sciences, Volume 175. March 2021). It is found within the Palala Shear Zone (PSZ), a tectonic lineament in Southern Africa that forms the southern boundary of the Limpopo Belt's Central Zone:

Within the map sheet, the northern lobe is a section of the Bushveld Igneous Complex that extends from south of Mokopane to Villa Nora in the north-west. It consists of a lower-layered ultra-mafic unit, a middle massive gabbro unit, and an upper-layered mafic unit [Rustenburg Layered Suite (Vrs)] capped by a red granite [Nebo Granite (Mn)] and granophyre unit [Rashedoep Granophyre (Mr)]. The Palala Granite (Mpa) located intermittently along the Abbottspoort and Melinda faults, is related to the Bushveld Complex.

### **Waterberg Supergroup**

The Bushveld Complex intrusion was followed by the deposition of the Soutpansberg (Msp) and Waterberg (Mw) Supergroups. The Waterberg Supergroup includes the Koedoesrand Formation (Mko).

The Waterberg Group was deposited in the basin formed by sagging of the cooling Bushveld Complex intrusion. The Waterberg Supergroup is preserved in two main basins, namely the Cullinan-Middelburg basin and the Waterberg Basin in which the Nylstroom, Matlabas and Kransberg Subgroups are preserved, (Jansen, Tankard *et al*, 1982). Sedimentary studies show that the source rocks were from the Transvaal Supergroup and Bushveld Complex and transported by an active river system. Locally material could be transported and deposited by wind action during arid periods, (Tankard *et al*, 1982).

Rocks of the Waterberg Supergroup were deposited in a fault-bounded basin in the northern part of the Kaapvaal craton. In the south the basin is bounded by the Polokwane-Murchison lineament and in the north the Palala shear zone, (Callaghan, 1987). This is the main basin and referred to as the Waterberg Basin.

An overview of the Waterberg Supergroup and Formations in the map area is as follows. Sediments were deposited in two overlapping basins. In the deep basin (Alma trough) beds of the Swaershoek, Alma and Sterkrivier Formations were laid down. The Schilpadkop and locally the Makgabeng Formation form the base of the succession in the younger, larger, but shallower basin. The entire succession is predominately arenaceous (consists of sand), but the Aasvoëlkop and Vaalwater Formations are partly arkosic (25% feldspar content). The oldest sub-division (Nylstroom) of which the lower portion is the Swaershoek

Formation is of late-Bushveld age and confined to proto basins of which the largest coincides approximately with the Nylstroom syncline (Council for Geoscience).

Trachytic lavas (composed mostly of alkali feldspar) are well developed and quartz porphyry occurs locally in the Swaershoek Formation. The Alma, Schilpadkop and Aasvoëlkop Formations are poorly exposed and mostly only the conglomerate beds are seen. The Alma Formation becomes less felspathic in the east. In the Sterk River area both the Swaershoek and Alma Formations decrease in thickness (Council for Geoscience). The Schilpadkop Formation wedges out to the north-east and the partly argillaceous (clayey) Aasvoëlkop Formation grades into the arenaceous Makgabeng Formation. The Sandriviersberg Formation, which occupies the southern Waterberg plateau grades to the east and north into the Makgabeng Formation, which locally contains numerous conglomerate layers (Council for Geoscience).

Sedimentary structures are well developed in the Sandriviersberg and Mogalakwena Formations (cross bedding) and the Vaalwater Formation (cross-bedding, ripple marks, convolute bedding, and lamination).

The undifferentiated Sandriviersberg and Mogalakwena Formations comprise mostly of coarse-grained sandstone, grit, and conglomerate. Groundwater occurs mainly in fault zones, sill/dyke contacts, fracture zones and fractures related to anticlines and bedding planes. Deep drilling (up to 250m) has indicated that fractures do occur at these depths within rocks of the Waterberg Supergroup and can be considered when developing groundwater as a water source. It is, however, difficult to trace these deeply seated fractures using geophysical methods. Diabase dykes and sills are major targets for good supplies and can easily be traced on aerial photographs. Not only is the diabase less resistant to weathering than the surrounding sandstone generally resulting in the formation of depression but also produces a more fertile soil that stimulates a dense vegetation growth along the dykes. These can sometimes be traced for many kilometers. Where sills are weathered and fractured to extended depths below the water level, good supplies can be obtained from them (See also the chapter on the diabase intrusions).

The Waterberg plateau in the south-western section of the map sheet is largely a succession of cross-bedded sandstone 1 250 m thick. The plateau is formed by resistive rocks of the Mogalakwena Formation with elevations between 800 and 1200mamsl.

### **Soutpansberg Supergroup**

The Soutpansberg Supergroup, named after the Soutpansberg Mountain range, underlies mountainous terrain that ranges from Vivo in the east towards the border of the Kruger National Park in the west. It is a volcanic sedimentary succession with a total thickness of approximately 12km, deposited in an elongated fault bounded depression which developed by rifting along a major zone of weakness between the central and southern marginal zones of the Limpopo Mobile Belt, (Jansen 1975).

The Soutpansberg Group is considered slightly older than the Waterberg Group and differs as it has a larger basaltic lava component in an otherwise essentially sedimentary sequence of sandstone and conglomerate.

Various fault zones varying in geological age transect the area in two prominent directions namely east to west and north to south. The Group is divided into six formations namely: Nzhelele, Musekwa, Wyllie's Poort, Fundudzi, Sibasa, and Tshifhefhe, respectively (SACS, 1980; Brandl, 1999 and Barker et al., 2006). Within the 1:250 000 hydrogeological Polokwane map sheet two formations is discussed as groundwater resource units each with a different mode of occurrence.

The first is the Sibasa Formation (Msi). It unconformably overlays basement gneisses with an estimated maximum thickness of 3300m and consists mainly of volcanic material and thin intercalations of arenaceous sediments. It is classed as an intergranular and fractured aquifer unit.

The second is the Wyllie's Poort Formation (Mwp). It usually occupies high ground and has a maximum thickness of 4000m in the Thengwe and Ha-Makuya areas. This Formation consists mainly of arenaceous

rocks comprising two main varieties, namely purple or reddish sandstone and a pink to white quartzite or quartzitic sandstone. It is classed as a fractured aquifer unit.

### **Diabase dykes and sills**

Diabase dykes and sills (N-Zd) are pervasive throughout the whole region. Most dykes are generally related to two main igneous events. The older dykes are thought to be of Bushveld Complex age and the younger dykes are generally of late and post Karoo age. The latter dykes were the feeder conduits to the Karoo basalt suggesting that the basalt outpouring probably covered the whole map sheet area prior to Gondwana break-up and their later removal by erosion.

### **Karoo Supergroup**

Within Southern Africa, rocks of the Karoo Supergroup were preserved within two major depositories in southern Africa viz. the Main Karoo and the Kalahari Basin. The accumulation of the sedimentary fill of these Karoo basins was under the influence of two main controls: tectonism and climate (Rust, 1975, Catuneanu et al, 2005). Tectonic regimes during the Karoo time varied from dominantly flexural in the south, in relation to processes of subduction, accretion and mountain building along the Panthalassan (palaeo-Pacific) margin of Gondwana, to extensional to the north, in relation to spreading processes along the Tethyan margin of Gondwana, (Rust, 1975, Tankard et al, 1982, Turner, 1986, Smith et al, 1993, Veevers et al, 1994a, Veevers et al, 1994b, Veevers et al, 1994c, Johnson et al, 1996, Visser and Praekelt, 1996, Selley, 1997, Catuneanu et al, 1998, Pysklywec and Mitrovica, 1999).

The smaller basins north of the main Karoo basin, such as the Springbok Flats, the Tuli, the Tshipise, Lebombo, and Ellisras (Waterberg) basins, tectonic regimes were dominated by extensional stresses or transtensional stresses. Extensional stresses will lead to linear zones of localized crustal extension (Rifts). Typical rift features are central linear depressions called grabens or more commonly a half-graben with normal faulting and rift-flank uplifts mainly on one side. Superimposed on the tectonic control on basin development, climatic fluctuations also left a mark on the stratigraphic record, which shows evidence of a general shift from cold and semi-arid conditions during the Late Carboniferous-earliest Permian interval, to warmer and eventually hot climates with fluctuating precipitation during the rest of Karoo time (Keyser, 1966, Johnson, 1976, Visser and Dukas, 1979, Stavrakis, 1980, Tankard et al, 1982, Visser, 1991a, Visser, 1991b).

Rocks of the Karoo Supergroup occur in three geographical areas within the map sheet. The first occurrence is bounded by the Melinda fault in the north-west, whilst the second occurrence is located on the northern map boundary where it crosses over onto the Messina 1:500 000 hydrogeological map sheet. Just east of the second appearance, basaltic lava of the Letaba Formation (Jle) covering rocks of the Waterberg/Soutpansberg Groups occurs.

Two Formations occur in the western section of the map sheet i.e. Swartrant Formation (Pst) of Permian and Wellington Formation (C-Pd) that are probable of glacial origin, (Dwyka).

### **Quaternary**

The Quaternary strata are characterised by thin deposits of Quaternary to Tertiary Aeolian Kalahari sand (not shown on map). However, it is the alluvial sand and gravel (Q) along the major drainages in the area that are the main targets for groundwater development and abstraction via sand points in the riverbed. These alluvial deposits are described as intergranular aquifers i.e. Tertiary-Quaternary Alluvial Deposits (Q) along the major rivers as indicated on the geological map sheet. Although not indicated as major deposits along the Mogalakwena River the alluvial deposits in the river forms important aquifers and was therefore included in the discussion.

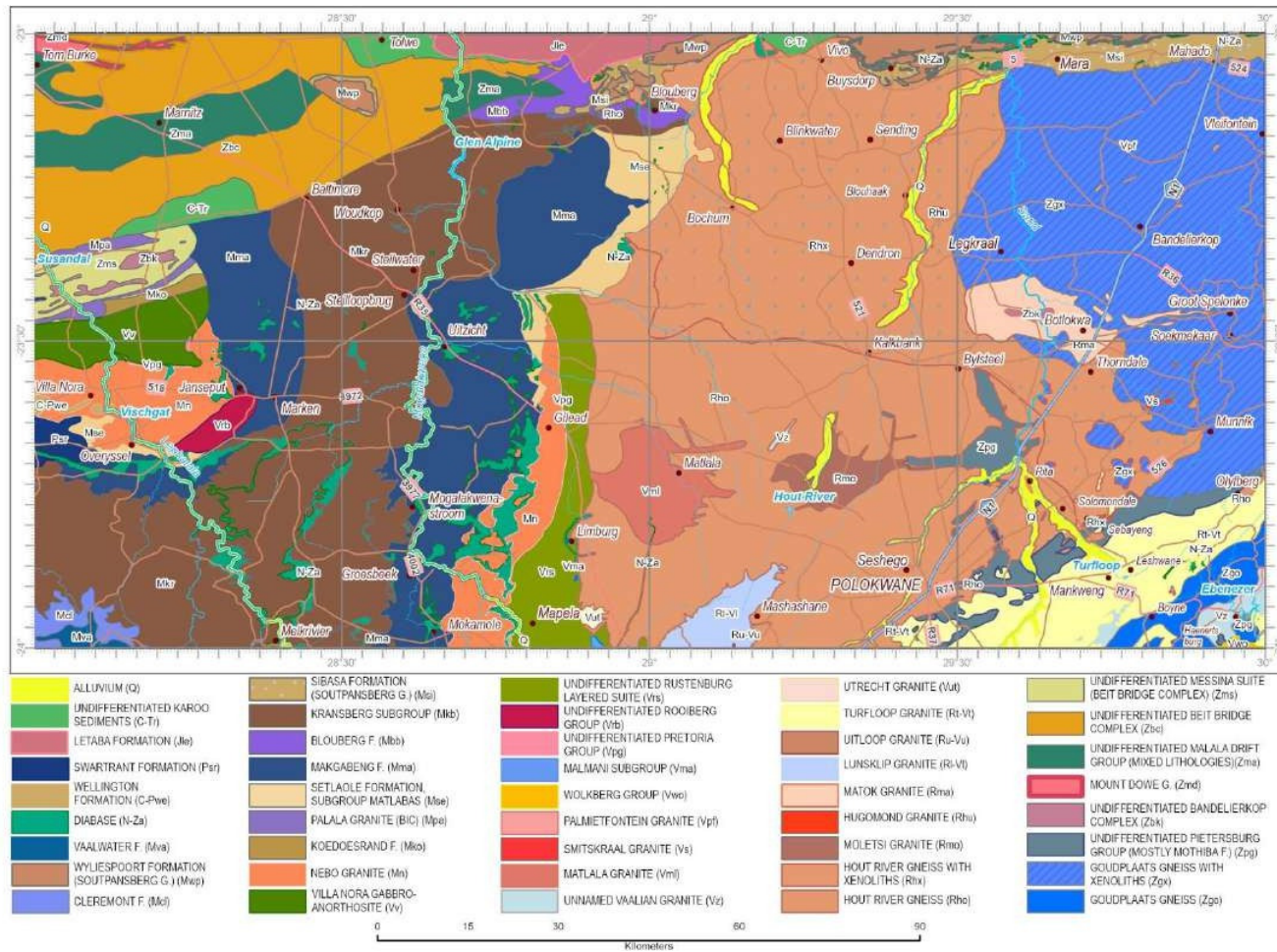


Figure 6: Simplified regional geology of the map area

## 5.2 Structural geology

### Dykes and sills

Dykes occurring within the Swazian rocks and granitic intrusives of Radian and Vaalian age, have a predominant north-easterly orientation. Fewer dykes occur in the Hout River Gneiss. These dykes have a predominantly east-north-east and north-west strike. Fewer dykes occur in the Swazian rocks north of the Melinda fault. These dykes as well as the dykes occurring within the Palala shear zone are trending east-north-east, a direction parallel to the Zoetfontein and Melinda fault zones. Fewer dykes occur within rocks of the Transvaal and Karoo Supergroups. Dyke intrusions in sedimentary rocks of the Waterberg Group are predominantly trending west-north-west and to a lesser extent north-north-east. Diabase sills are mainly limited to the Nebo Granite and Waterberg Supergroup.

The occurrence of sills and dykes (N-Za) of predominantly diabasic composition plays a major role in the occurrence of groundwater especially in the sedimentary rocks of the Waterberg Supergroup. If dykes and sills are ignored, the groundwater potential of the Waterberg Group is generally low. Diabase dykes and sills can easily be traced on aerial photographs. Not only is the diabase less resistant to weathering than the surrounding sandstone generally resulting in the formation of depression but also produces a more fertile soil that stimulates a dense vegetation growth along the dykes. These can sometimes be traced for many kilometres. Where sills are weathered and fractured to extended depths below the water level, good supplies can be obtained from them.

### Faults and shear zones

The Beit Bridge Complex is part of the Limpopo Metamorphic Belt which is subdivided into three domains i.e. a Central Zone and two flanking Marginal Zones. They are separated from each other and from the neighbouring Kaapvaal and Zimbabwe Cratons (Rhodesian Craton), by major shear zones.

The Palala shear zone is fault bounded, marks the southern boundary of the Central Zone and is approximately 10km wide occurring in the central eastern section of the map sheet as an east-west lineament. The feature forms a linear feature between the Melinda fault in the north and the Beaufort Shear Zone. Some high yielding, (8-20l/s), boreholes were drilled in the Melinda fault zone for the Mmaletswai Regional Water Scheme. The Beaufort Shear Zone and Abbottspoort Shear Zone (20m wide) is regarded to have a similar sense of movement, and it is believed that both were activated over time as brittle faults, (Brandl, 1996). It is possible that it continues under the Waterberg outcrop into the Blouberg area. In the southern marginal zone four periods of deformation have been recognized, (Du Toit 1979). The first event, (D1), produced isoclinal folds with east-west trending axial planes, the second event, (D2), resulted in the formation of hook folds and strong foliation imposed on the Goudplaats Gneiss and the rocks of the Bandelierkop Complex. In terms of groundwater occurrence areas in the gneiss with strong foliation usually led to higher yields than areas that show slightly developed foliation. The third fold event, (D3), is well established in the Matok area and is expressed as open cross folds which were produced about upright, north-west-trending axial planes. The last event (D4) is represented by north-east-trending shear zones. The Boyne lineament may relate to the last event, (explanatory booklet for the geological map). The north-easterly Boyne lineament occurs near Moria church and is underlain by Turfloop Granite. High yielding, (8-15l/s), boreholes in the area were linked in reports to the Boyne lineament.

The rocks of the Pietersburg Group excluding the Zandriverspoort Formation are thought to have been isoclinally folded, (the limbs of the fold are nearly parallel), mainly about north-east-trending axes. In the Zandriverspoort Formation four deformation events have been provisionally recognized, the history may be similar to that of the southern marginal zone, (explanatory booklet for the geological map).

The Sediments of the Koedoesrand Formation form a narrow, east-west-trending zone which is bounded on either side by faults. From the available groundwater information one moderate yielding, (6l/s), borehole was drilled on the southern fault zone. It supplies a rural village with water.

In the north-eastern sector of the map sheet, faults occur mainly within the rocks of the Soutpansberg Group. The predominant strike directions are east-north-east and north-west. Within the basement rocks and later granitic intrusions from the north-eastern striking fault near Matok is the most prominent feature. The Matok fault was drilled in the search for groundwater and produced moderate yields, (5-10l/s).

In the south-eastern sector of the map sheet a major fault zone is the north-easterly Welgevonden fault. Fault zones within the Wolkberg Group and Bushveld Complex are mostly of a north-easterly orientation. A high yielding borehole (maximum yield 14/s) was drilled in one of the smaller fault zones near Witrivier / Limburg for the old Gillimburg Farm. It was to supply water to a citrus orchard, (now inactive).

#### **Dolerite dykes and sills**

Intrusions after the deposition of the Karoo rocks are listed as dolerite intrusions. It is predominantly confined to the Karoo Supergroup. Reports on groundwater development indicate that dolerite was found in the Karoo rocks that occur north of Blouberg. The maximum yield of the boreholes was however less than 2l/s. In the pre-Karoo rocks, it seems to be very rare or absent (Brandl, 1996).

Figure 7 represents one of the products of the Groundwater Resource Information Project (GRIP). The map displays dykes, faults, and lineaments derived from remote sensing techniques using a combination of various research earth science satellite imagery. The map, (Figure 7), is included in the brochure but the interpreted structural features could not be displayed as an additional layer on the 1:250 000 Hydrogeological map sheet. This is as it would clutter the map considerably with the information already depicted. The dykes, faults, and lineaments that are included on the hydrogeological map sheet are the same as those depicted on the 1:250 000 Polokwane 2328 geological map.

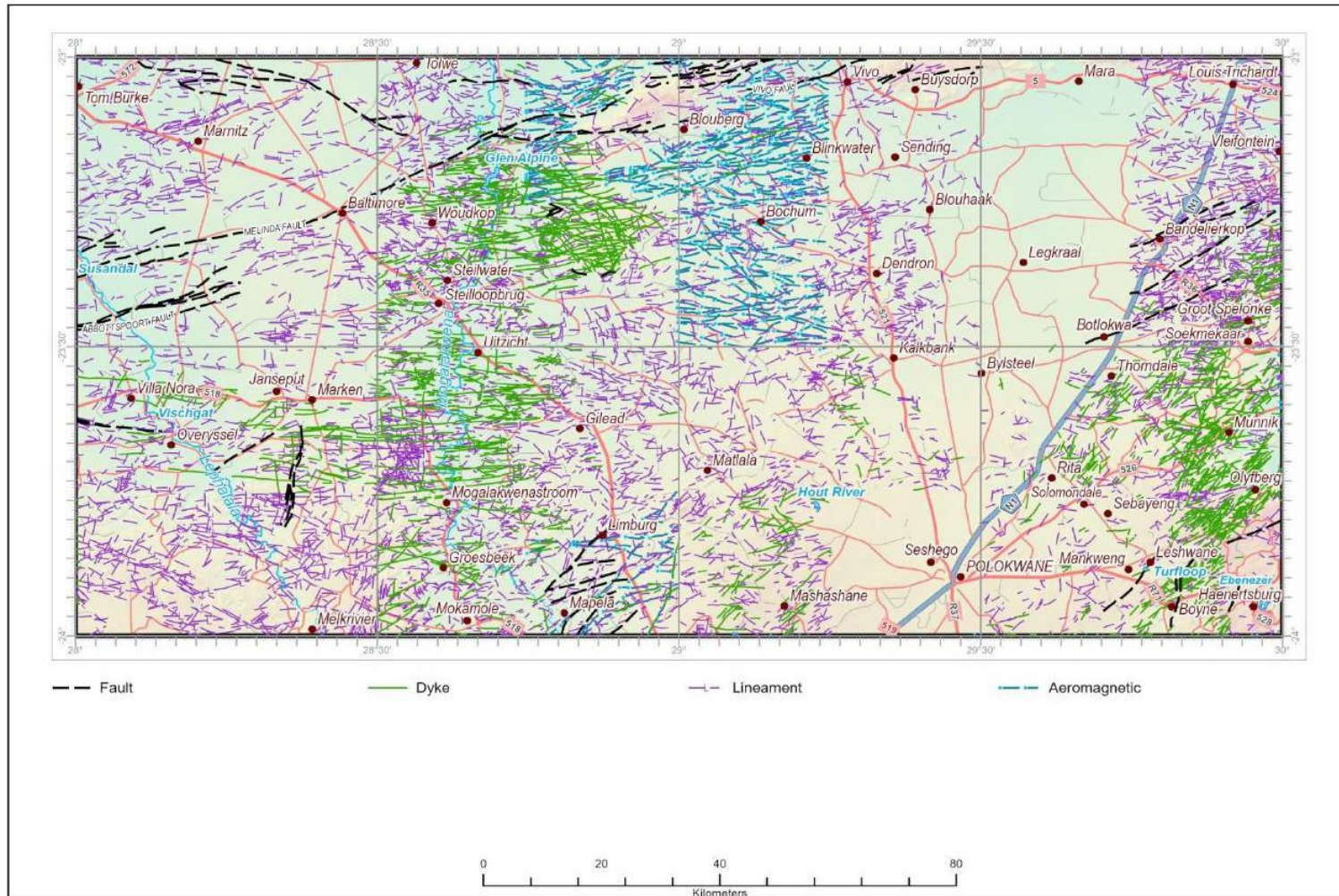


Figure 7: Inferred and observed geological lineaments.

## 6. GENERAL: HYDROCHEMISTRY AND AQUIFER UNITS

The chemical composition of groundwater is the result of interaction between rainwater, soils, and various rock types. Most of this interaction takes place in the unsaturated zone and later in the saturated zone along the groundwater flow path, where physical and geochemical properties of the rock types influence the type and character of the groundwater quality.

To characterise and compare the chemical composition of groundwater in the various rock formations, complete chemical analysis of 5 166 groundwater samples taken during the period from 1970 to 2008, was utilized.

The chemical data was predominantly obtained from WMS, NGA, e-WULAAS and from the database of the consultancy. The first combined data worksheet consisted of 41 942 data points for the area covered by the 1:500 000 Polokwane map sheet. After removing duplicates and calculating the harmonic mean for time series data the number of data points decreased to 13 320 data points.

Duplicates were first removed from the combined total list before the data points occurring on the Polokwane 1:250 000 map sheet were separated. Therefore, the total number of duplicates removed for the 1:250 000 Polokwane map sheet area is not known as it is part of the statistics for the larger area. The time series data were, however, counted for each borehole point. For the Polokwane map sheet and the cross over units in the Polokwane map sheet, 14 145 samples were available after the removal of duplicates. The number of data points after the calculation of the harmonic mean for time series data was 5 445 thus 8 700 samples represent time series data. Of these data, 5 166 analyses were used for the evaluation of chemistry with the results summarized in various tables. In total 2 246 analyses were used for the Piper and Durov diagrams.

The reason for the large number of duplicates was that in the past data was captured by many entities and at few occasions the various groundwater databases were combined with the DWS database and vice versa. The coordinates of the available analysis points were used to divide the data within the relevant Aquifer Units.

The accuracy of the chemical analysis was checked by the plausibility of the Electrical Conductivity (EC) and Electro Neutrality (E.N). The calculations are as follows:

$$EC = [\sum \text{anions (meq/L)} = \sum \text{cations (meq/L)}] = EC/100(\mu\text{S/cm}),$$

$$E.N. = [\sum \text{cations (meq/L)} + \sum \text{anions (meq/L)}] / [\sum \text{cations (meq/L)} - \sum \text{anions (meq/L)}] * 100\%, (\leq 10\%).$$

This was mainly for the samples that were plotted on the trilinear Piper and Durov diagrams as the major cations and anions are used. Samples that failed the (EN) and (EC) evaluation were predominantly due to incomplete data for the major anions and cations. For the summary tables listing statistical information such as the maximum and minimum concentration for parameters, some of the analysis was used even if the plausibility checks were not acceptable.

The Brochure for the 1: 500 000 Polokwane hydrogeological map sheet used a basic method of general characterisation of water composition known as the Kurlov method (Kurlov, 1928). It is based on the relative concentrations of (meq/l) of major cations and anions. The data was used to create a stiff diagram that was described in terms of the dominant cations and anions.

For the 1: 250 000 Polokwane map sheet, the limitations of the stiff diagram used as a single interpretation method were re-evaluated. Stiff diagrams are more suited to spatial comparisons by plotting each analysis on a map to identify trends and to identify water types on individual analysis. Spatial analysis based on stiff diagrams plotted on the map sheet area, was not done but can be considered as a methodology for possible future smaller scale hydrogeological maps.

For the chemical evaluation of each aquifer unit as described in this explanatory brochure for the map sheet, the methodology is as follows:

- A summary table within the general section of the document that lists the major cations, anions, and physical properties as presentations falling within the ideal, good, and moderate water ranges (DWS

guideline document, Class 0-2). The last range is called unacceptable and represents the DWS guideline Class 3 & 4.

- A summary table within the section of each aquifer unit that constitutes a list of the combined samples in each aquifer. Information in the table includes but not limited to the number of analyses, maximum, minimum, percentiles (10%, 50% & 90%), and statistics on variation.
- The use of Piper and Durov diagrams for the evaluation of the water chemistry for each unit. It was used to identify water types and hydrochemical processes.

For both the Piper and Durov diagrams, the major ions are displayed as percentages of milli-equivalents in two ternary (trilinear) graphs, one for cations and one for anions (each parameter plots on one of the three axis). For the piper, the plot point for the major cations ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Na}^{+} + \text{K}^{+}$ ) and anions ( $\text{HCO}_3^{-}$ ,  $\text{SO}_4^{2-}$ ,  $\text{Cl}^{-}$ ) for each sample, in their respective triangular fields are projected along lines parallel to the triangular grid axes, ensuring a unique location in the central diamond field where a single plot point is created. This single point represents the composition of the cations and anions for each water analysis.

A similar procedure is followed for the Durov diagram, but the plot points are extended into a central square field along lines parallel to the proportional axes of the triangular grid. This ensures a unique location (single plot point) in the square for each sample. This single point represents both the anions and cations (thus 6 values are presented as one point).

- The assertion is that most natural waters contain cations and anions in chemical equilibrium. It is assumed that the most abundant cations are two “alkaline earths” that is calcium ( $\text{Ca}^{2+}$ ) and magnesium ( $\text{Mg}^{2+}$ ) and one “Alkali” that is sodium ( $\text{Na}^{+}$ ). For the plot, sodium and potassium ( $\text{K}^{+}$ ) are combined on one axis. The most common anions are one “weak acid” viz. bicarbonate
- ( $\text{HCO}_3^{-}$ ) and two “strong acids” viz. sulphate ( $\text{SO}_4^{2-}$ ) and chloride ( $\text{Cl}^{-}$ ).

### Interpretation of the Piper and Durov diagrams:

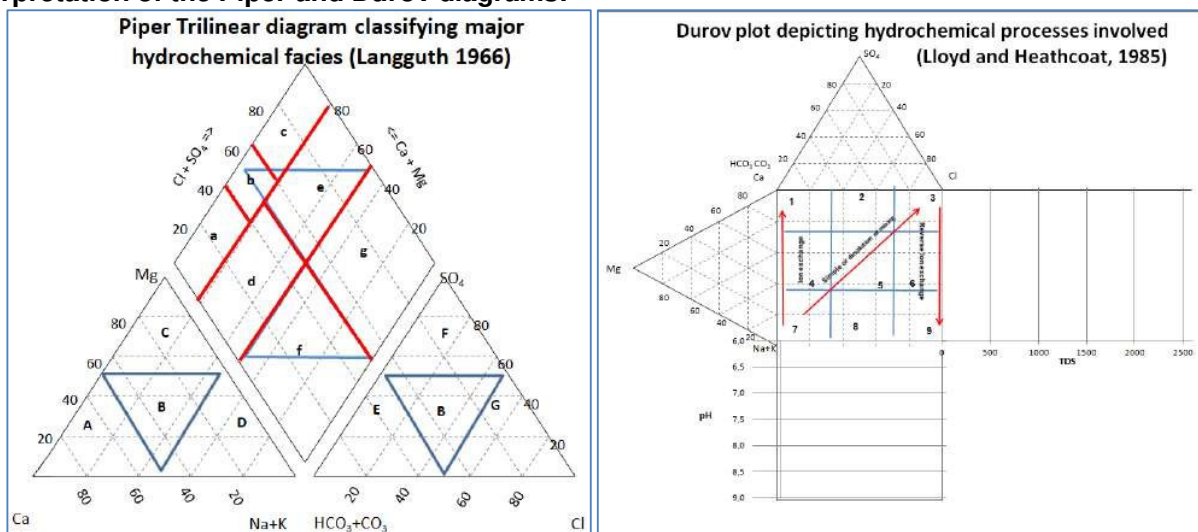


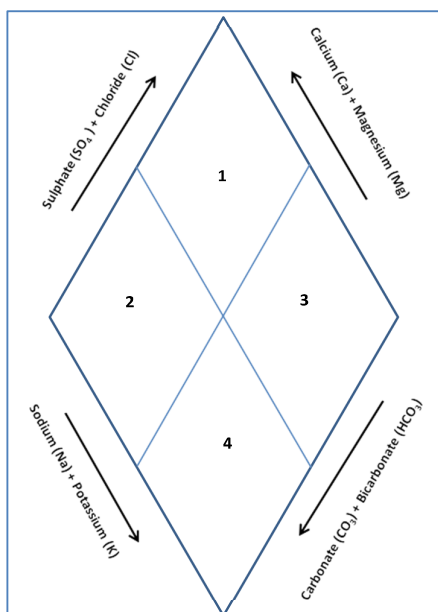
Table 18: Classification of water based on Piper diagram (Langguth, 1966), Water types

Section	Diamond shape diagram	Triangles	
a	Normal earth alkaline water with prevailing bicarbonate	A	Calcium type
b	Normal earth alkaline water with prevailing bicarbonate and sulphate or chloride	B	No Dominant type
c	Normal earth alkaline water with prevailing sulphate or chloride	C	Magnesium type
d	Earth alkaline water with increased portions of alkalis with prevailing bicarbonate	D	Sodium type
e	Earth alkaline water with increased portions of alkalis with prevailing sulphate and chloride	E	Bicarbonate type
f	Alkaline water with prevailing bicarbonate	F	Sulphate type
g	Alkaline water with prevailing sulphate or chloride	G	Chloride type

Table 19: Classification of water types based on Durov diagram (Lloyd and Heathcote, 1985)

Section	Water Types
1	HCO <sub>3</sub> <sup>-</sup> and Ca <sup>2+</sup> dominant frequently indicates recharging waters in limestone, sandstone and many other aquifers
2	The water is dominated by Ca <sup>2+</sup> and HCO <sub>3</sub> <sup>-</sup> , which typically suggests fresh, recharging groundwater, but if Mg <sup>2+</sup> is also present in significant amounts, it suggests ion exchange processes might be occurring. However, those samples in which Na <sup>+</sup> is significant and Ca <sup>2+</sup> /Mg <sup>2+</sup> < 1 an important ion exchange is presumed.
3	HCO <sub>3</sub> <sup>-</sup> and Na <sup>+</sup> are dominant, normally indicates ion exchanged water, although the generation of CO <sub>2</sub> at depth can produce HCO <sub>3</sub> <sup>-</sup> where Na <sup>+</sup> is dominant under certain circumstances.
4	SO <sub>4</sub> <sup>2-</sup> dominates, or anion discriminate and Ca <sup>2+</sup> dominant, Ca <sup>2+</sup> and SO <sub>4</sub> <sup>2-</sup> dominant, frequently indicates recharge water in lava and gypsiferous deposits, otherwise mixed water exhibiting simple dissolution may be indicated.
5	No dominant anion or cation indicates water exhibiting simple dissolution or mixing, plots along the dissolution or mixing line.
6	SO <sub>4</sub> <sup>2-</sup> dominates, or anion discriminate and Na <sup>+</sup> dominant, is a water type that is not frequently encountered and indicate probable mixing or uncommon dissolution influences.
7	Cl <sup>-</sup> and Na <sup>+</sup> dominant is frequently encountered unless cement pollution is present. Otherwise, the water may result from reverse ion exchange of Na-Cl waters.
8	Cl <sup>-</sup> dominant anion and Na <sup>+</sup> dominant cation, indicate that the ground waters be related to reverse ion exchange of Na-Cl waters
9	Cl <sup>-</sup> and Na <sup>+</sup> dominant is frequently indicated endpoint down gradient waters through dissolution.

### Interpretation: Piper diamond shaped diagram



Section	Hydrochemical facies, general interpretation of chemical dominance
1	Strong acids exceed weak acids, Alkaline earths exceed alkalines.
2	Weak acids exceed strong acids, Alkaline earths exceed alkalines.
3	Strong acids exceed weak acids, Alkaline exceed alkaline earths.
4	Weak acids exceed strong acids, Alkaline exceed alkaline earths.

The samples within division 1 & 2 represent the dominance of alkaline earths over alkalies viz.  $(Ca^{2+} + Mg^{2+}) > (Na^{+} + K^{+})$  and division 3 & 4 represents the dominance of alkalies over alkaline earths viz.  $(Na^{+} + K^{+}) > (Ca^{2+} + Mg^{2+})$ .

The samples within division 2 & 4 represent the dominance of weak acidic anions over strong acidic anions viz.  $(CO_3^{2-} + HCO_3^{-}) > (SO_4^{2-} + Cl^{-})$  and division 1 and 3 represent the dominance of strong acidic anions over weak acidic anions viz.  $(SO_4^{2-} + Cl^{-}) > (CO_3^{2-} + HCO_3^{-})$ .

### Water quality in terms of Electrical Conductivity (EC)

The general water quality in terms of EC in each of the units is described as:

- Ideal (EC < 70mS/m),
- Good (EC ≥ 70 < 150mS/m),
- Moderate (EC ≥ 150 < 370mS/m),
- Unacceptable (EC ≥ 370mS/m).

Table 20 below (after DWA, 1996), was used as reference document. This classification aligns more or less with the terminology used in the “Quality of Domestic Water Supplies, Volume 1: Assessment Guide” (DWA, 1998). While Table 20 uses the terminology, (suitable, tolerable, unacceptable, totally unacceptable) the terminology was not adopted in this mapping process. Instead, the preferred terms: ideal, good, moderate, and unacceptable, were consistently used for clarity. The SANS 241:2015 uses the terminology acceptable and unacceptable.

Table 20: Guidelines for groundwater quality and suitability (DWA, 1996)

ELECTRICAL CONDUCTIVITY RANGE (mS/m)	SUITABILITY		
	DOMESTIC	LIVESTOCK	IRRIGATION
<70	Suitable	Suitable	Suitable
70 - 150	Suitable - slightly salty taste	Suitable	Suitable - salt sensitive crops may show a 10% decrease in yield. Wetting of foliage should be prevented
150 - 370	Tolerable - a marked salty taste	Suitable	Suitable for moderately salt tolerant crops although a 10% decrease in yield can be expected. Wetting of foliage should be prevented
370 - 520	Unacceptable - tolerable for short term consumption	Suitable - some loss in productivity	Tolerable for moderately salt tolerant crops although a 20% decrease in yield can be expected. Wetting of foliage should be prevented
>570	Totally unacceptable	Tolerable - may be refused by animals not accustomed to the water	Generally unacceptable

Note: The water quality in terms of EC in the document is described as ideal (EC < 70mS/m); good (EC ≥ 70 < 150mS/m); moderate (EC ≥ 150 < 370mS/m); unacceptable (EC ≥ 370mS/m).

## 6.1 Aquifer Hydrochemistry

Data obtained from the National Water Quality Database (WMS), NGA, e-WULAAS and the groundwater data bank of the consultancy were utilised for hydrochemical data analysis and interpretation. Data was also received from various groundwater consultancies in the Limpopo Province. The data points were plotted and sorted for each aquifer unit.

Data is presented in various tables of which Table 21 to Table 38 are within Section 6 viz. General: Hydrochemistry and Aquifer Units.

Table 21 to Table 23 represents the identification of the water types for each unit by using the Piper Diagram and the classification as proposed by Langguth 1966. More than one water type was identified for most of the units. This is as many of the units have a large areal extent and interact with various other units in a lateral and vertical direction. The water types were identified but no attempt was made to link the different water types to a geolocation for further assessment.

Table 24 to Table 29 summarize statistics for the major cations and anions within each aquifer unit. In the summary tables, Table 24 to Table 26 the median value (50<sup>th</sup> percentile) is presented. This table will give an indication of the median concentration in mg/l for each of the major cations and anions within the aquifer but do not show the percentages of samples that fall within the acceptable or unacceptable range. Table 27 to Table 29 summarize the values of the 90<sup>th</sup> percentile for the major anions and cations.

Table 30 to Table 32 summarize the major anions and Table 33 to Table 35 the major cations within each aquifer unit. The data presented entails the percentages of each parameter that fall within the acceptable (ideal, good, marginal) and unacceptable limits for domestic use. These statistics are very useful in terms of problematic constituents that can be expected in each of the units during the planning phase of groundwater development projects. The water quality ranges used to divide the data for each parameter are according to the DWS guideline viz. Class 0, Class 1 and Class 2; the final range represents classes 3 & 4, referred to in the tables as the unacceptable limit range.

Table 36 to Table 38 represent the physical properties viz. Electrical Conductivity and pH as well as the anion Fluoride. The same methodology was followed as in Table 30 to Table 35.

For each of the aquifer units another summary table is included within the description for each unit. This gives statistics on concentrations for various parameters such as minimum, maximum, 10, 50 and 90<sup>th</sup> percentiles. It also includes the corrosiveness of the water and the suitability for irrigation in terms of the Sodium adsorption ratio (SAR) that can be used for desktop studies.

In total eight, (8) groundwater resource units did not have any chemistry data available for analysis. For the **fractured aquifers** it is the Undifferentiated Karoo Sediments (C-Tr), Wellington Formation (C-Pwe), Undifferentiated Rooiberg Group (Vrb) and Wolkberg Group (Vwo). For the **intergranular fractured aquifers**, it is the Undifferentiated Pretoria Group (Vpg), Hugomond Granite (Rhu), Uitloop Granite (Ru-Vu) and Smitskraal Granite (Vs).

Another seven (7) units have only between 1 to 10 analyses available that may result in a less accurate evaluation of the chemical characterization of the unit. For some of these the reader can consult the adjacent hydrogeological map sheets as it may contain additional information regarding a specific groundwater resource unit. The units without sufficient data are usually small in areal extent, or the unit falls outside rural villages. In the areas with rural villages, groundwater data is more comprehensive and available.

#### **A: Normal earth alkaline water with prevailing Bicarbonate**

##### **• Calcium Magnesium Bicarbonate water**

This water type is dominated by the cations  $Mg^{2+}$  and  $Ca^{2+}$  and the anion  $HCO_3^-$ . The units dominated by this water type are usually associated with dolomite. Within other rock types it can relate to recent recharge from precipitation or surface water with short residence time in the subsurface. The total mass of dissolved material per unit volume expressed as Total Dissolved Solids, (TDS), are low to moderate as the water was not subjected to prolonged ion exchange or significant water-rock interaction. This water type dominates 6 of the groundwater resource units viz. Clermont Formation (Mcl), Sibasa Formation (Msi), Turfloop Granite (Rt-Vt), Undifferentiated Messina Suite (Zms), Mount Dowe Group (Zmd), and Undifferentiated Bandelierkop Complex (Zbk).

It was identified as a non-dominant water type in another three of the units viz. Blouberg Formation (Mbb), Villa Nora Gabbro-Anorthosite (Vv), and Undifferentiated Rustenburg Layered Suite (Vrs). It constitutes 24.1%, 28% and 28.6% of the water types respectively. In the Hout River Gneiss (Rho) it constitutes 17.5% and it was also identified in another 9 groundwater units with percentages ranging between 0.4 and 14.3%.

##### **• Calcium Bicarbonate water**

This water type is dominated by the cation  $Ca^{2+}$  and the anion  $HCO_3^-$ . The water type is usually associated with limestone ( $CaCO_3$ ), dolomite ( $CaMg(CO_3)_2$ ) (if some  $Mg^{2+}$  is present, it may shift towards a Ca-Mg- $HCO_3$  type), marble (metamorphosed limestone, also rich in  $CaCO_3$ ) and calcareous sandstones or sediments (if they contain carbonate cement or shells). This water type was not identified as the dominant water type in any of the groundwater resource units, but it was identified as a water type in 6 of the units; it constitutes 0.4 to 10.5%.

#### • **Magnesium Bicarbonate water**

This water type is dominated by the cation  $Mg^{2+}$  and the anion  $HCO_3^-$ . See also the comments under the heading Calcium Bicarbonate water. It was identified as the dominant water type in the Malmani Subgroup (Vma) and as a secondary dominant type in Alluvium (Q, 24.2%), the Undifferentiated Pietersburg Group (Mostly Mothiba Formation) (Zpg, 21.2%), and the Koedoesrand Formation (Mko, 33.3%). It was also identified in another 10 units but constituting 0.2 to 11.5% of the water types.

#### **B: Normal earth alkaline water with prevailing Bicarbonate and Sulphate or Chloride**

The water type may represent a transition from fresh recharge water rich in  $(Ca-HCO_3)$ , towards more evolved groundwater influenced by additional mineral dissolution and ion exchange over time. This water type can be linked to carbonate (limestone, dolomite, and marble) and evaporite rocks [Gypsum ( $CaSO_4 \cdot 2H_2O$ ); Anhydrite ( $CaSO_4$ ) → Contribute  $Ca^{2+}$  and  $SO_4^{2-}$ ] and [Halite ( $NaCl$ ) → Introduces  $Cl^-$ ], thus shifting water chemistry from a bicarbonate dominance toward chloride influence. It may also be linked to some siliciclastic formations and mixed sediments; [Alluvial and glacial deposits with mixed lithology → Provide a combination of  $Ca^{2+}$ ,  $Mg^{2+}$ ,  $HCO_3^-$ ,  $SO_4^{2-}$ , and  $Cl^-$ ] and [Sandstones and conglomerates with carbonate cements → Release  $Ca^{2+}$  and  $HCO_3^-$  into solution].

#### • **Calcium Magnesium Bicarbonate Sulphate water**

This water type is dominated by the cations  $Mg^{2+}$  and  $Ca^{2+}$  and the anions  $HCO_3^-$  and  $SO_4^{2-}$ . Not one of the groundwater units on the map sheet is dominated by this water type; it however constitutes 1.2% of the unit Kransberg Subgroup (Mkr).

#### • **Calcium Magnesium Bicarbonate Chloride water**

This water type is dominated by the cations  $Mg^{2+}$  and  $Ca^{2+}$  and the anions  $HCO_3^-$  and  $Cl^-$ . It dominates only in one unit viz. Subgroup Kransberg (Mkr, 25.4%); it was also identified in the Villa Nora Gabbro-Anorthosite (Vv, 20%), and Mount Dowe Group (Zmd, 40%) as well as in another 8 units where it constitutes, 2.8% to 14.8%.

#### • **Calcium Bicarbonate Chloride water**

This water type is dominated by the cation  $Ca^{2+}$  and the anions  $HCO_3^-$  and  $Cl^-$ . No units were identified with this water type as the dominant type.

#### • **Magnesium Bicarbonate Chloride water**

This water type is dominated by the cations  $Mg^{2+}$  and the anions  $HCO_3^-$  and  $Cl^-$ . It dominates only in one unit viz. Wylliespoort Formation (Mwp, 33.4%); it was also identified in another 8 units where it constitutes, 1.1% to 9.8%.

#### **C: Normal earth alkaline water with prevailing Sulphate or Chloride**

This water type indicates groundwater that has evolved beyond the early recharge stage ( $Ca-HCO_3$  type) and has undergone additional mineral dissolution, cation exchange, or mixing with older water. If gypsum or halite is present, bicarbonate dominance may shift to sulphate or chloride. If sandstone and clays are present with evaporites as the binding chemical cementation, the water type can mitigate over time by slow dissolution of gypsum or halite from pore spaces.

#### • **Calcium Magnesium Sulphate water**

This water type is dominated by the cations  $Mg^{2+}$  and  $Ca^{2+}$  and the anion  $SO_4^{2-}$ . The sulphate water is usually associated with groundwater encountered in lavas and gypsum deposits. No units are dominated by this water type. The evaluation of the water types in the Lunsklip Granite (RI-VI) groundwater resource unit indicated that 2.6% is of this water type. None of the other units have this water type.

#### • **Calcium Magnesium Chloride water**

This water type is dominated by the cations  $Mg^{2+}$  and  $Ca^{2+}$  and the anion  $Cl^-$ . The water type may relate to evaporite dissolution, ion exchange, and deep or long-residence groundwater systems. Where  $Ca^{2+}$  and  $Mg^{2+}$  are dominant, water is related to reverse ion exchange (replacement of  $Na^+$  with  $Ca^{2+}$  and  $Mg^{2+}$ ). It was identified as the dominant water type in the Villa Nora Gabbro-Anorthosite (Vv, 32%), Undifferentiated Rustenburg Layered Suite (Vrs, 42.9%), Hout River Gneiss (Rho, 21.1%), Blouberg Formation (Mbb,

44.9%), and Setlaole Formation (Mse, 67.2%). It was also identified in another 8 units, viz. Wylliespoort Formation (Mwp, 33.3% and Undifferentiated Bandelierkop Complex (Zbk, 33.3%), but constituting, 0.4 to 10.6% of the water types in the other 6 units.

• **Magnesium Chloride water**

This water type is dominated by the cation  $Mg^{2+}$  and the anion  $Cl^-$ . This water type dominates in one of the units viz. Palmietfontein Granite (Vpf, 100%, only 1 available sample) and occurs as a high percentage in another viz. Wylliespoort Formation (Mwp, 33.3%, only 3 available samples). As indicated, the availability of chemical analysis was limited in both and may therefore not be an accurate representation of these units. It also constitutes a small percentage of the water types in another 8 units, (1.2% to 6.7%).

The water type may relate to evaporite dissolution, ion exchange, and deep or long-residence groundwater systems.

• **Calcium Chloride water**

This water type is dominated by the cation  $Ca^{2+}$  and the anion  $Cl^-$ . This water type is the only type identified in the groundwater within the rocks of the Swartrant Formation (Psr, 100%, only a single available sample). It also occurs as a minor water type in another two groundwater units but as low percentages, (0.8% to 1.2%).

**D: Earth alkaline water with increasing portions of alkalis with prevailing Bicarbonate**

This water type represents a transitional stage between calcium-magnesium-bicarbonate ( $Ca-Mg-HCO_3$ ) and sodium-bicarbonate ( $Na-HCO_3$ ) or mixed-alkali-bicarbonate ( $Na-K-HCO_3$ ) water types. It suggests progressive water evolution due to mineral dissolution, cation exchange, and prolonged groundwater interaction with rocks. Rock types associated with the evolution of this water type includes siliciclastic rocks and clay-rich sediments that will be the source of  $Na^+$  and  $K^+$ , it includes Feldspar-bearing rocks (granite, gneiss, arkosic sandstone) where the weathering of alkali feldspars (e.g., orthoclase, plagioclase) releases  $Na^+$  and  $K^+$ . This increases  $Na^+$  and  $K^+$  concentrations, shifting the water type toward an alkali dominance. Clay minerals such as illite, montmorillonite, kaolinite participate in cation exchange reactions, replacing  $Ca^{2+}$  and  $Mg^{2+}$  with  $Na^+$  and  $K^+$ . Volcanic Rocks such as basalt, rhyolite and trachyte is another potential source of alkalis and silica where weathering of volcanic glass and feldspar minerals releases  $Na^+$  and  $K^+$ , thus increasing the alkali contribution.

• **Mixed Calcium Magnesium Bicarbonate water**

This water type is dominated by the cations  $Mg^{2+}$  and  $Ca^{2+}$  but with increased  $Na^+$  concentration with the dominant anion  $HCO_3^-$ . In 22 of the groundwater resource units this water type was identified; it dominates the water type in 8 of these. The following units are dominated by this type: Vaalwater Formation (Mva, 45.7%), Koedoesrand Formation (Mko, 33.4%), Diabase (N-Za, 28.2%), Unnamed Granite Rocks (Vz, 100%), Undifferentiated Beit Bridge Complex (Zbc, 63.6%), Undifferentiated Malala Drift Group (Zma, 62.2%), Undifferentiated Pietersburg Group (Mostly Mothiba Formation) (Zpg, 44.3%), and the Goudplaats Gneiss with Xenoliths (Zgx, 33%).

Although not the dominant water type for the Lunsklip Granite (RI-VI) consists of 26.3% of the water types and for the Palala Granite (Mpa) it represents 27.3% of the water types. It also occurs in another 13 groundwater units, representing 7.3% to 17.3% of the water types.

**E: Earth alkaline water with increasing portions of alkalis with prevailing Sulphate and Chloride**

This water type represents a transition from calcium-magnesium dominance to increasing sodium and potassium proportions, with sulphate ( $SO_4^{2-}$ ) and chloride ( $Cl^-$ ) prevailing. The evolution of this water type can relate to a combination of evaporite dissolution, cation exchange, and prolonged groundwater residence time. The hydrochemical process and evaporite dissolution is a primary source of  $SO_4^{2-}$  and  $Cl^-$ . With the dissolution of gypsum, anhydrite, halite, and sylvite  $Ca^{2+}$ ,  $Na^+$ ,  $K^+$ ,  $SO_4^{2-}$ , and  $Cl^-$  are released. This is a major driver of sulphate-chloride dominance in groundwater.

The hydrochemical process in which cation exchange dominates relates the abundance of clay minerals such as illite, montmorillonite, smectite and kaolinite. Over time  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  is replaced with  $\text{Na}^+$  and  $\text{K}^+$  and will lead to a progressive shift from Ca-Mg-SO<sub>4</sub>-Cl water to Na-K-SO<sub>4</sub>-Cl water.

Other processes such as silicate weathering will release  $\text{Na}^+$  and  $\text{K}^+$ , thus enhancing the alkali proportions in the groundwater. This relates to the weathering of feldspar that contributes to the gradual enrichment of  $\text{Na}^+$  and  $\text{K}^+$  over time. This process occurs more in deep groundwater or areas with prolonged rock-water interaction.

• **Mixed Calcium Magnesium Sulphate water**

This water type is dominated by the cations  $\text{Mg}^{2+}$  and  $\text{Ca}^{2+}$  but with increased  $\text{Na}^+$  concentrations and the anion  $\text{SO}_4^{2-}$ . None of the units were identified with this water type as most of the dominant anions in the water are either  $\text{HCO}_3^-$  or  $\text{Cl}^-$ .

• **Mixed Calcium Magnesium Chloride water**

This water type is dominated by the cations  $\text{Mg}^{2+}$  and  $\text{Ca}^{2+}$  but with increased  $\text{Na}^+$  concentrations and the anion  $\text{Cl}^-$ . This type was identified in 20 of the aquifer units. It dominates in five viz. Makgabeng Formation (Mma, 45.4%), Letaba Formation (Jle, 38.1%), Nebo Granite (Mn, 51.9%), Matlala Granite (Vml, 51.9%), and the Hout River Gneiss with Xenoliths (Rhx, 38.8%).

Other units where this type constitute a high percentage are Koedoesrand Formation (Mko, 33.3%), Diabase intrusions (N-Za, 26.8%), Matok Granite (Rma, 29.3%), Undifferentiated Malala Drift Group (Zma, 24.3%), and the Goudplaats Gneiss with Xenoliths (Zgx, 23.6%).

In another 10 units this water type constitutes 2.2% to 18.2% of the water types.

• **Mixed Calcium Magnesium Bicarbonate Chloride water**

This water type is dominated by the cations  $\text{Mg}^{2+}$  and  $\text{Ca}^{2+}$  but with increased  $\text{Na}^+$  concentrations and the anions  $\text{HCO}_3^-$  and  $\text{Cl}^-$ . This water type was identified within 11 of the units, but dominates only in one viz. Palala Granite (Mpa, 36.4%) and occurs as a secondary dominated water type in the Utrecht Granite (Vut, 30%). For the remaining 9 groundwater resource units, this type constitutes 1.9% to 16.1% of the water types.

• **Mixed Calcium Magnesium Chloride Sulphate water**

This water type is dominated by the cations  $\text{Mg}^{2+}$  and  $\text{Ca}^{2+}$  but with increased  $\text{Na}^+$  concentrations and the anions  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$ . This water type was identified within three of the units where it accounts for 0.6% to 10.5% of the water types found in the unit.

**F: Alkaline water with prevailing Bicarbonate**

This water type is typically characterized by high  $\text{Na}^+$  and  $\text{K}^+$  concentrations with  $\text{HCO}_3^-$  as the dominant anion. It results from long-term rock-water interactions, cation exchange, and silicate weathering, with minimal influence from evaporite dissolution or seawater intrusion.

Associated rock types with this water type is feldspar-rich rocks such as igneous and metamorphic rocks (granites and gneisses); volcanic rocks (basalt, andesite, rhyolite, trachyte and tuff); carbonate rocks, (that may only be the original source of  $\text{HCO}_3^-$ ), quartz-rich sandstones, (contain feldspars and clay minerals that release  $\text{Na}^+$  and  $\text{K}^+$  upon weathering) and clay-rich sediments, (shale, mudstone, and alluvial deposits that contain clay minerals, (montmorillonite, illite, kaolinite), which exchange  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  for  $\text{Na}^+$  and  $\text{K}^+$  (cation exchange), thus shifting the groundwater chemistry to a Na-HCO<sub>3</sub> type.

#### • Sodium Bicarbonate water

This water type is dominated by the cation  $\text{Na}^+$  and the anion  $\text{HCO}_3^-$ . This type of water is generally related to the movement of groundwater from intensive recharge areas and normally indicates a cation exchange process. The water type was identified in 16 units, it dominates in 4 groundwater units, viz. Alluvium (Q, 31.3%), Moletsi Granite (Rmo, 25.9%), Matok Granite (Rma, 53.7%) and Lunsklip Granite (RI-VI, 39.5%). It constitutes a high percentage in the Turfloop Granite (Rt-Vt, 20.5%) and Hout River Gneiss (Rho, 20.1%).

In another 11 units this water type constitutes 1.9% to 15.8% of the water types.

#### G: Alkaline water with prevailing Sulphate or Chloride

This water type is dominated by  $\text{Na}^+$  and  $\text{K}^+$  as the primary cations, with  $\text{SO}_4^{2-}$  and/or  $\text{Cl}^-$  as the dominant anions. It is commonly associated with evaporite dissolution, cation exchange, and prolonged groundwater residence time. It often occurs in arid or semi-arid regions, deep aquifers, or coastal settings.

Associated rock types include evaporites (gypsum, anhydrite, halite, sylvite), feldspar-rich igneous/metamorphic rocks (granite, gneiss), volcanic rocks, (basalt, andesite, rhyolite, trachyte and tuff) and clay-rich sediments.

#### • Sodium Bicarbonate Chloride and or Sulphate water

This water type is dominated by the cation  $\text{Na}^+$  and the anion  $\text{HCO}_3^-$  and ( $\text{Cl}^-$  and/or  $\text{SO}_4^{2-}$ ). The sulphate water is usually associated with groundwater encountered in lavas and gypsum deposits. This water type was identified within 14 aquifer units but dominates in none, the percentages of these water types are 0.7% to 20%.

#### • Sodium Chloride water

This water type is dominated by the cation  $\text{Na}^+$  and the anion  $\text{Cl}^-$ . This water type was identified within 25 units. The units that have a large percentage of water falling within this type are Vaalwater Formation (Mva, 21.7%), Kransberg Subgroup (Mkr, 24.7%), Blouberg Formation (Mbb, 20.7%), Villa Nora Gabbro-Anorthosite (Vv, 22.2%), Undifferentiated Rustenburg Layered Suite (Vrs, 20%), and Matlala Granite (Vml, 23.1%),

The units that are dominated by this type are Utrecht Granite (Vut, 40%) and Goudplaats Gneiss (Zgo, 75.1%).

In 16 units this water type constitutes, 1.9% to 19%, of the water types.

#### • Sodium Chloride Sulphate water

This water type is dominated by the cation  $\text{Na}^+$  and the anions  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$ . This type of water was identified within 1 groundwater unit viz. Hout River Gneiss (Rho, 0.4%).

Other problematic chemical species, which occur in the area covered by the map sheet, include Nitrate and Fluoride (Figure 8, page 63). Nitrate and nitrite concentrations reported as N greater than 10mg/l can cause Methemoglobinemia (blue baby syndrome) in children younger than two years. Fluoride concentrations greater than 1.5mg/l can cause brown staining and the crumbling of teeth and bone structure.

Table 21: Interpretation of the hydrochemical facies as percentages, water type; first page.

Symbol and number of samples		A: Normal earth alkaline water with prevailing Bicarbonate			B: Normal earth alkaline water with prevailing Bicarbonate and Sulphate or Chloride			C: Normal earth alkaline water with prevailing Sulphate or Chloride			E: Earth alkaline water with increasing portions of alkalis with prevailing Sulphate and Chloride			G: Alkaline water with prevailing Sulphate or Chloride							
Aquifer Unit	Samples used	Calcium Magnesium Bicarbonate	Calcium Bicarbonate	Magnesium Bicarbonate	Calcium Magnesium Bicarbonate Sulphate	Calcium Magnesium Bicarbonate Chloride	Calcium Bicarbonate	Magnesium Bicarbonate Chloride	Calcium Magnesium Sulphate	Calcium Magnesium Chloride	Magnesium Chloride	Calcium-Chloride	Mixed Calcium Magnesium Bicarbonate	Mixed Calcium Magnesium Sulphate	Mixed Calcium Magnesium Chloride	Mixed Calcium Magnesium Bicarbonate Chloride	Mixed Calcium Magnesium Chloride-Sulphate	Sodium Bicarbonate water	Sodium Bicarbonate Chloride	Sodium Chloride water	Sodium Chloride Sulphate
<b>Category A: Intergranular aquifers</b>																					
Q	83			24.2						1.2		2.4			8.4	14.5		31.3	10.8	7.2	
<b>Category B: Fractured aquifers</b>																					
C-Tr	0																				
Psr	1									100.0											
C-Pwe	0																				
Mva	0		6.5	4.3				4.3				45.7		2.2	8.7	2.2		4.4	21.7		
Mcl	0	52.6	10.5						10.6								15.8				
Mkr	163	12.3	1.9	11.1	1.2	25.4			1.2	3.1	1.2			15.4		0.6	1.9		24.7		
Mbb	29	24.1							44.9			10.3								20.7	
Mma	178	1.7	5.6	0.6								16.3		45.4			12.4			18.0	
Mse	70								67.2			11.4		4.3						17.1	
Mko	3			33.3								33.4		33.3							
Mwp	3							33.4	33.3	33.3											
Vrb	0																				
Vwo	0																				
<b>Category C: Karst aquifers</b>																					
Vma	2			100.0																	
Note: Dominant type highlighted, values represent percentages (%)																					

Table 22: Interpretation of the hydrochemical facies as percentages, water type; second page.

Symbol and number of samples		A: Normal earth alkaline water with prevailing Bicarbonate			B: Normal earth alkaline water with prevailing Bicarbonate and Sulphate or Chloride			C: Normal earth alkaline water with prevailing Sulphate or Chloride			E: Earth alkaline water with increasing portions of alkalis with prevailing Sulphate and Chloride				G: Alkaline water with prevailing Sulphate or Chloride						
Aquifer Unit	samples used	Calcium Magnesium Bicarbonate	Calcium Bicarbonate	Magnesium Bicarbonate	Calcium Magnesium Bicarbonate Sulphate	Calcium Magnesium Bicarbonate Chloride	Calcium Bicarbonate Chloride	Magnesium Bicarbonate Chloride	Calcium Magnesium Sulphate	Calcium Magnesium Chloride	Magnesium-Chloride	Magnesium or Calcium Sulphate	Mixed Calcium Magnesium Bicarbonate	Mixed Calcium Magnesium Sulphate	Mixed Calcium Magnesium Chloride	Mixed Calcium Magnesium Bicarbonate Chloride	Mixed Calcium Magnesium Chloride-Sulphate	Sodium Bicarbonate water	Sodium Bicarbonate Chloride	Sodium Chloride	Sodium Chloride Sulphate
<b>Category D: Intergranular and Fractured aquifers</b>																					
Jle	21	14.3					4.8		4.8	4.8		14.1		38.1			4.8			14.3	
N-Za	72	8.5		4.2		2.8	1.4		2.8	4.2		28.2		26.8					2.8	18.3	
Mpa	11	9.1										27.3		9.1	36.4				18.1		
Msi	54	68.5		5.6		14.8			7.4											3.7	
Mn	27											18.5		51.9	3.7		3.7			22.2	
Vv	25	28.0				20.0	4.0		32.0											16.0	
Vrs	75	28.6				1.4			42.9	1.4							5.7			20.0	
Vpg	0																				
Vml	52											5.8		51.9			13.5	5.8		23.1	
Vs	0																				
Vpf	1									100.0											
Vz	2											100.0									
Vut	9											10.0			30.0			20.0	40.0		
Rt-Vt	121	42.6	2.5	4.1					8.2								20.5	5.7		16.4	

Table 23: Interpretation of the hydrochemical facies as percentages, water type; third page

Symbol and number of samples		A: Normal earth alkaline water with prevailing Bicarbonate			B: Normal earth alkaline water with prevailing Bicarbonate and Sulphate or Chloride				C: Normal earth alkaline water with prevailing Sulphate or Chloride				D: Earth alkaline water with increasing portions of alkalis with prevailing Bicarbonate	E: Earth alkaline water with increasing portions of alkalis with prevailing Sulphate and Chloride				F: Alkaline water with prevailing Bicarbonate	G: Alkaline water with prevailing Sulphate or Chloride		
Aquifer Unit	samples used	Calcium Magnesium Bicarbonate	Calcium Bicarbonate	Magnesium Bicarbonate	Calcium Magnesium Bicarbonate Sulphate	Calcium Magnesium Bicarbonate Chloride	Calcium Bicarbonate Chloride	Magnesium Bicarbonate Chloride	Calcium Magnesium Sulphate	Calcium Magnesium Chloride	Magnesium-Chloride	Magnesium or Calcium Sulphate	Mixed Calcium Magnesium Bicarbonate	Mixed Calcium Magnesium Sulphate	Mixed Calcium Magnesium Chloride	Mixed Calcium Magnesium Bicarbonate Chloride	Mixed Calcium Magnesium Chloride-Sulphate	Sodium Bicarbonate water	Sodium Bicarbonate Chloride	Sodium Chloride	Sodium Chloride Sulphate
Ru-Vu	0																				
RI-VI	30	2.6						2.6				26.3		5.3	7.9		39.5	13.2	2.6		
Rmo	58					12.1		1.7				17.2		8.6			25.9	15.5	19.0		
Rma	41											7.3		29.3	2.4		53.7	7.3			
Rhu	0																				
Rho	503	17.5		0.2		12.9				21.1							20.1	12.9	14.9	0.4	
Rhx	163	6.1		11.5		0.3		9.8			1.5	0.8	2.0		38.8	12.5	2.7		14.0		
Zms	21	61.9		9.5									4.8		14.3				9.5		
Zbc	44										2.3				18.2	6.8			9.1		
Zma	37							2.7							24.3		8.1		2.7		
Zmd	5	60.0				40.0															
Zbk	3	66.7										33.3									
Zpg	52	1.9		21.2		3.8								9.6	1.9		9.6	5.8	1.9		
Zgo	12					8.3											8.3	8.3	75.1		
Zgx	267	0.4	0.4	6.4				1.1		0.4	6.7		33.0		23.6	16.1		0.7	11.2		

Note: Dominant type highlighted, values represent percentages (%)

Table 24: Hydrochemistry of the Polokwane Map Area, 50th percentile (median); first page.

Symbol	Total number of samples				50 <sup>th</sup> Percentile (median) and comparison to SANS 241:2015 maximum acceptable limits										
	After manipulation	Missing major anions or cations	E.N. ? ±10% & EC ? 20%	Used for piper and Durov	pH Ideal 6 to 9	EC	NO <sub>3</sub>	F	TAL as (CaCO <sub>3</sub> )	Na	Mg	SO <sub>4</sub>	Cl	K	Ca
						mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
						370	20	1.5		400	200	600	600	100	300
<b>Category A: Intergranular aquifers</b>															
Q	120	12	60.8%	83	8.1	107	4.7	0.5	361	126	39	31	100	7.6	37.9
<b>Category B: Fractured aquifers</b>															
C-Tr	0														
Psr	1	0	100.0%	1	7.7	522	1.0	0.5	302	193	205	53	1650	2.7	545
C-Pwe	0														
Mva	60	0	51.7%	0	8.2	52	1.1	0.4	190	43	12	11	25	1.6	28
Mcl	31	0	35.5%	0	7.4	15	1.1	0.1	51	8	3	4	7	0.9	8
Mkr	367	16	53.4%	163	7.9	115	5.8	0.3	248	93	52	15	151	3.9	56
Mbb	52	4	46.2%	29	8.0	131	12.0	0.3	362	100	74	24	125	1.4	72
Mma	395	6	53.9%	178	7.9	113	6.6	0.5	275	102	43	12	141	2.4	66
Mse	142	6	69.0%	70	8.0	198	13.3	0.4	345	199	77	33	366	6.9	79
Mko	3	0	0.0%	3	8.1	106	31.1	0.4	298	106	42	29	96	2.1	71
Mwp	4	0	75.0%	3	8.2	116	2.9	0.2	301	79	77	60	123	2.3	54
Vrb	0														
Vwo	0														
<b>Category C: Karst aquifers</b>															
Vma	2	0	50.0%	2	8.4	66.7	9.5	0.3	356.9	28.6	65.3	8.4	17.0	4.5	30.0
<p><b>Manipulation of samples:</b> removing duplicates and calculation of the harmonic mean for time series data, further elimination in some cases by plausibility of EN and EC. In most of the units analysis with EN up to ±15% was used if the calculated EC difference was acceptable.</p>															

Table 25: Hydrochemistry of the Polokwane Map Area, 50<sup>th</sup> percentile (median); second page.

Symbol	Total number of samples				50 <sup>th</sup> Percentile (median) and comparison to SANS 241:2015 maximum acceptable limits										
Aquifer Unit	After manipulation	Missing major anions or cations	E.N. $\leq \pm 10\%$ & EC $\leq 20\%$	Used for piper and Durov	pH Ideal 6 to 9	EC	NO <sub>3</sub>	F	TAL as (CaCO <sub>3</sub> )	Na	Mg	SO <sub>4</sub>	Cl	K	Ca
						mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
						370	20	1.5		400	200	600	600	100	300
<b>Category D: Intergranular and Fractured aquifers</b>															
Jle	36	2	50.0%	21	8.0	113	14.8	0.2	289	83	41	28	105	2	77
N-Za	105	2	59.0%	72	8.0	112	6.8	0.5	296	71	41	15	124	2	64
Mpa	26	3	15.4%	11	8.2	141	32.1	2.1	386	141	70	35	129	9	65
Msi	107	10	44.9%	54	8.0	90	2.2	0.2	330	53	40	15	57	2	54
Mn	179	6	43.0%	27	8.0	106	9.4	1.6	252	105	33	28	123	2	62
Vv	34	1	35.3%	25	8.1	155	25.5	0.6	350	150	62	37	165	2	71
Vrs	146	4	41.8%	75	7.8	150	11.8	0.5	359	124	58	36	178	5	78
Vpg	0														
Vml	103	1	57.3%	52	8.1	130	11.4	0.9	310	145	45	24	193	7	63
Vs	0														
Vpf	1	0	100.0%	1	7.8	176	0.0	0.1	443	148	118	47	252	11	26
Vz	11	0	18.2%	2	7.0	70	8.9	0.1	127	61	31	18	34	2	41
Vut	11	0	72.7%	9	8.2	115	4.2	0.6	387	192	37	68	180	3	45
Rt-Vt	176	7	53.4%	121	7.8	84	4.4	0.7	268	87	29	20	69	2	38
<p><b>Manipulation of samples:</b> removing duplicates and calculation of the harmonic mean for time series data, further elimination in some cases by plausibility of EN and EC. In most of the unit's analysis with EN up to <math>\pm 15\%</math> was used if the calculated EC difference was acceptable.</p>															

Table 26: Hydrochemistry of the Polokwane Map Area, 50<sup>th</sup> percentile (median); third page.

Symbol	Total number of samples				50 <sup>th</sup> Percentile (median) and comparison to SANS 241:2015 maximum acceptable limits										
	After manipulation	Missing major anions or cations	E.N. $\leq \pm 10\%$ & EC $\leq 20\%$	Used for piper and Durov	pH Ideal 6 to 9	EC	NO <sub>3</sub>	F	TAL as (CaCO <sub>3</sub> )	Na	Mg	SO <sub>4</sub>	Cl	K	Ca
						mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
						370	20	1.5		400	200	600	600	100	300
Ru-Vu	0														
RI-VI	64	5	34.4%	38	7.9	41	6.1	1.6	133	42	10	8	22	2	21
Rmo	68	0	42.6%	58	7.9	73	10.1	1.1	200	91	19	20	68	5	33
Rma	73	5	38.4%	41	8.0	157	23.3	1.5	342	178	51	52	194	11	72
Rhu	0														
Rho	930	35	52.6%	503	7.9	88	6.8	0.4	271	93	29	20	81	8	40
Rhx	884	30	72.2%	163	8.1	121	7.3	0.3	368	119	67	35	149	13	48
Zms	66	3	16.7%	21	8.0	114	27.4	0.8	348	89	62	29	68	6	70
Zbc	129	7	21.71%	44	8.1	108	21.3	0.8	323	92	56	17	90	9	63
Zma	83	6	22.9%	37	8.0	115	18.4	0.7	350	94	57	20	92	5	75
Zmd	5	0	60.0%	5	8.4	107	11.9	0.8	386	85	56	16	108	10	60
Zbk	5	0	20.0%	3	7.8	106	23.2	0.8	305	54	71	24	61	4	76
Zpg	78	3	29.5%	52	7.9	86	8.2	0.4	327	67	44	19	38	7	38
Zgo	22	2	59.1%	12	8.0	133	10.1	0.5	335	165	38	46	154	11	51
Zgx	647	39	49.0%	267	8.0	114	8.6	0.3	331	101	62	27	112	6	48

**Manipulation of samples:** removing duplicates and calculation of the harmonic mean for time series data, further elimination in some cases by plausibility of EN and EC. In most of the units analysis with EN up to  $\pm 15\%$  was used if the calculated EC difference was acceptable.

Table 27: Hydrochemistry of the Polokwane Map Area, 90th percentile (median); first page.

Symbol	Total number of samples	90 <sup>th</sup> Percentile (median) and comparison to SANS 241:2015 maximum acceptable limits														
Aquifer Unit	After manipulation	pH Ideal 6 to 9	EC	NO <sub>3</sub>	F	TAL as (CaCO <sub>3</sub> )	Na	Mg	SO <sub>4</sub>	Cl	K	Ca	Fe	Mn	Zn	
			mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			370	20	1.5		400	200	600	600	100	300	2	1	10	
<b>Category A: Intergranular aquifers</b>																
Q	120	8.5	202.5	16.28	2.65	534.82	227.42	113.62	75.34	268.16	15.05	72.45	0.079	0.029	0.040	
<b>Category B: Fractured aquifers</b>																
C-Tr	0															
Psr	1	7.7	522.0	1.0	0.5	302.0	192.6	205.1	53.3	1649.5	2.7	544.6	0.0010	0.0010		
C-Pwe	0															
Mva	60	8.4	82.2	4.1	1.7	339.6	111.8	49.2	50.5	87.4	5.7	51.5	0.1666	0.0500	0.055	
Mcl	31	8.0	43.2	4.4	0.4	160.7	24.1	14.5	12.6	26.6	1.5	34.1	0.0500	0.0660	0.665	
Mkr	367	8.3	459.8	36.1	1.0	441.9	427.4	165.4	90.5	1152.7	14.2	198.6	0.0655	0.6252	2.154	
Mbb	52	8.3	393.7	20.4	0.5	493.3	348.3	210.0	127.8	824.6	6.6	159.5	0.0580	0.0500	0.074	
Mma	395	8.4	329.4	35.1	2.2	464.5	310.4	127.4	56.9	813.8	12.2	164.4	0.0500	0.2679	0.282	
Mse	142	8.4	609.8	30.9	0.7	498.6	606.3	234.2	149.8	1406.3	23.8	245.7	0.0331	0.1556	1.312	
Mko	3	8.3	116.9	32.5	0.4	367.2	120.7	54.8	35.2	120.0	2.4	85.7	0.0001	0.6680		
Mwp	4	8.4	219.1	15.5	0.3	487.2	152.2	190.9	68.0	467.8	8.3	107.2	0.0112	0.1121	0.251	
Vrb	0															
Vvo	0															
<b>Category C: Karst aquifers</b>																
Vma	2	8.5	67.5	9.5	0.3	379.7	33.2	66.6	8.6	17.2	4.7	30.9	0.0010	0.0001		
<b>Manipulation of samples:</b> removing duplicates and calculation of the harmonic mean for time series data, further elimination in some cases by plausibility of EN and EC. In most of the units analysis with EN up to ±15% was used if the calculated EC difference was acceptable.																

Table 28: Hydrochemistry of the Polokwane Map Area, 90<sup>th</sup> percentile (median); second page.

Symbol	Total number of samples	90 <sup>th</sup> Percentile (median) and comparison to SANS 241:2015 maximum acceptable limits													
Aquifer Unit	After manipulation	pH Ideal 6 to 9	EC	NO <sub>3</sub>	F	TAL as (CaCO <sub>3</sub> )	Na	Mg	SO <sub>4</sub>	Cl	K	Ca	Fe	Mn	Zn
			mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			370	20	1.5		400	200	600	600	100	300	2	1	10
<b>Category D: Intergranular and Fractured aquifers</b>															
Jle	36	8.41	241.4	38.83	0.38	382.53	152.88	135.98	57.19	481.87	4.37	175.51	0.050	0.103	0.891
N-Za	105	8.30	228.6	30.10	1.84	446.34	197.12	117.63	53.78	407.20	10.52	126.50	0.191	0.211	1.677
Mpa	26	8.71	431.6	71.33	4.11	442.97	444.15	108.68	387.00	982.49	13.37	196.63	0.042	1.254	1.273
Msi	107	8.58	169.4	23.51	0.50	478.64	129.35	96.81	69.11	189.61	7.13	97.34	0.080	0.050	0.062
Mn	179	8.30	305.0	49.06	4.11	486.65	300.30	86.45	91.97	499.43	14.13	131.50	0.108	0.273	0.305
Vv	34	8.51	224.8	48.01	1.78	470.01	270.81	105.80	122.00	445.08	5.84	109.80	0.050	0.049	0.177
Vrs	146	8.35	263.0	34.96	1.54	504.98	289.54	134.72	114.85	518.24	11.33	152.00	0.050	0.095	0.314
Vpg	0														
Vml	103	8.48	314.1	36.07	2.29	400.59	360.40	98.02	82.58	628.70	15.77	153.62	0.050	0.241	1.538
Vs	0														
Vpf	1	7.80	176.0	0.02	0.11	442.60	148.10	117.60	46.90	251.90	10.68	25.60	0.0001	0.0001	
Vz	11	7.30	92.1	20.10	0.36	208.58	101.20	45.76	29.50	56.00	5.54	51.61	0.011	0.020	0.292
Vut	11	8.34	186.0	32.49	1.03	551.40	306.10	40.96	97.00	253.80	5.02	72.80	0.011	0.010	0.004
Rt-Vt	176	8.39	151.0	19.79	1.75	481.50	221.38	65.33	63.83	192.70	7.16	70.53	0.050	0.113	2.674
<p><b>Manipulation of samples:</b> removing duplicates and calculation of the harmonic mean for time series data, further elimination in some cases by plausibility of EN and EC.                      In most of the unit's analysis with EN up to ±15% was used if the calculated EC difference was acceptable.</p>															

Table 29: Hydrochemistry of the Polokwane Map Area, 90<sup>th</sup> percentile (median); third page.

Symbol	Total number of samples	90 <sup>th</sup> Percentile (median) and comparison to SANS 241:2015 maximum acceptable limits														
Aquifer Unit	After manipulation	pH Ideal 6 to 9	EC	NO <sub>3</sub>	F	TAL as (CaCO <sub>3</sub> )	Na	Mg	SO <sub>4</sub>	Cl	K	Ca	Fe	Mn	Zn	
			mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			370	20	1.5		400	200	600	600	100	300	2	1	10	
<b>Category D: Intergranular and Fractured aquifers</b>																
Ru-Vu	0															
RI-VI	64	8.38	82.4	14.95	3.68	227.41	109.44	26.43	65.08	94.46	3.80	48.34	1.262	0.038	0.225	
Rmo	68	8.32	113.0	32.22	3.00	304.83	159.30	34.04	40.71	154.74	7.93	60.42	0.0722	0.8535	0.775	
Rma	73	8.54	245.7	73.30	2.72	434.30	307.64	90.76	112.13	532.57	25.52	139.76	0.050	0.065	0.069	
Rhu	0															
Rho	930	8.41	164.9	20.18	0.96	419.03	194.97	64.10	61.02	233.31	18.80	80.96	0.055	0.140	0.643	
Rhx	884	8.48	196.0	19.61	0.61	475.88	203.87	98.82	86.10	304.11	20.20	78.07	0.050	0.129	0.034	
Zms	66	8.72	189.9	44.66	1.20	439.01	150.08	93.80	74.51	286.10	7.95	97.67	0.070	0.136	0.045	
Zbc	129	8.51	323.0	62.36	1.31	412.35	175.14	146.80	104.16	584.35	17.72	121.15	0.073	0.323	0.004	
Zma	83	8.40		92.88	1.17	462.16	233.59	148.05	74.44	471.82	12.30	147.28	0.050	0.058	0.010	
Zmd	5	8.54	137.8	16.38	1.00	439.56	94.97	77.60	40.74	148.14	11.09	91.80	0.001	0.001		
Zbk	5	8.48	133.0	59.07	0.91	391.80	75.89	79.38	51.75	174.85	5.73	98.83	0.013	0.020	0.036	
Zpg	78	8.36	129.1	21.93	0.98	453.05	149.29	72.45	47.91	122.96	13.96	60.04	0.053	0.100	0.734	
Zgo	22	8.43	234.9	24.18	1.53	442.20	345.91	82.51	123.51	490.67	17.79	81.46	0.073	0.427	0.131	
Zgx	647	8.47	189.9	38.09	0.62	521.13	179.53	116.01	66.59	290.25	12.60	88.02	0.050	0.171	0.086	
<p><b>Manipulation of samples:</b> removing duplicates and calculation of the harmonic mean for time series data, further elimination in some cases by plausibility of EN and EC.                      In most of the unit's analysis with EN up to ±15% was used if the calculated EC difference was acceptable.</p>																

Table 30: Summarized Major Anions: Chloride, Nitrate and Sulphate concentration ranges within aquifer units, first page.

Anions		Chloride Cl (mg/l)				Nitrate NO <sub>2</sub> + NO <sub>3</sub> as N (mg/l)				Sulphate SO <sub>4</sub> (mg/l)			
Symbol	Number of samples after manipulation	Class 0 (Ideal)	Class I (Acceptable)	Class II (Maximum Allowable)	Un-acceptable	Class 0 (Ideal)	Class I (Acceptable)	Class II (Maximum Allowable)	Un-acceptable	Class 0 (Ideal)	Class I (Acceptable)	Class II (Maximum Allowable)	Un-acceptable
Limit Ranges		100	200	600	>600	6	10	20	>20	200	400	600	>600
<b>Category A: Intergranular aquifers</b>													
Q	120	50.0%	29.8%	16.7%	3.5%	60.2%	14.2%	21%	4.4%	97.2%	1.8%	0.9%	
<b>Category B: Fractured aquifers</b>													
C-Tr													
Psr	1				100.0%	100.0%				100.0%			
C-Pwe													
Mva	60	93.3%	3.3%	3.3%		94.8%	3.4%	1.7%		100.0%			
Mcl	31	100.0%				93.3%	3.3%			100.0%			
Mkr	367	40.6%	15.3%	26.7%	17.5%	50.6%	9.4%	17.8%	22.2%	98.0%	1.7%		0.3%
Mbb	52	46.2%	7.7%	26.9%	19.2%	29.2%	8.3%	50.0%	12.5%	96.0%	4.0%		0.0%
Mma	395	42.7%	15.6%	26.6%	15.1%	47.2%	8.8%	17.4%	26.7%	97.9%	1.0%		0.3%
Mse	142	5.7%	24.1%	31.9%	38.3%	22.1%	17.9%	35.7%	24.3%	95.0%	4.3%		0.7%
Mko	3	66.7%	33.3%			33.3%			66.7%	100.0%			
Mwp	4	50.0%	25.0%		25.0%	66.7%		33.3%	0.0%	100.0%			
Vrb													
Vwo													
<b>Category C: Karst aquifers</b>													
Vma	2	100.0%					100.0%			100.0%			
<b>Note: 0% occurrences removed to make the table more readable</b>													

Table 31: Summarized Major Anions: Chloride, Nitrate and Sulphate concentration ranges within aquifer units, second page.

Anions		Chloride Cl (mg/l)				Nitrate NO <sub>2</sub> + NO <sub>3</sub> as N (mg/l)				Sulphate SO <sub>4</sub> (mg/l)			
Symbol	Number of samples after manipulation	Class 0 (Ideal)	Class I (Acceptable)	Class II (Maximum Allowable)	Un-acceptable	Class 0 (Ideal)	Class I (Acceptable)	Class II (Maximum Allowable)	Un-acceptable	Class 0 (Ideal)	Class I (Acceptable)	Class II (Maximum Allowable)	Un-acceptable
Limit Ranges		100	200	600	>600	6	10	20	>20	200	400	600	>600
<b>Category D: Intergranular and Fractured aquifers</b>													
<b>Jle</b>	36	47.1%	14.7%	32.4%	5.9%	35.3%		20.6%	44.1%	97.1%		2.9%	
<b>N-Za</b>	105	41.0%	26.7%	26.7%	5.7%	45.6%	17.5%	20.4%	16.5%	99.0%	1.0%		
<b>Mpa</b>	26	26.9%	46.2%	11.5%	15.4%	4.0%	12.0%	8.0%	76.0%	84.0%	4.0%	8.0%	4.0%
<b>Msi</b>	107	64.6%	26.3%	8.1%	1.0%	59.4%	3.8%	21.7%	15.1%	97.9%	2.1%		
<b>Mn</b>	179	44.4%	19.1%	28.1%	8.4%	44.7%	7.1%	23.5%	24.7%	98.3%	1.7%		
<b>Vv</b>	34	26.5%	32.4%	35.3%	5.9%	15.2%	3.0%	15.2%	66.7%	94.1%	5.9%		
<b>Vrs</b>	146	31.5%	24.5%	38.5%	5.6%	25.9%	18.9%	25.9%	29.4%	95.8%	3.5%	0.7%	
<b>Vpg</b>													
<b>Vml</b>	103	31.4%	20.6%	36.3%	11.8%	19.6%	20.6%	28.4%	31.4%	97.0%	3.0%		
<b>Vs</b>													
<b>Vpf</b>	1			100.0%		100.0%				100.0%			
<b>Vz</b>	11	100.0%				27.3%	27.3%	27.3%	18.2%	100.0%			
<b>Vut</b>	11	45.5%	27.3%	27.3%		54.5%			45.5%	100.0%			
<b>Rt-Vt</b>	176	69.4%	23.1%	6.9%	0.6%	63.6%	17.3%	8.7%	10.4%	98.8%	1.2%		
<b>Note: 0% removed to make the table more readable</b>													

Table 32: Summarized Major Anions: Chloride, Nitrate and Sulphate concentration ranges within aquifer units, third page.

Anions		Chloride Cl (mg/l)				Nitrate NO <sub>2</sub> + NO <sub>3</sub> as N (mg/l)				Sulphate SO <sub>4</sub> (mg/l)			
Symbol	Number of samples after manipulation	Class 0 (Ideal)	Class I (Acceptable)	Class II (Maximum Allowable)	Un-acceptable	Class 0 (Ideal)	Class I (Acceptable)	Class II (Maximum Allowable)	Un-acceptable	Class 0 (Ideal)	Class I (Acceptable)	Class II (Maximum Allowable)	Un-acceptable
Limit Ranges		100	200	600	>600	6	10	20	>20	200	400	600	>600
<b>Category D: Intergranular and Fractured aquifers continue</b>													
Ru-Vu													
Rl-VI	64	94.9%	3.4%	1.7%		47.5%	23.7%	23.7%	5.1%	98.3%	1.7%		
Rmo	68	75.0%	22.1%	2.9%		25.4%	22.4%	37.3%	14.9%	100.0%			
Rma	73	24.3%	27.1%	42.9%	5.7%	12.5%	9.7%	25.0%	52.8%	95.7%	1.4%		2.9%
Rhu													
Rho	930	58.7%	27.2%	12.9%	1.2%	44.2%	22.5%	23.0%	10.3%	99.9%	0.1%		
Rhx	884	23.1%	47.2%	27.0%	2.6%	42.1%	23.9%	24.4%	9.6%	97.9%	1.4%	0.2%	0.5%
Zms	66	73.8%	12.3%	12.3%	1.5%	9.5%		12.7%	77.8%	95.2%	1.6%	3.2%	
Zbc	129	58.9%	13.2%	17.8%	10.1%	12.0%	13.6%	22.4%	52.0%	97.6%	1.6%	0.8%	
Zma	83	51.2%	18.3%	24.4%	6.1%	17.5%	12.5%	28.8%	41.3%	100.0%			
Zmd	5	40.0%	60.0%			40.0%		60.0%		100.0%			
Zbk	5	80.0%		20.0%			25.0%	25.0%	50.0%	100.0%			
Zpg	78	84.4%	14.3%	1.3%		36.8%	28.9%	21.1%	13.2%	100.0%			
Zgo	22	27.3%	31.8%	31.8%	9.1%	36.4%	13.6%	31.8%	18.2%	95.5%	4.5%		
Zgx	647	45.3%	33.6%	19.5%	1.6%	41.5%	13.3%	19.9%	25.3%	98.5%	0.8%	0.3%	0.3%
<b>Note:</b> 0% removed to make the table more readable													

Table 33: Summarized Major Cations: Calcium, Potassium, Magnesium and Sodium concentration ranges within aquifer units, first page.

Cations		Calcium Ca (mg/l)				Potassium K (mg/l)				Magnesium Mg (mg/l)				
Symbol	Number of samples after manipulation	Class 0 (Ideal)	Class I (Acceptable)	Class II (Max Allowed)	Un-acceptable	Class 0 (Ideal)	Class I (Acceptable)	Class II (Max Allowed)	Un-acceptable	Class 0 (Ideal)	Class I (Acceptable)	Class II (Max Allowed)	Un-acceptable	Class 0 (Ideal)
Limit Ranges		80	150	300	>300	25	50	100	>100	70	100	200	>200	100
<b>Category A: Intergranular aquifers</b>														
<b>Q</b>	120	89.8%	7.4%	0.9%	1.9%	98%	0.0%	0.9%	0.9%	73.1%	13.9%	11.1%	1.9%	23.1%
<b>Category B: Fractured aquifers</b>														
<b>C-Tr</b>														
<b>Psr</b>	1				100.0%	100.0%							100.0%	
<b>C-Pwe</b>														
<b>Mva</b>	60	98.3%	1.7%			100.0%				96.6%	1.7%	1.7%		83.3%
<b>Mcl</b>	31	100.0%				100.0%				100.0%				100.0%
<b>Mkr</b>	367	64.7%	20.5%	9.1%	5.7%	96.4%	2.7%	0.6%	0.3%	64.5%	14.0%	14.0%	7.4%	52.1%
<b>Mbb</b>	52	62.5%	25.0%	10.4%	2.1%	100.0%				47.9%	14.6%	22.9%	14.6%	50.0%
<b>Mma</b>	395	58.1%	29.8%	8.2%	3.9%	96.3%	2.7%	1.1%		67.1%	17.0%	12.6%	3.3%	48.6%
<b>Mse</b>	142	50.0%	24.3%	19.1%	6.6%	91.8%	6.7%	1.5%		44.9%	14.0%	28.7%	12.5%	21.3%
<b>Mko</b>	3	66.7%	33.3%			100.0%				100.0%				33.3%
<b>Mwp</b>	4	75.0%	25.0%			100.0%				50.0%	25.0%		25.0%	75.0%
<b>Vrb</b>														
<b>Vwo</b>														
<b>Category C: Karst aquifers</b>														
<b>Vma</b>	2	100.0%				100.0%				100.0%				100.0%
Note: 0% removed to make the table more readable														

Table 34: Summarized Major Cations: Calcium, Potassium, Magnesium and Sodium concentration ranges within aquifer units, second page.

Cations		Calcium Ca (mg/l)				Potassium K (mg/l)				Magnesium Mg (mg/l)				Sodium Na (mg/l)			
Symbol	Number of samples after manipulation	Class 0 (Ideal)	Class I (Acceptable)	Class II (Max Allowed)	Un-acceptable	Class 0 (Ideal)	Class I (Acceptable)	Class II (Max Allowed)	Un-acceptable	Class 0 (Ideal)	Class I (Acceptable)	Class II (Max Allowed)	Un-acceptable	Class 0 (Ideal)	Class I (Acceptable)	Class II (Max Allowed)	Un-acceptable
Limit Ranges		80	150	300	>300	25	50	100	>100	70	100	200	>200	100	200	400	>400
<b>Category D: Intergranular and Fractured aquifers</b>																	
<b>Jle</b>	36	52.9%	35.3%	5.9%	5.9%	100.0%				79.4%	5.9%	8.8%	5.9%	55.9%	38.2%	2.9%	2.9%
<b>N-Za</b>	105	63.1%	33.0%	1.9%	1.9%	98.0%	2.0%			74.8%	13.6%	9.7%	1.9%	57.3%	34.0%	6.8%	1.9%
<b>Mpa</b>	26	65.2%	13.0%	17.4%	4.3%	95.7%		4.3%		47.8%	34.8%	17.4%		8.7%	65.2%	13.0%	13.0%
<b>Msi</b>	107	81.4%	16.5%	2.1%		99.0%	1.0%			68.0%	23.7%	8.2%		74.0%	24.0%	2.1%	
<b>Mn</b>	179	65.3%	27.7%	6.4%	0.6%	96.5%	3.5%			86.1%	5.8%	5.8%	2.3%	46.2%	30.6%	17.3%	5.8%
<b>Vv</b>	34	60.6%	36.4%		3.0%	100.0%				57.6%	18.2%	21.2%	3.0%	27.3%	54.5%	18.2%	
<b>Vrs</b>	146	51.4%	37.9%	9.3%	1.4%	98.6%	0.7%	0.7%		62.1%	21.4%	12.1%	4.3%	37.1%	33.6%	27.9%	1.4%
<b>Vpg</b>																	
<b>Vml</b>	103	64.7%	24.5%	9.8%	1.0%	97.1%	2.0%	1.0%		78.4%	11.8%	7.8%	2.0%	28.7%	42.6%	19.8%	8.9%
<b>Vs</b>																	
<b>Vpf</b>	1	100.0%				100.0%						100.0%			100.0%		
<b>Vz</b>	11	90.9%	9.1%			100.0%				100.0%				81.8%	18.2%		
<b>Vut</b>	11	90.9%	9.1%			100.0%				100.0%				36.4%	18.2%	45.5%	
<b>Rt-Vt</b>	176	92.9%	7.1%			99.4%	0.6%			91.7%	7.7%	0.6%		55.4%	31.5%	12.5%	0.6%
<b>Note: 0% removed to make the table more readable</b>																	

Table 35: Summarized Major Cations: Calcium, Potassium, Magnesium and Sodium concentration ranges within aquifer units, third page.

Cations		Calcium Ca (mg/l)				Potassium K (mg/l)				Magnesium Mg (mg/l)				Sodium Na (mg/l)			
Symbol	Number of samples after manipulation	Class 0 (Ideal)	Class I (Acceptable)	Class II (Max Allowed)	Un-acceptable	Class 0 (Ideal)	Class I (Acceptable)	Class II (Max Allowed)	Un-acceptable	Class 0 (Ideal)	Class I (Acceptable)	Class II (Max Allowed)	Un-acceptable	Class 0 (Ideal)	Class I (Acceptable)	Class II (Max Allowed)	Un-acceptable
Limit Ranges		80	150	300	>300	25	50	100	>100	70	100	200	>200	100	200	400	>400
<b>Category D: Intergranular and Fractured aquifers</b>																	
Ru-Vu																	
RI-VI	64	100.0%				98.3%	1.7%			100.0%				88.1%	11.9%		
Rmo	68	98.5%	1.5%			98.5%	1.5%			98.5%		1.5%		63.2%	35.3%	1.5%	
Rma	73	58.8%	35.3%	2.9%	2.9%	88.1%	11.9%			75.0%	16.2%	7.4%	1.5%	4.4%	61.8%	29.4%	4.4%
Rhu																	
Rho	930	89.8%	7.9%	2.1%	0.1%	95.2%	2.9%	1.6%	0.2%	91.9%	5.9%	2.1%		55.7%	34.9%	9.1%	0.2%
Rhx	884	90.6%	7.6%	1.3%	0.5%	96.2%	3.2%	0.4%	0.2%	53.0%	37.5%	8.3%	1.2%	31.6%	57.5%	8.9%	2.0%
Zms	66	68.3%	28.6%		3.2%	100.0%				65.1%	25.4%	7.9%	1.6%	66.7%	27.0%	4.8%	1.6%
Zbc	129	73.0%	17.2%	7.4%	2.5%	95.1%	4.1%	0.8%		72.1%	7.4%	14.8%	5.7%	59.8%	30.3%	6.6%	3.3%
Zma	83	52.0%	38.7%	9.3%		100.0%				57.9%	11.8%	30.3%		55.8%	32.5%	11.7%	
Zmd	5	80.0%	20.0%			100.0%				80.0%	20.0%			100.0%			
Zbk	5	60.0%	40.0%			100.0%				40.0%	60.0%			100.0%			
Zpg	78	97.3%	2.7%			100.0%				88.0%	10.7%	1.3%		72.0%	25.3%	2.7%	
Zgo	22	90.0%		10.0%		100.0%				80.0%	15.0%	5.0%		15.0%	45.0%	35.0%	5.0%
Zgx	647	85.5%	12.8%	1.3%	0.3%	98.6%	1.2%	0.2%		57.5%	24.9%	17.0%	0.7%	49.5%	45.4%	4.4%	0.7%
<b>Note: 0% removed to make the table more readable.</b>																	

Table 36: Summarized Electrical Conductivity, pH, and Fluoride concentration ranges within aquifer units, first page.

Physical properties & F		Conductivity (mS/m)				pH (pH units)				Fluoride F (mg/l)			
Symbol	Number of samples after manipulation	Class 0 (Ideal)	Class I (Acceptable)	Class II (Maximum Allowable)	Un-acceptable	Acceptable Acidic	Ideal	Acceptable Alkali	Un-acceptable	Class 0 (Ideal)	Class I (Acceptable)	Class II (Maximum Allowable)	Un-acceptable
Limits Ranges		70	150	370	>370	4.0 -5.9	6.0-9.0	9.1 - 10.0	>10 & <4	0.7	1	1.5	>1.5
<b>Category A: Intergranular aquifers</b>													
Q	120	12.1%	63.8%	20.7%	3.4%		99.1%		0.9%	63.9%	11.1%	6.5%	18.5%
<b>Category B: Fractured aquifers</b>													
C-Tr	0												
Psr	1				100.0%		100.0%			100.0%			
C-Pwe	0												
Mva	60	80.0%	18.3%	1.7%		3.3%	96.7%			85.0%	1.7%	13.3%	
Mcl	31	96.7%	3.3%				100.0%			90.3%	3.2%	3.2%	3.2%
Mkr	367	27.8%	34.4%	24.2%	13.5%	1.4%	98.6%			81.9%	8.2%	4.8%	5.1%
Mbb	52	15.4%	36.5%	36.5%	11.5%		100.0%			97.9%	2.1%		
Mma	395	29.9%	32.0%	29.7%	8.4%	0.3%	99.5%	0.3%		63.5%	10.5%	8.7%	17.2%
Mse	142	2.1%	28.4%	45.4%	24.1%		100.0%			84.4%	13.5%	0.7%	1.4%
Mko	3	33.3%	66.7%				100.0%			100.0%			
Mwp	4	25.0%	50.0%	25.0%			100.0%			100.0%			
Vrb	0												
Vwo	0												
<b>Category C: Karst aquifers</b>													
Vma	2	100.0%					100.0%			100.0%			
Note: 0% occurrences removed to make the table more readable													

Table 37: Summarized Electrical Conductivity, pH, and Fluoride concentration ranges within aquifer units, second page.

Physical properties & the anion Fluoride (F)		Conductivity (mS/m)				pH (pH units)				Fluoride F (mg/l)			
Symbol	Number of samples after manipulation	Class 0 (Ideal)	Class I (Acceptable)	Class II (Maximum Allowable)	Un-acceptable	Acceptable Acidic	Ideal	Acceptable Alkali	Un-acceptable	Class 0 (Ideal)	Class I (Acceptable)	Class II (Maximum Allowable)	Un-acceptable
Limits Ranges		70	150	370	>370	4.0 -5.9	6.0-9.0	9.1 - 10.0	>10 & <4	0.7	1	1.5	>1.5
<b>Category D: Intergranular and Fractured aquifers</b>													
<b>Jle</b>	36	20.6%	41.2%	32.4%	5.9%		100.0%			97.1%		3%	
<b>N-Za</b>	105	25.7%	46.7%	22.9%	4.8%		100.0%			64.4%	11%	8%	17.3%
<b>Mpa</b>	26		57.7%	30.8%	11.5%		100.0%			8.0%	4%	8%	80.0%
<b>Msi</b>	107	43.4%	37.7%	17.9%	0.9%		96.1%	3.9%		96.1%	3%	1%	
<b>Mn</b>	179	27.5%	42.1%	24.2%	6.2%		100.0%			27.7%	8%	11%	53.2%
<b>Vv</b>	34	8.8%	38.2%	50.0%	2.9%		100.0%			57.6%	9%	21%	12.1%
<b>Vrs</b>	146	2.8%	46.9%	46.2%	4.2%		99.3%	0.7%		59.3%	14%	16%	10.7%
<b>Vpg</b>	0												
<b>Vml</b>	103	14.7%	38.2%	42.2%	4.9%		100.0%			43.6%	13%	9%	34.7%
<b>Vs</b>	0												
<b>Vpf</b>	1			100.0%			100.0%			100.0%			
<b>Vz</b>	11	54.5%	45.5%				100.0%			100.0%			
<b>Vut</b>	11	9.1%	54.5%	36.4%			100.0%			72.7%	9%	9%	9.1%
<b>Rt-Vt</b>	176	30.3%	58.9%	10.3%	0.6%		99.4%	0.6%		52.1%	12%	17%	19.0%
<b>Note: 0% removed to make the table more readable.</b>													

Table 38: Summarized Electrical Conductivity, pH, and Fluoride concentration ranges within aquifer units, third page.

Physical properties & the anion Fluoride (F)		Conductivity (mS/m)				pH (pH units)				Fluoride F (mg/l)			
Symbol	Number of samples after manipulation	Class 0 (Ideal)	Class I (Acceptable)	Class II (Maximum Allowable)	Un-acceptable	Acceptable Acidic	Ideal	Acceptable Alkali	Un-acceptable	Class 0 (Ideal)	Class I (Acceptable)	Class II (Maximum Allowable)	Un-acceptable
Limits Ranges		70	150	370	>370	4.0 -5.9	6.0-9.0	9.1 - 10.0	>10 & <4	0.7	1	1.5	>1.5
<b>Category D: Intergranular and Fractured aquifers</b>													
Ru-Vu	0												
RI-VI	64	83.1%	16.9%				100.0%			22.4%	10%	9%	58.6%
Rmo	68	35.3%	58.8%	4.4%	1.5%	0.0%	100.0%	0.0%	0.0%	35.3%	10%	18%	36.8%
Rma	73	1.4%	45.8%	48.6%	4.2%		100.0%			17.1%	10%	19%	54.3%
Rhu	0												
Rho	930	32.7%	54.3%	12.8%	0.2%		99.7%	0.2%	0.1%	83.8%	7%	5%	4.7%
Rhx	884	4.4%	69.6%	24.3%	1.6%		99.5%	0.3%	0.1%	92.7%	3%	3%	1.6%
Zms	66	1.5%	80.0%	15.4%	3.1%		100.0%			36.5%	38%	19%	6.3%
Zbc	129	7.0%	62.0%	24.0%	7.0%		99.2%	0.8%		41.9%	17%	36%	4.8%
Zma	83	6.2%	55.6%	38.3%			100.0%			52.5%	29%	16%	2.5%
Zmd	5		100.0%				100.0%			20.0%	60%	20%	
Zbk	5		100.0%				100.0%			50.0%	50%		
Zpg	78	32.5%	63.6%	3.9%			100.0%			79.2%	11%	7%	2.8%
Zgo	22	4.5%	54.5%	36.4%	4.5%		100.0%			54.5%	5%	27%	13.6%
Zgx	647	24.8%	46.0%	28.3%	0.9%	0.0%	99.7%	0.3%		93.0%	4%	2%	1.5%
<b>Note: 0% removed to make the table more readable.</b>													

## 6.2 Aquifer Units

The lithostratigraphy of the hydrogeological map sheet are based on the existing 1:250 000 geological map sheet 2328 Polokwane, that was used to sub-divide the map sheet area into hydrogeological relevant lithological units (referenced as aquifer units), which possess some degree of lithological homogeneity and similarities in rock properties. However, lithological homogeneity and similarities in rock properties were not the only consideration. Where geological formations were large enough, they were regarded as separate units, despite lithological homogeneity and similarities in rock properties with adjacent formations or lithologies.

The groundwater resource units or aquifer units are grouped together based on the interpreted groundwater occurrence viz. **Intergranular (a), Fractured (b), Karst (c) and Intergranular and Fractured (d)**.

A total of forty-four (44) groundwater resource units were identified, characterized, and discussed in terms of areal extent, general geology and statistics on yield and water quality. Additional aspects that were covered in some of the units are groundwater targets, proven geophysical methods and references to findings in previous groundwater reports. The methodology used for the characterization of each unit is similar throughout the report and is based on the same methodology used for the 1:500 000 hydrogeological map series.

The Intergranular aquifer consists of a single unit with an aerial extent of 281.57km<sup>2</sup> (1.2%); the Fractured aquifers consist of 13 units with an aerial extent of 6556.78km<sup>2</sup> (29.05%); the Karst aquifer consists of 1 unit with an aerial extent of 2.98km<sup>2</sup> (0.01%), and the Intergranular and Fractured aquifers consists of 29 units with an aerial extent of 15727.18km<sup>2</sup> (69.69%) of the map area. The Polokwane 1: 250 000 hydrogeological map covers an area of approximately 22 568.51km<sup>2</sup>. Surface water bodies cover an area that is less than 10km<sup>2</sup> (0.04%) of the map area and it was not used in the calculation of the total area as it is underlain by groundwater resource units.

Table 39: Basic information for the aquifer units and areal extent, first page.

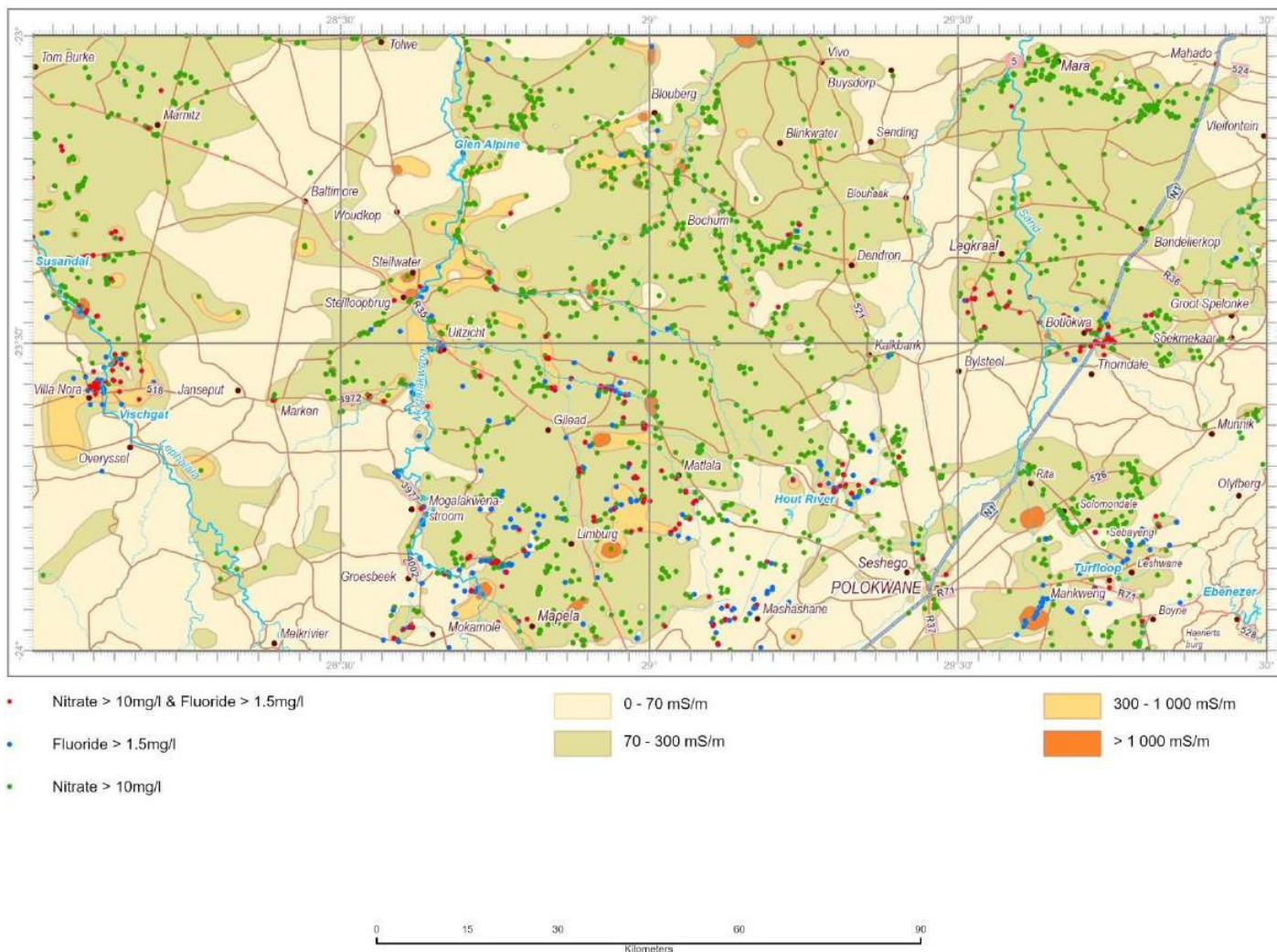
Unit symbol	Lithostratigraphy	Geochronology	Geological time period	Geological description	Areal extent (km <sup>2</sup> )	% Of map area
Surface water bodies, size not added to calculation for the total map extent					9.030	0.04%
<b>Category A: Intergranular aquifers</b>						
Q	Alluvium	Tertiary Quaternary	Tertiary Quaternary	Alluvium	281.571	1.2%
<b>Total for Alluvium aquifers</b>					281.571	1.2%
<b>Category B: Fractured aquifers</b>						
C-Tr	Undifferentiated Karoo Sediments	Karoo Supergroup	Permian	Integrated Madzaringwe, Fripp, Solitude, Klopperfontein, and Clarence Formations	138.544	0.61%
Psr	Swartrant Formation	Karoo Supergroup	Permian	Sandstone, "grit", siltstone, carbonaceous mudrock, coal seams	54.378	0.24%
C-Pwe	Wellington and lower Waterkloof Formation	Karoo Supergroup	Carboniferous to Permian	Mudrock (with angular dropstones), sandstone intercalations; Mudstone, siltstone, minor grit (Old Rock), diamictite	16.333	0.07%
Mva	Vaalwater Formation	Waterberg Supergroup	Mokolian	Feldspathic sandstone, arkose, siltstone, shale	37.151	0.16%
Mcl	Cleremont Formation	Waterberg Supergroup	Mokolian	Very coarse-grained, white sandstone with fine-grained, purple, micaceous sandstone at the base	83.936	0.37%
Mkr	Kransberg Subgroup (Integrated Sandriviersberg & Mogalakwena Formations)	Waterberg Supergroup	Mokolian	Sandstone, subordinate conglomerate, siltstone and shale	3228.017	14.30%
Mbb	Blouberg Formation	Waterberg Supergroup	Mokolian	Coarse-grained sandstone (feldspathic in places), "grit", conglomerate.	132.706	0.59%
Mma	Makgabeng Formation	Waterberg Supergroup	Mokolian	Fine- to medium- grained cross-bedded sandstone, slightly feldspathic at the base	1935.756	8.58%
Mse	Setlaole Formation	Waterberg Supergroup	Mokolian	Granule-rich sandstone, conglomerate, minor tuff and mudstone.	299.426	1.33%
Mko	Koedoesrand Formation	Waterberg Supergroup	Mokolian	Conglomerate, quartzite, shale	36.098	0.16%
Mwp	Wylliespoort Formation	Soutpansberg Supergroup	Mokolian	Consists of medium- to coarse grained almost entirely pink, in places whitish, and red quartzite.	520.456	2.31%
Vrb	Undifferentiated Rooiberg Group	Transvaal Supergroup	Vaalian	rhyolite with interbedded agglomerate and tuff	66.853	0.30%
Vwo	Wolkberg Group	Transvaal Supergroup	Vaalian	dark coloured shale with intercalations of whitish and grey quartzite and conglomerate	7.124	0.03%
<b>Total for Fractured aquifers</b>					6556.778	29.05%
<b>Category C: Karst aquifers</b>						
Vma	Malmani Subgroup	Transvaal Supergroup	Vaalian	Dolomite, subordinate chert, minor carbonaceous shale, limestone and quartzite	2.982	0.01%
<b>Total for Karst aquifers</b>					2.982	0.01%

Table 40: Basic information for the aquifer units and areal extent, second page.

Unit symbol	Lithostratigraphy	Geochronology	Geological time period	Geological description	Areal extent (km <sup>2</sup> )	% Of map area
<b>Category D: Intergranular and Fractured aquifers</b>						
Jle	Letaba Formation	Karoo Supergroup	Jurassic	Basalt	577.468	2.56%
N-Za	Diabase Intrusions	Intrusive	Vaalian	Diabase Intrusions	355.436	1.57%
Mpa	Palala Granite	Granite intrusions	Mokolian	pinkish-grey, medium- to coarse-grained granite	76.912	0.34%
Msi	Sibasa Formation	Soutpansberg Supergroup	Mokolian	Reddish or brown, medium- to coarse-grained sandstone and quartzite, minor conglomerate, basaltic lava and tuff. Comprising Tshishefhe, Sibasa, Wylliespoort Formations.	520.456	2.31%
Mn	Nebo Granite	Bushveld Igneous Complex	Mokolian	Granite, Granophyric, porphyric, pegmatitic or aplitic	728.348	3.23%
Vv	Villa Nora Gabbro-Anorthosite	Bushveld Igneous Complex	Mokolian	Magnetite gabbro, anorthosite, magnetite; Villa Norra Gabbro	263.696	1.17%
Vrs	Undifferentiated Rustenburg Layered Suite	Bushveld Igneous Complex	Vaalian	Includes Molendraai magnetite gabbro and Mapela Formation.	169.702	0.75%
Vpg	Undifferentiated Pretoria Group	Transvaal Supergroup	Vaalian	Andesitic lava, subordinate pyroclastic rocks, minor quartzite, shale and conglomerate	7.534	0.03%

Table 41: Basic information for the aquifer units and areal extent, third page.

Unit symbol	Lithostratigraphy	Geochronology	Geological time period	Geological description	Areal extent (km <sup>2</sup> )	% Of map area
<b>Category D: Intergranular and Fractured aquifers- continue</b>						
Vml	Matalala Granite	Granite intrusions	Randian to Vaalian	Fine-grained grey to pink biotite granite, coarse grained and in places porphyritic	268.070	1.19%
Vs	Smitskraal Granite	Granite intrusions	Vaalian	Unnamed Granite (Leucocratic biotite granite)	81.651	0.36%
Vpf	Palmietfontein Granite	Granite intrusions	Vaalian	Shale, quartzite, minor conglomerate Palmietfontein formation	2.532	0.01%
Vz	Unnamed Granite Rocks	Granite intrusions	Vaalian	leucocratic, whitish, medium-to coarse-grained granite as well as syenite	91.666	0.41%
Vut	Utrecht Granite	Granite intrusions	Vaalian	Pink, fine-grained, granodioritic biotite granite	12.840	0.06%
Rt-Vt	Turfloop Granite	Granite intrusions	Randian to Vaalian	Grey to pink, medium- to coarse-grained, adamellitic/granodioritic biotite granite	641.219	2.84%
Ru-Vu	Uitloop Granite	Granite intrusions	Randian to Vaalian	Reddish, fine- to coarse-grained biotite granite	0.199	0.00%
RI-VI	Lunsklip Granite	Granite intrusions	Randian to Vaalian	Pink, medium- to coarse-grained, hornblende-biotite granite	143.255	0.63%
Rmo	Moletsi Granite	Granite intrusions	Randian	Coarse-grained, porphyritic, pink and grey biotite granite, in places hornblende granite	132.215	0.59%
Rma	Matok Granite	Granite intrusions	Randian	Coarse-grained, porphyritic, pink and grey biotite granite, in places hornblende granite	232.815	1.03%
Rhu	Hugomond Granite	Granite intrusions	Randian	arse-grained, sometimes porphyritic, grey biotite	4.587	0.02%
Rho	Hout River Gneiss	Basement Gneisses	Randian	Leucocratic, strongly migmatized biotite gneiss and greyish, weakly migmatized biotite gneiss; minor leucogneiss and dark grey biotite gneiss	3128.202	13.86%
Rhx	Hout River Gneiss with Xenoliths	Basement Gneisses	Randian	Leucocratic, strongly migmatized biotite gneiss and greyish, weakly migmatized biotite gneiss; minor leuco gneiss and dark grey biotite gneiss with xenoliths	3136.729	13.90%
Zms	Undifferentiated Messina Suite	Beit Bridge Complex	Swazian	Mylonitised Bushveld, Beit Bridge and Constantia rocks	196.539	0.87%
Zbc	Undifferentiated Beit Bridge Complex	Beit Bridge Complex	Swazian	Undifferentiated rocks and various mixed lithologies. Undifferentiated Beit Bridge Complex	1436.740	6.37%
Zma	Undifferentiated Malala Drift Group	Beit Bridge Complex	Swazian	Leucogneiss with metaquartzite, hornblende granitoid gneiss, amphibolite, metapelite and calc-silicate rocks	518.297	2.30%
Zmd	Mount Dowe Group	Beit Bridge Complex	Swazian	Metaquartzite, leucogneiss, pink biotite-hornblende granitoid gneiss. Mount Dowe	49.976	0.22%
Zbk	Undifferentiated Bandelierkop Complex	Banderlierkop Complex	Swazian	Amphibolite, mafic granulite. Undifferentiated Bandelierskop	35.820	0.16%
Zpg	Undifferentiated Pietersburg Group (mostly Mothiba Formation)	Pietersburg Group	Swazian	talc-chlorite & amphibole-chlorite schist, amphibolite, Greenstone Belt	244.912	1.09%
Zgo	Goudplaats Gneiss	Basement Gneisses	Swazian	Leucocratic, strongly migmatized biotite gneiss and greyish, weakly migmatized biotite gneiss; minor leucogneiss and dark grey biotite gneiss	40.818	0.18%
Zgx	Goudplaats Gneiss with Xenoliths	Basement Gneisses	Swazian	Leucocratic, strongly migmatized biotite gneiss and greyish, weakly migmatized biotite gneiss; minor leucogneiss and dark grey biotite gneiss with xenoliths	2628.544	11.65%
<b>Total for Intergranular and Fractured aquifers</b>					<b>15727.178</b>	<b>69.69%</b>
<b>Total areal extent of map area, South Africa</b>					<b>22568.5</b>	



*Figure 8: Distribution of Electrical conductivity (EC) and boreholes with Nitrate and Fluoride values exceeding the acceptable levels for human consumption.*

An Explanation of the 1:250 000 Hydrogeological Map Sheet 2328 Polokwane.

## 7. HYDROGEOLOGY OF THE VARIOUS GEOLOGICAL GROUPS AND FORMATIONS

In this chapter the hydrogeology of the various geological groups and formations is briefly described in terms of its geographical location, occurrence, general use, and quality. Hydrogeology is supported by a statistical analysis of the borehole data available for each group or formation. For yield data, the results are portrayed as borehole yield frequency diagrams and for the hydrochemistry as Piper and Durov diagrams. Table 42 shows the percentage boreholes in each yield range as obtained from the yield frequency diagrams.

Table 42: Summary of borehole yield distributions.

Aquifer Unit	Total number dry boreholes	Total number wet boreholes	Total boreholes with no information	0-0.01	0.1-0.5	0.5-2	2-5	5-10	>10
				(ℓ/s)	(ℓ/s)	(ℓ/s)	(ℓ/s)	(ℓ/s)	(ℓ/s)
<b>Category A: Intergranular aquifers</b>									
<b>Q</b>	49	141	377	2.1%	3.5%	19.1%	17.7%	24.1%	33.3%
<b>Category B: Fractured aquifers</b>									
<b>C-Tr</b>	47	39	55	20.5%	17.9%	23.1%	25.6%	5.1%	7.7%
<b>Psr</b>	0	21	7	33.3%	23.8%	42.9%			
<b>C-Pwe</b>	0	3	2		33.3%	33.3%		33.3%	
<b>Mva</b>	198	431	135	16.5%	21.3%	32.5%	21.3%	6.5%	1.9%
<b>Mcl</b>	20	225	30	20.9%	24.9%	24.9%	16.0%	8.0%	5.3%
<b>Mkr</b>	468	799	125	15.3%	31.2%	31.7%	16.0%	4.4%	1.5%
<b>Mbb</b>	61	54	40	7.4%	14.8%	33.3%	33.3%	9.3%	1.9%
<b>Mma</b>	28	642	224	10.3%	25.4%	32.6%	19.5%	8.6%	3.7%
<b>Mse</b>	76	158	100	9.5%	27.8%	19.6%	17.1%	14.6%	11.4%
<b>Mko</b>	4	5	2	0.0%	0.0%	60.0%	20.0%	20.0%	
<b>Mwp</b>	0	7	9	28.6%	28.6%	42.9%			
<b>Vrb</b>	0	26	14	23.1%	23.1%	50.0%	3.8%		
<b>Vwo</b>	No information								
<b>Category C: Karst aquifers</b>									
<b>Vma</b>	1	3	0			66.7%	33.3%		
<b>Category D: Intergranular and Fractured aquifers</b>									
<b>Jle</b>	31	32	19		18.8%	59.4%	12.5%	6.3%	3.1%
<b>N-Za</b>	101	162	51	13.6%	23.5%	37.0%	16.7%	7.4%	1.9%
<b>Mpa</b>	9	31	32	19.4%	16.1%	25.8%	16.1%	16.1%	6.5%
<b>Msi</b>	92	106	61	10.4%	17.0%	42.5%	20.8%	8.5%	0.9%
<b>Mn</b>	182	140	69	20.7%	29.3%	25.7%	13.6%	8.6%	2.1%
<b>Vv</b>	23	60	38	16.7%	15.0%	31.7%	18.3%	16.7%	1.7%
<b>Vrs</b>	194	218	191	7.3%	20.6%	31.7%	22.0%	11.9%	6.4%
<b>Vpg</b>	0	1	5					100.0%	
<b>Vml</b>	108	80	57	11.3%	35.0%	22.5%	13.8%	8.8%	8.8%
<b>Vs</b>	0	0	1						
<b>Vpf</b>	0	0	1						
<b>Vz</b>	7	17	3	5.9%	11.8%	41.2%	23.5%	11.8%	5.9%
<b>Vut</b>	14	10	3		30.0%	60.0%	10.0%		
<b>Rt-Vt</b>	151	258	150	8.9%	36.4%	25.6%	15.1%	9.3%	4.7%
<b>Ru-Vu</b>	No information								
<b>RI-VI</b>	25	42	33	14.3%	23.8%	35.7%	11.9%	9.5%	4.8%
<b>Rmo</b>	24	43	36		25.6%	27.9%	30.2%	4.7%	11.6%
<b>Rma</b>	71	86	121	15.1%	20.9%	24.4%	14.0%	10.5%	15.1%
<b>Rhu</b>	0	0	1						
<b>Rho</b>	323	1045	1414	7.8%	17.6%	22.1%	19.2%	16.1%	17.1%
<b>Rhx</b>	693	720	1233	6.4%	14.6%	23.5%	20.8%	16.9%	17.8%
<b>Zms</b>	24	61	40	1.6%	31.1%	13.1%	26.2%	14.8%	13.1%
<b>Zbc</b>	81	194	247	21.1%	25.3%	29.9%	19.6%	4.1%	
<b>Zma</b>	35	112	61	4.5%	19.6%	36.6%	19.6%	12.5%	7.1%
<b>Zmd</b>	0	16	7	37.5%	6.3%	37.5%	18.8%		
<b>Zbk</b>	1	5	2			60.0%	20.0%	20.0%	
<b>Zpg</b>	45	87	147	6.9%	12.6%	21.8%	27.6%	21.8%	9.2%
<b>Zgo</b>	27	39	29	7.7%	5.1%	12.8%	20.5%	12.8%	41.0%
<b>Zgx</b>	632	940	1089	11.5%	20.0%	26.3%	22.6%	13.5%	6.2%

## 7.1 PRIMARY AQUIFERS

### 7.1.1 CATEGORY A: INTERGRANULAR AQUIFERS

Within the map sheet, intergranular aquifers are restricted to the alluvium deposits (tertiary-quaternary alluvial deposits) within and in the immediate flood planes or palaeo channels along some of the Tributaries of the Limpopo River, (Figure 9). It covers approximately 1.2% of the map area.

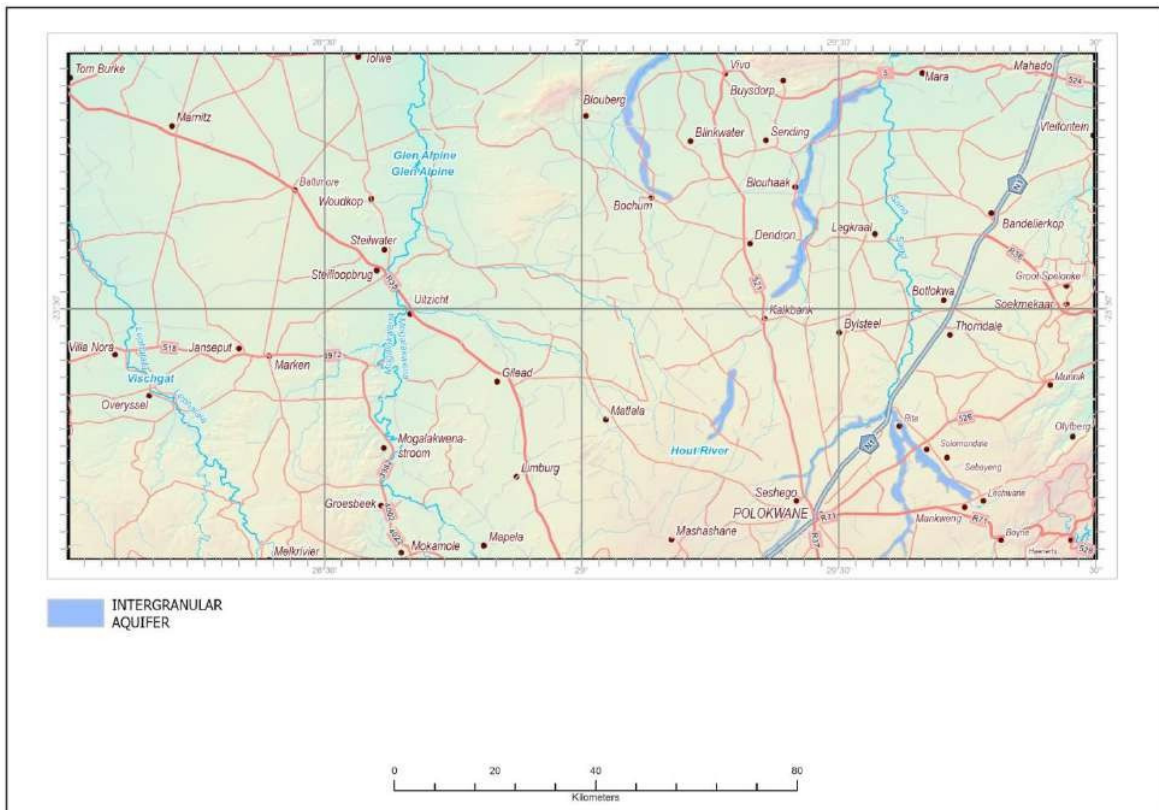


Figure 9: Geographical distribution of the intergranular aquifers (tertiary-quaternary alluvium deposits).

#### 7.1.1.1 TERTIARY-QUATERNARY ALLUVIUM DEPOSITS (Q)

Groundwater occurs in tertiary-quaternary alluvium deposits of limited lateral extent and thickness along most of the larger river terraces in the map area. Accumulatively it only covers approximately 1.2% of the total map area (Figure 9). In general, the alluvium consists of a clay/silt layer overlying poorly to well-sorted sand and gravel layers. Thicknesses of up to 30m have been found along the Sand River at the Mara Research Station, but in general it seldom exceeds 20m.

Except for cases where sand points have been installed in places, the alluvial aquifers in the map area are mostly utilized in conjunction with the underlying weathered and fractured bedrock aquifers. Water levels respond quickly during recharge events, i.e. when the rivers flow. Due to its limited extent laterally and vertically, the aquifers are vulnerable to over-abstraction, especially during periods of drought when rivers are dry or with limited flow that influence the recharge to the aquifers. The well field at the Mara Research Station is an example where the alluvial aquifer is being depleted due to lack of recharge. Borehole yields are generally high.

### **Lephalala River**

The alluvium along the river is not indicated on the geological map sheet for the area and no comprehensive studies could be found on the alluvium aquifer related to the Lephalala River. Data obtained from a report by W.D. Rech, 1970, states that water for irrigation was mostly from surface water. There were numerous boreholes and shallow wells along and within the river, but the contribution to water demand was less than direct surface water abstraction from the river.

The river arises in the Waterberg Plateau and flows north-westerly. At the foothills of the plateau, the first large scale irrigation fields can be seen when evaluating Google Imagery. From this point the scale of irrigation along the river is constant. Rural villages occur from the tar road (R516), along the river with smaller scale irrigation fields restricted to the area immediately west of the river. Groundwater east of the river is mostly used for domestic, livestock and game watering. In the far north-western stretch of the river, which falls outside the map area, no rural villages occur, and the land use is dominated by livestock and game farming with large scale irrigation occurring up to the confluence with the Limpopo River. Within the map area two small dam walls or weirs are located within the river.

The Witpoort service centre that manage water supply in the area for the rural villages, uses a combination of boreholes and sand points within or in the vicinity of the river for water supply. In times when the river is flowing large volumes of water are pumped from these sources. The scenario is the same for the farmers along the river. The alluvium is generally shallow (4-10m), consisting of fine-coarse grained sand as sourced from drilling logs. The small dam walls or weirs were built to enable pumping from the river and to provide some storage for a short period when the river dries up. Major fault zones transect the river (Melinda and Abbottspoort), that resulted in the development of high yielding boreholes used in conjunction with surface water, and/or surface water pumped from the alluvial deposits.

Satellite imagery reveals large scale irrigation along the river from some high yielding boreholes plotting near the river. Near Setateng village (along the Palala River but outside the map area), a borehole log indicates coarse grained alluvial sand up to 3m with a blow yield of 0.6l/s. The main water strike was, however, within fractured Nebo Granite with a blow yield of 7l/s. Shallow wells (10) were reported to be operational and managed by the Witpoortjie cost centre. It was also reported that in times when the river dries up the shallow well dries up as well.

### **Mogalakwena River**

The occurrences of alluvium along the river are not indicated on the geological map sheet; but various groundwater development projects were done along and within the riverbed. The data was obtained from the NGA and groundwater reports from other consultancies. The alluvial deposits are mostly restricted to the riverbed, but in some sections, they extend up to 50 meters from the riverbank. The available information does not indicate the existence of paleo-channels further from the current riverbed that could be targeted for groundwater development.

Near Mokopane in the south (outside the map area), the alluvial deposits are thick, reaching up to 20 meters along stretches of the river, especially at the confluences with smaller streams. The alluvium is reported to consist of layered clays, fine-grained sand to gravel, and boulders in certain areas. Along the upstream tributaries (not within the map area), such as the Dorps River, Rooisloot, Nyl, and Sandsloot, various well-known well fields have been developed, targeting alluvium and deeper fracture zones overlain by alluvium.

Within the stretch of the river that falls within the map sheet, the consistency and thickness of the alluvium vary considerably. Shallow caissons (porous concrete reservoirs) up to 6 meters in depth are found within the river from Mabaladihlare (near Bakenberg), for a stretch of approximately 40 km to Segole in the north. During times of surface flow, abstraction from these points can be increased, but during periods of no flow, the water level in the sand decreases, leading to reduced yields. This phenomenon has also been reported for shallow wells and boreholes within and near the Mokolo and Crocodile Rivers, where large-scale

irrigation occurs. For the Mokolo and Crocodile Rivers and associated alluvial deposits, regular planned surface water releases from dams enable economic activities such as irrigation and mining.

The possibility of constructing a dam within the river to ensure sustainable large-scale abstraction should be investigated. Such an intervention may have been considered in the past, but no information could be obtained from reports, studies or proposals.

Due to the weathering of the Nebo Granite into coarse-grained sand, the alluvium in the area between Mabuladihlare and Segole is predominantly sandy, with a fine-grained to coarse-grained texture. The primary porosity (pore space or openings) of this sand can be up to 30%. Alluvium up to 12 meters was reported in some boreholes drilled within the river, with an average thickness estimated to be between 4 and 6 meters. Some of the higher-yielding boreholes near the river are associated with deeper secondary fractures. These fractures are primarily encountered along dyke and sill contacts, with a low number of fractures related to fault zones. In these aquifers, the alluvium acts as both storage and flow paths to the deeper fracture zones within the underlying rock.

From Segole to the north, the alluvium deposits become increasingly inconsistent in both depth and extent. Stretches without alluvium deposits are more frequently observed than in the south. In these stretches, the abstraction points primarily consist of shallow boreholes, with some shallow (4-6 meters) caissons or shallow pre-cast concrete-inserted rings used to extract water. During dry periods, these shallow abstraction points often dry up.

#### **Brak River**

Along this tributary of the Sand River, alluvium is indicated on the geological map sheet. However, no formal studies could be found that provides information on the groundwater-bearing properties of the alluvium. High-yielding boreholes drilled within the alluvial deposits suggest that the high yields are due to deep-seated fractures within the underlying hard rock aquifer rather than the alluvium itself. Alluvium is not identified in any report as a primary target for groundwater extraction, and no shallow wells occur within the alluvium. Although available data suggests that the alluvium along this river is not a primary groundwater source, it facilitates enhanced recharge to the underlying intergranular and fracture zones.

#### **Hout River**

Similar to the Brak River, alluvium is indicated along this tributary of the Sand River on the geological map sheet. No formal studies provide information on the groundwater-bearing properties of the alluvium, and very limited data is available regarding borehole yields and depths in this area. It is expected that high-yielding boreholes drilled within the alluvial deposits are associated with deep fractures in the underlying hard rock aquifer. The alluvium is not identified in any report as a primary groundwater target, and no shallow wells are present within it. Based on available data, the alluvium along this river is not considered a primary target for groundwater extraction but may contribute to the recharge of the underlying aquifer.

#### **Diepsloot (Sandsloot) and Turfloop Rivers**

Along these tributaries of the Sand River, alluvium is indicated on the geologic map sheet. No formal studies provide information on the groundwater-bearing properties of the alluvium. From groundwater development projects done in the Mankweng area, the alluvium deposits within the rivers are not very deep (1-6m). The sand, however, is fine-to course-grained with some layers consisting of gravel that can be attributed to the granitoid and gneissic geological environment. Large volumes of sand for building purposes are removed by legal and illegal entities along stretches of the river. The exposed riverbed consists in many cases of hardpan calccrete layers. Drawdown curves obtained from pump testing data from boreholes occurring near the river were evaluated for an indication of recharge boundaries. No evidence of recharge boundaries could be identified. The river was not flowing at the time and the riverbed up to the exposed bedrock and/or hardpan surface, was dry. A paleochannel was encountered in one borehole that is approximately 100m from the current riverbed. Fine-to course-grained sand was encountered up to a depth of 16m, but the blow yield was a disappointing 1.5ℓ/s. Deep fractures were struck between 24 and 40m that resulted in a moderate blow yield (6ℓ/s).

A statistical analysis of boreholes indicates that the higher yielding boreholes are predominantly located near rivers or the numerous low laying zones, (long valleys). This is as the weathered and fractured zones tend to be deeper. Pegmatite, deep weathering, and areas with a strong foliation in the gneiss, will be the main groundwater targets in the area. As solid outcrop and higher elevated areas are common, the trend is to target groundwater in lower laying areas or along the rivers. Although available data suggests that the alluvium along this river is not a primary groundwater source, it facilitates enhanced recharge to the underlying intergranular and fracture zones.



Plate 1: Alluvial deposits along the Diep River (Sandsloot), the removal of sand by mining and the layered nature of the riverbank, photos taken 2023, C.J. Sonnekus.

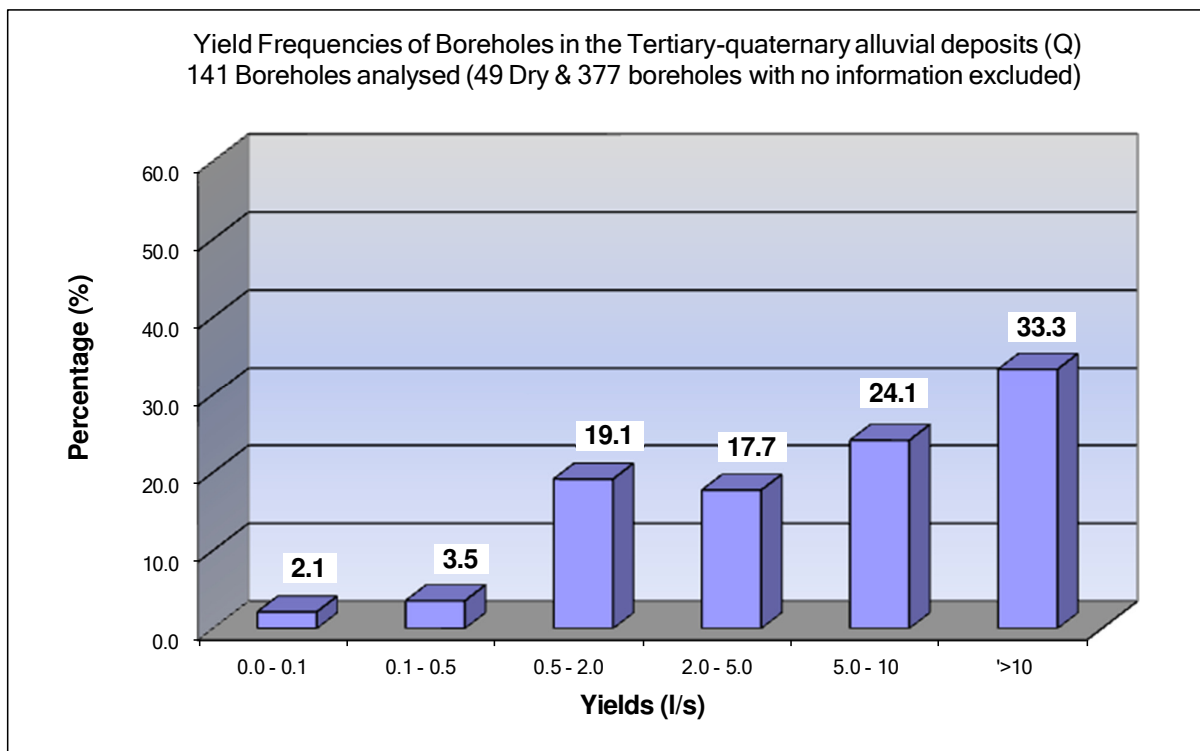


Figure 10: Yield frequency for Tertiary-Quaternary alluvial (Q) aquifers.

Figure 10 is a representative yield frequency diagram of yields within the alluvial aquifers. The diagram shows that existing borehole yields are generally high with 57.4% of the successful boreholes yielding more than 5l/s. The yield diagram may not represent the true nature of the contribution of alluvium to high yields in deep boreholes. The high percentage of deep boreholes, (>20m), in this unit with high yields, are in many instances related to water strikes within deeper fracture zones. In areas with deep alluvial deposits (>6m) and a shallow water table it may contribute to recharge to deeper laying fractures and storage. Within the areas underlain by granitoids and gneissic rocks, low laying areas are targeted as a rule due to the probability that the average depth of weathering will be deeper than in higher elevated areas where these rocks tend to outcrop as unweathered bedrock.

The static water level ranges from zero meters below ground level (mbgl) to 41.79mbgl, with a median of 12.18mbgl and an average of 12.74mbgl (based on 121 points). The maximum recorded depth is 162m, with an average and median depth of 64m and 60m respectively (169 points). The minimal installation depth is 8m that may or may not correspond to the depth of the alluvium in the Limpopo River.

The maximum installation depth recorded is 100m with an average of 40m (88 data points). From the statistics on the installation and borehole depths, the statistics predominantly include boreholes that targeted deeper fractured zones overlain by alluvium. The maximum recommended daily abstraction on record is 1123.2 cubic meters per day (m<sup>3</sup>/day) with the 90<sup>th</sup> and 80<sup>th</sup> percentiles for daily abstraction at 544.3m<sup>3</sup>/day and 432m<sup>3</sup>/day respectively with an average of 218.2m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 88.

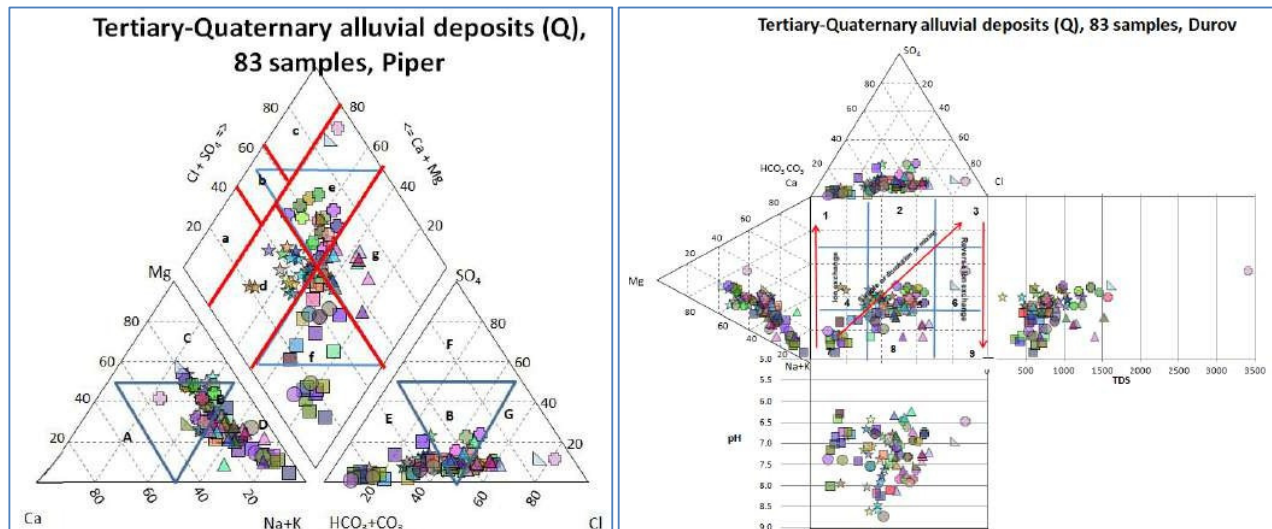


Figure 11: Trilinear diagrams, Piper and Durov for the Tertiary-quaternary alluvial deposits (Q).

The trilinear Piper diagram, (Figure 11) provides a visual representation of water chemistry by illustrating the concentrations of the major cations and anions, allowing for the classification of hydrochemical facies. The first evaluation on the chemical dominance is as follows: Alkali earths > Alkali (50.6%), Weak acidic anions > Strong acidic anions (57.8%); Alkali > Alkali earths (49.4%); Strong acids > Weak acids (42.2%).

The type of water within this unit, is a function of the geology within the upper catchment area, the time of year (dry or wet river), borehole depth (only within alluvial or deeper fractures), the layering of the deposit (layered permeability-clay/sand), and the timing of the sampling (after longer pumping, water from the underlying fractured zones may dominate).

From the available data and ignoring the above influences in this groundwater resource unit, the water classifies as:

- Sodium-Bicarbonate type (31.3%),
- Magnesium-Bicarbonate type (24.2%);
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type with increasing Sodium (14.5%);
- Sodium-Bicarbonate-Chloride (10.8%);
- Mixed Calcium-Magnesium-Chloride type with increasing Sodium (8.4%).
- Sodium Chloride type (7.2%).
- Mixed Calcium-Magnesium-Bicarbonate type with increasing Sodium (2.4%);
- Magnesium-Chloride type (1.2%);

The trilinear Durov diagram defines hydrochemical processes along with the water type. The interpretation is as follows:

- No dominant anion or cation indicates fresh recent recharged water exhibiting simple dissolution or mixing (49.4%), points plot along the dissolution or mixing line,
- Cl dominant anion and Na dominant cation, reverse ion exchange of Na-Cl waters (26.5%),
- Cl and Na dominant, reverse ion exchange of Na-Cl waters (15.7%),
- Anion discriminates and Ca or SO<sub>4</sub> dominant, mixed water or water exhibiting simple dissolution (6%),
- Anion discriminates and Na dominant, probable mixing, or uncommon dissolution influences (2.4%),
- The high TDS is some of the samples that may be indicative of long residence times in the aquifer allowing reactions to be complete. These samples may relate to the underlying geology, thus deeper fractures contributing more to the supply than from the alluvium. In other study on a section of the Limpopo River, high TDS values were found in the sand aquifer after a very high local rainfall event. The section of the river affected was downstream from the inflow point of a local tributary i.e. Soutsloot. The high TDS was contradictive to the expectation. It was concluded that local rainfall events in the surrounding arid environment mobilized build up salts to wash into the Limpopo River.

Table 43: Chemical statistics for the Tertiary-quaternary alluvial deposits (Q)

Element / Parameter	Statistics Drawn from a population of 2 data points for the Malmani Subgroup (Vma).									
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation
pH	2	8.27	8.52	8.39	8.40	8.30	8.40	8.50	0.18	2.1%
Electrical Conductivity (mS/m EC)	2	65.70	67.70	66.69	66.70	65.90	66.70	67.50	1.41	2.1%
Total Dissolved Salts (mg/l TDS)	2	588.00	674.00	628.07	631.00	596.60	631.00	665.40	60.81	9.6%
Calcium (mg/l Ca)	2	28.80	31.10	29.91	29.95	29.03	29.95	30.87	1.63	5.4%
Magnesium (mg/l Mg)	2	63.60	66.90	65.21	65.25	63.93	65.25	66.57	2.33	3.6%
Sodium (mg/l Na)	2	22.80	34.40	27.42	28.60	23.96	28.60	33.24	8.20	28.7%
Potassium (mg/l K)	2	4.37	4.70	4.53	4.54	4.40	4.54	4.67	0.23	5.1%
Chloride (mg/l Cl)	2	16.80	17.20	17.00	17.00	16.84	17.00	17.16	0.28	1.7%
Sulphate (mg/l SO <sub>4</sub> )	2	8.10	8.60	8.34	8.35	8.15	8.35	8.55	0.35	4.2%
Total Alkalinity (mg/l CaCO <sub>3</sub> )	2	328.30	385.40	354.57	356.85	334.01	356.85	379.69	40.38	11.3%
Nitrate (mg/l N)	2	9.48	9.48	9.48	9.48	9.48	9.48	9.48	0.00	0.0%
Fluoride (mg/l F)	2	0.19	0.33	0.24	0.26	0.20	0.26	0.32	0.10	38.1%
Silicon as Si	2	39.85	40.72	40.28	40.29	39.94	40.29	40.63	0.62	1.5%
Iron (Fe)	2	0.0010	0.001	0.001	0.001	0.001	0.001	0.001	0.00	0.0%
Manganese (Mn)	2	0.0001	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.0%
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	2	0.031	0.057	0.040	0.044	0.034	0.044	0.054	0.02	41.8%
ZAR	2	0.54	0.80	0.65	0.67	0.57	0.66	0.77	0.18	26.8%
LSI	2	Langelier Saturation Index (LSI)			Slightly Scaling	100.0%	Highly Scaling		0.0%	
		Highly corrosive	0.0%		Slightly corrosive	0.0%	Balanced Corrosion		0.0%	

Table 43 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality for the unit in terms of Electrical conductivity (EC) is ideal to be good in 75.9% of the analysis, of a moderate quality in

20.7% and unacceptable only in 3.4% (values above 370mS/m). The Total Dissolved Solids (TDS) is acceptable in 83.33% of the samples, (TDS  $\leq$  1200mg/l).

An evaluation of the major cations and anions in 120 samples shows elevated concentrations of Fluoride (F > 1.5 mg/L) in 18.5% of the samples, Nitrate (N > 20 mg/L) in 4.4%, Chloride (Cl > 600 mg/L) in 3.5%, Sodium (Na > 400 mg/L) in 1.9%, Magnesium (Mg > 200 mg/L) in 1.9%, Calcium (Ca > 300 mg/L) in 1.9%, and Potassium (K > 100 mg/L) in 0.9% of the analyses. The pH value exceeds the maximum allowable limit in one sample, indicating acidity.

The Langelier Saturation Index (LSI) indicates that the water is highly to slightly corrosive in 1% of the samples, slightly scaling in 62.7%, and balanced in 36.3%. The ZAR index indicates that 40.7% of the water is of fair quality for irrigation (ZAR < 3).

Due to the shallow nature of the aquifer, microbiological risks will always be a factor to consider when using it for domestic purposes.

## **7.2 SECONDARY AQUIFERS**

Consolidated hard rocks cover approximately 98.8% of the map area. The secondary aquifers in this region include all fractured, intergranular & fractured, and karst aquifers. The rock mass was formed over a span of around 3 800 million years, nearly covering the entire geological history of South Africa. Tectonic deformation processes (such as folding and faulting), along with weathering, dissolution, (carbonate rocks), and erosion-driven unloading, have generated or enhanced fractures, interstices, and solution cavities within the hard rocks. These processes have significantly influenced the current groundwater environment across various geological groups and formations. Accordingly, the aquifer types represented on the Hydrogeological Map Sheets for secondary aquifers are classified as karst, fractured, and intergranular & fractured.



### 7.2.1.1 UNDIFFERENTIATED KAROO SEDIMENTS (C-Tr)

The groundwater resource unit comprises an assembly of the Madzaringwe, Fripp, Solitude, Klopperfontein, Bosbokpoort and Clarens Formations. Within the map area three occurrences are indicated, (Figure 13). In the Marnitz area, the Melinda Fault forms the southern boundary that may be the reason for one high yielding, (8.4l/s) borehole that is in the vicinity of the fault. The unit covers approximately 0.61% of the total map area.

In the Tolwe and Marnitz areas, the Madzaringwe Formation unconformably overlies rocks of the Beit Bridge Complex and the Soutpansberg Supergroup. The thickness of this formation varies between 60 and 110m in the Tolwe area and between 20 and 50m in the Marnitz area. It consists of carbonaceous shale and mudstone with minor light-grey feldspathic sandstone, which is present in the lower third part of the formation. Coal seams are developed throughout. The reported maximum thickness of the Fripp Formation is 8m and is only locally developed at places. The Solitude Formation attains a thickness of about 50m in the Tolwe area and about 20m in the Marnitz area comprising of massive dark-grey, red, and purple mudstone with scattered silty and sandy beds. The Klopperfontein Formation consists of coarse-grained, feldspathic, micaceous sandstone with conglomerate occasionally developed near the base. The sandstone layer varies from 2-12m but can reach a thickness of 30m when intercalations of brown and purple shale are present. The Bosbokpoort Formation consists of red massive mudstone with a thickness of 45m. The Clarens Formation which represents the final stages of sedimentary deposition of the Karoo Strata consists of fine-grained equigranular cream-coloured sandstone with a maximum thickness of 80m, (Explanation booklet, and geological map sheet 2328 page 30 to 32).

Groundwater targets in the unit will be fault zones, dykes or contact zones. Deep drilling (226m) targeting the contact with the basement rock did not yield any water. This information is from a borehole drilled just north of the Blouberg. Various contact zones were encountered that included a dolerite sill, but with no water strikes. The evaluation of available information indicates that the fault zones if present will be the primary target for groundwater development. Deep fractures within the Clarens Sandstone (if present and thick); usually result in moderate yielding boreholes with good to ideal water quality, (based on data from the adjacent map sheet).

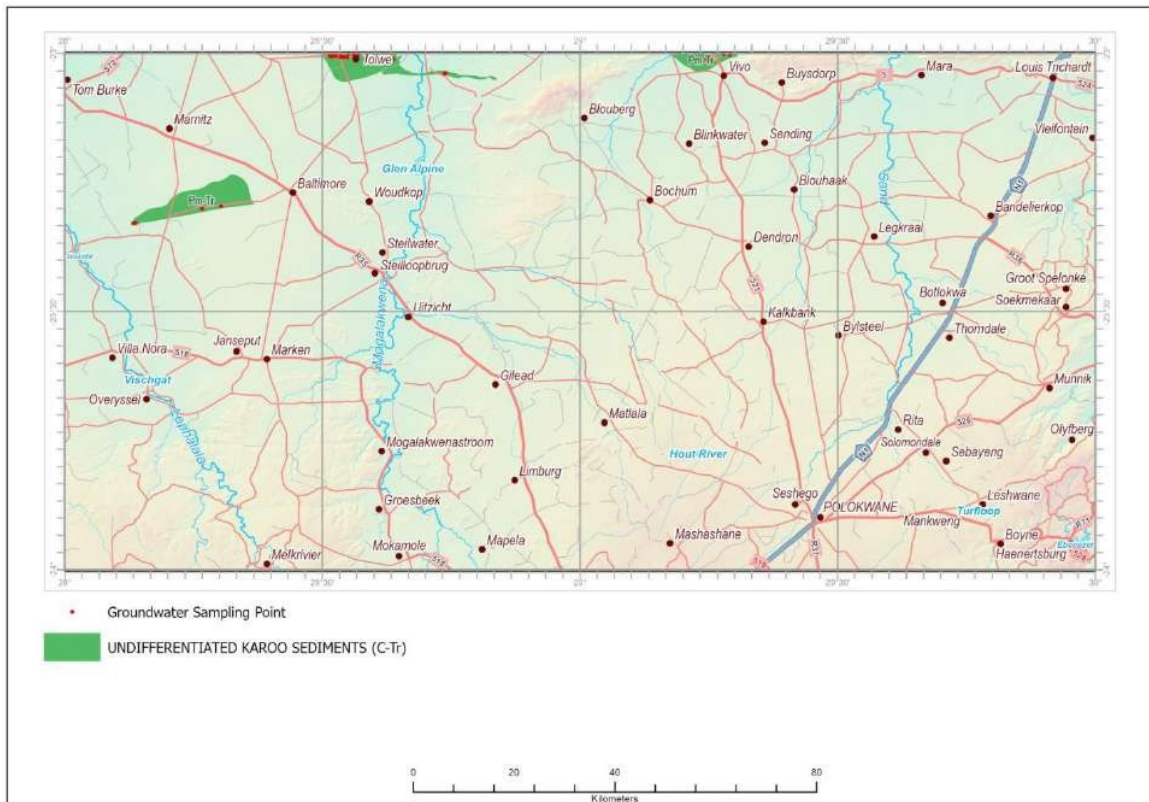


Figure 13: Geographical distribution of the Undifferentiated Karoo Sediments (C-Tr) and the associated groundwater sampling points.

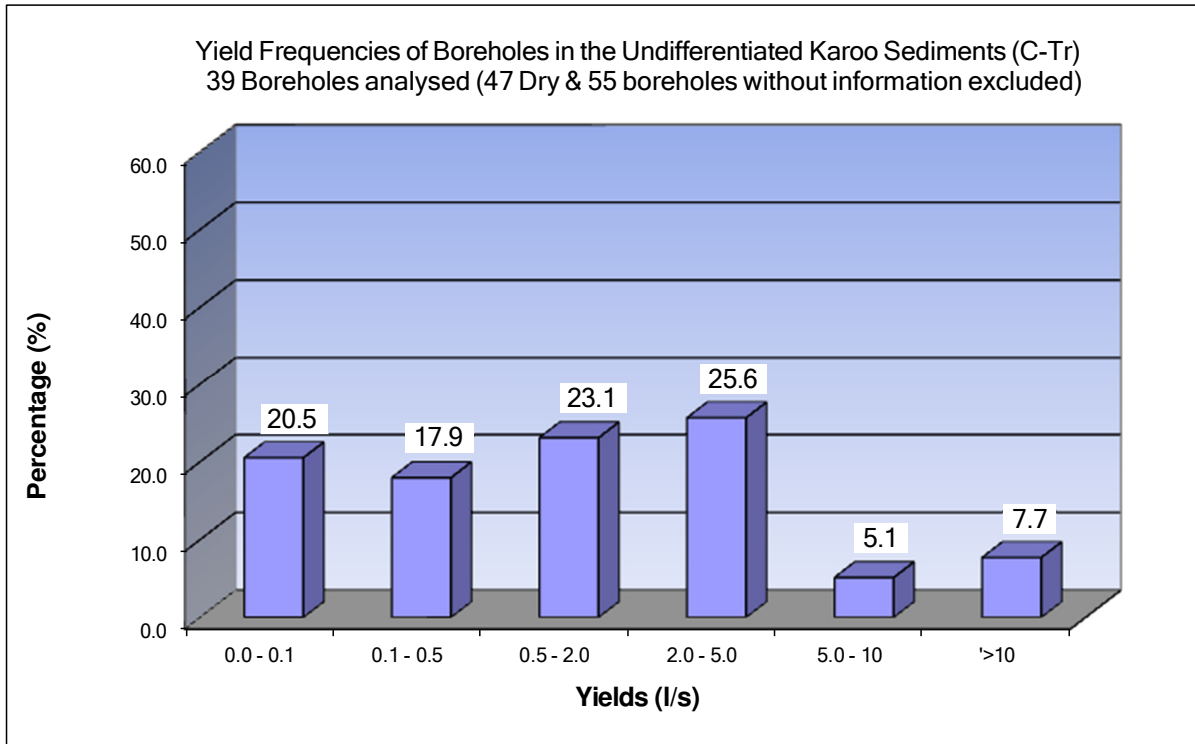


Figure 14: Yield frequency for the fractured aquifers of the Undifferentiated Karoo Sediments (C-Tr).

The statistical analysis of 39 borehole records, (Figure 39) indicates that 38.5% of the successful boreholes have yields that are suitable for small households (>0.001ℓ/s to 0.5ℓ/s). In total 23.1% boreholes have yields between 0.5ℓ/s and 2ℓ/s: with 25.6% of the boreholes yielding between 2ℓ/s and 5ℓ/s and 12.8% yielding more than 5ℓ/s.

The static water level ranges from 7 meters below ground level (mbgl) to 32.94mbgl with a median and an average static water level of 24.2mbgl and 22.11mbgl, (based on 14 data points) respectively. The maximum depth recorded is 120m with an average and a median depth of 74.4m and 67.5m, (24 data points) respectively. The installation depth is 36m and the recommended daily abstraction is 345.6 cubic meters per day (m<sup>3</sup>/day), (1 data point).

There is no information available on water chemistry. Groundwater from this unit is used for irrigation and other farming activities in all three areas where it occurs.

### **7.2.1.2 SWARTRANT FORMATION (Psr)**

The Grootegeluk, Goedgedacht, and Swartrant Formations are part of the Ecca Group of the Karoo Supergroup. The Swartrant Formation (similar to the Vryheid Formation of the main Karoo Basin), outcrops in various locations within the Ellisras Basin. The outcrop within the Polokwane map sheet represents the eastern side of the Ellisras Karoo Basin, (also referred to as the Waterberg Karoo Basin).

The unit occurs in two sections on the western side of the Polokwane map sheet and cross over to the Lephalale map sheet, (see Figure 15). Although the cross-boundary units are physically connected, the yield and chemical data were not combined for the relevant diagrams. The reason being, that most of the available data for the unit within the Lephalale map sheet occurs in the central and western part of the Ellisras Karoo Basin, while the data within the Polokwane map sheet falls within the eastern part of the Basin. The Pietersburg geological map sheet, 2328, lists the two outcrops to be equivalent to the Madzaringwe Formation. The groundwater resource unit covers approximately 0.24% of the total map area.

The Swartrant Formation consists of sandstone, grit, siltstone, carbonaceous mudrock, and coal seams. The thickness of this formation within the eastern part of the Ellisras Basin varies from 7m to 50m. Borehole data was used to divide the formation into a lower, middle, and upper zone. At the base of the lower zone, a succession with a thickness of 6m to 10m of alternating sandstone and siltstone is overlain by flaser-bedded and ripple cross-laminated sandstone. This is in turn overlain by medium- to coarse- grained cross-bedded sandstone with a thickness of 17m to 26m. Locally this coarse-grained sandstone is overlain by a meter thick coal seam ("No. 1 coal seam").

The lower zone consists of alternating sandstone, siltstone and coal seams. The coarse-grained sandstone was interpreted as deposited in a delta front, and the coal seams formed from a marshy cover on the delta plain when the progradation of the delta ceased, (Brandl, 1996).



*Plate 2: Tafelkoppe, one of three mesa-type (flat-topped hills), made up of whitish, feldspathic, coarse-grained, and cross-bedded sandstone of the Swartrant Formation. The other nearby hills are Ga-Mabula and Tambotiepiek which are along the R518 approximately 25km east-south-east of Lephalale. (Photograph: Louwlardus Safaris, 18 November 2020).*

At the base of the middle zone, with a thickness of 15m, a thin (<2m), coarse-grained, light-colored sandstone is present, overlain by grey, horizontally laminated mudstone with a thickness of 1.5m to 3.6m. This mudstone grades into a fine- to coarse-grained, light-colored sandstone (0.2m to 5.9m), which becomes greyish towards the top. The zone is capped by a 3.2m to 5.9m thick unit of alternating coal and mudstone (No. 2 coal seam), (Brandl, 1996).

The upper zone has been divided into northern (13.6m to 36.4m) and southern (10m to 33m) facies. In the southern facies, the base of the upper zone consists of a thick (10m) greyish - white, coarse - to very coarse-grained, cross-bedded sandstone which has a sharp erosion contact with the underlying No. 2 coal seam. Near its top, the sandstone grades into a mudstone (up to 6m thickness) which locally contains a thin, impure coal seam. This unit is overlain by whitish, feldspathic, coarse-grained, and cross-bedded sandstone (up to 16m thick) which grades up into a grey, carbonaceous fine-grained sandstone or siltstone, (Brandl, 1996).

The northern facies are characterised by a 3m to 13m basal unit consisting of alternating upward -coarsening mudstone and siltstone beds which are interspersed with coal seams and upward-fining sandstone beds. An erosion contact separates it from coarse-grained, cross-bedded, 16.5m to 30m thick feldspathic sandstone with a whitish colour, (Brandl, 1996).

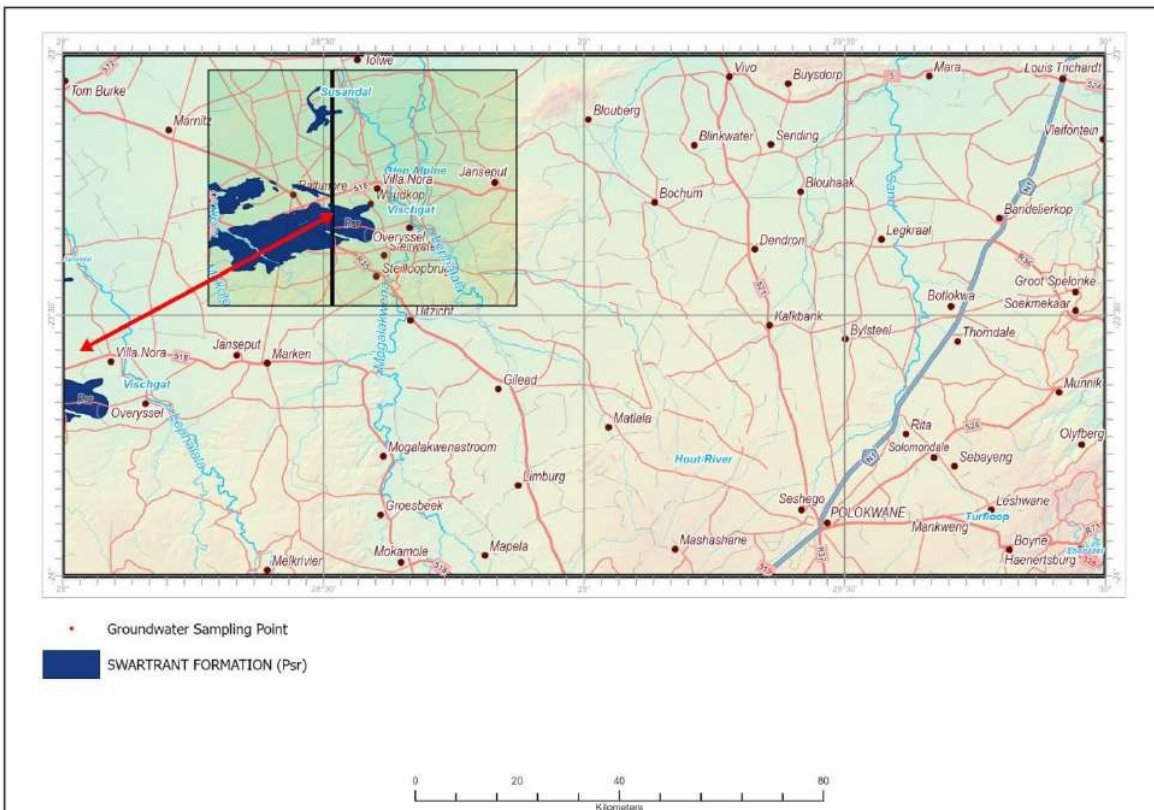


Figure 15: Geographical distribution of the Swartrant Formation (Psr.)

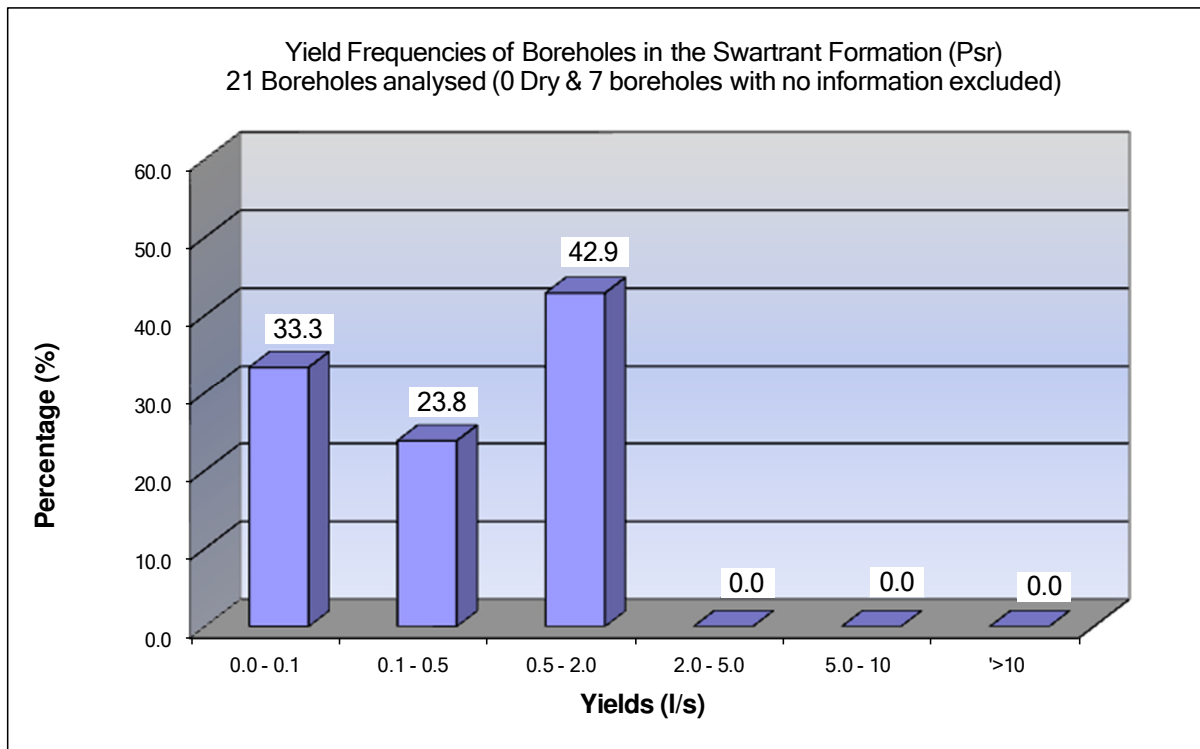


Figure 16: Yield frequency for the fractured aquifers of the Swartrant Formation (Psr).

The analysis of 21 borehole records, (Figure 16) indicates that 42.9% of the maximum yields are between 0.5l/s and 2l/s and that 57.1% of the boreholes yield less than 0.5l/s.

Within the Polokwane map sheet boundary, no information on borehole depth, installation depth, static water level or daily abstraction volumes calculated from pumping tests, were available. The adjacent Lephalale map sheet and brochure can be consulted for more information. The characterization of the unit in the Lephalale brochure is however more representative of the occurrence of the unit within the central and western section of the Ellisras Karoo Basin. This is due to the distribution of available information; the unit occurring within the eastern part of the basin did not have any groundwater data on record.

In general, the groundwater occurrence in sedimentary rocks is either controlled by lithology such as the contact zones between various sediments or by secondary structures such as fractures or joints locally developed along bedding planes. Within the Lephalale map sheet some high yielding boreholes relate to fault zones. Within the Polokwane map sheet one fault zone transects the unit in an easterly direction. However, no borehole points plot near the fault zone. The occurrence of Dolerite intrusive sills and dykes are limited in the Ellisras Karoo Basin and are therefore not expected to contribute much to groundwater occurrences.

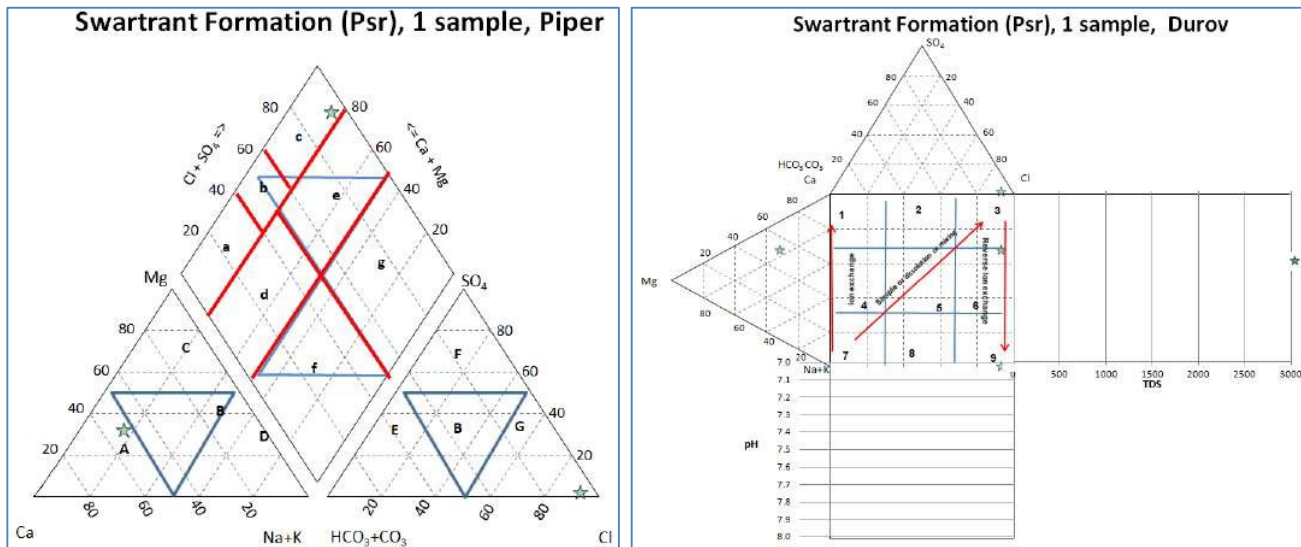


Figure 17: Trilinear diagrams, Piper and Durov for the Swartrant Formation (Psr).

The characterization of the unit in terms of the water type and hydrochemical processes are based on a single available analysis and the findings may not be representative of the unit. The trilinear Piper diagram, (Figure 17) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (100%) and Strong acids > Weak acids (100%).

The second evaluation was on the water type:

- Calcium-Chloride type (100%).

The trilinear Durov diagram defines hydrochemical processes along with the water type. The interpretation is as follows:

- A possible explanation may relate to cation exchange, in clay-rich aquifers, Sodium ( $\text{Na}^+$ ) from NaCl may replace calcium ( $\text{Ca}^{2+}$ ) in the aquifer matrix.
- This process increases  $\text{Ca}^{2+}$  in groundwater while decreasing  $\text{Na}^+$ , leading to a dominant Ca-Cl water type.
- The high TDS in the sample may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 44: Chemical statistics for the Swartrant Formation (Psr)

Element / Parameter	Statistics Drawn from a population of 1 data points for the Swartrant Formation (Psr).									
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation
pH	1	7.71	7.71	7.71	7.71	7.71	7.71	7.71		
Electrical Conductivity (mS/m EC)	1	522.00	522.00	522.00	522.00	522.00	522.00	522.00		
Total Dissolved Salts (mg/l TDS)	1	3021.00	3021.00	3021.00	3021.00	3021.00	3021.00	3021.00		
Calcium (mg/l Ca)	1	544.60	544.60	544.60	544.60	544.60	544.60	544.60		
Magnesium (mg/l Mg)	1	205.10	205.10	205.10	205.10	205.10	205.10	205.10		
Sodium (mg/l Na)	1	192.60	192.60	192.60	192.60	192.60	192.60	192.60		
Potassium (mg/l K)	1	2.70	2.70	2.70	2.70	2.70	2.70	2.70		
Chloride (mg/l Cl)	1	1649.50	1649.50	1649.50	1649.50	1649.50	1649.50	1649.50		
Sulphate (mg/l SO <sub>4</sub> )	1	53.30	53.30	53.30	53.30	53.30	53.30	53.30		
Total Alkalinity (mg/l) CaCO <sub>3</sub>	1	302.00	302.00	302.00	302.00	302.00	302.00	302.00		
Nitrate (mg/l N)	1	1.01	1.01	1.01	1.01	1.01	1.01	1.01		
Fluoride (mg/l F)	1	0.52	0.52	0.52	0.52	0.52	0.52	0.52		
Silicon as Si	1	30.01	30.01	30.01	30.01	30.01	30.01	30.01		
Iron (Fe)	1	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
Manganese (Mn)	1	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	1	0.013	0.013	0.013	0.013	0.013	0.013	0.013		
ZAR	1	1.79	1.79	1.79	1.79	1.79	1.79	1.79		
LSI	1	Langelier Saturation Index (LSI)			Slightly Scaling		100.0%	Highly Scaling		0.0%
		Highly corrosive		0.0%	Slightly corrosive		0.0%	Balanced Corrosion		0.0%

Table 44 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. The following is based on one available analysis. The overall water quality in terms of the Electrical conductivity (EC) is unacceptable (EC > 370mS/m).

The Total Dissolved Solids (TDS) is not acceptable, (TDS ≤ 1200mg/l). The evaluation of the major cations and anions from one sample shows elevated concentrations of Chloride (Cl > 600mg/l) and Calcium (Ca > 300).

The Langelier Saturation Index (LSI) indicates that the water may be slightly scaling. The ZAR index indicates that the water is of a fair quality for irrigation (ZAR < 3).

The water is abstracted for livestock, game watering, and domestic purposes for households. No irrigation fields occur within the unit on the Polokwane map area as based on an evaluation using Google Earth imagery.

### 7.2.1.3 WELLINGTON FORMATION (C-Pwe)

The Wellington Formation which is of Carboniferous to Permian age, comprises sandstone, conglomerate, shale, and mudstone. It crosses over onto the Lephala map sheet.

Palynological evidence indicates that the Carboniferous/Permian boundary is roughly in the middle of the Wellington Formation, (MacRae, 1991), but there is no geological indication of this boundary in the lithological succession (Brandl, 1996). Therefore, some literature lists the unit as part of the Lower Ecca and some as part of the Dwyka Group. The Wellington and underlying Waterkloof Formation is included as part of the Dwyka Group within this report.

The unit occurs in four small sections in the western side of the Polokwane map sheet and crosses over to the Lephala map sheet, (see Figure 18). Due to the resistant nature of the sandstone to weathering, the outcrops form conspicuous hills.

Although the cross-boundary units are physically connected, the yield and chemical data were not combined for the relevant diagrams. The reason being that most of the available data that falls within the Lephala map sheet is representative of the central and western part of the Ellisras Karoo Basin and that the cross-boundary occurrence falls within the eastern part of the Basin. The Pietersburg geological map

sheet 2328, lists the outcrops to be equivalent to the Madzaringwe Formation. Wellington Formation covers approximately 0.07% of the total map area.

The thickness of the Wellington Formation is generally between 20m to 30m but reaches a maximum thickness of 180m in the south-eastern section of the Basin. Where the formation is fully developed, the base comprises a unit with dark grey, horizontally laminated mudstone and siltstone containing sandstone lenses and scattered grit-sized grains, possibly small dropstones, (isolated fragments of rock found within finer-grained water-deposited sedimentary rocks). This unit becomes siltier and lighter coloured towards the top and exhibits upward - coarsening cycles, (Brandl, 1996).

The Waterkloof Formation represents the base of the Karoo Sequence with no outcrops occurring within the map sheet. The formation lay unconformably on Waterberg and pre-Waterberg rocks. The pre- Waterberg rocks are deeply weathered with paleo soil in some drill samples recovered, (Brandl, 1996).

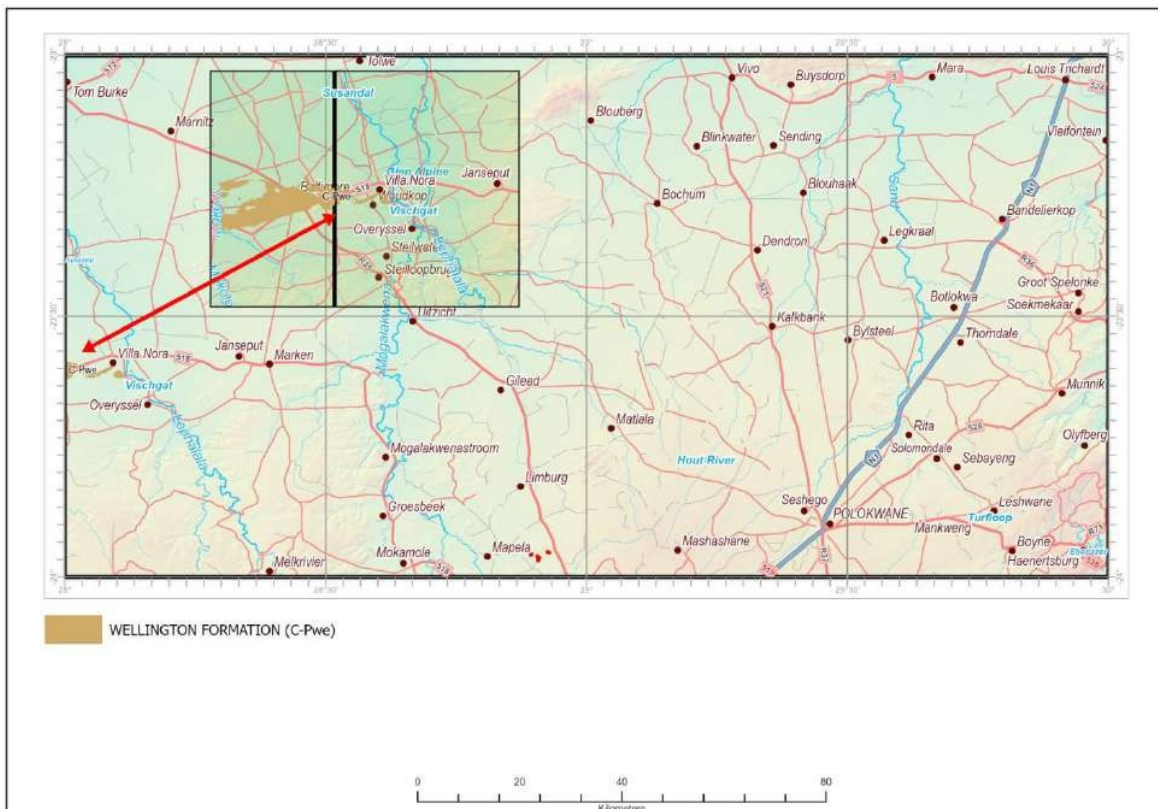


Figure 18: Geographical distribution of the Wellington Formation (C-Pwe).

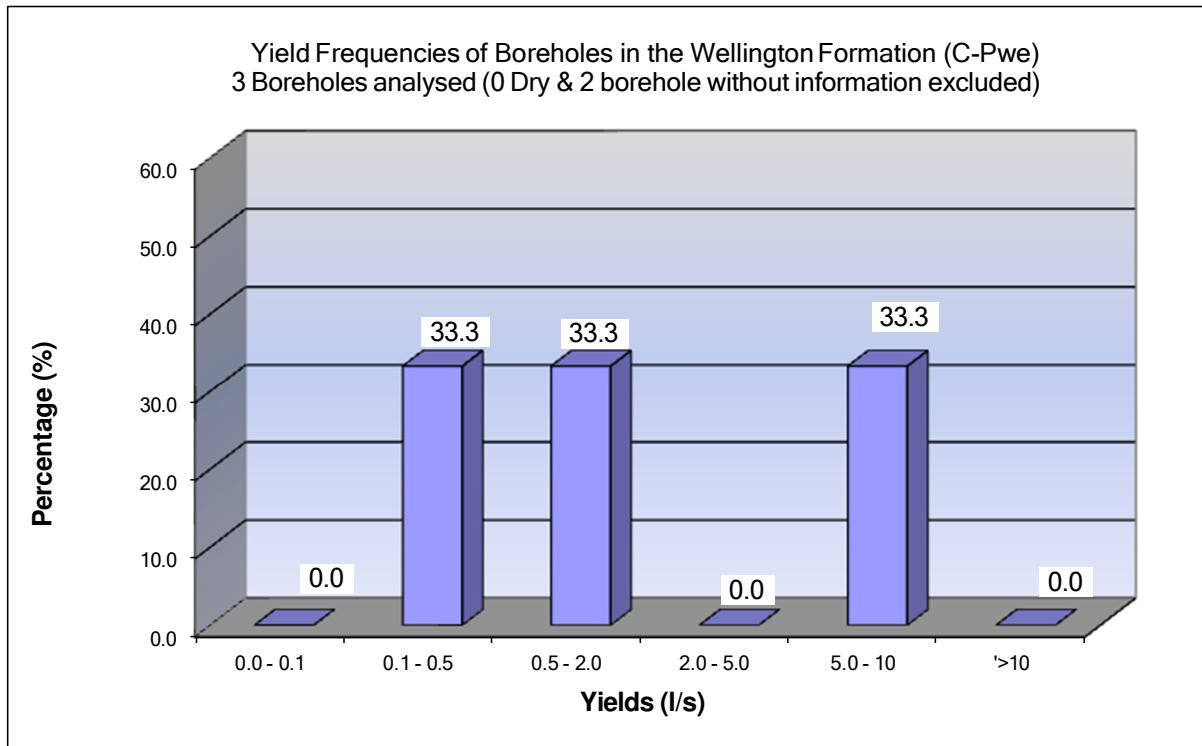


Figure 19: Yield frequency for the fractured aquifers of the Wellington Formation (C-Pwe).

The analysis of three borehole records within the Polokwane map sheet area is not sufficient for an accurate characterization of the aquifer. In the Lephalale map sheet area 71.5% of the maximum yields are less than 0.5l/s.

No information is available on the static water level, borehole depths, water strike depths, water chemistry, and recommended daily abstraction volumes calculated from pumping tests.

Due to the fine-grained nature of the sedimentary rocks, this Formation have low to very low primary permeability with low storage potential.

The Lephalale map sheet and brochure can be consulted for more information; the characterization of the unit in the Lephalale brochure is, however, more representative of the occurrence of the unit within the central and western section of the Ellisras Karoo Basin. This is due to the distribution of available information. Part of the unit occurring within the eastern part of the basin did not have any groundwater data on record.

The area underlain by the unit is preliminary used for game farming.

#### 7.2.1.4 VAALWATER FORMATION (Mva)

The Vaalwater Formation is described as a separate groundwater resource unit although it is part of the Kransberg Subgroup of the Waterberg Supergroup. Structurally the Kransberg Subgroup falls within the Nylstroom Syncline which is a large, shallow synclinal fold (a trough-shaped fold where the youngest rocks are in the core). The Vaalwater Formation comprises fine-grained felspathic sandstone as well as micaceous sandstone, arkose, siltstone, and shale. Cross bedding and ripple marks are abundantly developed. It forms the roof or top layer of the Kransberg Subgroup (Explanation booklet, geological map sheet 2328 page 25 to 26).

The section of the unit within the Polokwane map sheet covers approximately 0.16% of the total map area. The Vaalwater Formation occurs within a small area in the south-western section of the map sheet, (Figure 20). This unit occurs on 3 maps (Polokwane, Thabazimbi and Modimole). The cross-boundary occurrence is physically connected as shown on the inset map, (Figure 20).

The yield frequency diagram that represents the cross-boundary data (Figure 21) gives an indication of the expected yield of the boreholes. It shows that 70.3% of the successful boreholes yield less than 2l/s and 29.7% yields more than 2l/s.

The Vaalwater Formation has been intruded extensively by sills and dykes of predominantly diabase composition. These diabase intrusions (N-Za) play a major role in the occurrence of groundwater. If dykes and sills are ignored, the groundwater potential of the Waterberg Group is generally low. For more information on the hydrogeological properties of the diabase intrusions Section 7.2.3.2 DIABASE (N-Za), Page 127 can be consulted.

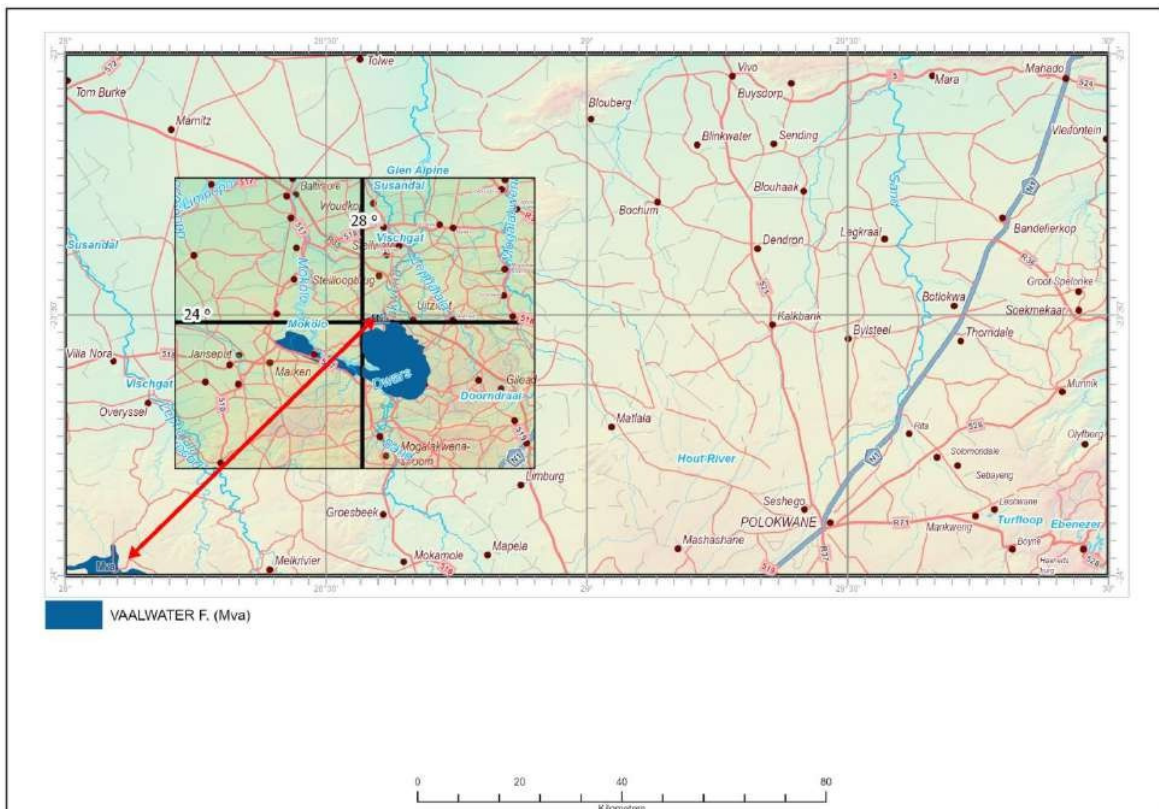


Figure 20: Geographical distribution of the Vaalwater Formation (Mva.)

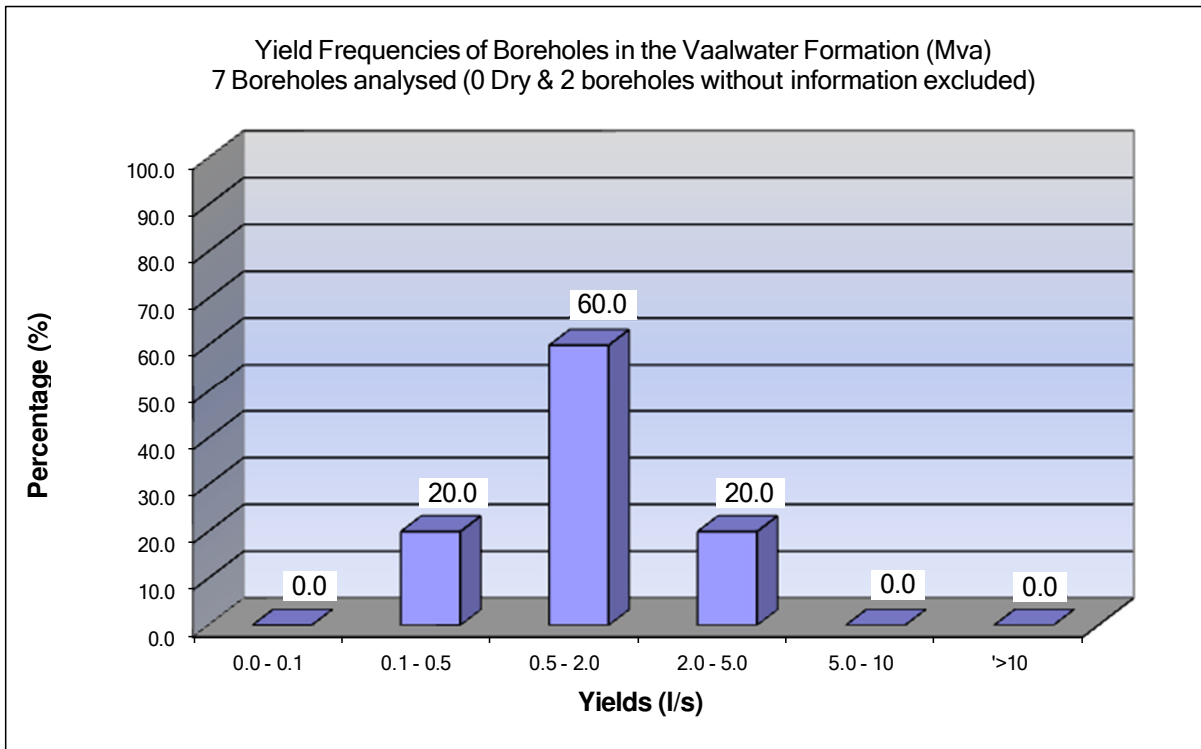


Figure 21: Yield frequency for the fractured aquifers of the Vaalwater Formation (Mva), only Polokwane data used.

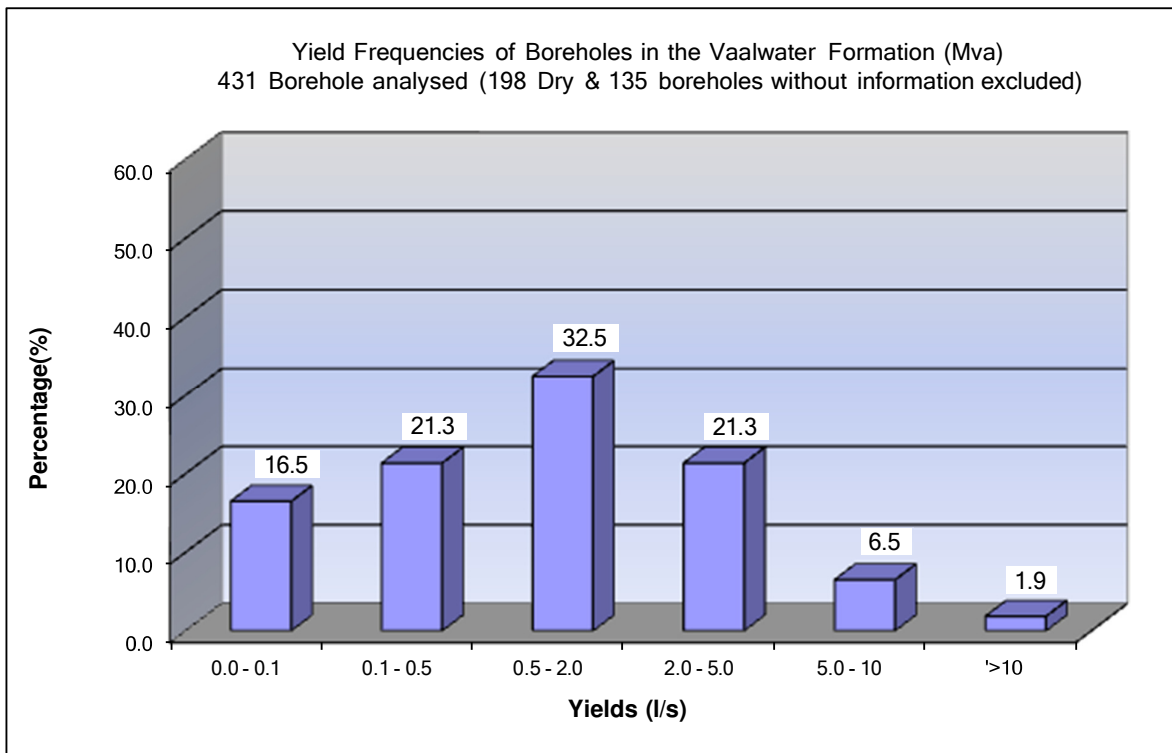


Figure 22: Yield frequency for the fractured aquifers of the Vaalwater Formation (Mva), data used from 3 map sheet areas, (cross-boundary occurrence).

The groundwater resource unit occurs on three maps that are interconnected (cross-boundary occurrence). The maps are Polokwane, Thabazimbi, and Modimolle. In terms of boreholes with water, 5 data points fall within the boundary of the Polokwane map sheet: 562 data points fall on the Modimolle map sheet and 62 data points fall on the Thabazimbi map sheet. The data for each map sheet was plotted in a yield diagram and compared, the Thabazimbi map sheet indicates that 26% of the boreholes has yields exceeding 5l/s. This was attributed to available borehole data in the vicinity of the Bulge River Fault, this fault zone extent into the Modimolle map sheet. No boreholes with data on yield was however available on boreholes along this fault within the Modimolle map sheet. No known faults occur within the unit that falls within the boundaries of the Polokwane map sheet and the yield diagram lean more to the 0.5l/s and 2l/s (60%) range, (see Figure 21). The combined yield diagram using the information from all three maps will be representative of the unit and was thus used for this brochure, (see Figure 22). Higher yielding boreholes are possible along fault zones and diabase intrusive.

The analysis of 431 borehole records, (Figure 22) indicates that 37.8% of the maximum yields are suitable for small households (>0.1l/s to 0.5l/s). A further 32.5% of the boreholes yield between 0.5l/s and 2l/s, with 21.3% of the borehole yielding between 2l/s and 5l/s and 8.4% yielding more that 5l/s.

For the data within the Polokwane map sheet, 6 data points was available with basic site information; the static water level ranges from 6.09 meters below ground level (mbgl) to 50mbgl with a median of 12.19mbgl and an average static water level of 19.14mbgl, (one data point of 74mbgl was ignored as it may relate to a pump drawdown measurement). No other information was available on borehole depths, installation depths or pump testing information.

When using the combined data of the three map sheets the static water level ranges from artesian (one data point) to 114.3mbgl. The median is 21.34mbgl, and the average static water level is 26.39mbgl. The 95<sup>th</sup> percentile is 60.43mbgl, (based on 332 data points). The maximum depth recorded is 248m, with an average depth of 115.7m, and a median depth of 101.8m, (38 data points). The maximum installation depth is 120m and the average is 63.4m, (22 data points). The maximum recommended daily abstraction on record is 432 cubic meters per day (m<sup>3</sup>/day) and the average is 130.8m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 22.

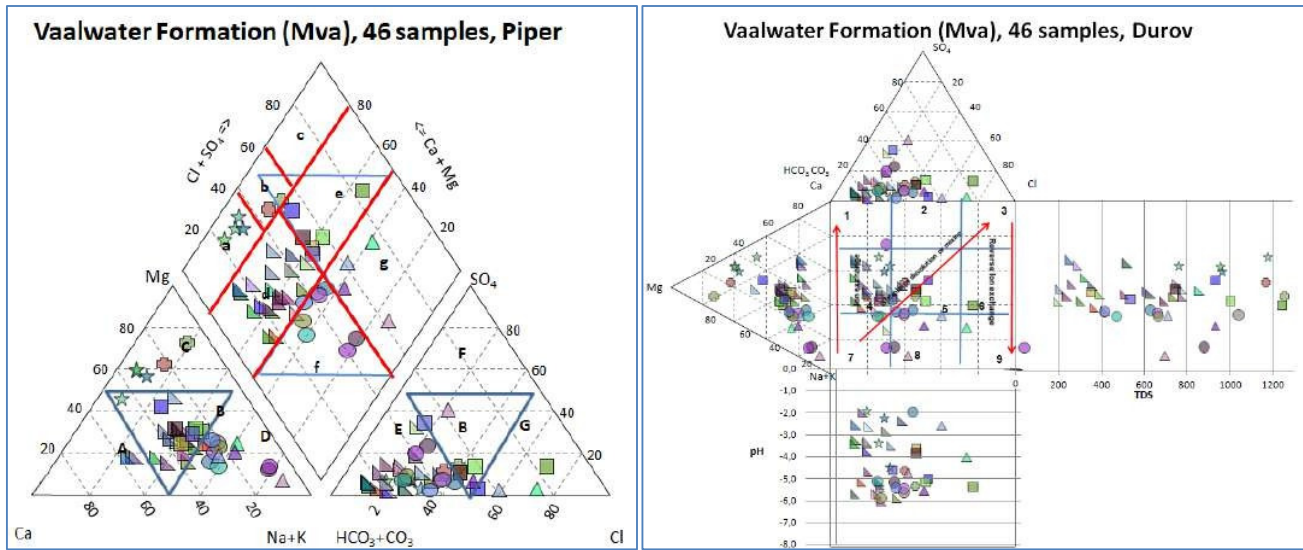


Figure 23: Trilinear diagrams, Piper and Durov for the Vaalwater Formation (Mva)

The groundwater resource unit occurs as a cross-boundary occurrence on three adjacent maps (Polokwane, Thabazimbi and Modimolle). In total 38 data points with chemical analyses falls on the Modimolle map sheet; 22 on the Thabazimbi map sheet and none on the Polokwane map sheet. The accuracy of the chemical analysis was checked by the plausibility of the Electrical Conductivity (EC) and Electro Neutrality (E.N). Only 46 analyses could be used as 14 analyses were not considered accurate

The trilinear Piper diagram, (Figure 23) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (73.9%), Weak acidic anions > Strong acidic anions (76.1%); Alkali > Alkali earths (16.1%); Strong acids > Weak acids (23.9%).

The second evaluation was on the water type:

- Mixed Calcium-Magnesium-Bicarbonate with prevailing Sodium type (45.7%);
- Sodium-Chloride type (21.7%);
- Mixed Calcium-Magnesium-Bicarbonate-Chloride with prevailing Sodium type (8.7%);
- Calcium-Bicarbonate type (6.5%);
- Magnesium-Bicarbonate-Chloride type (4.3%);
- Magnesium-Bicarbonate type (4.3%);
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type with increased Sodium and Sulphate (2.2%);
- Mixed Calcium-Magnesium-Chloride with prevailing Sodium type (2.2%);
- Sodium-Bicarbonate-Chloride type (2.2%);
- Sodium-Bicarbonate with prevailing Chloride and Sulphate type (2.2%);

The trilinear Durov diagram defines hydrochemical processes along with the water type. The interpretation is as follows:

- Anion discriminates and Ca dominant indicating mixed water or water exhibiting simple dissolution (47.8%),
- No dominant anion or cation indicates water exhibiting simple dissolution or mixing (30.4%), plot along the dissolution or mixing line,
- Cl dominant anion and Na dominant cation, reverse ion exchange of Na-Cl waters (8.7%),
- Cl and Na dominant, reverse ion exchange of Na-Cl waters (6.5%),
- Anion discriminate and Na dominant, probable mixing or uncommon dissolution influences (2.2%),
- Cl and Na dominant, is frequently indicative of end-point gradient waters through Dissolution (2.2%),
- HCO<sub>3</sub> and Ca dominant, indication of recharge in sandstone (2.2%),
- The high TDS is some of the samples that may be indicative of long residence times in the aquifer allowing reactions to be fairly complete.

Table 45: Chemical statistics for the Vaalwater Formation (Mva)

Element / Parameter	Statistics Drawn from a population of 60 data points for the Vaalwater Formation (Mva), 22 data points from the Thabazimbi map area, the rest from Modimolle map area										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	60	5.30	8.60	7.85	7.92	7.45	8.18	8.44	0.68	8.6%	
Electrical Conductivity (mS/m EC)	60	2.5	189.8	29.1	53.1	19.4	52.0	82.2	30.6	57.7%	
Total Dissolved Salts (mg/l TDS)	60	26.0	1278.0	227.1	378.0	147.1	370.0	623.2	217.5	57.5%	
Calcium (mg/l Ca)	59	0.50	91.70	10.49	30.23	8.66	28.16	51.50	17.65	58.4%	
Magnesium (mg/l Mg)	59	0.50	100.20	7.51	20.33	5.39	12.00	49.18	19.76	97.2%	
Sodium (mg/l Na)	60	5.00	253.80	27.13	52.96	12.30	43.09	111.84	43.02	81.2%	
Potassium (mg/l K)	59	0.50	15.09	1.44	2.49	0.82	1.58	5.66	2.78	111.5%	
Chloride (mg/l Cl)	60	1.50	402.80	13.32	41.00	5.69	25.01	87.36	62.16	151.6%	
Sulphate (mg/l SO <sub>4</sub> )	60	2.00	95.70	6.93	20.92	3.19	11.28	50.48	23.29	111.3%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	46	12.40	403.00	129.72	201.31	103.78	190.30	339.55	92.61	46.0%	
Nitrate (mg/l N)	58	0.02	13.00	0.16	1.86	0.05	1.09	4.11	2.40	129.0%	
Fluoride (mg/l F)	60	0.10	4.00	0.29	0.72	0.16	0.36	1.70	1.11	153.8%	
Silicon as Si	57	4.00	29.22	12.06	13.87	10.08	12.80	20.24	4.71	34.0%	
Iron (Fe)	27	0.005	0.370	0.021	0.072	0.008	0.050	0.167	0.10	134.2%	
Manganese (Mn)	27	0.001	0.070	0.006	0.032	0.002	0.050	0.050	0.02	71.1%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	50	0.006	0.800	0.020	0.166	0.009	0.022	0.800	0.28	169.3%	
ZAR	59	0.25	7.79	1.16	2.11	0.64	1.58	5.80	1.83	86.9%	
LSI	44	Langelier Saturation Index (LSI)			Slightly Scaling		40.9%		Highly Scaling		0.0%
		Highly corrosive		4.5%	Slightly corrosive		4.5%	Balanced Corrosion		50.0%	

This unit occurs on three maps that are physically connected and is therefore classified as a cross-boundary groundwater resource unit with similar properties. The adjacent maps are Thabazimbi and Modimolle. For the chemical statistics no data points are available for the Polokwane map sheet, 22 data points are within the Thabazimbi map sheet and 38 data points fall on the Modimolle map sheet.

Table 45 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality in terms of the Electrical conductivity (EC) is ideal to good (98.3%) and marginal in 1.7% of the analysis (EC < 370mS/m). The values range from 2.5mS/m to 189.8mS/m, the 90<sup>th</sup> percentile is 82.2mS/m.

The Total Dissolved Solids (TDS) is acceptable in 98.3% of the samples (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 60 samples show no problematic elements.

The Langelier Saturation Index (LSI) indicates that the water is slightly highly corrosive in 9% of the samples; slightly scaling in (40.9%) and predominantly balanced (50%). The ZAR index indicates that 84.8% of the water is of a fair quality for irrigation (ZAR < 3).

Groundwater in this unit is abstracted for game watering and domestic purposes. No irrigation occurs as the area is predominantly used for game farming.

#### **7.2.1.5 CLEREMONT FORMATION (Mcl)**

The Cleremont Formation is described as a separate groundwater resource unit although it is part of the Kransberg Subgroup of the Waterberg Supergroup. Structurally the Kransberg Subgroup falls within the Nylstroom Syncline which is a large, shallow synclinal fold (a trough-shaped fold where the youngest rocks are in the core). Within the Polokwane map sheet the Cleremont Formation rests conformably on the Mogalakwena Formation and is, together with the Vaalwater Formation, restricted to the extreme south-western part of the map area. The section of the unit within the Polokwane map sheet covers approximately 0.37% of the total areal extent thereof, (Figure 24). The unit extent west into the Lephalale and south-west into the Thabazimbi map sheet and south-easterly into the Modimolle map sheet area. The combined larger outcrop when mapped appears to form a ring around the Vaalwater Formation, (see inset map Figure 24).

The Cleremont Formation comprises sandstone with minor shale and forms a thin cover on the Mogalakwena Formation. It reaches a maximum thickness of 60m to 100m, (Weinert, 1955 & Neetling; De Vries, 1971)

The sandstone is medium to coarse-grained, well sorted with a high percentage of quarts; locally gritty and whitish in colour. Rare occurrences of the sedimentary rock with a light-pink or light red colour occur and are apparently restricted to the base of the formation, (Callaghan, 1987, Callaghan and Brandl, 1991).

In 3.3% of the water samples at least one element exceeds the maximum allowed limit for domestic use. For this unit the anions of concern is Nitrate followed by Fluoride that exceeds the maximum allowable concentration for human consumption in 3% of the available analysis.

The yield frequency diagram, (Figure 25) gives an indication of the expected yield of the boreholes, with 70.7% of the successful boreholes yielding less than 2ℓ/s and 29.3% of the boreholes yielding more than 2ℓ/s.

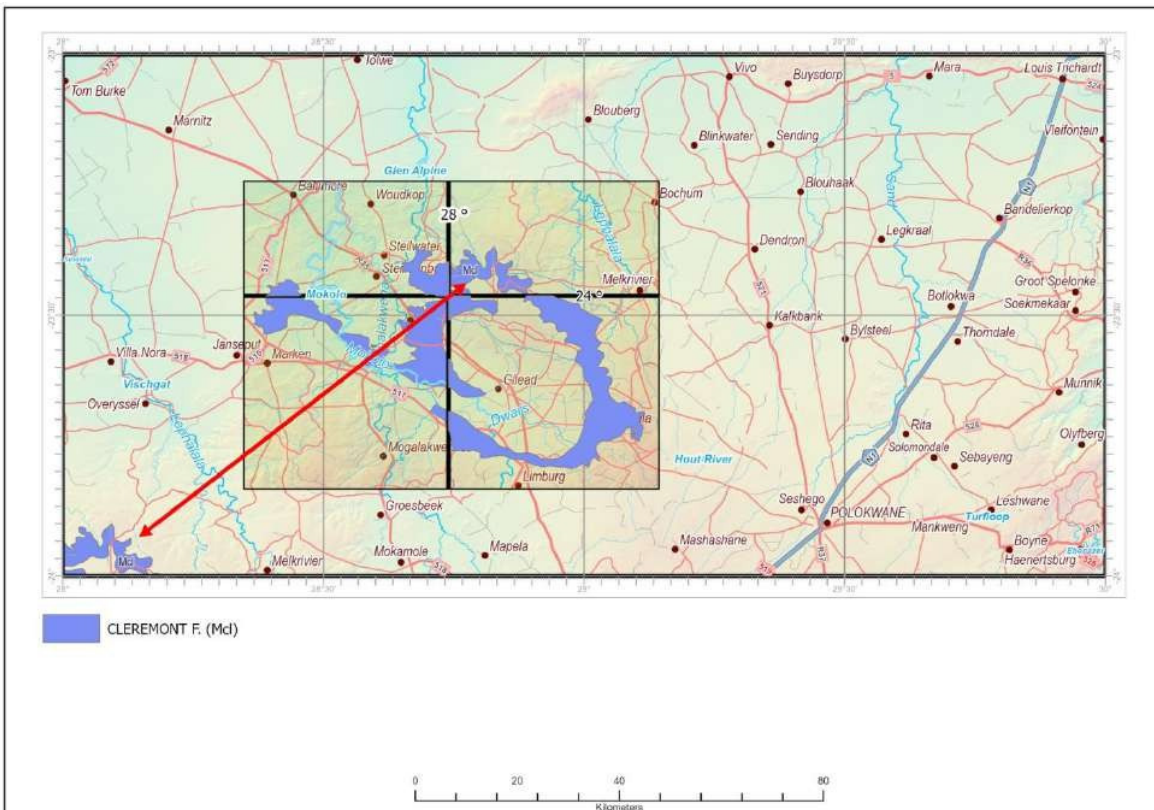


Figure 24: Geographical distribution of the Cleremont Formation (Mcl).

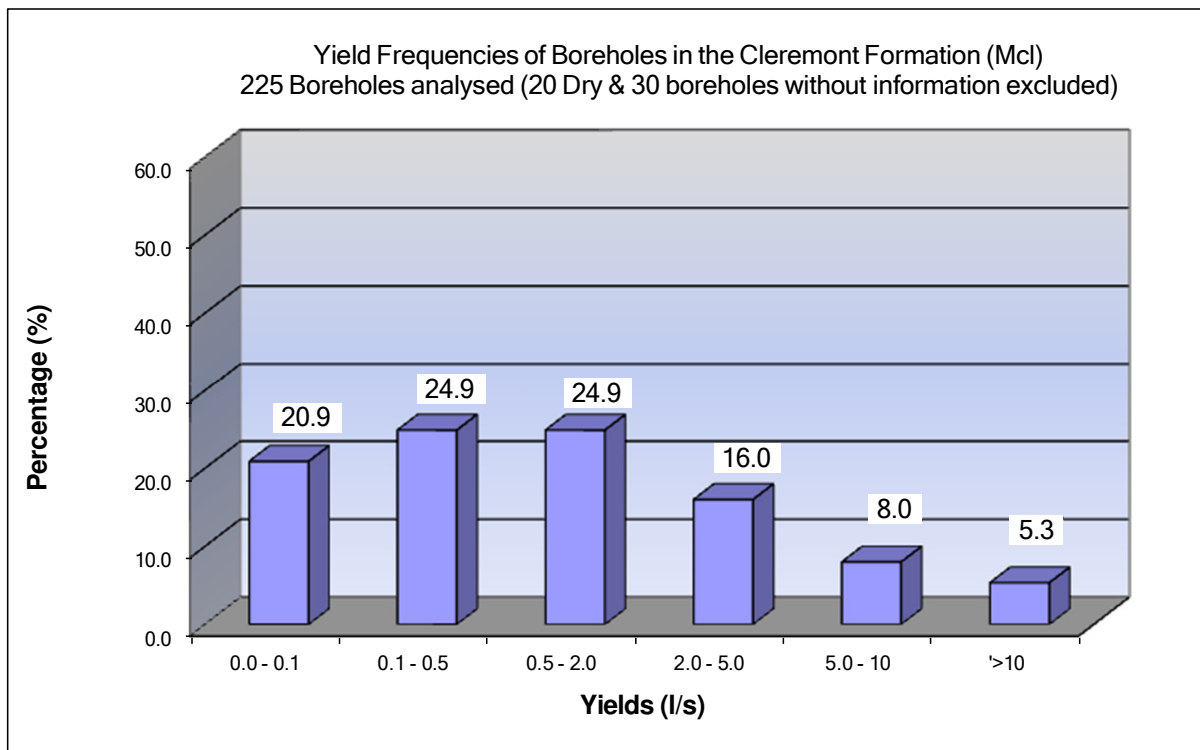


Figure 25: Yield frequency for fractured aquifers of the Cleremont Formation (Mcl)

The groundwater resource unit occurs at the intersection of four map boundaries: Modimolle, Lephallale, Polokwane, and Thabazimbi. For the yield frequency compilation, 275 data points were available, of which 136 fall on the Modimolle map sheet, 41 on the Lephallale map sheet, 2 on the Polokwane map sheet, and 47 on the Thabazimbi map sheet. Only 225 data points have recorded water strikes, 20 were dry, and 30 had no information regarding yield.

The analysis of 225 borehole records indicates that 45.8% of the maximum yields are suitable for small households (>0.001ℓ/s to 0.5ℓ/s). A further 24.9% of the boreholes yield between 0.5ℓ/s and 2ℓ/s and 16% of the boreholes yield between 2ℓ/s and 5ℓ/s. In addition, 13.3% of the boreholes are yielding more than 5ℓ/s.

Similar in characteristics to the Mogalakwena Formation, groundwater occurs mainly in fault zones, sill/dyke contacts, fracture zones and fractures related to anticlines and bedding planes. No information is available to determine if the underlying contact with the Mogalakwena Formation will result in water strikes.

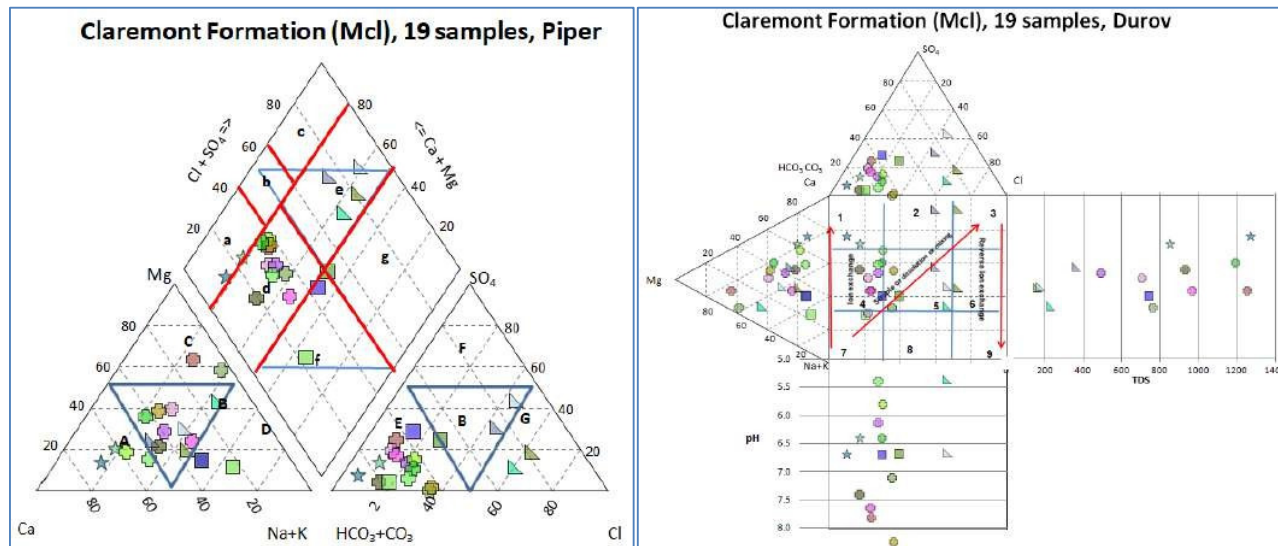


Figure 26: Trilinear diagrams, Piper and Durov for the Claremont Formation (Mcl).

The groundwater resource unit extent into three adjacent map sheets, namely Modimolle, Lephallale and Thabazimbi. For the chemical data 28 data points fall on the Modimolle map sheet: 2 on the Lephallale map sheet, 1 on the Thabazimbi map sheet and 0 data points on the Polokwane map sheet. The accuracy of the chemical analysis was checked by the plausibility of the Electrical Conductivity (EC) and Electro Neutrality (E.N). Only 19 analyses could be used as 12 analyses were not considered accurate.

The trilinear Piper diagram, (Figure 26) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (84.2%), Weak acidic anions > Strong acidic anions (79%); Alkali > Alkali earths (15.8%); Strong acids > Weak acids (21%).

The second evaluation was on the water type: mixed

- Calcium-Magnesium-Bicarbonate type (42.1%);
- Calcium-Bicarbonate type (21.1%).
- Sodium-Bicarbonate type (15.8%);
- Mixed Calcium-Magnesium-Chloride type with prevailing Sodium and Sulfate (10.5%);
- Mixed Calcium-Magnesium-Chloride type (10.5%);

The trilinear Durov diagram defines hydrochemical processes along with the water type. The interpretation is as follows:

- Anion discriminates and Ca dominant indicating mixed water or water exhibiting simple dissolution (42.9%),
- No dominant anion or cation indicates fresh recent recharged water exhibiting simple dissolution or mixing (28.6%), plots along the dissolution or mixing line,
- HCO<sub>3</sub> and Ca dominant, indication of recharge in sandstone (14.3%),
- HCO<sub>3</sub> and Ca dominant, with prevailing Na, an important ion exchange is presumed (4.8%),
- Anion discriminate and Na dominant, probable mixing or uncommon dissolution influences (4.8%),
- HCO<sub>3</sub> and Na dominant, indication of ion exchanged water (4.8%),

Table 46: Chemical statistics for the Cleremont Formation (Mcl).

Element / Parameter	Statistics Drawn from a population of 31 data points for the Cleremont Formation (Mcl)									
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation
pH	30	6.06	8.36	7.19	7.25	6.08	7.41	7.95	0.67	9.3%
Electrical Conductivity (mS/m EC)	30	2.54	95.95	8.95	20.76	3.40	15.10	43.18	20.35	98.1%
Total Dissolved Salts (mg/l TDS)	30	17.2	721.3	64.5	157.1	24.6	115.5	308.3	152.6	97.2%
Calcium (mg/l Ca)	26	0.67	77.70	2.77	14.85	0.82	7.92	34.11	17.81	119.9%
Magnesium (mg/l Mg)	26	0.67	45.16	2.43	6.45	1.09	3.17	14.51	9.34	144.7%
Sodium (mg/l Na)	26	1.50	59.50	5.31	12.09	2.57	7.64	24.08	13.12	108.5%
Potassium (mg/l K)	26	0.35	6.81	0.73	1.10	0.39	0.86	1.47	1.23	111.7%
Chloride (mg/l Cl)	30	2.98	62.00	6.51	11.27	3.48	6.67	26.62	12.46	110.5%
Sulphate (mg/l SO <sub>4</sub> )	29	0.09	19.87	1.52	5.69	1.47	4.00	12.63	4.99	87.7%
Total Alkalinity (mg/l CaCO <sub>3</sub> )	27	4.0	287.3	15.3	69.7	5.5	51.0	160.7	72.3	103.8%
Nitrate (mg/l N)	30	0.02	29.53	0.20	2.59	0.08	1.06	4.44	5.44	209.6%
Fluoride (mg/l F)	31	0.05	5.15	0.14	0.38	0.09	0.15	0.43	0.92	241.1%
Silicon as Si	26	4.34	32.56	6.98	8.78	4.69	7.94	13.90	5.93	67.6%
Iron (Fe)	11	0.0050	0.0900	0.0104	0.0282	0.0054	0.0205	0.0500	0.03	99.7%
Manganese (Mn)	6	0.0092	0.0820	0.0299	0.0485	0.0296	0.0500	0.0660	0.02	47.7%
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	29	0.005	0.800	0.017	0.130	0.010	0.019	0.800	0.27	210.2%
ZAR	26	0.21	3.11	0.49	0.68	0.32	0.50	1.11	0.57	82.8%
LSI	26	Langelier Saturation Index (LSI)			Slightly Scaling		3.8%	Highly Scaling		0.0%
		Highly corrosive			46.2%	Slightly corrosive		38.5%	Balanced Corrosion	

The data points used for the chemical statistics are from all four maps as the outcrop represents a single groundwater resource unit.

Table 46 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. In terms of the electric conductivity (EC), the overall water quality is ideal; it varies between 2.5 and 95.9mS/m. The Total Dissolved Solids (TDS) is acceptable in 100% of the samples (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 31 samples show elevated concentrations of Nitrate, (N >20mg/l) in 3.3% and Fluoride (F >1.5mg/l) in 3% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water may be predominantly corrosive (84.7%); slightly scaling (3.8%) and balanced in 11.5% of the analysis. The ZAR index indicates that 96.2% of the water is of a fair quality for irrigation (ZAR < 3).

Groundwater is abstracted for game watering and domestic purposes for private game reserves with associated lodges and overnight facilities. Water is also used for farm homesteads and livestock watering. No evidence of large-scale irrigation could be found.

### 7.2.1.6 KRANSBERG SUBGROUP (Mkr)

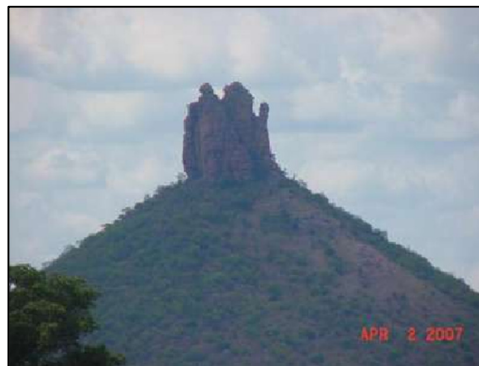
The Waterberg basin has been sub-divided into three subgroups viz. Nylstroom, Matlabas and Kransberg. The basin is bounded on the southern side by the Waterberg and Sandriviersberg mountains and by Karoo rocks on the northern side, the contact being a fault, (Figure 41). The Kransberg Subgroup comprises two undifferentiated formations on the Modimolle map sheet i.e. Sandriviersberg and Mogalakwena Formations. Only the Mogalakwena Formation appears on the Polokwane map sheet, but as both formations consist predominantly of sandstone, it was decided to retain the groundwater resource unit name 'Kransberg Subgroup' instead of creating a new symbol/code for Mogalakwena. The Mogalakwena formation rests with a mainly conformable contact, on the Makgabeng Formation. In the Blouberg area, however, it unconformably overlies the Blouberg Formation as well as rocks of Swazian and Randian age. It consists of purplish brown, coarse-grained sandstone with interbedded conglomerate and boulder conglomerate. It has been intruded extensively by sills and dykes of predominantly diabasic composition. These diabase intrusions (N-Zd) play a major role in the occurrence of groundwater in the Waterberg Group. If dykes and sills are ignored, the groundwater potential of the Waterberg Group is generally low.

The yield distribution, (Figure 28), indicates that 78.1% of the boreholes have maximum yields of less than 2l/s. The findings correlate with the 82.6% of the boreholes with yields less than 2l/s within the Lephalale map sheet and the 77.7% from the Thabazimbi and Modimolle map sheets.

In terms of groundwater quality, 22.2% of the water samples contain at least one element that exceeds the maximum allowable concentration limit for domestic use. For this unit, the anion of concern is Nitrate. In terms of areal extent, the unit represents the largest aquifer resource within the map sheet, covering approximately 14.3% of the total map area.



*Plate 3: Intensely fractured Mogalakwena Formation on the farm Klipfontein 797 LR, which consists of purplish brown, coarse grained sandstone with interbedded conglomerate and boulder conglomerate (Photograph: WH du Toit).*



*Plate 4 & Plate 5: Weathering of the sandstone of the Mogalakwena Formation produces extraordinary and beautiful scenery and rock shapes as illustrated in the photographs (Photograph: WH du Toit).*



Plate 6: Bushman paintings engraved in sandstone of the Mogalakwena Formation on the farm Waterval 601 LQ south of Lephalale (Ellisras) (Photograph: WH du Toit).

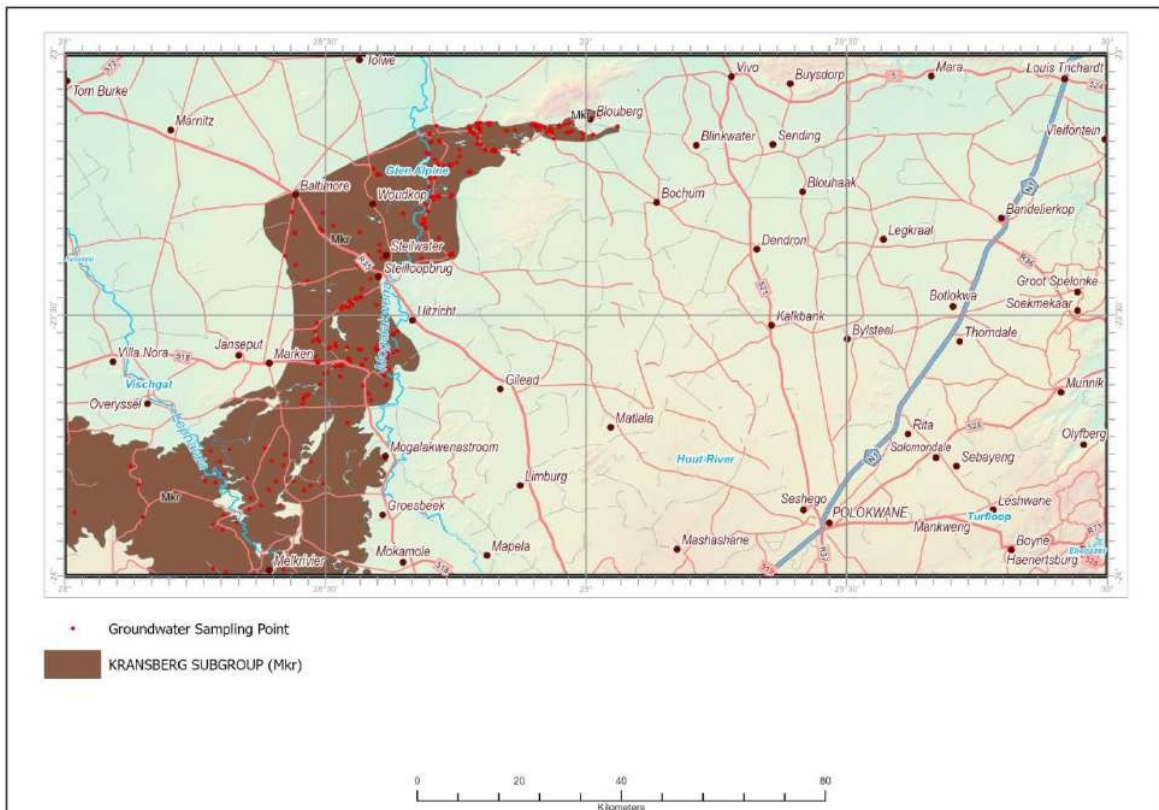


Figure 27: Geographical distribution of the Kransberg Subgroup (Mkr) and associated groundwater data points.

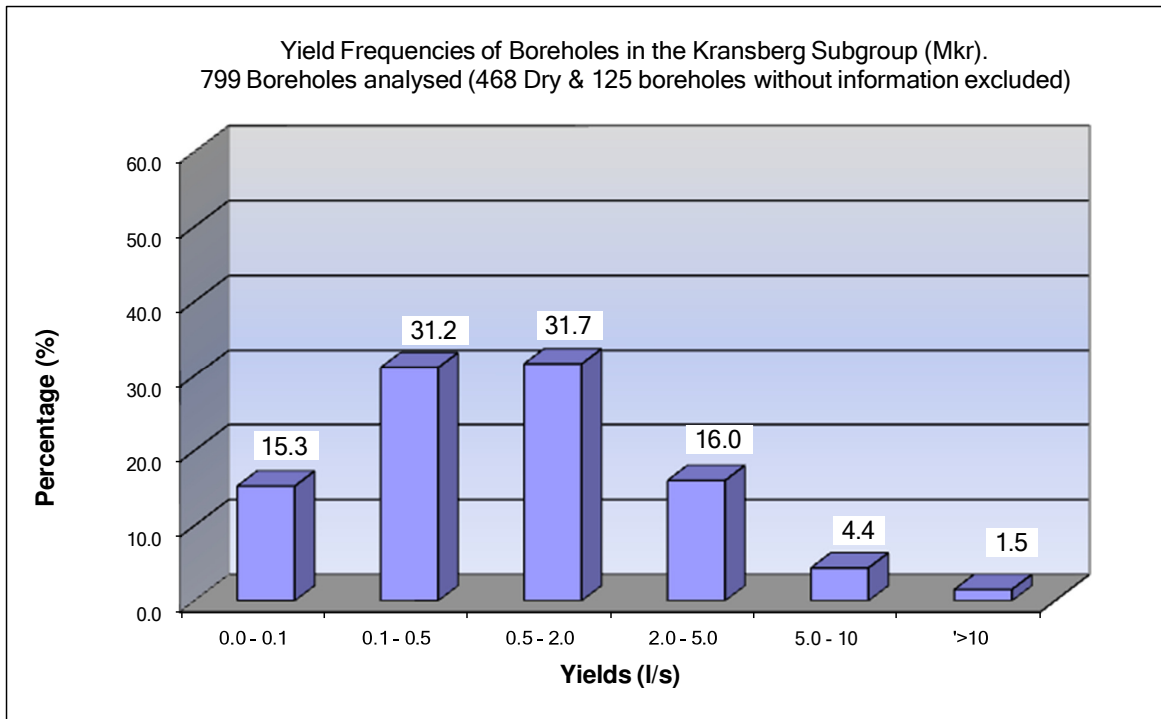


Figure 28: Yield frequency for fractured aquifers of the Kransberg Subgroup (Mkr).

The yield distribution, (Figure 28) compiled for the Kransberg Subgroup that falls within the Polokwane map sheet boundary, is similar to the distribution of the maximum yields for boreholes falling within the Thabazimbi and Modimolle map sheet boundaries.

An analysis of 799 borehole records indicates that 46.4% of the maximum yields are suitable for small households (>0.001l/s to 0.5l/s). A further 31.7% of the boreholes have yields between 0.5l/s and 2l/s; with 16% of the boreholes yielding between 2l/s and 5l/s and 5.9% yielding more that 5l/s.

The static water level ranges from artesian to 80 meters below ground level (mbgl), with a median of 12.41mbgl, and an average of 14.89mbgl, (based on 305 data points of which 3 have water levels are deeper than 51m). The maximum depth recorded is 291m, with an average of 75.9m and a median depth of 67.8m, (370 data points). The maximum installation depth is 171m and the average is 39.4m, (195 data points). The maximum recommended daily abstraction on record is 691.2 cubic meters per day (m<sup>3</sup>/day) with an average of 48.9m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 196.

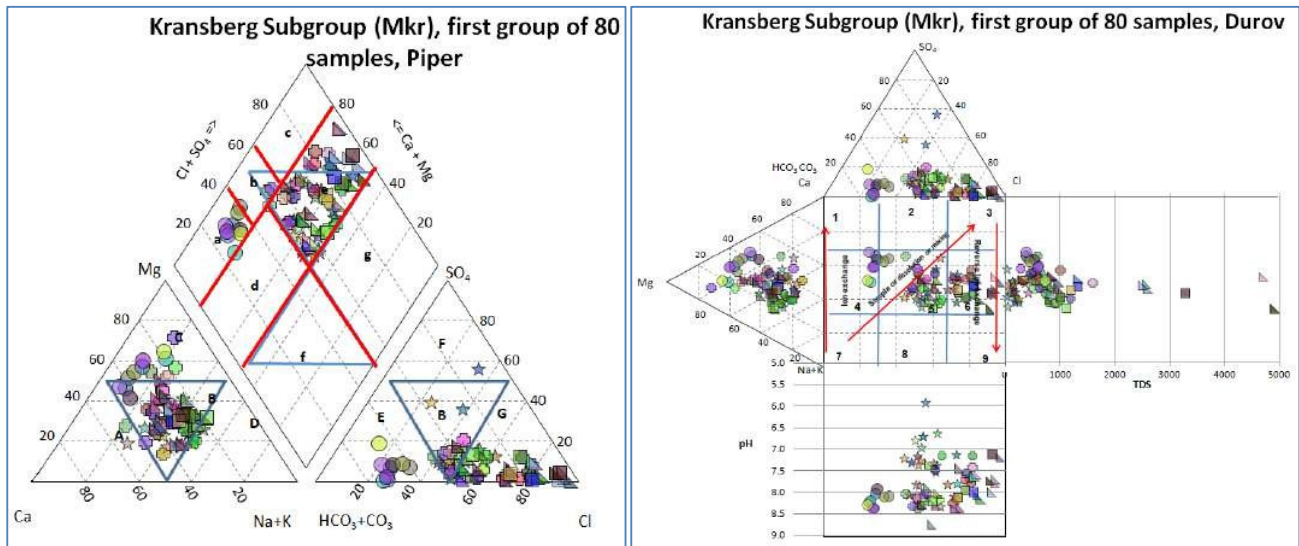


Figure 29: Trilinear diagrams, Piper and Durov for the Kransberg Subgroup (Mkr) first group of 80 samples.

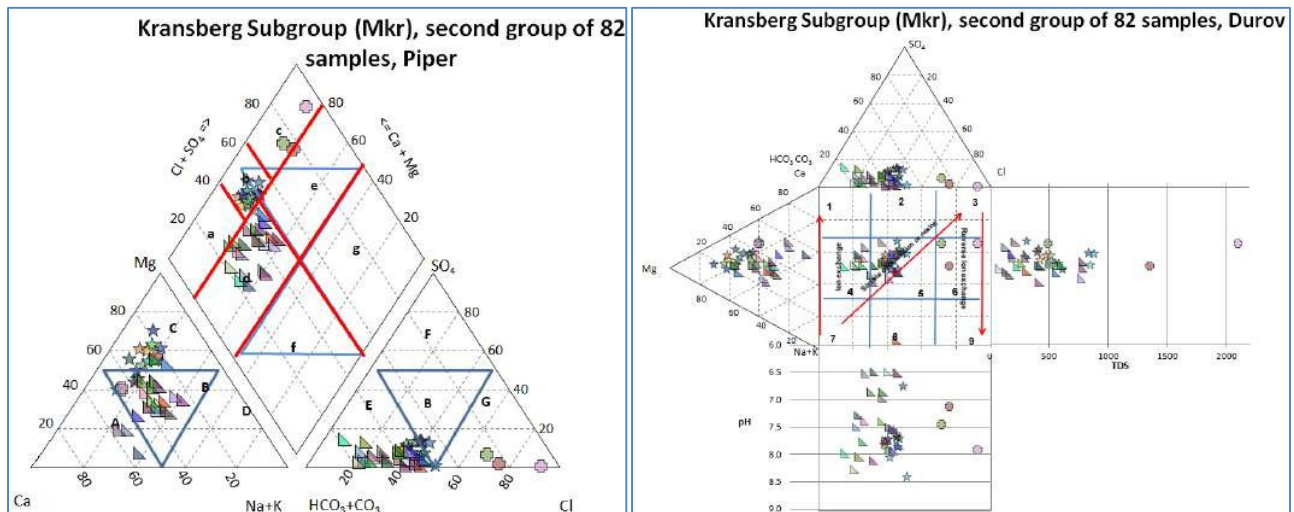


Figure 30: Trilinear diagrams, Piper and Durov for the Kransberg Subgroup (Mkr) second group of 82 samples.

The trilinear Piper diagram, (Figure 29 & Figure 30) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (73.5%), Weak acidic anions > Strong acidic anions (25.3%); Alkali > Alkali earths (26.5%); Strong acids > Weak acids (74.7%).

The groundwater in this unit classifies as:

- Mixed Calcium-Magnesium-Bicarbonate-Chloride type (25.4%),
- Sodium-Chloride type (24.7%),
- Mixed Calcium-Magnesium-Chloride with increasing Sodium type (15.4%),
- Mixed Calcium-Magnesium-Bicarbonate type (12.3%),
- Magnesium-Bicarbonate type (11.1%),
- Magnesium-Chloride type (3.1%),
- Calcium-Bicarbonate type (1.9%),
- Sodium-Bicarbonate type (1.9%),
- Mixed Calcium-Magnesium-Chloride type (1.2%),
- Calcium-Chloride type (1.2%),

- Mixed Calcium-Magnesium-Bicarbonate-Chloride with increasing Sulphate type (1.2%),
- Mixed Calcium-Magnesium-Sulphate type (0.6%).

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- No dominant anion or cation indicates fresh recent recharge water exhibiting simple dissolution or mixing (51.9%), plot along the dissolution or mixing line,
- -Anion discriminates and Na dominant, probable mixing or uncommon dissolution influences (21%),
- SO<sub>4</sub> dominates, or anion discriminant and Ca dominant, frequently indicates recharge in gypsiferous deposits, otherwise mixed water or water exhibiting simple dissolution. (10.5%),
- Cl and Na dominant, is frequently indicative of end-point gradient waters through Dissolution (9.9%),
- Cl dominant ion and Na dominant cation indicative of reverse ion exchange of Na-Cl waters (6.8%),
- The high TDS values in some of the samples may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 47: Chemical statistics for the Kransberg Subgroup (Mkr)

Element / Parameter	Statistics Drawn from a population of 367 data points for the Kransberg Subgroup (Mkr).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	360	4.60	8.85	7.65	7.70	6.90	7.86	8.34	0.63	8.1%	
Electrical Conductivity (mS/m EC)	363	3.8	1130.1	60.3	181.7	25.3	114.6	459.8	190.5	104.8%	
Total Dissolved Salts (mg/l TDS)	352	26.7	18593.0	392.4	1209.2	154.5	798.8	2655.4	1477.6	122.2%	
Calcium (mg/l Ca)	351	2.00	657.49	30.23	87.18	14.35	55.70	198.61	93.75	107.5%	
Magnesium (mg/l Mg)	349	0.77	1152.70	15.74	73.96	5.86	52.25	165.44	92.80	125.5%	
Sodium (mg/l Na)	338	2.15	3816.40	39.24	183.53	15.65	93.12	427.38	294.97	160.7%	
Potassium (mg/l K)	336	0.15	132.33	2.26	6.76	0.89	3.92	14.18	10.58	156.5%	
Chloride (mg/l Cl)	360	4.30	9985.45	54.29	400.09	20.09	150.93	1152.68	761.43	190.3%	
Sulphate (mg/l SO <sub>4</sub> )	355	0.50	690.40	7.72	37.93	2.82	15.48	90.46	61.74	162.7%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	295	2.00	696.60	71.63	254.11	47.80	248.00	441.92	148.79	58.6%	
Nitrate (mg/l N)	360	0.02	283.43	0.31	14.71	0.10	5.76	36.12	26.12	177.6%	
Fluoride (mg/l F)	353	0.02	8.30	0.23	0.62	0.12	0.31	0.98	1.22	197.7%	
Silicon as Si	335	0.60	53.62	14.33	25.14	6.94	25.69	41.08	12.97	51.6%	
Iron (Fe)	176	0.002	2.140	0.009	0.050	0.004	0.011	0.065	0.19	376.3%	
Manganese (Mn)	173	0.001	4.348	0.004	0.178	0.001	0.018	0.625	0.46	258.1%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	305	0.001	1.500	0.015	0.061	0.009	0.019	0.064	0.17	278.3%	
ZAR	351	0.00	21.62		3.34	0.50	1.87	7.28	3.83	114.8%	
LSI	286	Langelier Saturation Index (LSI)			Slightly Scaling		54.2%		Highly Scaling		0.0%
		Highly corrosive			7.0%		Slightly corrosive		12.2%		Balanced Corrosion

Table 47 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value and standard deviation will give an indication of the scale of the problem.

The overall water quality in terms of the Electrical conductivity (EC) is ideal to good (62.3%); marginal, (EC < 370mS/m), in 24.2% and unacceptable in 13.5% of the analysis. The values range from 3.8mS/m to 1130.1mS/m with the 90th percentile being 459.8mS/m. The Total Dissolved Solids (TDS) is acceptable in 69.6% of the samples (TDS ≤ 1200mg/l).

An evaluation of the major cations and anions from 367 samples shows elevated concentrations of Nitrate (N >10mg/l) in 22.2%; Chloride (Cl > 600mg/l) in 17.5%; Sodium (Na > 400mg/l) in 12.1%; Magnesium (Mg > 200mg/l) in 7.4%; Calcium (Ca > 300) in 5.7%; Fluoride (F >1.5mg/l) in 5.1%; Potassium (K > 100mg/l) in 0.3% and Sulphate (SO<sub>4</sub> >600mg/l) in 0.3% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water may be slightly to highly corrosive (19.2%), to slightly scaling (54.2%) and 26.6% balanced. The ZAR index indicates that 64.1% of the water is of a fair quality for irrigation (ZAR < 3).

The unit forms part of the Waterberg Plateau, with the southern mountainous region primarily used for game reserves viz. Moepel, Masebe, and Wonderkop. At the foot of the plateau, in the eastern and north-eastern parts of the unit, various rural villages are located. Water for these villages is mainly pumped from caissons and boreholes within and along the Mogalakwena River.

Groundwater targets in the hard rock consist of deep secondary fractures related to faults and diabase dykes and sills (particularly along contact zones). Within and near the river, the main groundwater target consists of secondary fractures overlain by thick alluvial deposits. Contact zones between different sedimentary layers, such as sandstone and conglomerate, are generally not favorable targets for groundwater exploration.

#### **7.2.1.7 BLOUBERG FORMATION (Mbb)**

The Blouberg Formation (Mbb) which occurs only around Lehu Mountain in the Blouberg area, unconformable overlies rocks of Swazian and Randian age. It represents a sedimentary-volcanic assemblage and has been divided into seven sedimentary members and a volcanic member at the top, (Meinser and Jansen, 1974, Jansen 1976). These members are not shown or discussed separately. Deposition was largely in small, partly isolated yoked or closed basins and troughs formed on down-faulted blocks in the basement, (Jansen 1976 p 285-287). Owing to intense faulting in the Blouberg area, complete succession is nowhere fully developed.

The Blouberg Formation consists of conglomerate, felspathic grit, arkose, and sandstone. Variegated shale (exhibiting different colours) and mudstone occur as lenticular intercalations. The sandstone often exhibits large-scale, trough-type cross bedding. The volcanic rocks are largely amygdaloidal and well exposed around Lehu Mountain and on the southern slopes of the Blouberg Mountain. The rocks are often epidotised, but where fresh, the mineralogical composition suggests there are also trachytes, trachyandesites and andesite present. The lavas are presently grouped with the Blouberg Formation, but there is a strong possibility that they are part of the largely volcanic Sibasa Formation of the Soutpansberg Group.

The unit within the Polokwane map sheet covers approximately 0.59% of the total areal extent. It occurs within the central-northern section of the map sheet, (Figure 31).

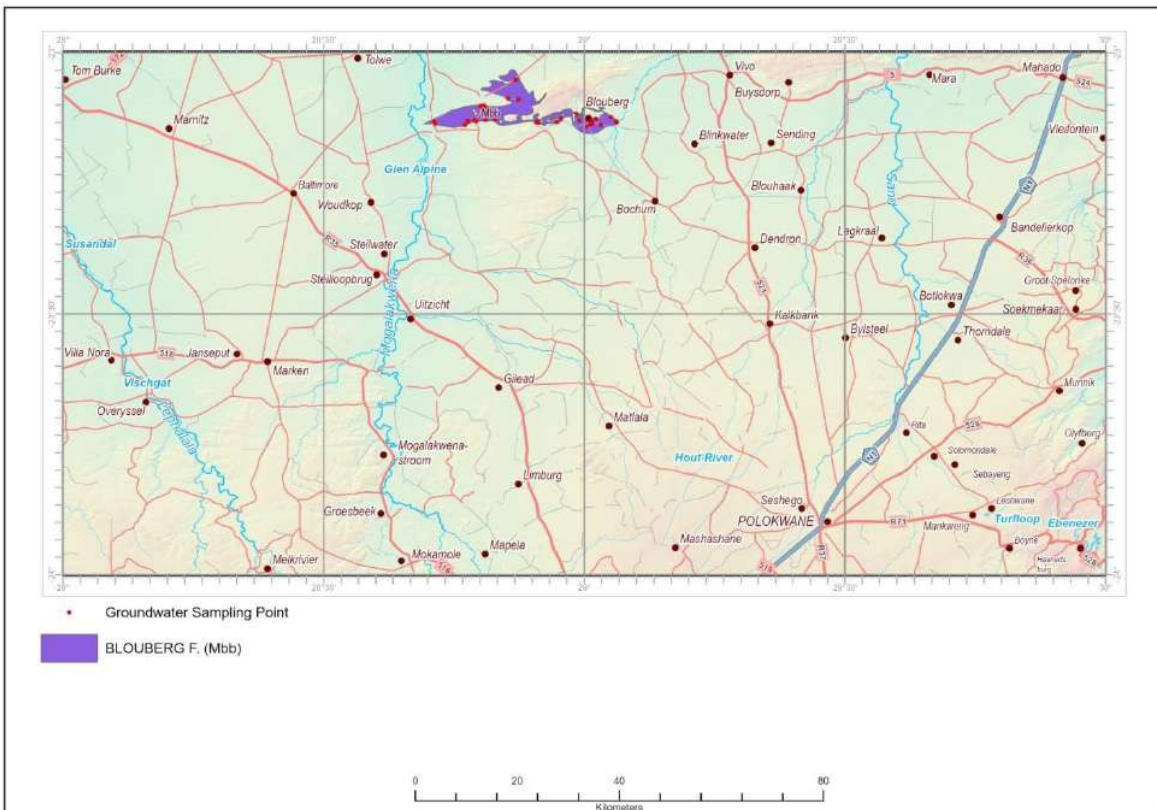


Figure 31: Geographical distribution of the Blouberg Formation (Mbb) and the associated groundwater data points.

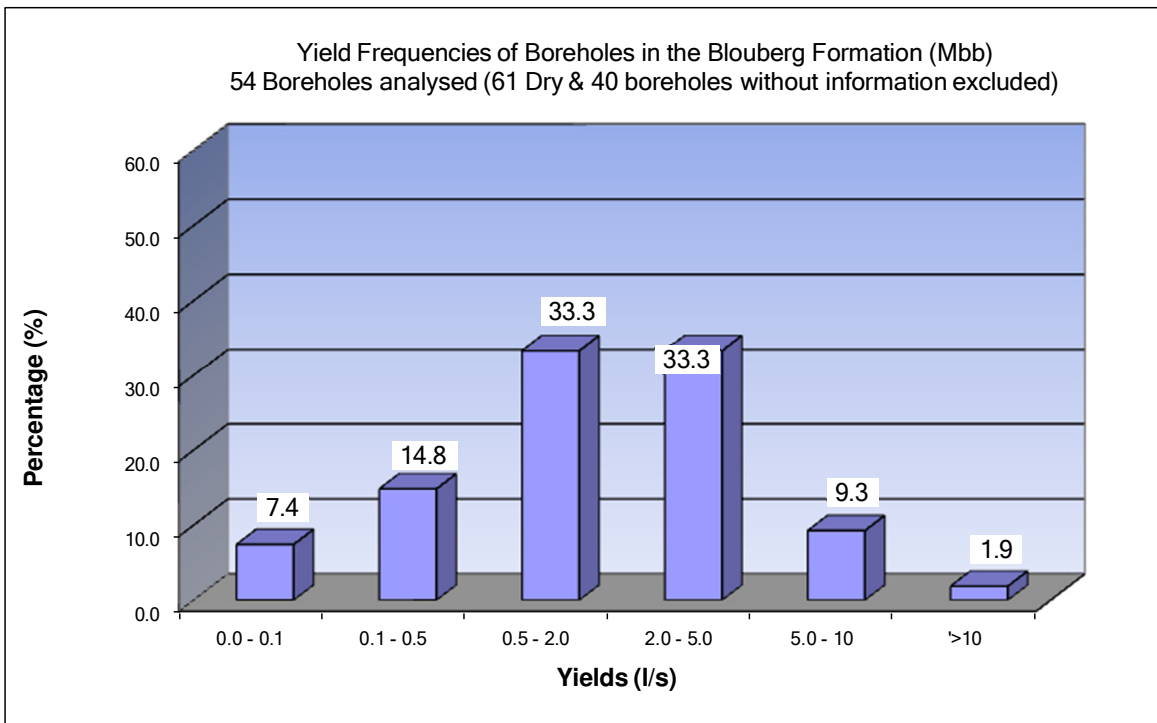


Figure 32: Yield frequency for fractured aquifers of the Blouberg Formation (Mbb)

The analysis of 54 borehole records indicates that 22.2% of the maximum yields are suitable for small households (>0.001l/s to 0.5l/s). A further 33.3% of the boreholes have yields ranging between 0.5l/s and 2l/s, with 33.3% of the boreholes yielding between 2l/s and 5l/s and 11.1% that yields more that 5l/s.

The static water level ranges from 3.8 meters below ground level (mbgl) to 79.4mbgl, with a median of 19.8mbgl and an average static water level of 25.2mbgl, (based on 56 data points). The maximum depth recorded is 248.5m. The average depth is 101.6m and the median depth is 100m (86 data points). The maximum recorded installation depth is 138m, with an average of 51.6m (24 data points). The maximum recommended daily abstraction on record is 1296 cubic meters per day (m<sup>3</sup>/day) and an average of 152.6m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 31.

Groundwater occurs mainly in fault zones, sill/dyke contacts, fracture zones, and possible bedding planes. The mountainous and rugged terrain significantly limits access for groundwater development.

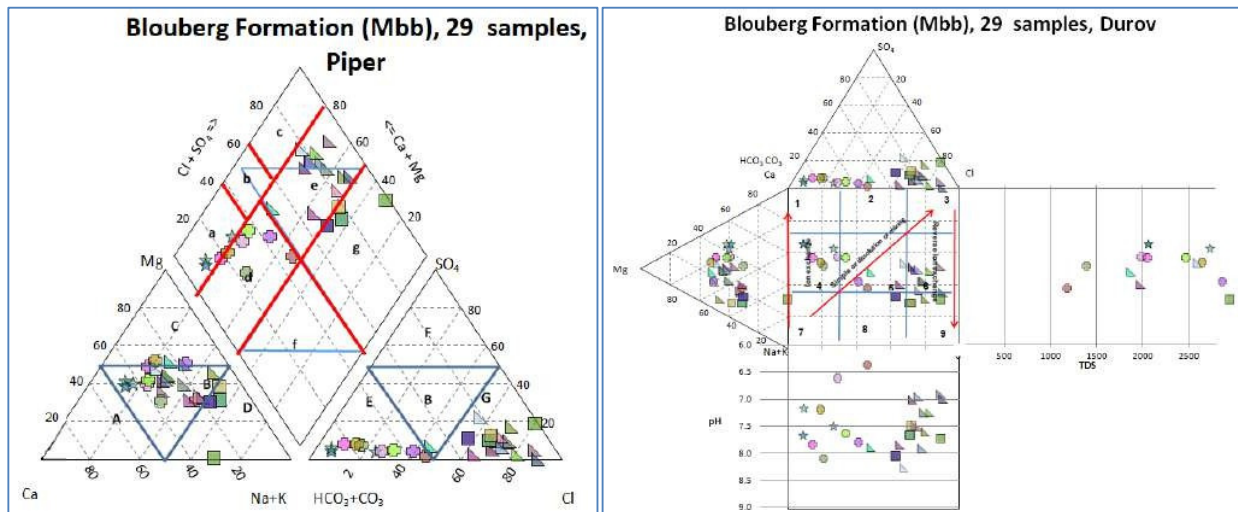


Figure 33: Trilinear diagrams, Piper and Durov for the Blouberg Formation (Mbb).

The trilinear Piper diagram, (Figure 33) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (75.9%), Weak acidic anions > Strong acidic anions (79.3%); Alkali > Alkali earths (24.1%); Strong acids > Weak acids (20.7%).

The second evaluation was on the water type:

- Mixed Calcium-Magnesium-Chloride type (44.9%);
- Mixed Calcium-Magnesium-Bicarbonate type (24.1%);
- Sodium-Chloride type (20.7%);
- Mixed Calcium-Magnesium-Bicarbonate type with increased Sodium (10.3%).

The trilinear Durov diagram defines hydrochemical processes along with the water type. The interpretation is as follows:

- SO<sub>4</sub> dominates, or anion discriminates and Na dominant, mixed water or water exhibiting simple dissolution influences (37.9%),
- No dominant anion or cation indicates fresh recent recharged water exhibiting simple dissolution or mixing (20.7%), plots along the dissolution or mixing line,
- SO<sub>4</sub> dominates, or anion discriminant and Ca dominant, frequently indicates recharge in gypsiferous deposits, otherwise mixed water or water exhibiting simple dissolution (20.7%),
- Cl and Na dominant, frequently indicative of end-point gradient waters through Dissolution (17.2%).
- Cl dominant anion and Na dominant cation, indicate that the groundwater be related to reverse ion exchange of Na-Cl waters (3.4%),

- The high TDS is some of the samples that may be indicative of long residence times in the aquifer allowing reactions to be fairly complete.

Table 48: Chemical statistics for the Blouberg Formation (Mbb).

Element / Parameter	Statistics Drawn from a population of 52 data points for the Blouberg Formation (Mbb).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	52	6.04	8.52	7.87	7.90	7.38	8.04	8.35	0.47	6.0%	
Electrical Conductivity (mS/m EC)	52	14.4	4700.0	99.6	267.3	56.1	130.7	393.7	639.2	239.2%	
Total Dissolved Salts (mg/l TDS)	49	89.0	3225.5	685.4	1205.9	376.6	950.6	2258.7	759.1	62.9%	
Calcium (mg/l Ca)	48	11.20	323.50	57.88	85.98	36.02	71.78	159.48	58.32	67.8%	
Magnesium (mg/l Mg)	48	1.00	263.59	24.10	95.26	22.05	73.78	210.02	68.13	71.5%	
Sodium (mg/l Na)	48	10.50	435.40	59.31	151.67	26.19	100.24	348.25	127.31	83.9%	
Potassium (mg/l K)	48	0.15	16.10	1.17	3.10	0.66	1.40	6.58	3.84	123.8%	
Chloride (mg/l Cl)	52	7.50	1698.21	52.12	326.92	19.71	125.17	824.58	387.21	118.4%	
Sulphate (mg/l SO <sub>4</sub> )	50	1.10	304.00	9.24	58.64	3.09	23.73	127.80	70.03	119.4%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	39	14.94	513.23	188.07	338.84	179.00	361.90	493.27	131.77	38.9%	
Nitrate (mg/l N)	48	0.04	55.90	0.70	12.41	0.36	11.97	20.41	11.61	93.6%	
Fluoride (mg/l F)	48	0.02	0.85	0.24	0.36	0.19	0.34	0.51	0.15	41.7%	
Silicon as Si	45	4.05	93.06	25.01	30.63	17.56	30.44	36.51	11.95	39.0%	
Iron (Fe)	23	0.002	0.240	0.011	0.042	0.006	0.021	0.058	0.06	150.3%	
Manganese (Mn)	23	0.001	0.340	0.003	0.026	0.001	0.005	0.050	0.07	271.0%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	43	0.003	0.800	0.014	0.042	0.007	0.019	0.050	0.12	287.8%	
ZAR	48	0.46	5.75	1.43	2.54	0.62	2.17	5.53	1.78	69.9%	
LSI	39	Langelier Saturation Index (LSI)			Slightly Scaling		79.5%		Highly Scaling		0.0%
		Highly corrosive			0.0%		Slightly corrosive		5.1%		Balanced Corrosion

Table 48 gives a summary of the physical properties, the major anions, cations, and some of the minor elements.

Where the coefficient of variation is above 100%, the 90th percentile, the maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality for the unit in terms of Electrical conductivity (EC) is ideal to good in 51.9% of the analysis, of a moderate quality in 36.5% and unacceptable in 11.5% (values above 370mS/m). The Total Dissolved Solids (TDS) is acceptable in 53.1% of the samples, (TDS ≤ 1200mg/l).

An evaluation of the major cations and anions from 52 samples show elevated concentrations of Chloride (Cl > 600mg/l) in 19.2%; Magnesium (Mg > 200mg/l) in 14.6%; Nitrate (N >10mg/l) in 12.5%; Sodium (Na > 400mg/l) in 4.2% and Calcium (Ca > 300) in 2.1% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water may be slightly corrosive (5.1%); predominantly slightly scaling (79.5%) and 15.4% balanced. The ZAR index indicates that 64.6% of the water is of a fair quality for irrigation (ZAR < 3).

The unit is in a rural area, with multiple villages situated to the north, west, and south of the Blouberg Mountain. Groundwater targets associated with fault zones are generally inaccessible due to the rugged terrain. Water supply to the villages is primarily sourced from boreholes drilled into the nearby gneiss. Groundwater is mainly used for livestock watering and domestic purposes. No evidence of large-scale irrigation was observed.

The Blouberg Formation underlies a mountainous region characterized by rugged terrain. This topography results from the formation's geological history, including its resistance to weathering and the influence of tectonic forces.

### 7.2.1.8 MAKGABENG FORMATION (Mma)

The Waterberg Supergroup has been sub-divided into three Subgroups, namely Nylstroom, Matlabas and Kransberg Subgroups. The Makgabeng Formation is part of the Matlabas Subgroup and consists of a monotonous development of fine- to medium-grained sandstone, thinly laminated, yellowish sandstone which displays large-scale cross bedding, and asymmetrical ripple marks. It is sometimes felspathic in places. It was thought that the sandstone is largely of aeolian origin, and the transportation direction is mainly from the north-east. It conformably overlies the Setlaole Formation. The unit is extensively covered by quaternary sand and soil, especially in the west and south. It covers approximately 8.58% of the map sheet, (Figure 34).

Within the map area the larger section of the unit can be regarded to generally underlying a broad valley with the Waterberg Plateau to the west, (260m difference in elevation, Kransberg Subgroup) and to the east various diabase sills giving rise to localized plateaus (Tutlane Hills) and rugged terrain with scattered boulders, (Buffelshoek). Scattered hills and high elevated areas are formed by Nebo Granite, (Bakenberg). The diabase sills are extensively developed throughout the unit with varying groundwater potential and landscape features. The upper contact of the sill at Kobeana was targeted with success while the sills at Buffelshoek and Vlakkfontein had poor water bearing characteristics. To the north, (Kirstenspruit) the unit gives rise to a large conspicuous plateau. Numerous rural villages occur in the lower valley area. Water for these villages is mainly pumped from caissons and boreholes within and along the Mogalakwena River. Figure 35 indicates that the Groundwater bearing properties of the larger area of the unit are generally poor as 68.3% of the borehole records show maximum yields that are less than 2l/s. In 26.7% of the water samples at least one element exceeds the maximum allowed limit for domestic use. For this unit it is the anion Nitrate.

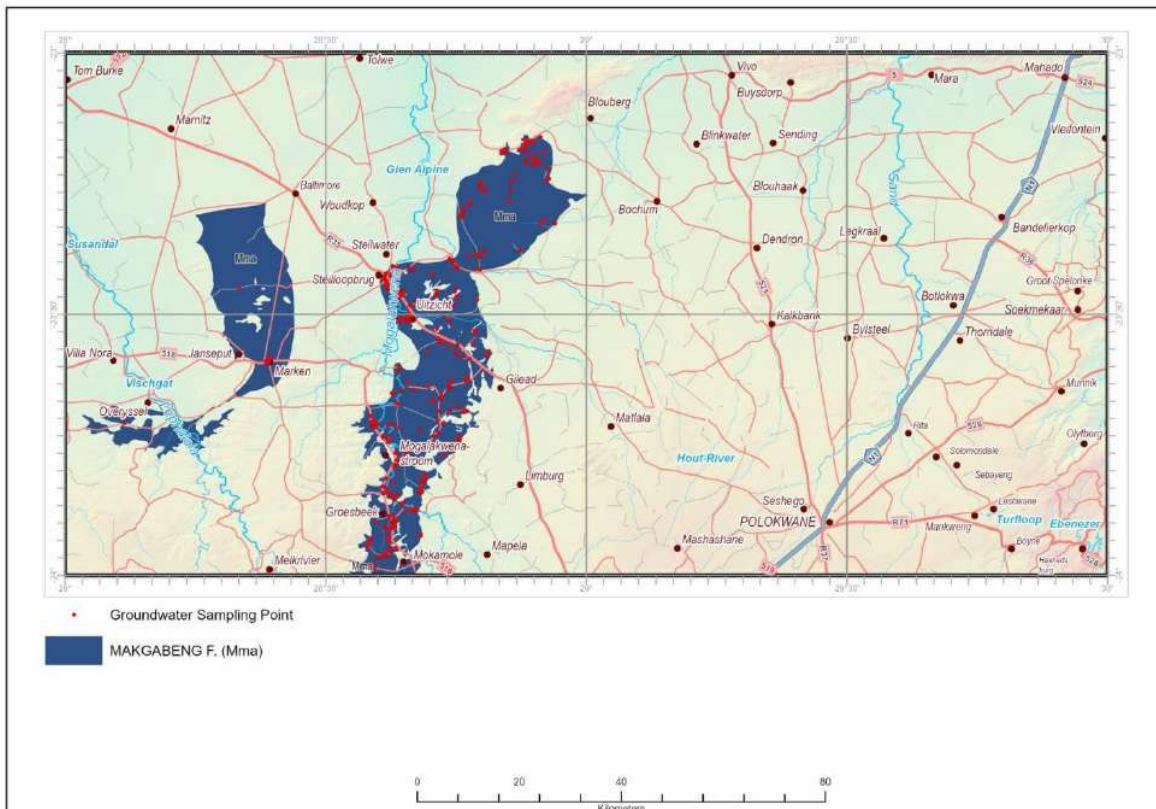


Figure 34: Geographical distribution of the Makgabeng Formation (Mma) and the associated groundwater data points.

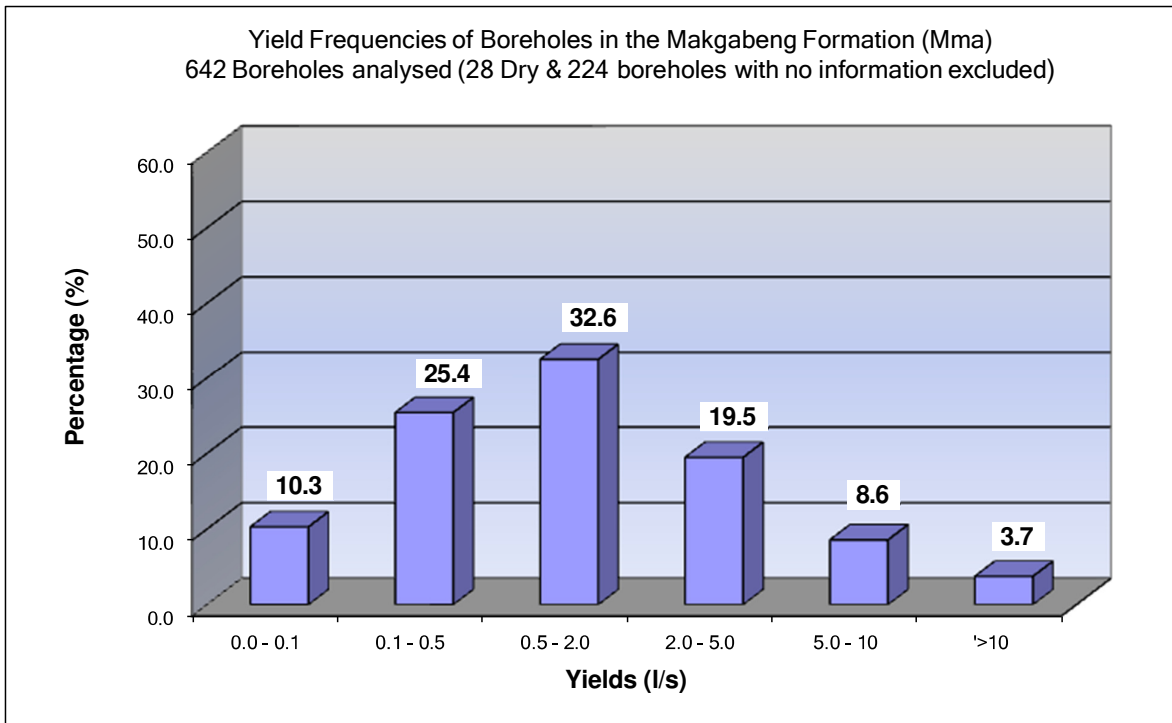


Figure 35: Yield frequency for the fractured aquifers of the Makgabeng Formation (Mma).

The yield distribution, (Figure 35) for the Makgabeng Formation (Polokwane occurrence), is similar to the distribution of yields in the Modimolle map sheet.

The analysis of 642 borehole records indicates that 35.7% of the maximum yields are suitable for small households (>0.001l/s to 0.5l/s). A further 32.6% of the boreholes have yields ranging between 0.5l/s and 2l/s, with 19.5% of the boreholes yielding between 2l/s and 5l/s and 12.3% of the boreholes with yields exceeding 5l/s.

The static water level ranges from artesian to 66.58 meters below ground level (mbgl), with a median of 10.08mbgl, and an average of 13.19mbgl, (based on 340 data points). The maximum depth recorded is 250m with a median of 63.1m and an average of 68.1m, (468 data points).

The installation depth from 265 records indicates a maximum installation depth of 178m and an average of 36.4m. The maximum abstraction on record is 604.8 cubic meters per day (m<sup>3</sup>/day); with an average of 65m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 265.

Data from 265 records indicate a maximum borehole installation depth of 178m, with an average installation depth of 36.4m. The maximum recorded groundwater abstraction is 604.8 cubic meters per day (m<sup>3</sup>/day), while an average of 65m<sup>3</sup>/day. Available data indicate that 265 boreholes within this unit have undergone pump testing.

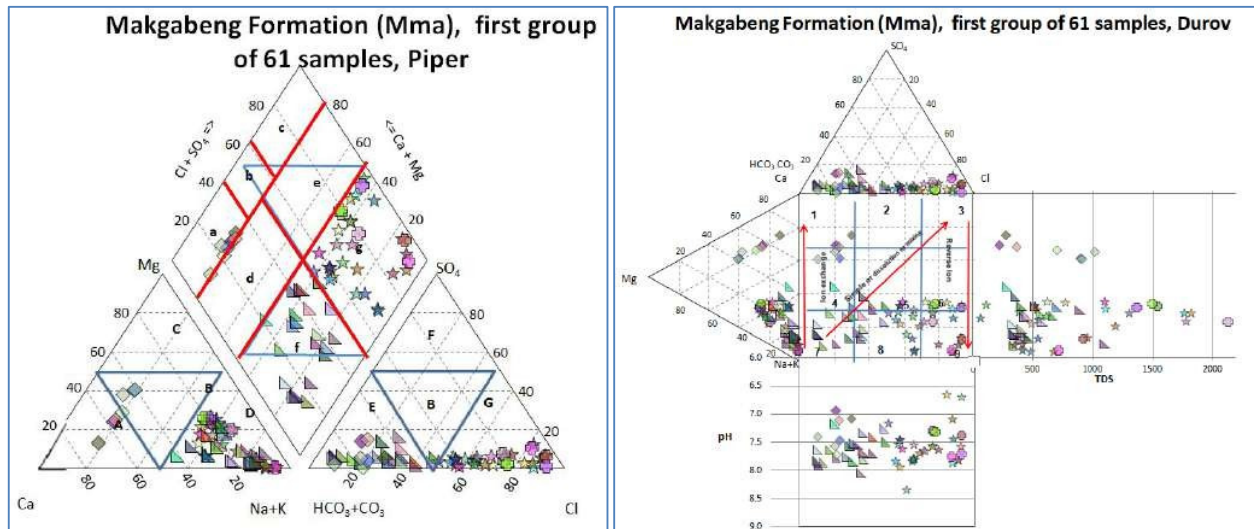


Figure 36: Trilinear diagrams, Piper, and Durov for the Makgabeng Formation (Mma), first group of 61 samples.

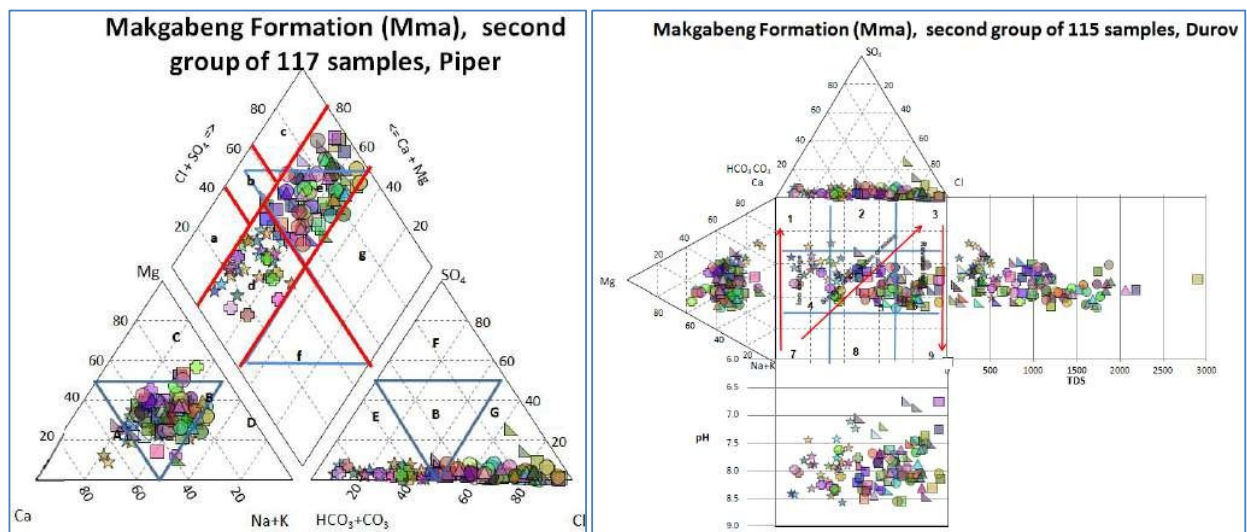


Figure 37: Trilinear diagrams, Piper, and Durov for the Makgabeng Formation (Mma), second group of 115 samples.

The trilinear Piper diagram, (Figure 36 & Figure 37) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (69.3%), Weak acidic anions > Strong acidic anions (36.9%); Alkali > Alkali earths (30.7%); Strong acids > Weak acids (63.1%).

The second evaluation was on the water type:

- Mixed Calcium-Magnesium-Chloride type with increased Sodium (45.4%);
- Mixed Calcium-Magnesium-Bicarbonate with increased Sodium type (16.3);
- Sodium-Chloride type (18%);
- Sodium-Bicarbonate type (12.4%);
- Calcium-Bicarbonate type (5.6%),
- Mixed Calcium-Magnesium-Bicarbonate type (1.7);
- Magnesium-Bicarbonate type (0.6%),

The trilinear Durov diagram defines hydrochemical processes along with the water type. The interpretation is as follows:

- No dominant anion or cation, plots along the dissolution line can be attributed to fresh recent recharge water exhibiting simple dissolution or mixing (36.4%),
- SO<sub>4</sub> dominates, or anion discriminates and Na dominant, mixed water or water exhibiting simple dissolution influences (29%),
- SO<sub>4</sub> dominates, or anion discriminant and Ca dominant, frequently indicates recharge in gypsiferous deposits, otherwise mixed water or water exhibiting simple dissolution (10.2%),
- Cl dominates anion and Na dominant cation, indicates that the ground water to relate to reverse ion exchange of Na-Cl waters (9.7%),
- Cl and Na dominant, is frequently indicative of end-point gradient waters through dissolution (6.3%),
- Cl and Na dominant, reverse ion exchange of Na-Cl waters (5.7%),
- HCO<sub>3</sub> and Ca dominant, indication of recharge in sandstone (2.8%),
- The high TDS is some of the samples that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 49: Chemical statistics for the Makgabeng Formation (Mma)

Element / Parameter	Statistics Drawn from a population of 395 data points for the Makgabeng Formation (Mma).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	390	5.40	9.09	7.78	7.81	7.20	7.90	8.35	0.48	6.1%	
Electrical Conductivity (mS/m EC)	391	6.1	1403.0	76.0	168.2	38.1	112.9	329.4	178.6	106.2%	
Total Dissolved Salts (mg/l TDS)	389	40.0	7500.8	497.9	1075.2	269.0	830.0	1986.2	1058.4	98.4%	
Calcium (mg/l Ca)	389	0.50	533.25	27.13	85.06	15.74	65.58	164.44	80.00	94.0%	
Magnesium (mg/l Mg)	389	0.11	422.98	7.89	58.36	5.27	42.95	127.35	60.97	104.5%	
Sodium (mg/l Na)	389	1.47	2560.40	51.46	175.56	23.67	102.20	310.4	276.2	157.3%	
Potassium (mg/l K)	375	0.00	96.00	0.53	5.45	0.93	2.37	12.18	9.78	179.5%	
Chloride (mg/l Cl)	391	1.98	3853.34	51.43	334.07	19.80	140.60	813.80	522.51	156.4%	
Sulphate (mg/l SO <sub>4</sub> )	389	0.80	674.60	7.75	30.35	3.65	12.13	56.95	66.15	217.9%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	324	4.22	1068.00	130.86	286.92	109.32	275.45	464.54	152.55	53.2%	
Nitrate (mg/l N)	386	0.02	233.45	0.30	14.14	0.12	6.59	35.10	20.63	145.8%	
Fluoride (mg/l F)	389	0.02	11.80	0.35	1.13	0.17	0.51	2.24	1.86	165.1%	
Silicon as Si	361	0.57	89.53	14.03	24.61	7.09	25.74	39.33	12.96	52.7%	
Iron (Fe)	237	0.001	0.520	0.008	0.028	0.003	0.010	0.050	0.06	220.3%	
Manganese (Mn)	234	0.001	1.103	0.004	0.082	0.001	0.010	0.268	0.18	214.4%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	327	0.003	0.800	0.017	0.053	0.009	0.020	0.056	0.14	258.1%	
ZAR	389	0.02	36.53	1.41	3.81	0.89	2.42	7.72	4.49	117.8%	
LSI	323	Langelier Saturation Index (LSI)			Slightly Scaling		59.8%		Highly Scaling		0.0%
		Highly corrosive		2.5%	Slightly corrosive		7.1%	Balanced Corrosion		30.7%	

Table 49 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality in terms of the Electrical conductivity (EC) is ideal to good in 61.9%; marginal, (EC < 370mg/l), in 29.7% and unacceptable in 8.4% of the samples. The values range from 6.1mS/m to 1403mS/m with 329.4mS/m representing the 90<sup>th</sup> percentile. The Total Dissolved Solids (TDS) is acceptable in 71.7% of the samples (TDS ≤ 1200mg/l).

An evaluation of the major cations and anions of 395 samples show that elevated concentrations of Nitrate (N >10mg/l) in 26.7%; Fluoride (F >1.5mg/l) in 17.2%; Chloride (Cl > 600mg/l) in 15.1%; Sodium (Na > 400mg/l) in 6.9%; Calcium (Ca > 300) in 3.9%; Magnesium (Mg > 200mg/l) in 3.3% and Sulphate (SO<sub>4</sub> >600mg/l) in 0.3% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water may be highly to slightly corrosive 9.6%; predominantly slightly scaling (59.8%) and balanced 30.7%. The ZAR index indicates that 58.9% of the water is of a fair quality for irrigation (ZAR < 3).

### 7.2.1.9 SETLAOLE FORMATION (Mse)

As indicated in previous sections of the report, the Waterberg Supergroup has been subdivided into three subgroups: Nylstroom, Matlabas, and Kransberg. The Setlaole Formation is part of the Matlabas Subgroup and occurs in the north-eastern part of the Alma Trough, where the Schilpadkop and Aasvoëlkop Formations grade into the Setlaole Grit and Makgabeng Sandstone Formations (Meinster & Tickell, 1975, p191). Within the map sheet, this formation is at the base of the Waterberg Supergroup and rests unconformably on the Hout River Gneiss, the Rooiberg Group, and the Nebo Granite. It consists of medium- to coarse-grained, dark-coloured sandstone with intercalations of conglomerate, feldspathic grit, arkose, and blackish mudstone.

Outcrops are limited, as the area is flat and extensively covered with sand and soil. The section of the unit within the Polokwane map sheet covers approximately 1.33% of its total areal extent. For this unit 57% of the borehole yields less than 2ℓ/s, while 43% yield more than 2ℓ/s, of which 11.4% exceeds 10ℓ/s, (Figure 39). In 38.3% of the water samples, at least one element exceeds the maximum allowed limit for domestic use. For this unit, the anion of concern is Chloride, followed by the cation Sodium (27.9%) and the anion Nitrate (24.3%).

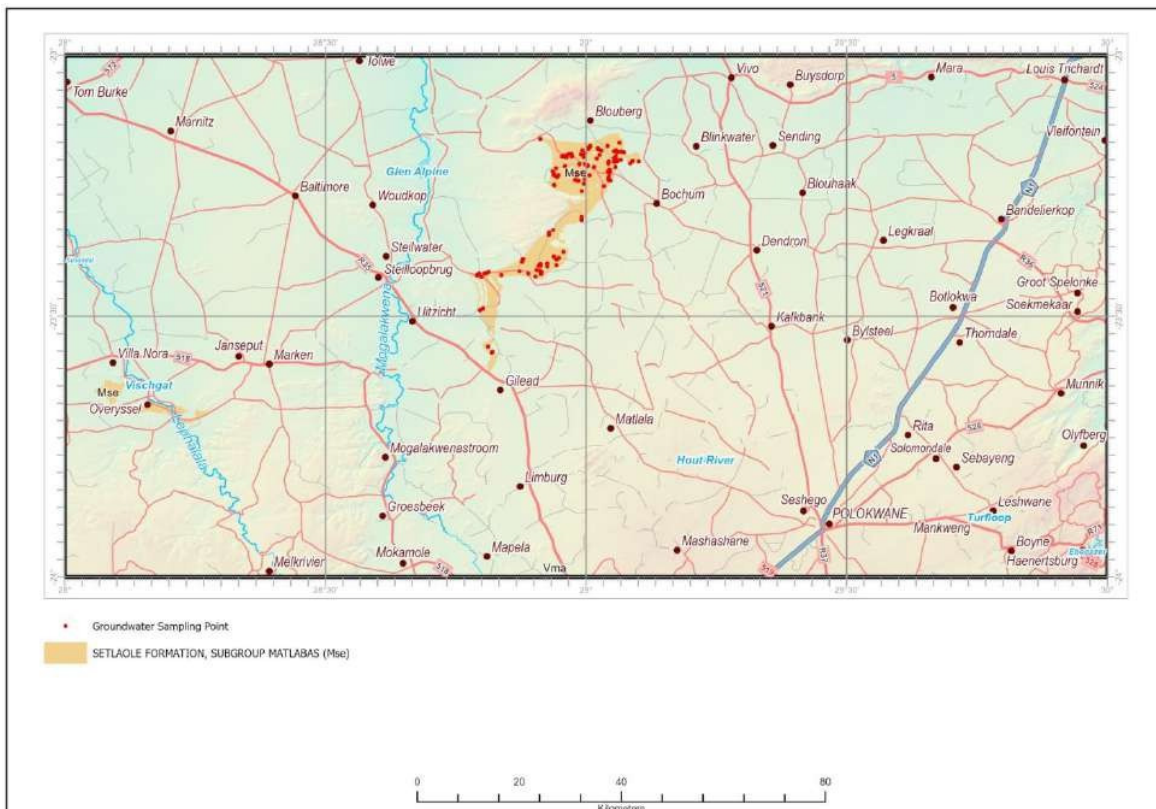


Figure 38: Geographical distribution of the Setlaole Formation (Mse) and the associated groundwater data points.

In general, the groundwater occurrence in the sedimentary rocks is either controlled by lithology such as the contact zones between various sediments or by secondary structures such as fractures or joints locally developed along bedding planes. Groundwater targets such as faults and diabase dykes and sill boundaries can also be targeted in the search for groundwater. For more detail on diabase intrusions the reader is referred to the section on the diabase intrusive unit.

Numerous diabase sills and dykes occur on the Polokwane map sheet, as indicated on the Polokwane geological map and identified using remote sensing techniques. The remote sensing interpretation of dykes, faults, and lineaments, as depicted in Figure 7, page 31, was conducted as part of the DWS GRIP project (Department of Water and Sanitation, Groundwater Resource Assessment). Secondary fractures associated with diabase intrusions are the dominant targets in this unit for groundwater exploration, as fault zones are less commonly occurring

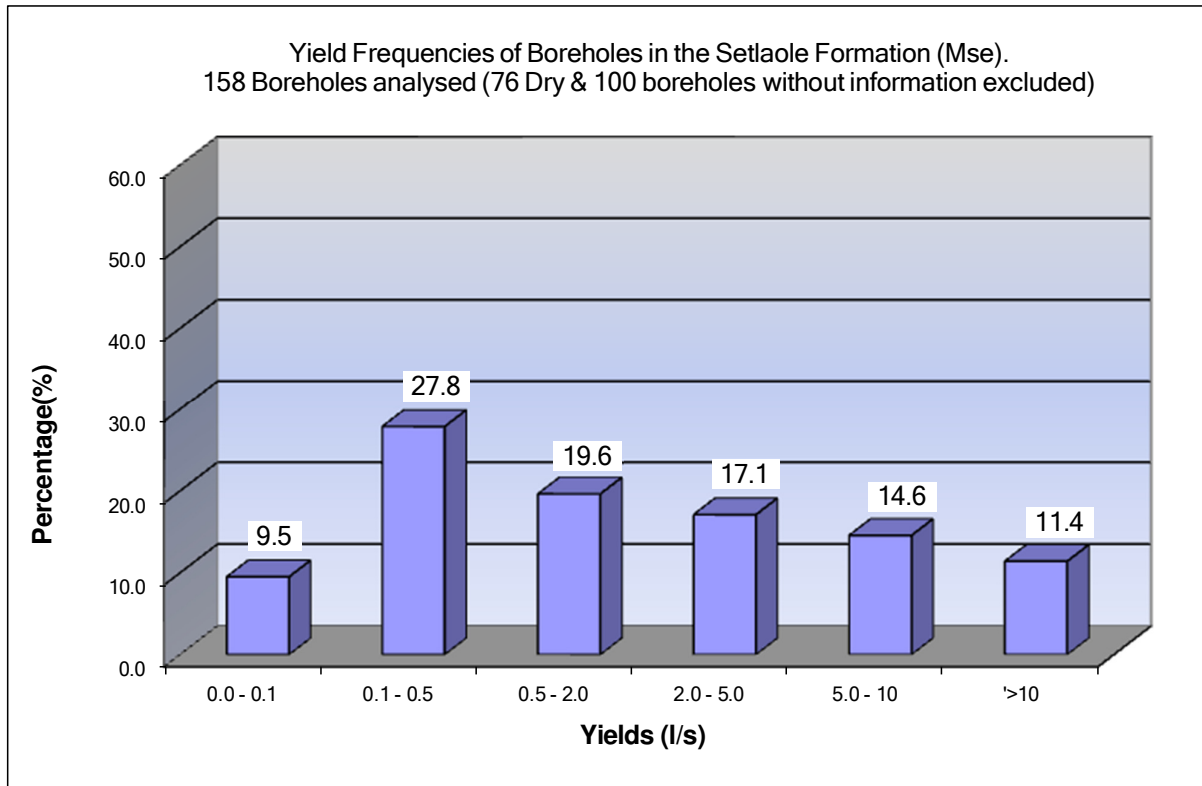


Figure 39: Yield frequency for the fractured aquifers of the Setlaole Formation (Mse).

Statistical analysis of 158 borehole records indicates that 37.3% of the successful boreholes are suitable for small households (yielding between >0.001l/s and 0.5l/s). An additional 19.6% yield between 0.5l/s and 2l/s, with 17.1% of the boreholes yielding between 2l/s and 5l/s, and 25.9% yielding more than 5 l/s, (Figure 39).

The static water level ranges from 1.54 meters below ground level (mbgl) to 52.18mbgl, with a median of 7.78mbgl and an average static water level of 11.54mbgl (based on 126 data points). The maximum depth recorded is 212m, with an average of 70.95m and a median depth of 66m (185 data points). The maximum installation depth is 102m, with an average installation depth of 36.39m, (86 data points). The depth of installation can be indicative of water strike depths if compared to the average depth and static water levels of the boreholes.

The maximum recommended daily abstraction on record is 604.8 cubic meters per day (m<sup>3</sup>/day), with an average of 90.71m<sup>3</sup>/day. The 90th percentile of daily abstraction is 233.2m<sup>3</sup>/day and the 80th percentile is 145.15m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 87.

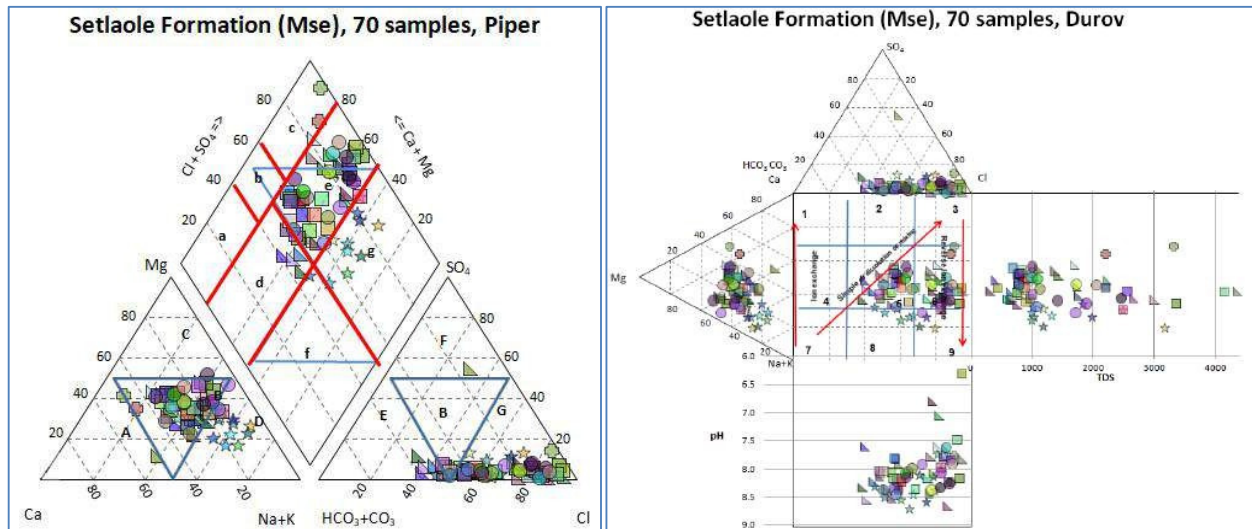


Figure 40: Trilinear diagrams, Piper, and Durov for the Setlaole Formation (Mse).

The trilinear Piper diagram, (Figure 40) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (82.9%), Weak acidic anions > Strong acidic anions (7.1%); Alkali > Alkali earths (17.1%); Strong acids > Weak acids (92.9%).

The second evaluation was on the water type:

- Mixed Calcium-Magnesium-Chloride type (67.2%),
- Sodium-Chloride type (17.1%),
- Mixed Calcium-Magnesium-Bicarbonate type with increased Sodium (11.4%),
- Mixed Calcium-Magnesium-Chloride type with increased Sodium (4.3%).

The trilinear Durov diagram defines hydrochemical processes along with the water type. The interpretation is as follows:

- $\text{SO}_4$  dominates, or anion discriminates and Na dominant, mixed water or water exhibiting simple dissolution influences. (45.7%)
- No dominant anion or cation, plots along the dissolution line can be attributed to fresh recent recharge water exhibiting simple dissolution or mixing (41.4%),
- Cl and Na dominant, is frequently indicative of end-point gradient waters through Dissolution (7.1%),
- Cl dominant anion and Na dominant cation reverse ion exchange of Na-Cl waters (5.7%),
- The high TDS in some of the samples may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 50: Chemical statistics for the Setlaole Formation (Mse)

Element / Parameter	Statistics Drawn from a population of 142 data points for the Setlaole Formation (Mse).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	140	6.25	8.68	7.88	7.91	7.30	8.01	8.39	0.44	5.6%	
Electrical Conductivity (mS/m EC)	141	52.4	9400.0	187.8	347.1	108.8	198.2	609.8	794.2	228.8%	
Total Dissolved Salts (mg/l TDS)	141	327.5	7615.2	1244.1	1846.4	738.8	1354.8	3477.9	1352.7	73.3%	
Calcium (mg/l Ca)	136	9.12	577.28	68.60	117.38	41.13	79.30	245.70	98.86	84.2%	
Magnesium (mg/l Mg)	136	10.88	472.15	68.45	113.73	40.35	77.07	234.20	89.26	78.5%	
Sodium (mg/l Na)	136	40.30	1668.79	153.15	295.86	72.70	198.87	606.29	265.97	89.9%	
Potassium (mg/l K)	134	0.39	77.29	4.30	11.00	1.96	6.89	23.84	11.97	108.8%	
Chloride (mg/l Cl)	141	22.11	3770.48	244.57	664.92	128.90	366.20	1406.34	737.60	110.9%	
Sulphate (mg/l SO <sub>4</sub> )	139	2.97	735.52	23.54	67.49	10.70	32.81	149.76	90.10	133.5%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	122	12.80	660.00	221.17	342.60	174.27	345.11	498.56	129.99	37.9%	
Nitrate (mg/l N)	140	0.05	113.82	1.73	15.08	1.95	13.34	30.88	13.62	90.3%	
Fluoride (mg/l F)	141	0.04	1.81	0.30	0.44	0.18	0.37	0.75	0.27	61.2%	
Silicon as Si	128	2.038	48.765	27.522	33.189	20.193	34.880	40.739	8.462	25.5%	
Iron (Fe)	87	0.002	0.200	0.007	0.016	0.003	0.010	0.033	0.026	159.9%	
Manganese (Mn)	89	0.001	0.449	0.002	0.044	0.001	0.002	0.156	0.089	202.9%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	121	0.003	0.800	0.017	0.037	0.011	0.021	0.043	0.10	270.9%	
ZAR	136	0.92	16.58	3.02	4.62	1.55	3.48	9.21	3.31	71.7%	
LSI	122	Langelier Saturation Index (LSI)			Slightly Scaling		82.0%		Highly Scaling		0.0%
		Highly corrosive			0.8%	Slightly corrosive		3.3%	Balanced Corrosion		13.9%

Table 50 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value, and standard deviation will give an indication on the extent of the problem. The overall water quality in terms of the Electrical conductivity (EC) is ideal to good (30.5%), marginal, (EC < 370mg/l) in 45.4% and unacceptable in 24.1% of the samples. The values range from 52.4mS/m to 9400mS/m with 609.8mS/m representing the 90<sup>th</sup> percentile.

The Total Dissolved Solids (TDS) is acceptable in 43.3% of the samples (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 142 samples show elevated concentrations of Chloride (Cl > 600mg/l) in 38.3%; Sodium (Na > 400mg/l) in 27.9%; Nitrate (N >20mg/l) in 24.3%; Magnesium (Mg > 200mg/l) in 12.5%; Calcium (Ca > 300) in 6.6%; Fluoride (F >1.5mg/l) in 1.4%; and Sulphate (SO<sub>4</sub> >600mg/l) in 0.7% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water may be slightly to highly corrosive (4.1%), predominantly slightly scaling (82%) and balanced in 13.9% of the analysis. The ZAR index indicates that 41.2% of the water is of a fair quality for irrigation (ZAR < 3).

Groundwater is primarily abstracted for game, livestock watering, and domestic use in rural villages, with a lesser extent used for farming homesteads. Cultivated fields do occur; however, they appear to be dryland farms. The only centre pivots observed within the groundwater resource unit are in the western-central section of the map sheet along the Lephalala River, where irrigation mainly relies on surface water.

Within the larger outcrop of the unit, [west of Senwabarwana (Bochum)], high-yielding boreholes supplying regional water schemes are mostly drilled into the Hout River Gneiss and pumped to villages within the unit.

### 7.2.1.10 KOEDOESRAND FORMATION (Mko)

As indicated in previous sections of the report, the Waterberg Basin has been subdivided into three sub-groups: the Nylstroom, Matlabas and Kransberg Subgroups. The Koedoesrand Formation (Mko), which occupies a narrow strip north of Villa Nora, is part of the Waterberg Supergroup. This Supergroup is composed of sandstone, conglomerate, shale, grit, and siltstone.

The sediments of the Koedoesrand Formation form a narrow, east-west trending zone that is fault-bounded to the north and south, (Figure 41). The southern boundary is marked by the Abbotspoort Fault, which results in prominent topographic features. According to Visser (1953), the formation generally consists of a 90m-thick basal unit of light-coloured quartzitic sandstone, shaly rocks, and quartz-sericite schist, overlain by approximately 130m of mainly conglomerate. The uppermost portion comprises around 300m of sandstone and grit, interspersed with occasional pebble beds. The formation is also intruded by the Palala Granite.

Within the Polokwane map sheet, this unit covers approximately 0.16% of the total areal extent.

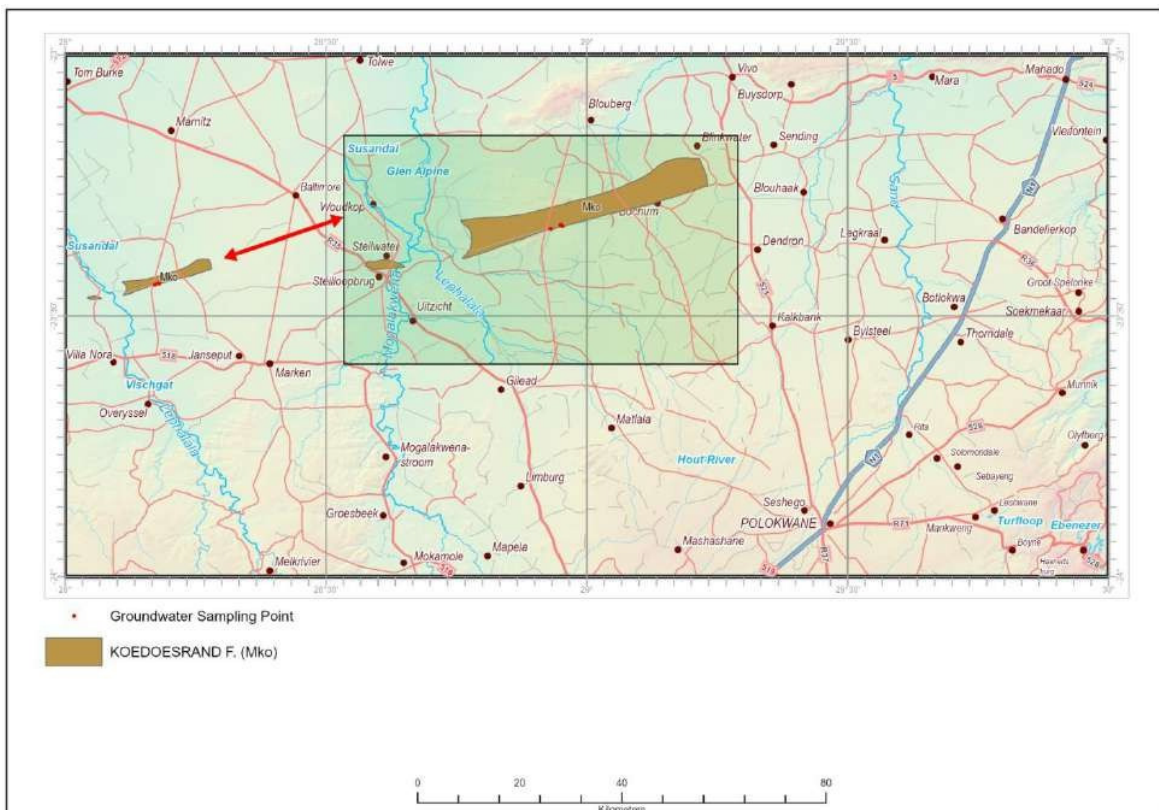


Figure 41: Geographical distribution of the Koedoesrand Formation (Mko) and the associated groundwater data points

Groundwater in the area is primarily associated with fault zones located to the north and south of the unit. A high-yielding borehole (6 l/s), which supplies water to a nearby village, is situated along the southern fault zone. Given the sedimentary nature of the succession, groundwater targets may also include sill and dyke contacts, fracture zones, and fractures associated with anticlines and bedding planes. However, diabase sills and dykes are not commonly observed in the north-western section of the map.

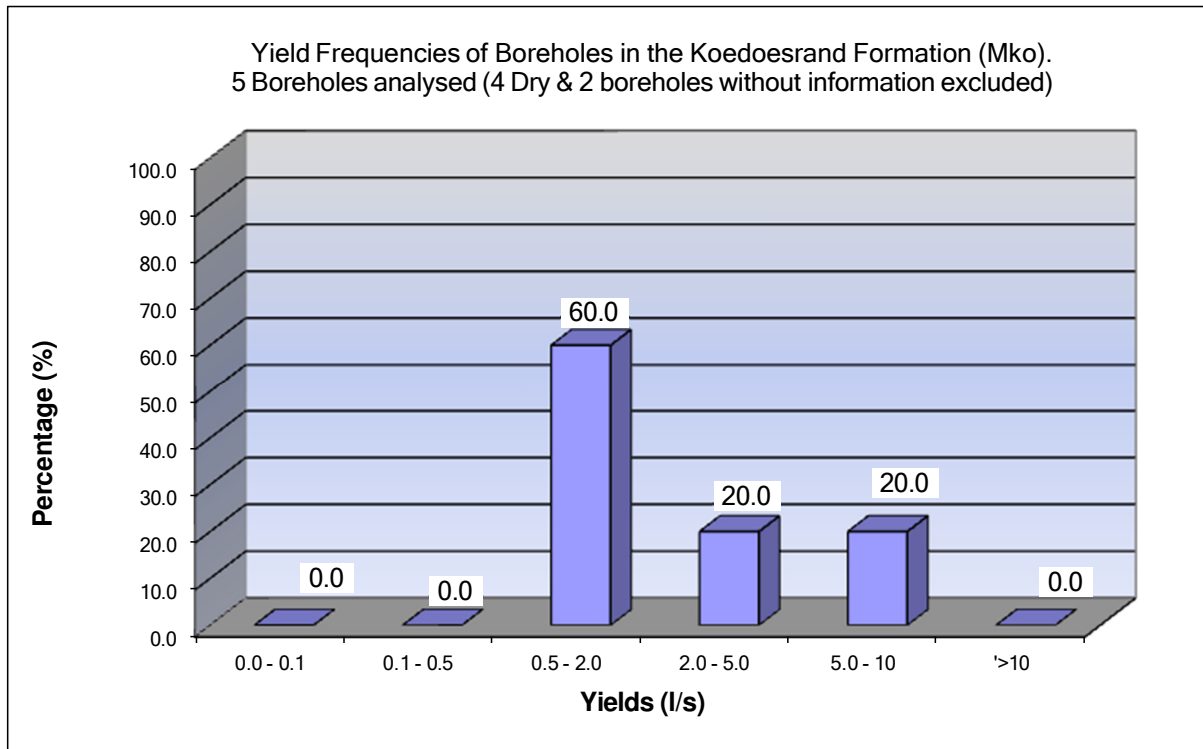


Figure 42: Yield frequency for the fractured aquifers of the Koedoesrand Formation (Mko).

Due to limited data, a fully representative characterization of the unit is not possible. Statistical analysis of 5 borehole records, (Figure 42) indicates that 60% of the boreholes yield between 0.5l/s and 2l/s, while 40% yield between 2l/s and 10l/s. The higher-yielding boreholes are likely associated with fault zones in the area.

Basic site information was available for one borehole, which includes a static water level of 4.4 meters below ground level (mbgl), a total depth of 52.4m, an installation depth of 45m, and a recommended abstraction rate of 55.3 cubic meters per day (m<sup>3</sup>/day) based on pump test data interpretation.

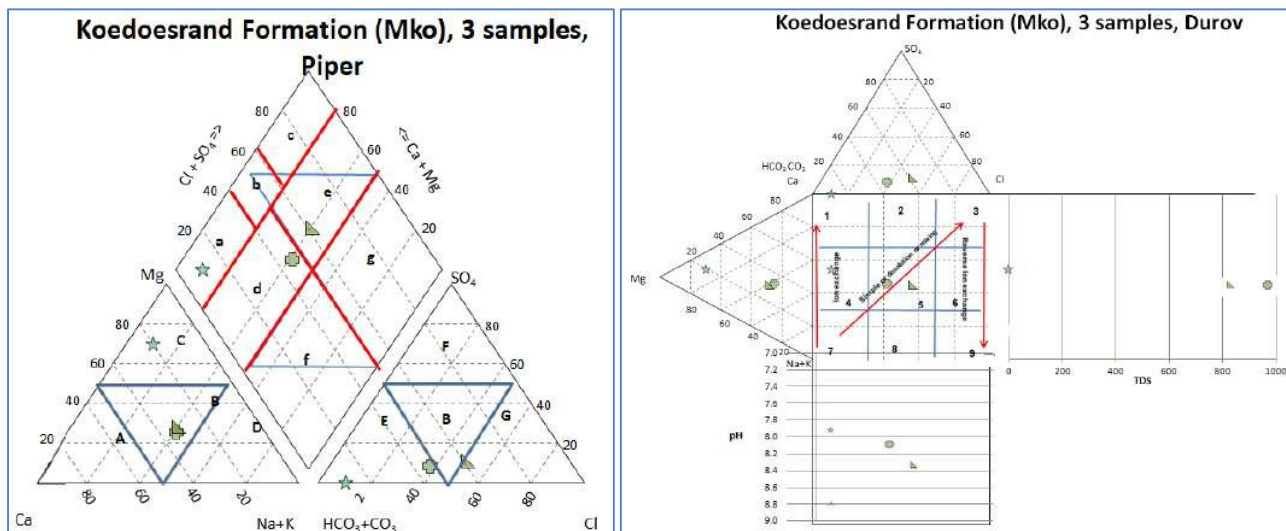


Figure 43: Trilinear diagrams, Piper and Durov for the Koedoesrand Formation (Mko).

The trilinear Piper diagram, (Figure 43) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The

initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (100%), Weak acidic anions > Strong acidic anions (66.7%); Alkali > Alkali earths (0%); Strong acids > Weak acids (33.3%).

The second evaluation was on the water type:

- Mixed Calcium-Magnesium-Bicarbonate type with increasing Sodium (33.4%);
- Magnesium-Bicarbonate type (33.3%);
- Mixed Calcium-Magnesium-Chloride type with prevailing increasing Sodium (33.3%).

The trilinear Durov diagram defines hydrochemical processes along with the water type. The interpretation is as follows:

- No dominant anion or cation, plots along the dissolution line can be attributed to fresh recent recharged water exhibiting simple dissolution or mixing (66.7%),
- Mixed water or water exhibiting simple dissolution (33.3%),

Table 51: Chemical statistics for the Koedoesrand Formation (Mko).

Element / Parameter	Statistics Drawn from a population of 3 data points for the Koedoesrand Formation (Mko).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	3	7.88	8.37	8.11	8.12	7.93	8.10	8.32	0.24	3.0%	
Electrical Conductivity (mS/m EC)	3	55.9	119.7	84.0	93.7	65.9	105.5	116.9	33.5	35.7%	
Total Dissolved Salts (mg/l TDS)	3	6.7	989.9	19.9	615.2	175.2	849.0	961.7	531.6	86.4%	
Calcium (mg/l Ca)	3	27.20	89.46	48.33	62.49	35.92	70.80	85.73	31.95	51.1%	
Magnesium (mg/l Mg)	3	39.00	58.05	44.84	46.21	39.52	41.59	54.76	10.33	22.4%	
Sodium (mg/l Na)	3	14.75	124.25	35.18	81.77	33.06	106.30	120.66	58.73	71.8%	
Potassium (mg/l K)	3	1.89	2.53	2.15	2.18	1.94	2.12	2.45	0.32	14.8%	
Chloride (mg/l Cl)	3	11.74	126.00	28.98	77.86	28.56	95.83	119.97	59.21	76.0%	
Sulphate (mg/l SO <sub>4</sub> )	3	1.00	36.70	2.83	22.36	6.68	29.39	35.24	18.86	84.3%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	3	264.30	384.54	308.02	315.61	271.04	298.00	367.24	62.03	19.7%	
Nitrate (mg/l N)	3	4.10	32.90	9.78	22.69	9.49	31.06	32.53	16.12	71.1%	
Fluoride (mg/l F)	3	0.12	0.41	0.22	0.30	0.17	0.36	0.40	0.15	52.2%	
Silicon as Si	2	30.62	39.76	34.59	35.19	31.53	35.19	38.84	6.46	18.4%	
Iron (Fe)	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.0%	
Manganese (Mn)	2	0.001	0.742	0.002	0.372	0.075	0.372	0.668	0.52	141.0%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	2	0.0140	0.0270	0.018	0.021	0.015	0.021	0.026	0.01	44.8%	
ZAR	3	0.37	2.72	0.86	1.87	0.80	2.52	2.68	1.31	69.8%	
LSI	3	Langelier Saturation Index (LSI)			Slightly Scaling		66.7%		Highly Scaling		0.0%
		Highly corrosive			0.0%		Slightly corrosive		0.0%		Balanced Corrosion

Table 51 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Only three chemical analyses were available for the unit. The overall water quality for the unit in terms of Electrical conductivity (EC) is ideal to be good in all three of the analysis. The Total Dissolved Solids (TDS) is acceptable in all the samples, (TDS ≤ 1200mg/l).

An evaluation of the major cations and anions of 3 samples show elevated concentrations of Nitrate (N >10mg/l) in 66.7% of the analysis. The Langelier Saturation Index (LSI) indicates that the water is slightly scaling in (66.7%) and balanced (33.3%). The ZAR index indicates that all the water is of a fair quality for irrigation (ZAR < 3).

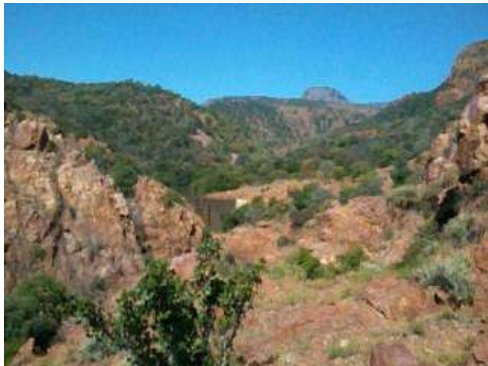
Groundwater is abstract for 6 rural villages, game, livestock watering and farm homesteads. No large-scale irrigation fields were observed within this unit; although north of the unit some large scale irrigation can be observed along the Lephalala River (Google imagery). It is possible that water is abstracted from the river and high yielding boreholes on the northern boundary of the unit where a fault zone occurs. The topography is flat except in the north-east where two prominent ridges are on the northern and southern boundary with a valley within.

### 7.2.1.11 WYLLIESPOORT FORMATION (SOUTPANSBERG SUPERGROUP) (Mwp)

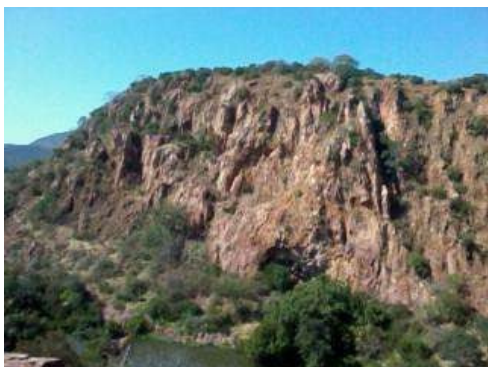
The Soutpansberg Supergroup comprises a sedimentary-volcanic assemblage and is regarded as slightly older than the Waterberg Supergroup. Regionally it has been divided into seven formations of which two appear on the Polokwane map sheet i.e. Sibasa, (volcanic) and Wyllies Poort, (sedimentary). Therefore, the Soutpansberg Supergroup appears on the map as both a fractured and an intergranular & fractured aquifer. The Supergroup was deposited in a narrow, fault bounded rift valley or aulacogen. It probably represents the failed spreading arm of a plume-generated triple junction, (Explanation booklet, geological map sheet 2328 page 28 to 29).

It outcrops north of Blouberg and Louis Trichardt, (Figure 44), where the unit underlies rugged, mountainous country characterised by steep-sided, cliffed southern slopes and gently dipping northern slopes. The fractured aquifer, (Wyllies Poort Formation), is almost entirely arenaceous and comprises of a medium-to fine-grained pink or whitish quartzite or quartzitic sandstone and coarse-grained purple or reddish sandstone with interbedded grit, conglomerate, shale, mudstone, siltstone, and lava). The explanatory brochure for the geological map sheet, Messina, indicates that the formation has a maximum thickness of 4000m in the Thengwe and Ha-Makuya area and it decreases considerably to the east and west. The groundwater resource unit covers approximately 2.31% of the total map area.

The 1:500 000 Hydrogeological map series, map sheet 2230, Messina, (predominant area of occurrence of the unit), states that the quartzite and sandstone of the Wylliespoort Formation has a reasonable potential as 37% of the boreholes yield between 0.5ℓ/s and 2ℓ/s and 21% more than 2ℓ/s. Numerous faults cut through the unit, which are the main targets for good groundwater supplies.



*Plate 7: In the background (south) is the concrete wall of the Blouberg dam, the cliff face in the foreground represents an east-west striking fault zone, Wylliespoort Formation, photo 2014, C.J. Sonnekus.*



*Plate 8: In the foreground is the Blouberg dam, in the background (east), another east-west fault zone can be seen in the cliff face, Wylliespoort Formation, photo 2014, C.J. Sonnekus.*

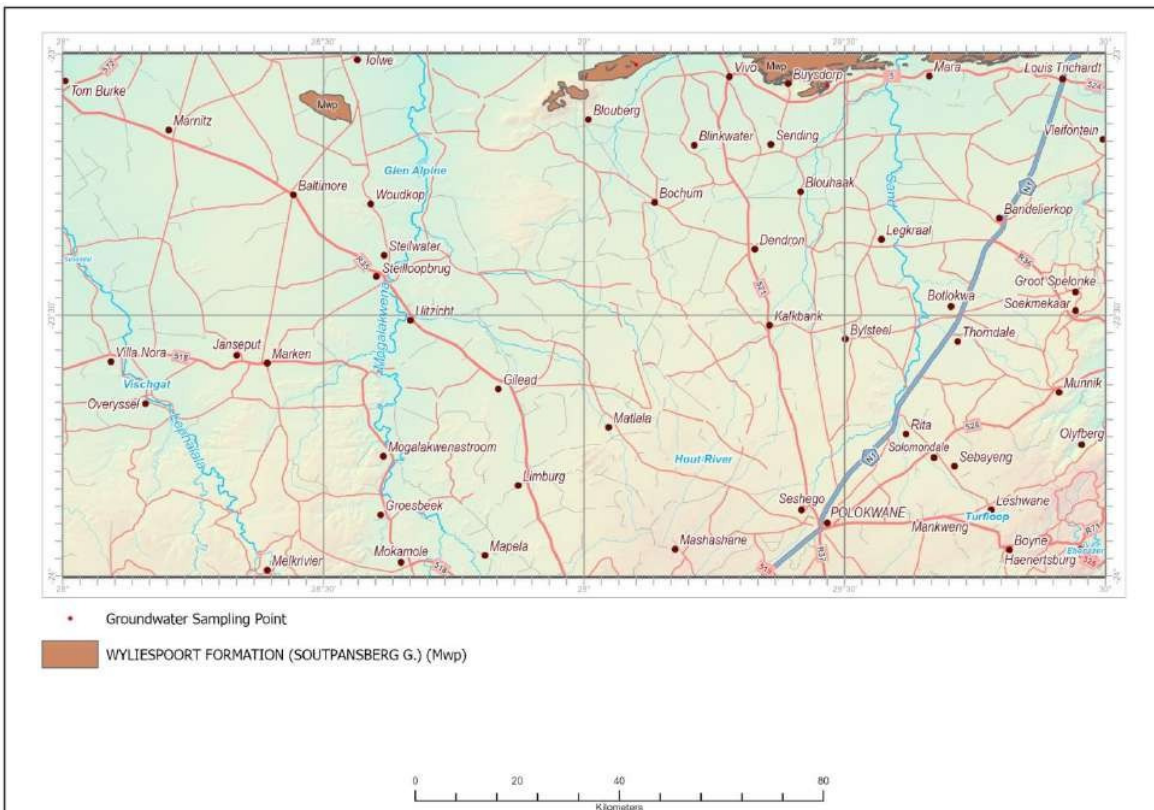


Figure 44: Geographical distribution of the Wylliespoort Formation (Mwp) and the associated groundwater data points.

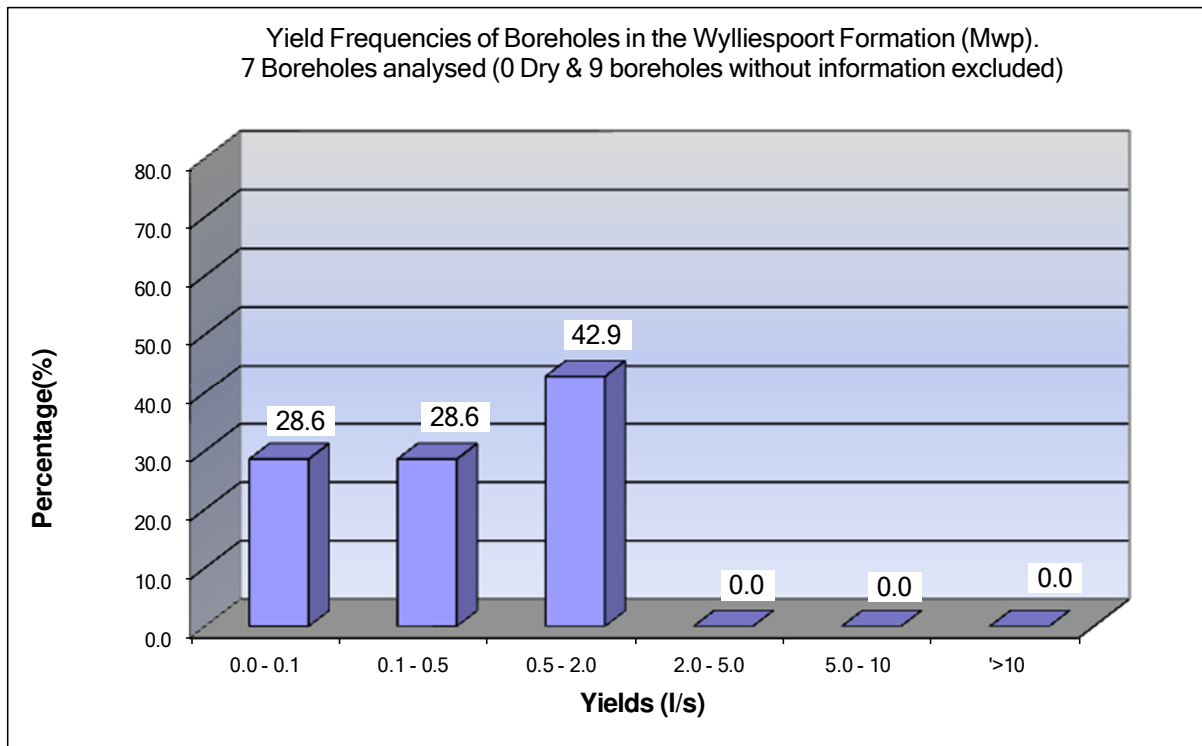


Figure 45: Yield frequency for the fractured aquifers of the Wylliespoort Formation (Mwp).

The analysis of 7 borehole records, (Figure 45) indicates that 57.2% of the maximum yields are suitable for small households (>0.001/s to 0.5l/s). In addition, 42.9% of the boreholes have yields between 0.5l/s and 2l/s. The data available does not give an accurate characterization of the maximum yield ranges.

The 1:500 000 hydrogeological map sheet of Messina 2127, (Mussina) indicate that 34.7% of the boreholes have maximum yields less than 0.5l/s, with 31% of the boreholes yielding between 0.5l/s to 2l/s. A further 19% of the boreholes yield between 2l/s to 5l/s and 18% of boreholes are yielding more than 5l/s. The Messina map statistics were from a population of 398 data points.

The static water level ranges from 14.02 meters below ground level (mbgl) to 34mbgl, with a median of 22.48mbgl and an average static water level of 23.5mbgl, (based on 3 data points). The maximum depth recorded is 119m, with an average depth of 79.5m and a median depth of 73.5; (4 data points). The maximum installation depth is 33m and the average is 28.6m (2 data points). The maximum recommended daily abstraction on record is 51.8 cubic meters per day (m<sup>3</sup>/day) and an average of 34.99m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 2.

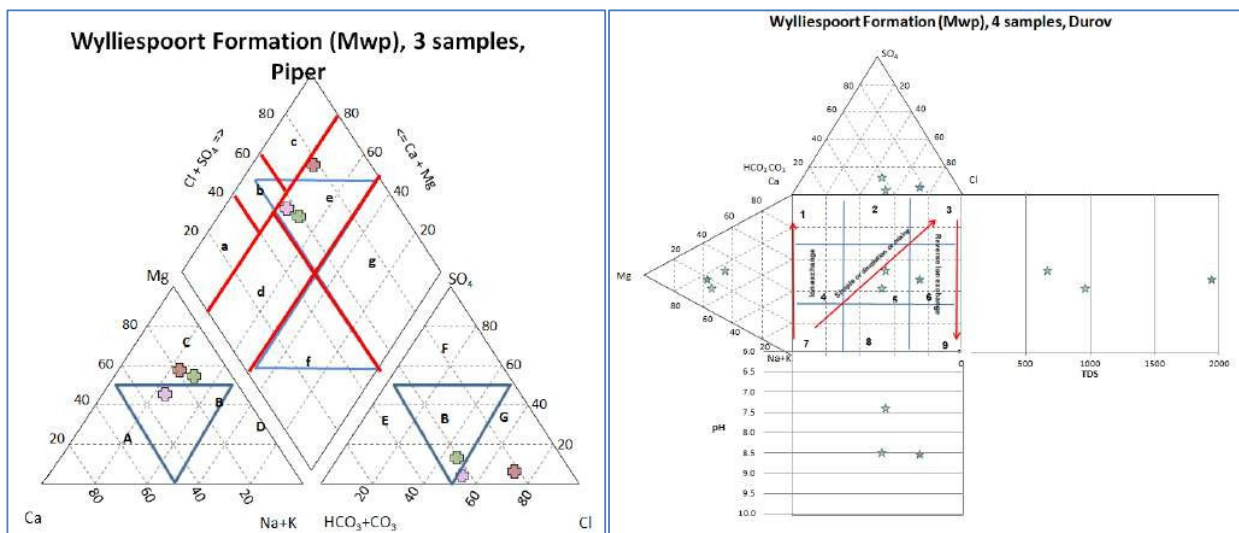


Figure 46: Trilinear diagrams, Piper and Durov for the Wylliespoort Formation (Mwp).

The trilinear Piper diagram, (Figure 46) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (100%), Weak acidic anions > Strong acidic anions (0%); Alkali > Alkali earths (0%); Strong acids > Weak acids (100%).

From the available data, and ignoring the above influences in this groundwater resource unit, the water classifies as:

- Magnesium-Bicarbonate-Chloride type (33.4%);
- Mixed Calcium-Magnesium-Chloride type (33.3%),
- Magnesium-Chloride type (33.3%),

The trilinear Durov diagram defines hydrochemical processes along with the water type. The interpretation is as follows:

- No dominant anion or cation indicates fresh recent recharge water exhibiting simple dissolution or mixing (66.7%), points plot along the dissolution or mixing line,
- Probable mixing or uncommon dissolution influences (33.3%),
- The high TDS is some of the samples that may be indicative of long residence times in the aquifer allowing reactions to be fairly complete.

Table 52: Chemical statistics for the Wylliespoort Formation (Mwp).

Element / Parameter	Statistics Drawn from a population of 4 data points for the Wylliespoort Formation (Mwp).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	4	7.66	8.53	8.15	8.16	7.83	8.23	8.45	0.36	4.5%	
Electrical Conductivity (mS/m EC)	4	35.4	257.7	80.8	131.4	55.9	116.3	219.1	93.0	70.8%	
Total Dissolved Salts (mg/l TDS)	3	657.6	1937.4	972.8	1183.3	717.1	955.0	1740.9	669.8	56.6%	
Calcium (mg/l Ca)	4	24.97	125.28	45.90	64.36	30.11	53.59	107.22	43.82	68.1%	
Magnesium (mg/l Mg)	4	22.15	232.16	52.03	102.08	33.30	77.00	190.92	91.64	89.8%	
Sodium (mg/l Na)	4	9.92	174.83	29.98	85.88	24.72	79.38	152.23	69.70	81.2%	
Potassium (mg/l K)	4	0.71	10.34	1.40	3.92	0.77	2.32	8.35	4.49	114.5%	
Chloride (mg/l Cl)	4	9.81	600.49	32.98	214.04	33.17	122.93	467.80	264.67	123.7%	
Sulphate (mg/l SO <sub>4</sub> )	3	8.97	69.98	21.06	46.35	19.20	60.10	68.01	32.75	70.7%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	4	159.84	526.04	256.95	321.76	173.26	300.58	487.21	170.57	53.0%	
Nitrate (mg/l N)	3	1.13	18.63	2.33	7.54	1.48	2.86	15.48	9.64	127.9%	
Fluoride (mg/l F)	3	0.17	0.31	0.22	0.23	0.18	0.22	0.29	0.07	30.7%	
Silicon as Si	4	23.91	34.84	28.82	29.51	24.69	29.63	34.21	5.14	17.4%	
Iron (Fe)	3	0.006	0.012	0.008	0.009	0.006	0.008	0.011	0.00	35.3%	
Manganese (Mn)	3	0.001	0.139	0.002	0.048	0.001	0.003	0.112	0.08	166.0%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	4	0.006	0.022	0.009	0.014	0.006	0.014	0.022	0.01	66.0%	
ZAR	4	0.35	2.14	0.86	1.43	0.63	1.61	2.08	0.81	56.6%	
LSI	3	Langelier Saturation Index (LSI)			Slightly Scaling		66.7%		Highly Scaling		0.0%
		Highly corrosive			0.0%		Slightly corrosive		0.0%		Balanced Corrosion

Table 52 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality for the unit in terms of Electrical conductivity (EC) is ideal to good in 75% of the analysis and of a moderate quality in 25%, (EC < 370mS/m). The Total Dissolved Solids (TDS) is acceptable in 66.7% of the samples, (TDS ≤ 1200mg/l).

An evaluation of the major cations and anions of 120 samples show that elevated concentrations of Chloride (Cl > 600mg/l) in 25% and Magnesium (Mg > 200mg/l) in 25% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water is predominantly slightly scaling (66.7%) and 33.3% balanced. The ZAR index indicates that the water from all the boreholes is of a fair quality for irrigation (ZAR < 3).

Within the 1:250 000 Polokwane hydrogeological map sheet, the extent of the unit is minimal compared to the adjacent 1:500 000 hydrogeological map sheet 2127 Messina, where it serves as an important aquifer for water supply to game, livestock, rural villages, lodges, and farmsteads. Within the Soutpansberg Mountain Range, numerous interflow zones and fountains occur within the unit.

### 7.2.1.12 UNDIFFERENTIATED ROOIBERG GROUP (Vrb)

The Rooiberg Group consists of the Schrikkloof and Kwaggasnek Formations and is regarded as part of the Transvaal Supergroup. The two formations are not distinguished on the Polokwane map and the groundwater resource unit is referred to as the Undifferentiated Rooiberg Group. It occurs on the map sheet as an elongated ridge trending north-east, (174m higher than the plains to the north-west but 200m lower than the Waterberg Plateau to the south-east). The contrast between the volcanic rocks and the sedimentary Waterberg rocks is visible when exploring the area using Google Earth. The unit exhibits parallel north-easterly-trending lineaments and/or jointing while the sedimentary rocks are transected by north-westerly and easterly trending lineaments that are most likely related to diabase intrusive dykes.

Within the map area the unit is located as a single outcrop south-west of Marken, (Figure 47). It comprises of rhyolite with interbedded agglomerate and tuff. The rhyolite is red and dark blue on fresh surfaces but weathers into a reddish brown colour, occasionally exhibiting flow structures. The rock consists of phenocrysts of quartz, orthoclase, and albite set in a groundmass of quartz, chlorite, feldspar, and some magnetite. The intrusion of the Bushveld Complex has resulted in contact metamorphism of the surrounding rocks, including those of the felsic volcanic rocks of the Rooiberg Group.

The groundwater resource unit covers approximately 0.3% of the total map area.



Plate 9: Graben structure in rhyolite of the Kwaggasnek Formation in a road cutting along the N1 about 10 km south of Mookgophong (Naboomspruit), photograph WH du Toit.

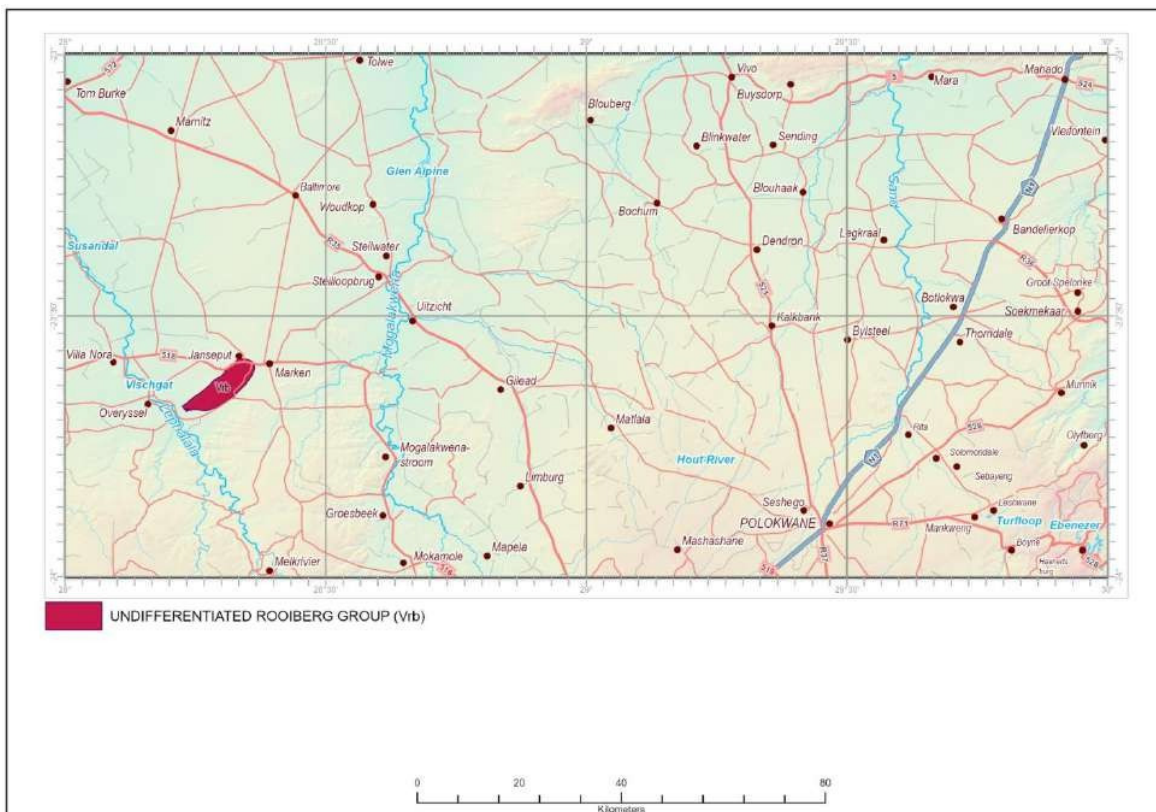


Figure 47: Geographical distribution of the Undifferentiated Rooiberg Group (Vrb) and the associated groundwater data points

The groundwater potential of this unit is generally poor due to the low permeability and storativity of the rhyolite, resulting in diminishing or failing yields after prolonged use of production boreholes. These factors, along with the unit's limited extent, classify it as an insignificant aquifer.

Groundwater targets include faults and associated shear zones, joints, fracture zones, and dyke contacts. The topography consists of subdued ridges with shallow depressions. These depressions or shallow valleys appear to have formed along geological structural features and are likely to be targeted in groundwater exploration.

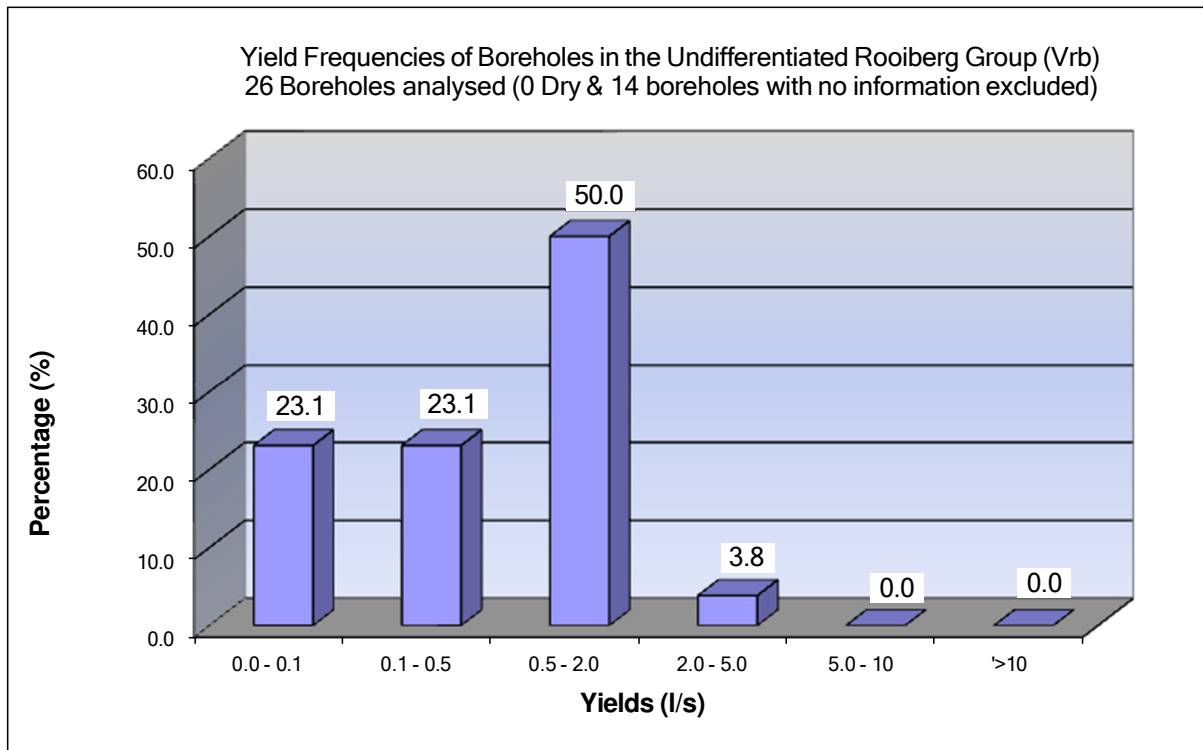


Figure 48: Yield frequency for fractured aquifers of the Undifferentiated Rooiberg Group (Vrb).

Statistical analysis of 26 borehole records, (Figure 48) indicates that 46.2% of the successful boreholes yield between >0.001l/s and 0.5l/s, making them suitable for small household use. Additionally, 50% yield between 0.5l/s and 2l/s, while only 3.8% yield more than 2l/s.

No data was available regarding static water levels, water chemistry, borehole depths, or results from pumping tests.

Information on groundwater use within the unit is also limited. However, in the northeastern section near Marken, small irrigation fields visible on Google Earth suggest potential dryland farming activity. The presence of trees indicates that no crops have been planted recently. Groundwater in this unit is most likely used for game and livestock watering and, to a limited extent, by lodges or farm steads.

### 7.2.1.13 WOLKBERG GROUP (Vwo)

The Wolkberg Group and Black Reef Formation are developed in the extreme south-eastern part of the mapped area where it gives rise to a prominent escarpment. Both lithologies have been grouped together under the Wolkberg Group. It rests unconformable on Swazian and Randian age rocks and is composed of dark coloured shale with intercalations of whitish and grey quartzite and conglomerate. The shale has a tuffaceous aspect in places. At the base, lava may be developed. The Wolkberg rocks are generally deeply weathered. The thickness of the group within the map sheet boundary is more or less 300m thick. The overlying Black Reef Formation has a minimum thickness of about 50m and comprises greyish white medium-grained quartzite with occasional conglomerate beds, (Explanation booklet, geological map sheet 2328 page 19 to 20).

The section of the unit within the Polokwane map sheet covers approximately 0.03% of the total area. No groundwater is abstracted from this unit within the map sheet, the only economic activity relates to forestry, and the areas not accessible are in a natural state.

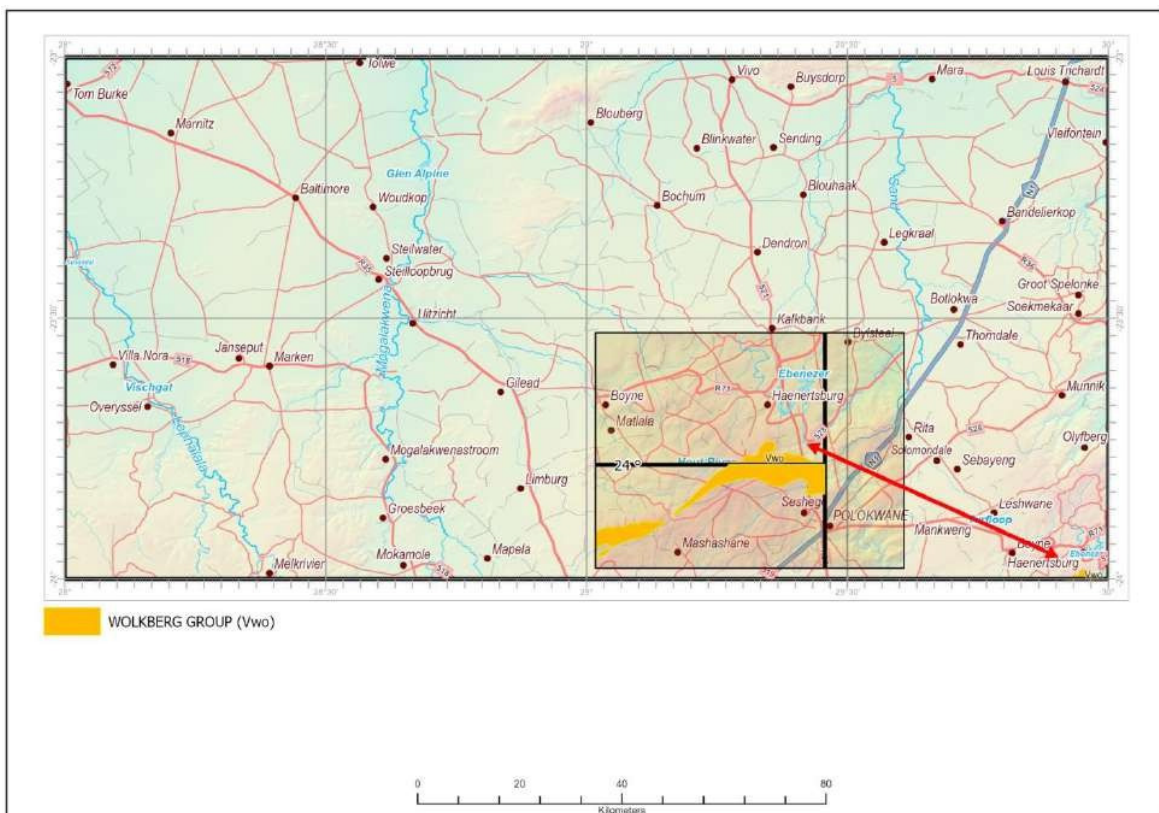


Figure 49: Geographical distribution of the Wolkberg Group (Vwo).

No borehole data (either yield or water quality) is available on the Polokwane map sheet to support the characterization of this unit. It occupies a very small area in the far south-eastern part of the map, (Figure 49). For further information on the characteristics of this unit, the reader is referred to the Modimolle hydrogeological map and its accompanying brochure.

## 7.2.2 CATEGORY C: KARST AQUIFERS

The hydrogeological map series and accompanied brochures follow the same methodology for consistency. The Karst aquifer occurrence on the map sheet consists of one unit viz. Malmani Subgroup (Vma).

Karst aquifers cover approximately 0.01% of the total map area. Figure 50 shows the Geographical distribution of the Karst aquifers.

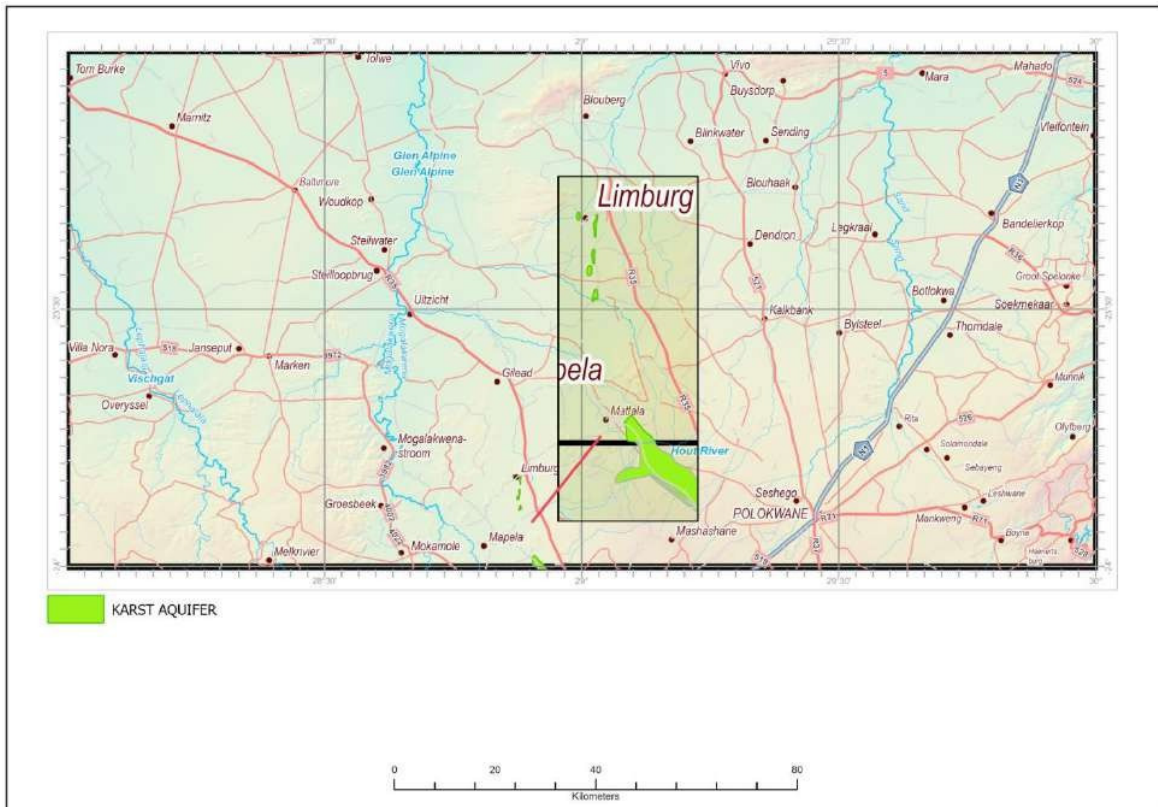


Figure 50: Geographical distribution of the Karst aquifers rock aquifers

### 7.2.2.1 MALMANI SUBGROUP (Vma)

The Malmani Subgroup (part of the Chuniespoort Group of the Transvaal Supergroup) is present on the map sheet within the southern-central section of the map sheet, (Figure 51). It occurs as a small, thin ( $\pm 1\text{km}$  to  $1.8\text{km}$  wide) steeply dipping, metamorphosed, and serpentized dolomite outcrop near the floor contact of the northern limb of the Bushveld Igneous Complex (BIC). The dolomite overlies Archean basement rock (predominantly Hout River Gneiss in the map area). The footwall of the BIC within the map area is formed by layered mafic rocks of the Platreef, a 30m to 400m wide platinum group mineral (PGM) enriched zone, which overlies progressively older sediments of the Transvaal Supergroup along strike from south to north, as well as Archean basement rocks in the north.

Figure 51 shows the Malmani Subgroup within the Polokwane map sheet, as well as a piece of the section that falls within the Modimolle map sheet. In the Modimolle map sheet, younger rocks of the Transvaal Supergroup overlie the dolomite unconformably, namely the Penge Formation (banded ironstone) and the Duitsland Formation (limestone, dolomite, chert, shale, and quartzite), which, in turn, are overlain by rocks of the Rustenburg Layered Suite (RLS). Further to the south, rocks of the younger Timeball Hill Formation (shale, hornfels, and quartzite) are overlain by the RLS, which, in turn, are underlain by older Chuniespoort

Group rocks. Outcrops of the older Wolkberg Group and Black Reef rocks are not indicated on the geological map sheet but may be present at depth.

The nature of the contacts between the sedimentary and intrusive rocks varies from sharp to transitional. Intercalated zones of sedimentary rocks and magmatic units persist over centimeters to hundreds of meters. The degree of metamorphism, metasomatism, and/or melting of the assimilated sedimentary clasts varies according to the sedimentary rock type and the magmatic unit that intruded into the sediment. Dolomite and limestone xenoliths have been metamorphosed and melted retrogressively into calc-silicate and marble, with associated metasomatic and mineral replacement processes leading to the formation of localized skarn assemblages, (Grobler et al., 2018). Metamorphic-metasomatic rocks (skarns) are formed when hot, mineral-rich fluids from the intruding magma interact with surrounding carbonate-rich rocks.

Groundwater yield data within the unit falling within the Polokwane sheet is restricted to three boreholes. In the unit south of the map sheet, extensive geophysical surveys were conducted using various methods, including the gravity method. The survey was conducted on the farm Rietfontein 2 KS. The data and subsequent drilling indicated that the dolomite is not characterized by karst features (such as caves or dissolution cavities). Two boreholes (GPR-22 and GPR-25) were drilled to depths of 98 and 150 meters below ground level (mbgl) to investigate the dolomite. Very low yields (0.05l/s to 0.1l/s) were encountered at shallow depths (<29mbgl) at bedding plane contact zones within the dolomite formation. No water strikes in dolomite formations were encountered at depth (Golder, 2012). The findings correspond to the poor groundwater investigation results in the unit occurring south of the Polokwane map sheet boundary, at various villages up to the Nyl Toll Gate Plaza (NGA data).

Groundwater targets in the dolomite include fault zones and diabase dykes (when present), which may result in higher yields, such as at the Mokopane Municipal Uitloop Well Field, where 0.5MI/day is abstracted.

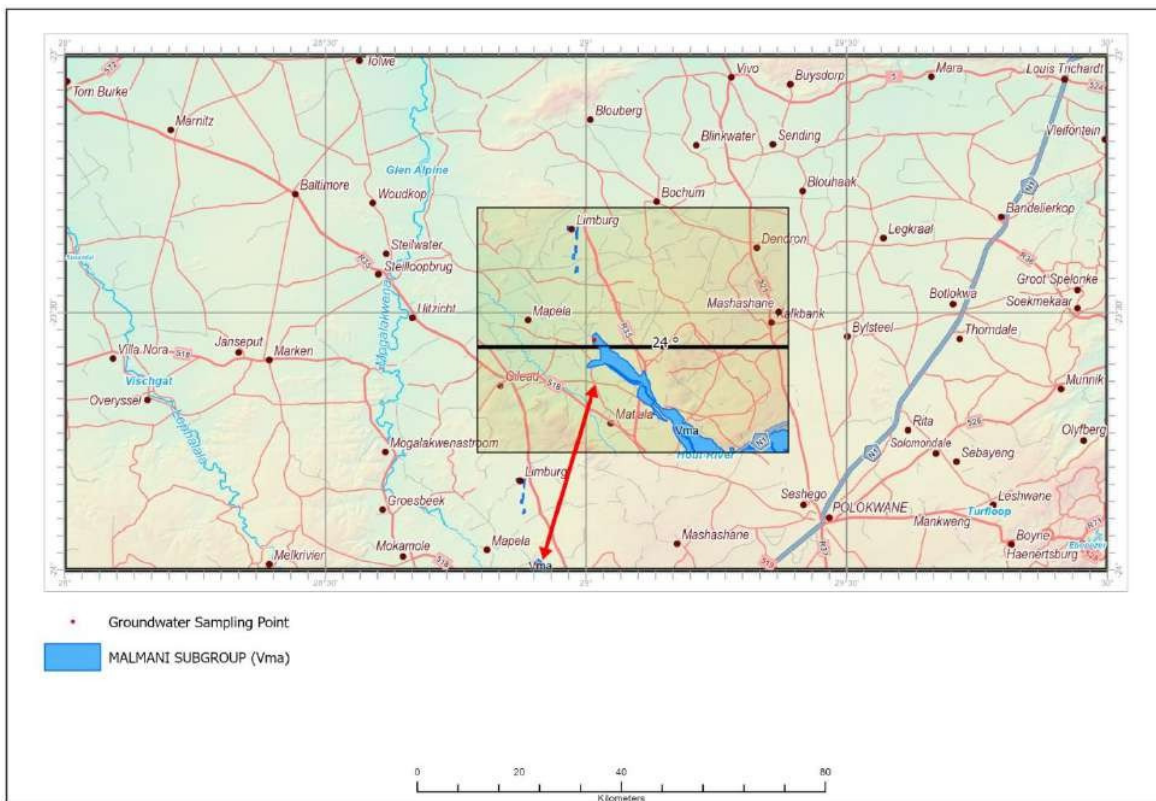


Figure 51: Geographical distribution of the Malmani Subgroup (Vma) and the associated groundwater data points.

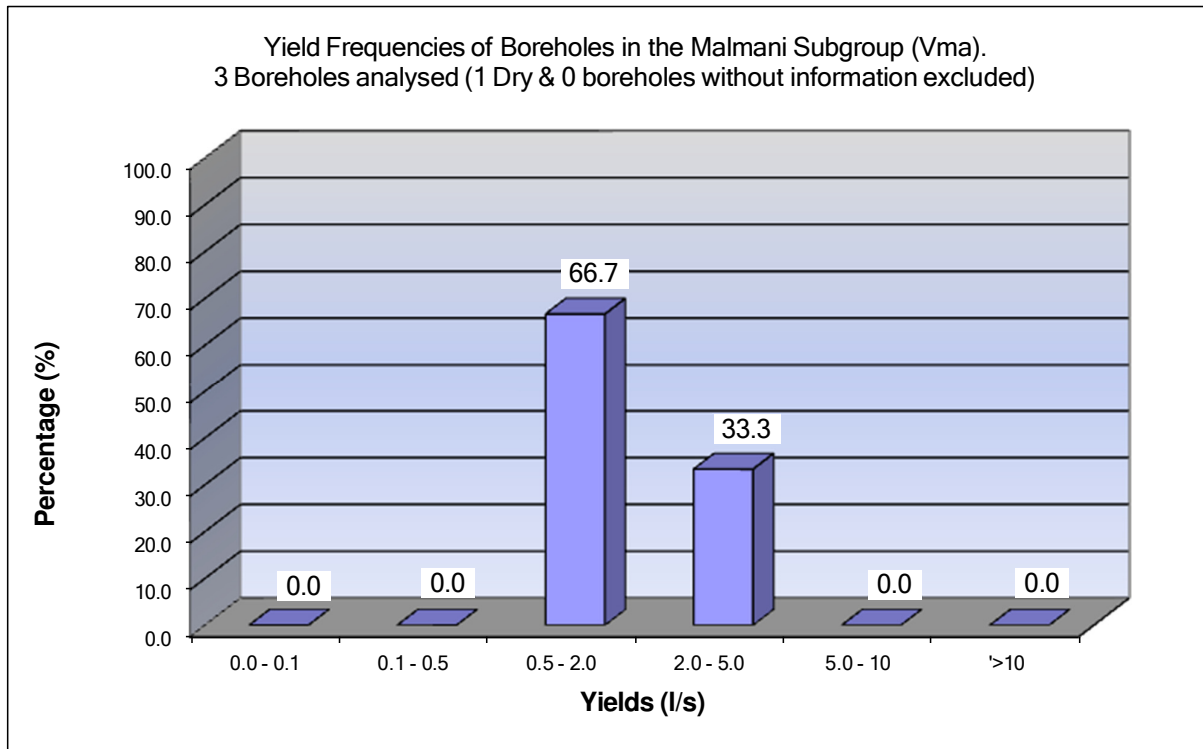


Figure 52: Yield frequency for fractured aquifers of the Malmani Subgroup (Vma).

The yield frequency distribution, (Figure 52) represents a population of 3 records on yield. It will therefore not accurately represent the yield distribution within the unit. For the adjacent Modimolle map sheet, the unit occurs more widespread and can be consulted if more information is required.

In total 2 records were available with information on the static water level, installation depth and recommended daily abstraction. The static water level ranges from 13.29 meters below ground level (mbgl) to 13.76mbgl. The installation depth is between 18m to 21m, and the recommended daily abstraction is between 43.2 cubic meters per day (m<sup>3</sup>/day) and 51.8m<sup>3</sup>/day. The maximum depth recorded is 100.9m, with an average depth of 85.31m and a median depth of 100m, (3 data points).

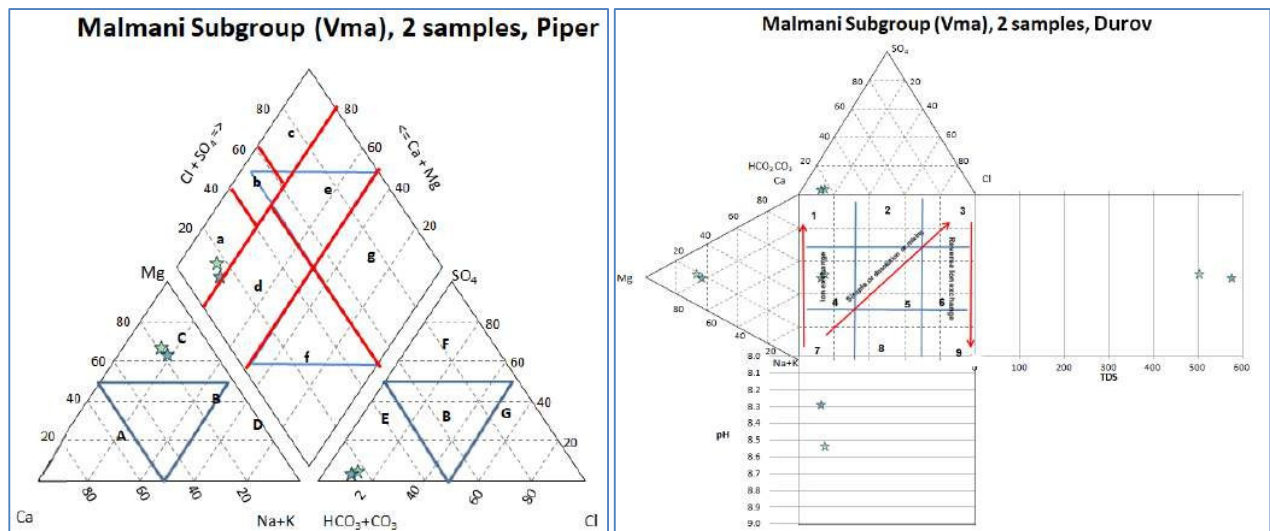


Figure 53: Trilinear diagrams, Piper and Durov for the Malmani Subgroup (Vma).

The trilinear Piper diagram, (Figure 53) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (100%), Weak acidic anions > Strong acidic anions (100%); Alkali > Alkali earths (0%); Strong acids > Weak acids (0%).

The groundwater in this unit classifies as:

- Magnesium-Bicarbonate type (100%).

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- Anion discriminate and Ca dominant indicating mixed water or water exhibiting simple dissolution (100%).

Table 53: Chemical statistics for the Malmani Subgroup (Vma).

Element / Parameter	Statistics Drawn from a population of 2 data points for the Malmani Subgroup (Vma).									
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation
pH	2	8.27	8.52	8.39	8.40	8.30	8.40	8.50	0.18	2.1%
Electrical Conductivity (mS/m EC)	2	65.70	67.70	66.69	66.70	65.90	66.70	67.50	1.41	2.1%
Total Dissolved Salts (mg/l TDS)	2	588.00	674.00	628.07	631.00	596.60	631.00	665.40	60.81	9.6%
Calcium (mg/l Ca)	2	28.80	31.10	29.91	29.95	29.03	29.95	30.87	1.63	5.4%
Magnesium (mg/l Mg)	2	63.60	66.90	65.21	65.25	63.93	65.25	66.57	2.33	3.6%
Sodium (mg/l Na)	2	22.80	34.40	27.42	28.60	23.96	28.60	33.24	8.20	28.7%
Potassium (mg/l K)	2	4.37	4.70	4.53	4.54	4.40	4.54	4.67	0.23	5.1%
Chloride (mg/l Cl)	2	16.80	17.20	17.00	17.00	16.84	17.00	17.16	0.28	1.7%
Sulphate (mg/l SO <sub>4</sub> )	2	8.10	8.60	8.34	8.35	8.15	8.35	8.55	0.35	4.2%
Total Alkalinity (mg/l) CaCO <sub>3</sub>	2	328.30	385.40	354.57	356.85	334.01	356.85	379.69	40.38	11.3%
Nitrate (mg/l N)	2	9.48	9.48	9.48	9.48	9.48	9.48	9.48	0.00	0.0%
Fluoride (mg/l F)	2	0.19	0.33	0.24	0.26	0.20	0.26	0.32	0.10	38.1%
Silicon as Si	2	39.85	40.72	40.28	40.29	39.94	40.29	40.63	0.62	1.5%
Iron (Fe)	2	0.0010	0.001	0.001	0.001	0.001	0.001	0.001	0.00	0.0%
Manganese (Mn)	2	0.0001	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.0%
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	2	0.031	0.057	0.040	0.044	0.034	0.044	0.054	0.02	41.8%
ZAR	2	0.54	0.80	0.65	0.67	0.57	0.66	0.77	0.18	26.8%
LSI	2	Langelier Saturation Index (LSI)			Slightly Scaling	100.0%	Highly Scaling	0.0%		
		Highly corrosive	0.0%	Slightly corrosive	0.0%	Balanced Corrosion	0.0%			

Table 53 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. The overall water quality is ideal in all three available water analyses in terms of the Electrical conductivity (EC) with values ranging between 65.7 and 67.7mS/m.

The Total Dissolved Solids (TDS) is acceptable in 100% of the samples (TDS ≤ 1200mg/l). The Langelier Saturation Index (LSI) indicates that the water is predominantly slightly scaling. The ZAR index indicates that 100% of the water is of a fair quality for irrigation (ZAR < 3).

Platinum mines, rural villages and farms are the economic activities in the unit. Due to the low yield of the unit, water supply is mainly from resources outside the unit.

### 7.2.3 CATEGORY D: INTERGRANULAR AND FRACTURED AQUIFERS

- Letaba Formation (Jle)
- Diabase (N-Za)
- Palala Granite (Mpa)
- Sibasa Formation (Soutpansberg Supergroup), (Msi)
- Nebo Granite (Mn)
- Villa Nora Gabbro-Anorthosite (Vv)
- Undifferentiated Rustenburg Layered Suite (Vrs)
- Undifferentiated Pretoria Group (Vpg)
- Matlala Granite (Vml)
- Smitskraal Granite (Vs)
- Palmietfontein Granite (Vpf)
- Unnamed Granite Rocks (Vz)
- Utrecht Granite (Vut)
- Turfloop Granite (Rt-Vt)
- Uitloop Granite (Ru-Vu)
- Lunsklip Granite (RI-VI)
- Moletsi Granite (Rmo)
- Matok Granite (Rma)
- Hugomond Granite (Rhu)
- Hout River Gneiss (Rho)
- Hout River Gneiss with Xenoliths (Rhx)
- Undifferentiated Messina Suite (Zms)
- Undifferentiated Beit Bridge Complex (Zbc)
- Undifferentiated Malala Drift Group (Zma)
- Mount Dowe Group (Zmd)
- Undifferentiated Bandelierkop Complex (Zbk)
- Undifferentiated Pietersburg Group, (Mostly Mothiba Formation), (Zpg)
- Goudplaats Gneiss (Zgo)
- Goudplaats Gneiss with Xenoliths (Zgx)

Intergranular and fractured aquifers cover approximately 69.7% of the total map area. Figure 54 shows the Geographical distribution of the intergranular and fractured aquifers.

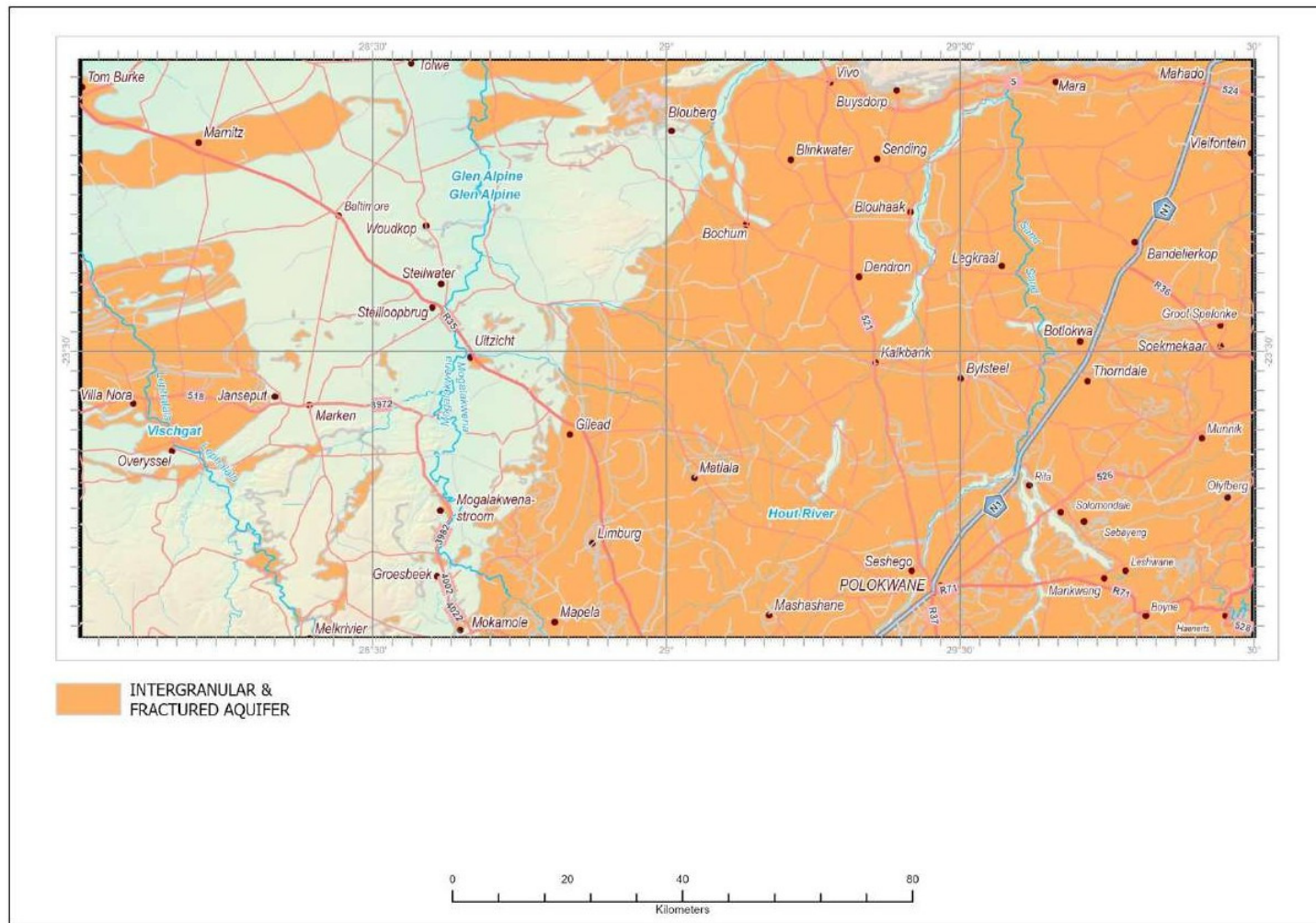


Figure 54: Geographical distribution of the intergranular and fractured aquifers



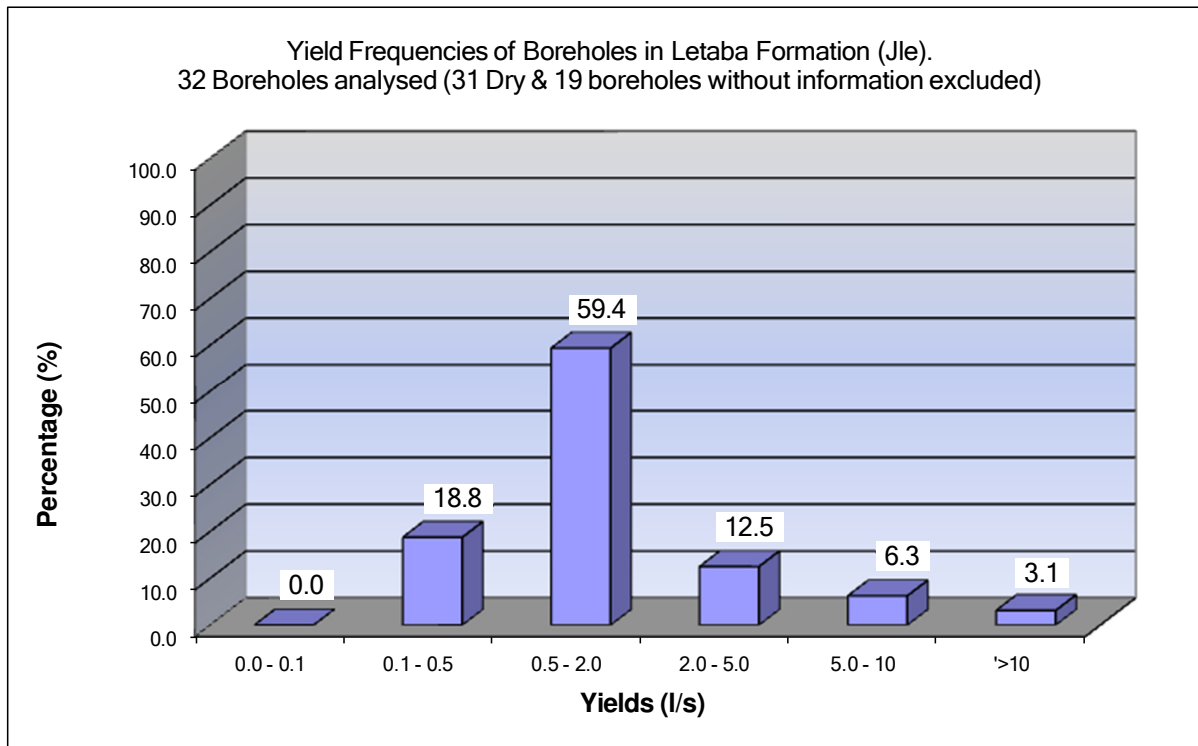


Figure 56: Yield frequency for the intergranular and fractured aquifers of the Letaba Formation (Jle).

The yield frequency diagram gives an indication of the expected yield of the boreholes within this unit. Figure 56, represents the maximum yields of 32 boreholes that occur within the map sheet area. The indication is that 78.1% of the successful boreholes have maximum yields that are less than 2l/s. Only 18.8% of the yields are between 2l/s and 10l/s with a mere 3.1% of the boreholes with yields that exceeds 10l/s.

The static water level ranges from 6.1 meters below ground level (mbgl) to 54.37mbgl, with a median of 20.59mbgl and an average of 23.75mbgl, (based on 27 data points). The maximum depth recorded is 190.6m, with an average depth of 89.86m and a median depth of 85m; (41 data points). The maximum installation depth is 92m and the average depth is 47.8m (23 data points). The maximum recommended daily abstraction on record is 630 cubic meters per day (m<sup>3</sup>/day) and with an average of 63.6m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 23.

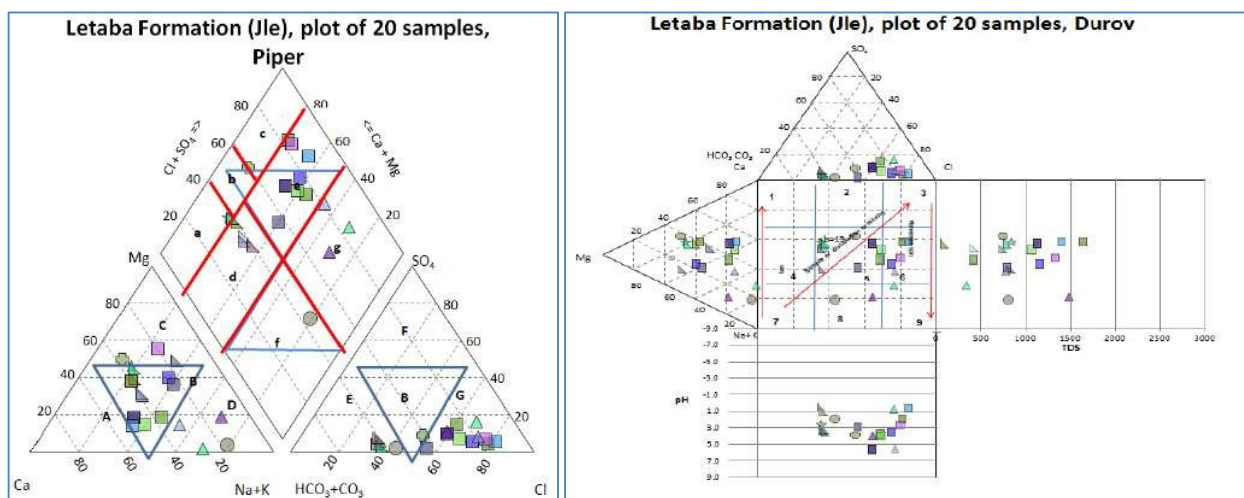


Figure 57: Trilinear diagrams, Piper and Durov for the Letaba Formation (Jle).

The trilinear Piper diagram, (Figure 57) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (81%), Weak acidic anions > Strong acidic anions (35.7%); Alkali > Alkali earths (19%); Strong acids > Weak acids (64.3%).

The groundwater in this unit classifies as:

- Mixed Calcium-Magnesium-Chloride type with increased Sodium (38.1%);
- Mixed Calcium-Magnesium-Bicarbonate type (14.3%);
- Mixed Calcium-Magnesium-Bicarbonate type with increased Sodium (14.1%);
- Sodium-Chloride type (14.3%)
- Mixed Calcium-Magnesium-Chloride type (4.8%);
- Magnesium-Chloride type (4.8%),
- Magnesium-Bicarbonate-Chloride type (4.8%);
- Sodium-Bicarbonate type (4.8%)

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- No dominant anion or cation indicates fresh recent recharge water exhibiting simple dissolution or mixing (55%), plot along the dissolution or mixing line,
- -SO<sub>4</sub> dominates, or anion discriminates and Na dominant, mixed water or water exhibiting simple dissolution influences (30%),
- Cl dominant anion and Na dominant cation reverse ion exchange of Na-Cl waters (10%),
- Cl and Na dominant, frequently indicative of end-point gradient waters through Dissolution (5%),
- The high TDS is some of the samples that may be indicative of long residence times in the aquifer allowing reactions to be fairly complete.

Table 54: Chemical statistics for the Letaba Formation (Jle).

Element / Parameter	Statistics Drawn from a population of 36 data points for the Letaba Formation (Jle).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	34	7.10	8.44	7.90	7.92	7.49	7.96	8.41	0.35	4.4%	
Electrical Conductivity (mS/m EC)	34	11.9	1019.1	84.8	158.4	50.1	113.1	241.4	171.9	108.6%	
Total Dissolved Salts (mg/l TDS)	34	86.0	7162.4	593.5	1077.8	334.4	799.4	1491.2	1183.2	109.8%	
Calcium (mg/l Ca)	34	8.10	786.25	54.64	110.37	34.03	77.24	175.51	135.02	122.3%	
Magnesium (mg/l Mg)	34	0.84	482.48	14.13	64.84	14.05	41.20	135.98	85.66	132.1%	
Sodium (mg/l Na)	34	5.30	776.64	50.94	111.94	33.40	82.89	152.88	132.19	118.1%	
Potassium (mg/l K)	34	0.43	14.08	1.49	2.63	0.89	1.74	4.37	2.70	102.7%	
Chloride (mg/l Cl)	34	8.7	3556.2	48.9	283.5	18.6	104.7	481.9	609.7	215.1%	
Sulphate (mg/l SO <sub>4</sub> )	34	2.00	406.03	11.20	39.78	3.86	28.05	57.19	68.37	171.9%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	31	43.20	447.30	202.46	269.77	143.34	289.10	382.53	98.00	36.3%	
Nitrate (mg/l N)	34	0.08	92.70	0.70	17.94	0.31	14.76	38.83	19.57	109.1%	
Fluoride (mg/l F)	34	0.02	1.19	0.18	0.28	0.13	0.24	0.38	0.19	66.7%	
Silicon as Si	33	2.36	46.14	19.56	29.39	12.35	33.96	39.68	11.14	37.9%	
Iron (Fe)	20	0.003	0.050	0.009	0.018	0.005	0.011	0.050	0.02	96.3%	
Manganese (Mn)	20	0.002	0.740	0.006	0.067	0.002	0.013	0.103	0.16	245.9%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	33	0.003	0.800	0.017	0.106	0.009	0.024	0.283	0.23	217.6%	
ZAR	34	0.36	7.95	1.43	2.22	0.95	1.82	3.96	1.75	79.0%	
LSI	31	Langelier Saturation Index (LSI)			Slightly Scaling		67.7%		Highly Scaling		0.0%
		Highly corrosive			0.0%		Slightly corrosive		6.5%		Balanced Corrosion

Table 54 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value, and standard deviation will give an indication of the scale of the problem. The overall water quality is ideal to good in (61.8%); marginal in (32.4%) and unacceptable (EC > 370mS/m), in 5.9% of the analysis in terms of the Electrical conductivity (EC) with values ranging between 11.9 and 1019.1mS/m.

The Total Dissolved Solids (TDS) is acceptable in 76.5% of the samples, (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 36 samples indicate elevated concentrations of Nitrate (N >20mg/l) in

44.1%; Chloride (Cl > 600mg/l) in 5.9%; Calcium (Ca > 300) in 5.9%; Magnesium (Mg > 200mg/l) in 5.9%; and Sodium (Na > 400mg/l) in 2.9% of the analysis

The Langelier Saturation Index (LSI) indicates that the water is slightly corrosive (6.5%), predominantly slightly scaling (67.7%) and balanced (25.8%). The ZAR index indicates that 85.3% of the water is of a fair quality for irrigation (ZAR < 3).

Various rural villages occur within this unit, with water supplied by regional water schemes that source groundwater from within the unit as well as from aquifers in adjacent units. West of the Mogalakwena River, irrigation fields identified through Google Earth imagery likely use a combination of groundwater and surface water.

### **7.2.3.2 DIABASE (N-Za)**

This unit consists of diabase intrusions, including sills and dykes, which occur in almost all the pre-Karoo formations in the area. Irrespective of the regional geology, diabase dykes are more prevalent compared with other geological lineaments such as faults. Thus, in many cases the only available groundwater target in an area earmarked for development (schools, hospitals etc.) will be a diabase dyke; therefore, this unit will represent all types of water user's namely domestic, commercial, agriculture, mining etc.

Sills predominantly occur within the sedimentary rocks of the Waterberg and Soutpansberg Supergroups. They are also extensively preserved in areas underlain by Nebo Granite, where the younger Waterberg rocks have been removed by erosion.

In the Swazian rocks and Hout River Gneiss, dykes often form ridges, but in the sedimentary rocks, they usually form negative topographic features. The scale of maps prohibits the inclusion of all dyke intrusions, but it provides some indication of their frequency and trend of occurrence in certain groundwater resource units. The groundwater resource unit (in the form of sills), underlies approximately 1.57% of the map sheet area, (Figure 58).

For this unit, 74.1% of the borehole yields are less than 2l/s, while 25.9% exceed 2l/s, (Figure 63). In 17.3% of the water samples, at least one element exceeds the maximum allowed limits for domestic use. The most problematic anion in this unit is fluoride, followed by nitrate, which is unacceptable in 16.5% of the samples.

The Groundwater Resource Information Project (GRIP), conducted by DWS, included the identification of possible geological lineaments on a regional scale. This was achieved using remote sensing techniques, and the results are shown in Figure 7, page 31. The majority of the identified lineaments correspond to diabase dyke intrusions.

Diabase occurrences within the map sheet vary from aphanitic (very fine-grained, with crystals indistinguishable to the naked eye) to coarse-grained. The rock is greenish black, has a gabbroic composition, and exhibits an ophitic texture (random plagioclase laths enclosed by pyroxene or olivine). A specimen north of Villa Nora consists typically of augite, oligoclase plagioclase, and hornblende, with accessory hypersthene, quartz, biotite, and iron ore (Geological map sheet explanatory brochure).

In groundwater exploration, secondary fractures in the host rock associated with diabase intrusions are sometimes targeted. Due to their abundance, sills and dykes are the most common targets for groundwater exploration within the sedimentary rocks of the Waterberg Supergroup. However, within the sedimentary rocks of the Soutpansberg Supergroup, dykes are the second priority after fault zones, as the latter are more widespread than in other lithologies.

Dykes are commonly targeted in the Swazian, Randian, and Vaalian granitoids and gneissic rocks due to their abundance and the lack of other groundwater targets (such as deep weathering zones), especially

when the target area is relatively small (e.g., clinic and school yards). The results when targeting diabase intrusions are varied, but they usually result in some water strikes.

Sills, on the other hand, are difficult targets in groundwater exploration. The options for dealing with sills include:

- Target either one or both contact zones (upper or lower). This option depends on the depth of the sill; if on the surface it will only be one contact (lower). The thickness of the sill must also be considered.
- When the sills occur near the surface, the first target is deeply weathered and fractured zones, followed by the lower contact zone. Deep weathered and fractured zones are structurally controlled by faults, joints, or younger dyke intrusions into the sill. Geophysical methods are used to detect these zones and determine the thickness of the sill.
- Targeting the 'vertical' contact i.e. the edge of the sill. In such a case, the target zone will be similar as when dealing with a dyke.
- Sills are more likely to be found in the Waterberg and Soutpansberg Supergroups than in other pre-Karoo geological settings, where diabase in the form of dykes is more common. The term 'dolerite' is of similar composition but of post-Karoo age that intruded the Karoo Sedimentary rocks predominantly as dykes.
- The use of geophysical instruments and geological observations is highly recommended when searching for groundwater near diabase intrusions. Extensive soil coverage in the map area hampers visual discoveries, especially in the non-Waterberg Sediments.

When dealing with intrusive dykes, remote sensing techniques, (Figure 7) areal magnetic surveys, and geophysical methods are highly recommended for groundwater exploration. In most cases, anomalies found in geophysical data will correspond to diabase dykes. The magnetic method is particularly effective when searching for diabase dykes.

However, targeting dykes for groundwater exploration does not always result in successful water strikes. Several factors must be considered, including:

- Type of host rock,
- Static water level,
- Lateral extent of the lineament,
- Regional stress directions,
- Nature of the detected anomaly (i.e., whether it truly corresponds to a diabase intrusion or another rock type with a distinct magnetic signature from the regional background magnetic intensity).

Anomalies may also be produced by other rock types, such as amphibolite, syenite, and greenstone xenoliths, which are more common in the older gneissic areas.

Additional factors to consider when targeting diabase dykes include:

- Thickness/width of the dyke,
- Dip and strike of the dyke,
- Weathering characteristics, such as spherical weathering or 'blokkies klip' (blocky) fracturing.

Drilling positions in thin dykes (less than 7m) are usually positioned with the expectancy to find water within the dyke. With wider dykes (7m to 15m) the most successful zone is usually within 2m of the contact zone. When dealing with very wide dykes (> 40m) the contact zone may not be the best target. When dealing with these wide dykes the use of geophysical instruments may show weathered zones further from the dyke contact that can be targeted in the search for groundwater. Yields can differ on each side of the dyke as well as along the strike.

When using interpreted aerial magnetic data presented as maps showing the magnetic intensity over a large area, dykes are usually targeted on the ground in areas along the strike where there is possible

weathering (lower background readings), or where joints, faults, or fracture zones transect the dyke (displacement).

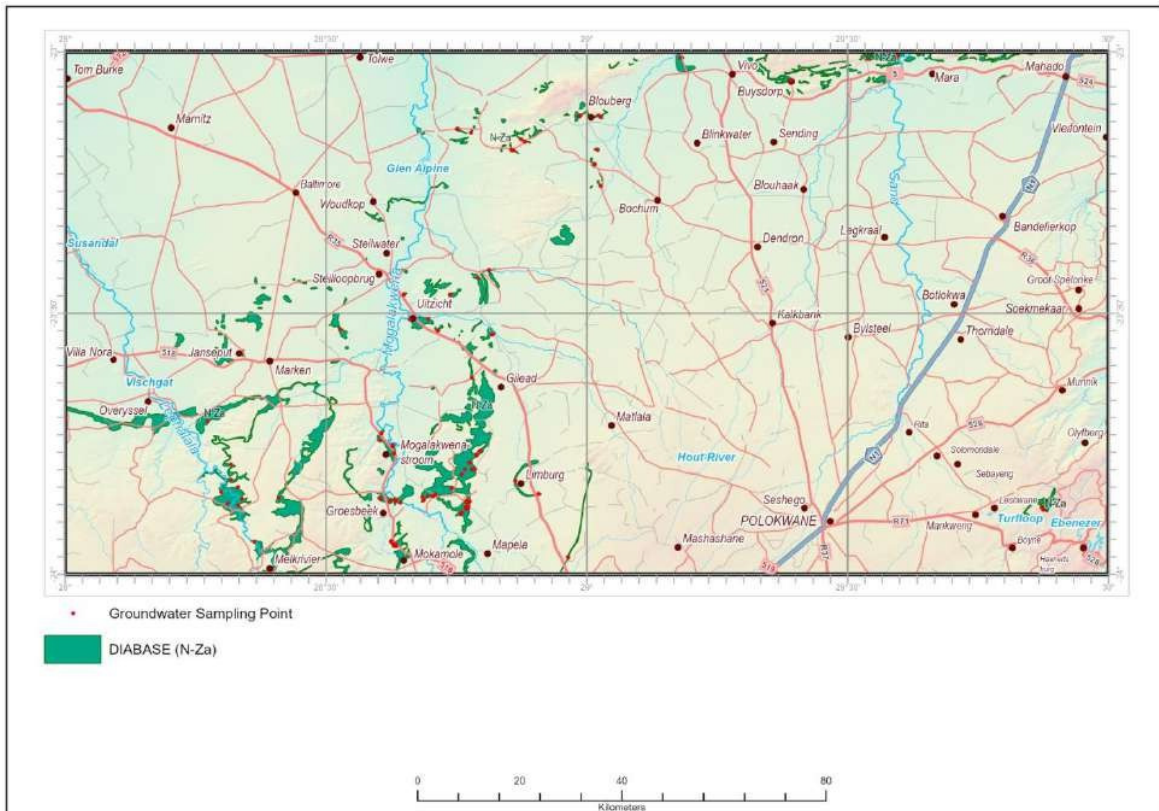


Figure 58: Geographical distribution of the Diabase intrusions (N-Za) and the associated groundwater data points.

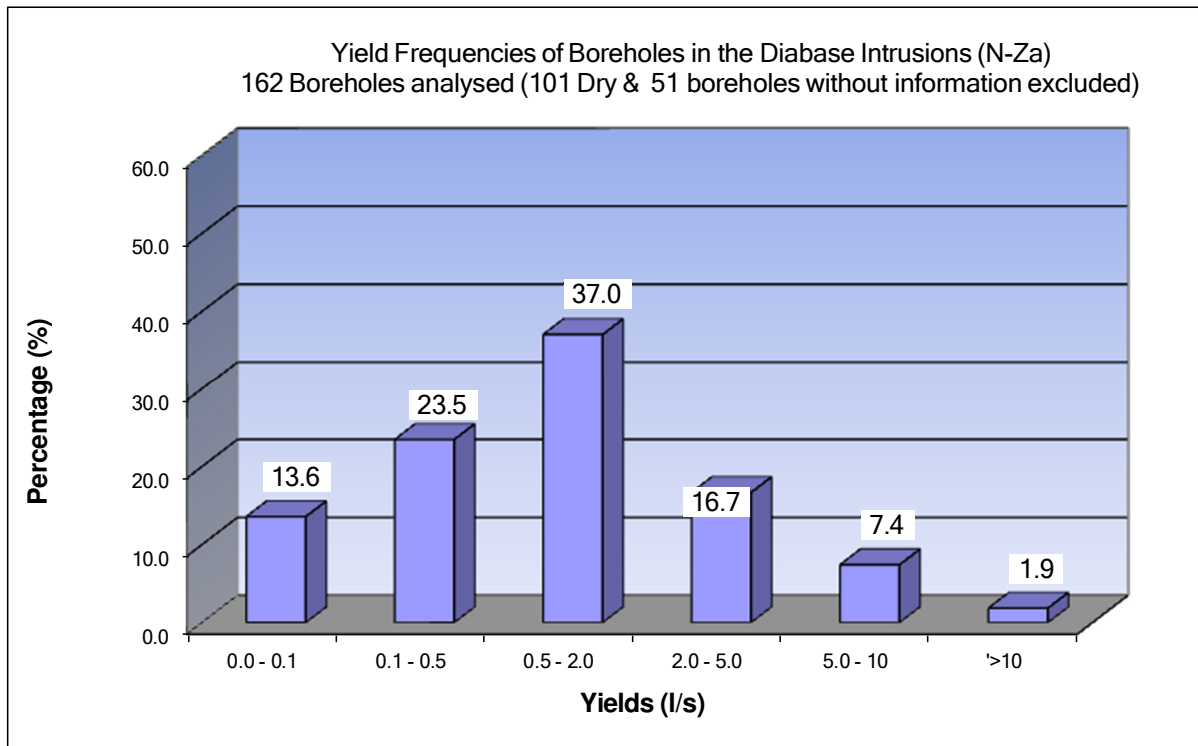


Figure 59: Yield frequency for the intergranular and fractured aquifers of the Diabase intrusions (N-Za).

For this unit, (Figure 59) represents the maximum yields of boreholes drilled into diabase sill intrusions. The distribution of the sills is depicted in Figure 58. Boreholes targeting the numerous dyke intrusions are not included in the analysis due to the scale limitations of the map sheet. The data show that 37% of the successful boreholes have maximum yields that are less than 0.5l/s; another 37% yield between 0.5l/s to 2l/s, with 16% falling in the range between 2l/s and 5l/s, and 9.3% of the boreholes yielding more than 5l/s.

The static water level ranges from 1.95 meters below ground level (mbgl) to 45.2mbgl, with a median of 12.93mbgl, and an average of 14.67mbgl (based on 78 data points). The maximum depth recorded is 150m, with an average depth of 73.1m, and the median depth of 68.85m, (114 data points). The maximum installation depth is 76m with an average of 36.5m, (60 data points). The depth of installation can be indicative of water strike depths if compared to the average depth and static water levels of the boreholes. The maximum recommended daily abstraction on record is 630 cubic meters per day (m<sup>3</sup>/day) and the average is 79m<sup>3</sup>/day. The 90th percentile for daily abstraction is 224.6m<sup>3</sup>/day and the 80th percentile is 98.5m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 60.

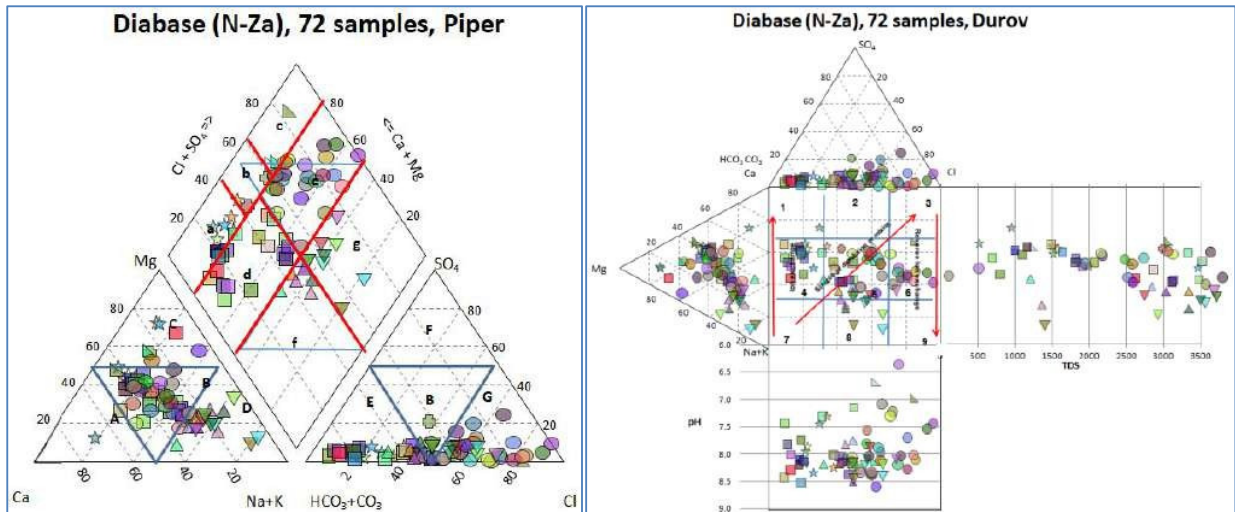


Figure 60: Trilinear diagrams, Piper, and Durov for Diabase (N-Za).

The trilinear Piper diagram, Figure 60 facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (77.8%), Weak acidic anions > Strong acidic anions (51.4%); Alkali > Alkali earths (22.2%); Strong acids > Weak acids (48.6%).

The second evaluation was on the water type:

- Mixed Calcium-Magnesium-Bicarbonate type with increased Sodium (28.2%),
- Mixed Calcium-Magnesium-Chloride type with increased Sodium (26.8%),
- Sodium-Chloride type (18.3%),
- Mixed Calcium-Magnesium-Bicarbonate type (8.5%),
- Magnesium-Bicarbonate type (4.2%),
- Magnesium-Chloride type (4.2%),
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type (2.8%),
- Mixed Calcium-Magnesium-Chloride type (2.8%),
- Sodium-Bicarbonate-Chloride type (2.8%),
- Magnesium-Bicarbonate-Chloride type (1.4%).

The trilinear Durov diagram defines the hydrochemical processes along with the water type;

- No dominant anion or cation indicates fresh recent recharge water exhibiting simple dissolution or mixing (47.2%), plot along the dissolution or mixing line,
- Anion discriminant and Ca dominant, frequently indicate recharge in gypsiferous deposits, otherwise mixed water or water exhibiting simple dissolution (23.6%),
- Anion discriminates and Na is dominant, some  $\text{SO}_4$  probable mixing or uncommon dissolution influences (20.9%),
- Cl dominant anion and Na dominant cation, indicate that the groundwater is related to reverse ion exchange of Na-Cl waters (6.9%),
- $\text{HCO}_3$  and Ca dominant, frequently indicates recharging water in limestone, sandstone, and many other aquifers (1.4%),
- The samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 55: Chemical statistics for the Diabase (N-Za).

Element / Parameter	Statistics Drawn from a population of 105 data points for the DIABASE (N-Za).									
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation
pH	105	6.04	8.57	7.76	7.80	7.16	7.99	8.30	0.50	0.06
Electrical Conductivity (mS/m EC)	105	7.40	5760.00	75.04	181.55	42.96	111.50	228.60	557.29	3.07
Total Dissolved Salts (mg/l TDS)	105	30.10	3698.00	485.04	856.56	292.25	819.00	1330.47	554.32	0.65
Calcium (mg/l Ca)	103	2.43	398.70	39.89	75.72	23.90	63.80	126.50	58.76	0.78
Magnesium (mg/l Mg)	103	2.40	261.90	26.13	53.45	14.38	40.80	117.63	44.37	0.83
Sodium (mg/l Na)	103	1.99	504.40	32.08	103.18	17.94	71.00	197.12	95.50	0.93
Potassium (mg/l K)	100	0.15	28.99	1.28	4.37	0.63	2.36	10.52	5.52	1.26
Chloride (mg/l Cl)	105	4.60	1920.40	42.17	203.20	13.26	124.00	407.20	272.08	1.34
Sulphate (mg/l SO <sub>4</sub> )	102	1.10	240.00	7.67	25.69	4.10	14.52	53.78	36.14	1.41
Total Alkalinity (mg/l CaCO <sub>3</sub> )	94	9.46	623.20	182.76	296.45	149.61	295.55	446.34	126.44	0.43
Nitrate (mg/l N)	103	0.01	72.99	0.34	11.29	0.11	6.76	30.10	13.25	1.17
Fluoride (mg/l F)	104	0.02	6.72	0.26	0.84	0.12	0.49	1.84	1.02	1.22
Silicon as Si	93	2.43	61.00	19.46	27.36	12.84	28.30	39.37	10.79	0.39
Iron (Fe)	50	0.002	0.669	0.007	0.062	0.003	0.010	0.191	0.14	228.4%
Manganese (Mn)	50	0.001	0.378	0.003	0.059	0.001	0.006	0.211	0.10	170.2%
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	86	0.003	0.800	0.015	0.043	0.008	0.020	0.057	0.12	277.0%
ZAR	103	0.05	14.03	0.95	2.24	0.50	1.47	4.66	1.95	86.8%
LSI	94	Langelier Saturation Index (LSI)			Slightly Scaling		57.4%	Highly Scaling		0.0%
		Highly corrosive		2.1%	Slightly corrosive		4.3%	Balanced Corrosion		36.2%

Table 55 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value, and standard deviation will give an indication of the scale of the problem. The overall water quality is ideal to good (72.4%); marginal in (22.9%) and unacceptable (EC > 370mS/m), in 4.8% of the analysis in terms of the Electrical conductivity (EC) with values ranging between 7.4 and 5760mS/m. The 90<sup>th</sup> percentile is 228.6mS/m.

The Total Dissolved Solids (TDS) is acceptable in 85.7% of the samples, (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 105 samples indicates elevated concentrations of Fluoride (F > 1.5mg/l) in 17.3%; Nitrate (N > 20mg/l) in 16.5%; Chloride (Cl > 600mg/l) in 5.7%; Calcium (Ca > 300) in 1.9%; Magnesium (Mg > 200mg/l) in 1.9%; and Sodium (Na > 400mg/l) in 1.9% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water is slightly to highly corrosive (6.4%); predominantly slightly scaling (57.4%) and balanced (36.2%). The ZAR index indicates that 71.8% of the water is of a fair quality for irrigation (ZAR < 3).

Nature reserves such as Moepel and Masebe, as well as large private game reserves such as the Lepalala Wilderness Game Reserve, occupy the Waterberg plateau. Diabase sills cover a large section of the Bellevue Reserve in the eastern part of the scattered unit. Various rural villages are located in the lower areas.

Some of the sills give rise to rugged, inaccessible terrain, which is primarily used for livestock grazing. Water from this unit is used for game, livestock, and domestic purposes by rural villages, farmsteads, and lodges. No large scale irrigation occurs within this unit.

### 7.2.3.3 PALALA GRANITE (Mpa)

The Palala Granite occurs in two narrow, linear bodies orientated in an east-north-east direction to the north of Villa Nora. The first occurrence forms a narrow wedge between the Beaufort and Abbottspoor Shear Zones within the Lephalale map sheet and extends east into the Polokwane map sheet. The second occurrence is located between the Palala Shear Zone and the Melinda Fault in the north, extending west

into the Lephalale map sheet, (inset map in Figure 61). Both occurrences are therefore fault / shear- bounded. This groundwater resource unit covers approximately 0.34% of the total map area

The granite is a pinkish-grey, medium- to coarse-grained rock with a generally weakly developed tectonic fabric, which is parallel to the margins of the zones, although locally- well-developed fabrics have been reported. It is not considered a separate intrusion but is rather part of the adjacent Nebo Granite (Bushveld Complex). The rock weathers into a coarse-sandy soil. The Palala Shear Belt occurs north of the Beaufort Shear Zone and south of the Melinda Fault. It is approximately 10km wide and represents the southern boundary of the Central Zone of the Limpopo Mobile Belt, (Brandl, 1996).

Groundwater is primarily found in fault and shear zones. Due to its very limited extent, the groundwater resources of the Palala Granite are considered insignificant. Although yield data are limited, the yield frequency diagram indicates that, despite the insignificance of this unit as a resource, reasonable yields can be obtained from the Palala Granite. For this unit 61.3% of the borehole yields less than 2ℓ/s and 38.7% are more than 2ℓ/s, (Figure 62).

In 80% of the water samples, at least one element exceeds the maximum allowed limits for domestic use. For this unit the primary concern is the anion Fluoride followed by a high percentage (76%) sources with elevated Nitrate concentrations that exceed the maximum limit for domestic use.

The boundary between the Lephalale and Polokwane map sheets is longitude 28°E. The unit occurs on both maps and since they are physically connected and with the same hydrogeological setting, it was decided to use all the available data from both map sheets Polokwane and Lephalale, (inset map Figure 61). The groundwater data falling on both maps for the unit consisted of 68 data points. Within the Polokwane map boundary 31 had water strikes, 9 were dry and 33 data points did not have any information regarding yields. On the Lephalale map sheet 8 groundwater points occurs without any data on yield.

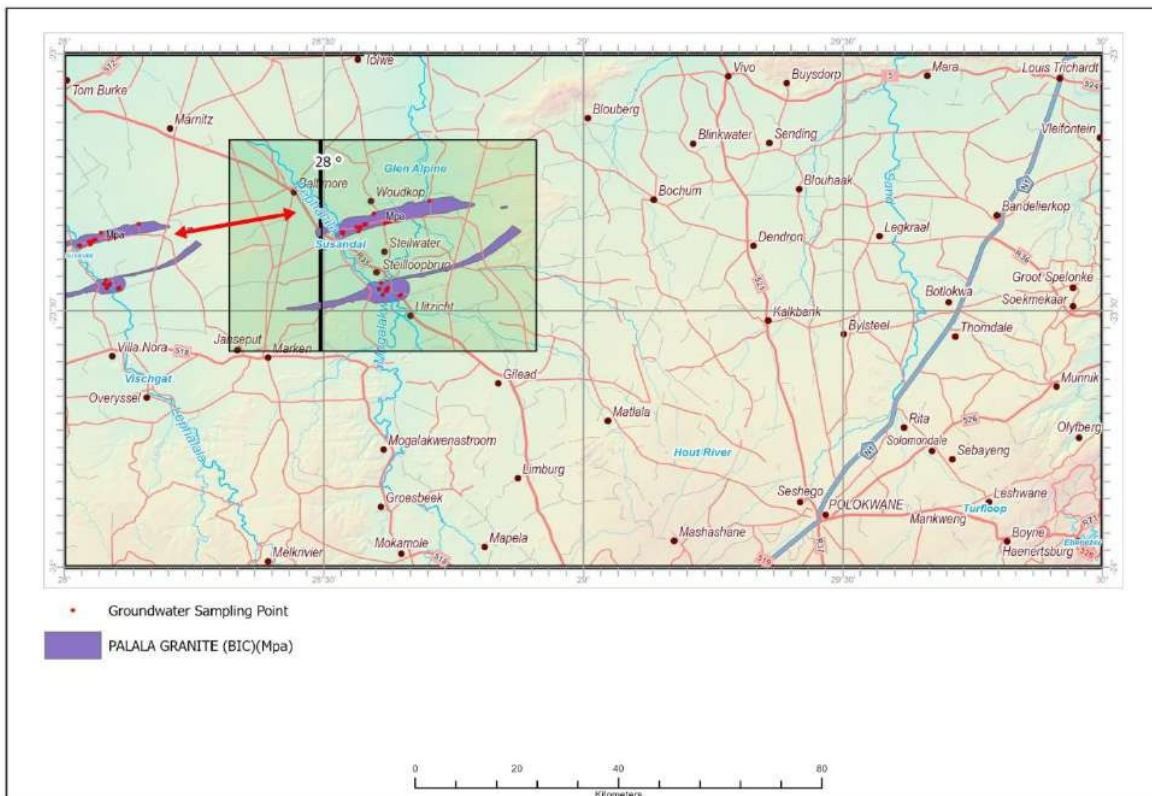


Figure 61: Geographical distribution of the Palala Granite (Mpa) and the associated groundwater data points.

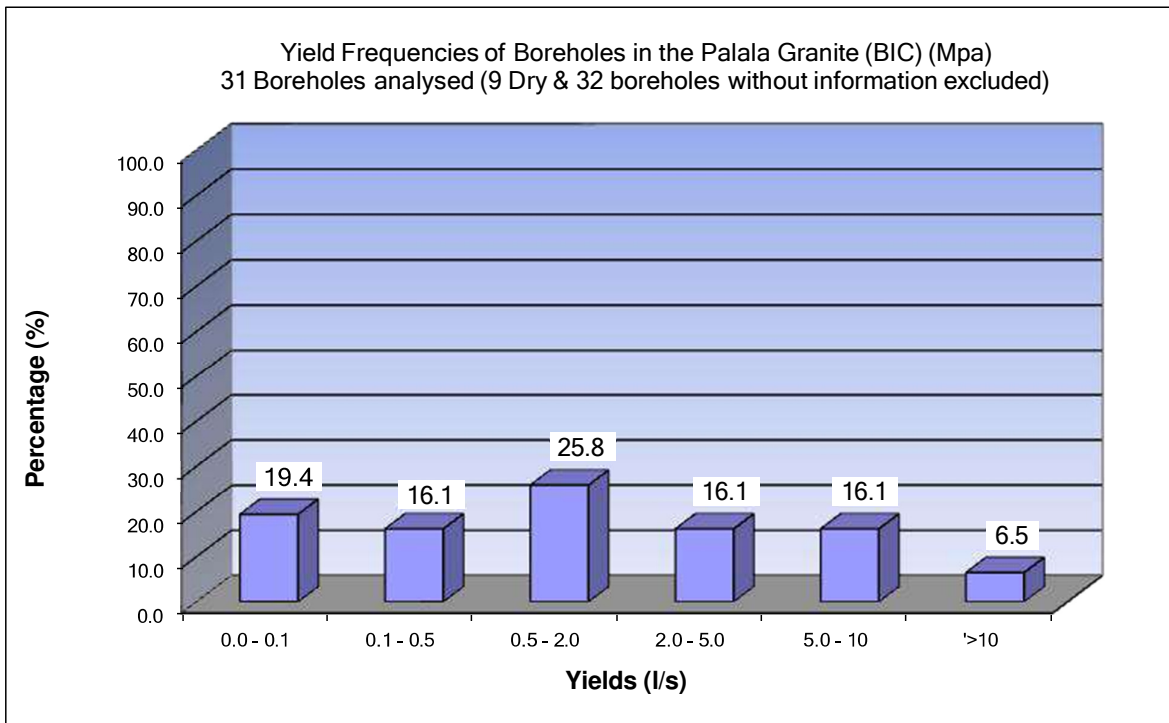


Figure 62: Yield frequency for fractured aquifers of the Palala Granite (Mpa)

The analysis of 31 borehole records indicates that 61.3% of the boreholes have maximum yields of less than 2l/s, with 32.3% between 2l/s and 10l/s, and 6.5% of the boreholes with yields exceeding 10l/s.

The static water level ranges from 0.58 meters below ground level (mbgl) to 24.07mbgl, with a median of 6.54mbgl and an average static water level of 7.49mbgl, (based on 21 data points). The maximum borehole depth recorded is 72.6m, with an average depth of 40.9m, and a median depth of 50m, (23 data points).

The maximum installation depth is 45m, with an average installation depth of 29.9m, (based on 16 data points). The installation depth, the average depth of the boreholes and the regional static water table provide an indication of the water strike depths.

Information is available for 17 boreholes that were tested. The average daily recommended abstraction is 86.5 cubic meters per day (m<sup>3</sup>/day), the 80<sup>th</sup> percentile is 126.4m<sup>3</sup>/day and the maximum daily recommended abstraction is 432m<sup>3</sup>/day.

The occurrence of the unit covers a small section on both the Lephalale and Polokwane map sheets. The potential of the granite itself with some exceptions is insignificant. However, the fault zones which are associated shear zones forming the boundaries of the unit, are important for groundwater development.

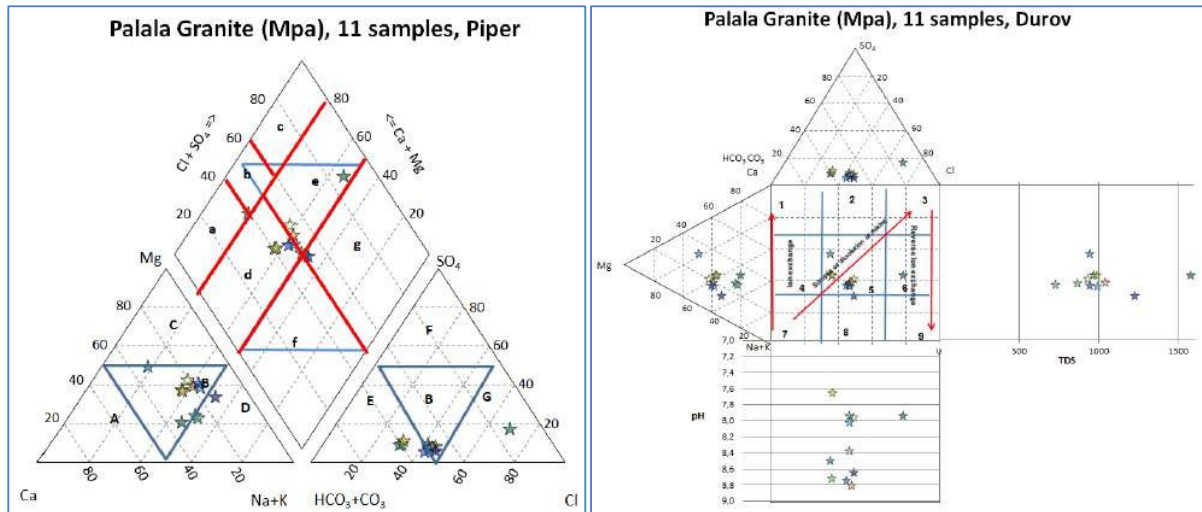


Figure 63: Trilinear diagrams, Piper, and Durov for the Palala Granite (Mpa) data points.

No chemical analyses were available within the Lephalale map sheet boundary. Within the Polokwane map sheet boundary, 26 chemical analyses were available, of which only 11 were suitable for use in the Piper and Durov diagrams. The trilinear Piper diagram, (Figure 63) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (81.8%), Weak acidic anions > Strong acidic anions (45.5%); Alkali > Alkali earths (18.2%); Strong acids > Weak acids (54.5%).

The groundwater in this unit classifies as:

- Mixed Calcium-Magnesium-Bicarbonate-Chloride type with increased Sodium (36.4%),
- Mixed Calcium-Magnesium-Bicarbonate type with increased Sodium (27.3%),
- Sodium-Bicarbonate-Chloride type (18.1%),
- Mixed Calcium-Magnesium-Chloride type with increased Sodium (9.1%),
- Mixed Calcium-Magnesium-Bicarbonate type (9.1%).

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- No dominant anion or cation indicates water exhibiting simple dissolution or mixing (81.8%), plot along the dissolution or mixing line,
- Anion discriminate and Na dominant, indicates probable mixing or uncommon dissolution influences (9.1%),
- Cl is the dominant anion and Na the dominant cation, indicative that the groundwater is related to reverse ion exchange of Na-Cl waters (9.1%),
- Some samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 56: Chemical statistics for the Palala Granite (Mpa).

Element / Parameter	Statistics Drawn from a population of 26 data points for the Palala Granite (BIC) (Mpa).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	26	7.0	8.9	8.1	8.1	7.4	8.2	8.7	0.5	6.1%	
Electrical Conductivity (mS/m EC)	26	99.1	1217.0	157.3	239.7	109.4	140.7	431.6	254.2	106.0%	
Total Dissolved Salts (mg/l TDS)	25	723.4	7220.0	1204.5	1740.6	889.8	1101.6	2957.5	1696.9	97.5%	
Calcium (mg/l Ca)	23	30.5	457.3	69.5	103.6	48.1	64.7	196.6	97.6	94.2%	
Magnesium (mg/l Mg)	23	30.0	121.3	66.9	74.4	55.2	70.2	108.7	22.8	30.7%	
Sodium (mg/l Na)	23	49.7	1972.6	141.7	259.3	107.9	140.5	444.1	390.9	150.8%	
Potassium (mg/l K)	23	0.5	69.7	2.9	10.1	1.0	8.7	13.4	13.6	135.1%	
Chloride (mg/l Cl)	26	52.7	2326.0	132.4	370.4	75.6	128.7	982.5	588.7	158.9%	
Sulphate (mg/l SO <sub>4</sub> )	25	22.0	2225.7	45.9	188.8	27.8	34.5	387.0	445.7	236.1%	
Total Alkalinity (mg/l) CaCO <sub>3</sub> )	18	35.6	767.8	237.7	366.8	231.2	385.7	443.0	143.7	39.2%	
Nitrate (mg/l N)	25	0.6	107.1	9.6	37.9	8.9	32.1	71.3	25.9	68.2%	
Fluoride (mg/l F)	25	0.17	5.13	1.17	2.28	0.83	2.07	4.11	1.25	54.6%	
Silicon as Si	22	4.3	82.6	28.6	41.6	25.9	43.8	49.0	15.2	0.4	
Iron (Fe)	4	0.010	0.050	0.015	0.023	0.010	0.017	0.042	0.02	81.1%	
Manganese (Mn)	5	0.001	2.070	0.002	0.422	0.001	0.010	1.254	0.92	218.1%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	21	0.009	0.247	0.019	0.038	0.013	0.000	0.029	0.06	158.6%	
ZAR	23	0.94	24.89	2.84	4.33	2.31	2.84	5.06	4.86	112.1%	
LSI	18	Langellier Saturation Index (LSI)			Slightly Scaling		94.4%		Highly Scaling		0.0%
		Highly corrosive		0.0%	Slightly corrosive		0.0%	Balanced Corrosion		5.6%	

Table 56 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90<sup>th</sup> percentile, the maximum value, and standard deviation will give an indication of the scale of the problem. The overall water quality is good (58%), marginal (30.8%), and unacceptable in 11.5% of the analysis in terms of the Electrical conductivity (EC) with values ranging between 99.1 and 1217mS/m.

The Total Dissolved Solids (TDS) is acceptable in 56% of the samples, (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 26 samples indicates elevated concentrations of Fluoride (F >1.5mg/l) in 80%; Nitrate (N >20mg/l) in 76%; Chloride (Cl > 600mg/l) in 15.4%; Sodium (Na > 400mg/l) in 13%; Calcium (Ca > 300) in 4.3% and Sulphate (SO<sub>4</sub> >600mg/l) in 4% of the analysis.

The Langellier Saturation Index (LSI) indicates that the water is predominantly slightly scaling (95%) and balanced (5%). The ZAR index indicates that 56.5% of the water is of a fair quality for irrigation (ZAR < 3).

This unit occurs on both sides of the map boundaries (Lephalale and Polokwane) and is physically connected. Both data sets were therefore used for the characterization. None of the boreholes with data, however, fall within the adjacent Lephalale boundary, thus 100% of the chemical analysis and yield data used, are from boreholes falling within the Polokwane map area.

There are a few rural villages within this groundwater unit. The water supply to these villages comes from groundwater; the boreholes were drilled targeting the Melinda Fault zone and another nearby fault striking eastward. High yields and Transmissivity (T) values are reported for these boreholes (highest T = 292). Three samples are reported with high E coli counts; these boreholes are located 360m to 1400m from the nearest village. Irrigation is along the Palala River, and it is most likely as within other groundwater resource units near the river that surface water dominates water supply to irrigation.

### 7.2.3.4 SIBASA FORMATION (SOUTPANSBERG GROUP (Msi))

The Soutpansberg Supergroup comprises a sedimentary-volcanic assemblage and is considered slightly older than the Waterberg Supergroup. Regionally, it has been divided into seven formations, of which two appear on the Polokwane map sheet: Sibasa (volcanic) and Wyllies Poort (sedimentary). Therefore, the Soutpansberg Supergroup appears on the map as both a fractured and intergranular & fractured aquifer. The Supergroup was deposited in a narrow, fault-bounded rift valley or aulacogen, and likely represents the failed spreading arm of a plume-generated triple junction (Jansen, 1975b).

The Sibasa Formation occurs north of Blouberg and Louis Trichardt, (Figure 44) where the unit underlies rugged, mountainous country characterised by steep-sided, cliffed southern slopes and gently dipping northern slopes.

The Sibasa Formation consists predominantly of lava flows, while the Wyllies Poort Formation consists of quartzite and sandstone, interbedded with grit, conglomerate, shale, mudstone, siltstone and lava. Only the Sibasa Formation will be discussed here, due to the intergranular and fractured characteristics of the basalt. The unit occupies only a small area north of Blouberg and Louis Trichardt.

The outcrops of the unit within the Polokwane map sheet cover approximately 2.31% of its total areal extent, (Figure 64).

The yield frequency diagram, (Figure 65) provides an indication of the expected borehole yields; 69.8% of the successful boreholes yield less than 2l/s and 30.2% yields more than 2l/s. In 15.1% of the water samples, at least one element exceeds the maximum allowed limits for domestic use. For this unit the anion of concern is Nitrate.

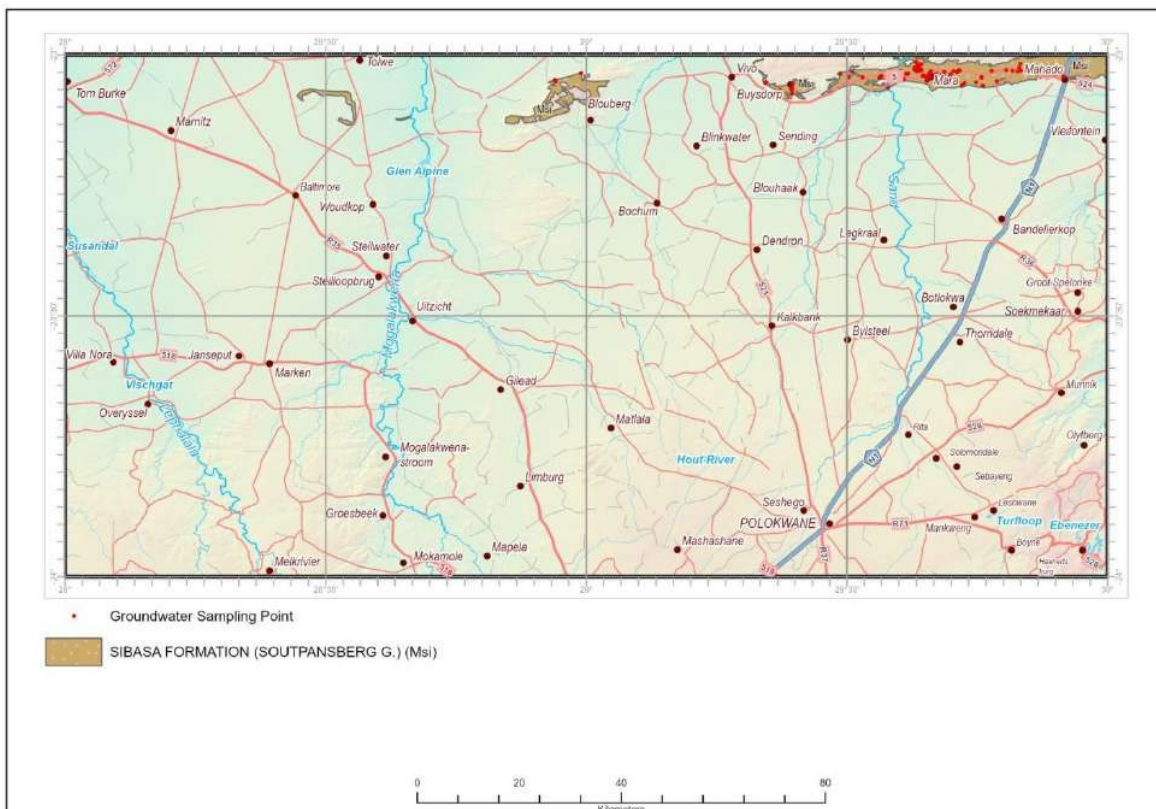


Figure 64: Geographical distribution of the Sibasa Formation (Soutpansberg Group) (Msi) and the associated groundwater data points

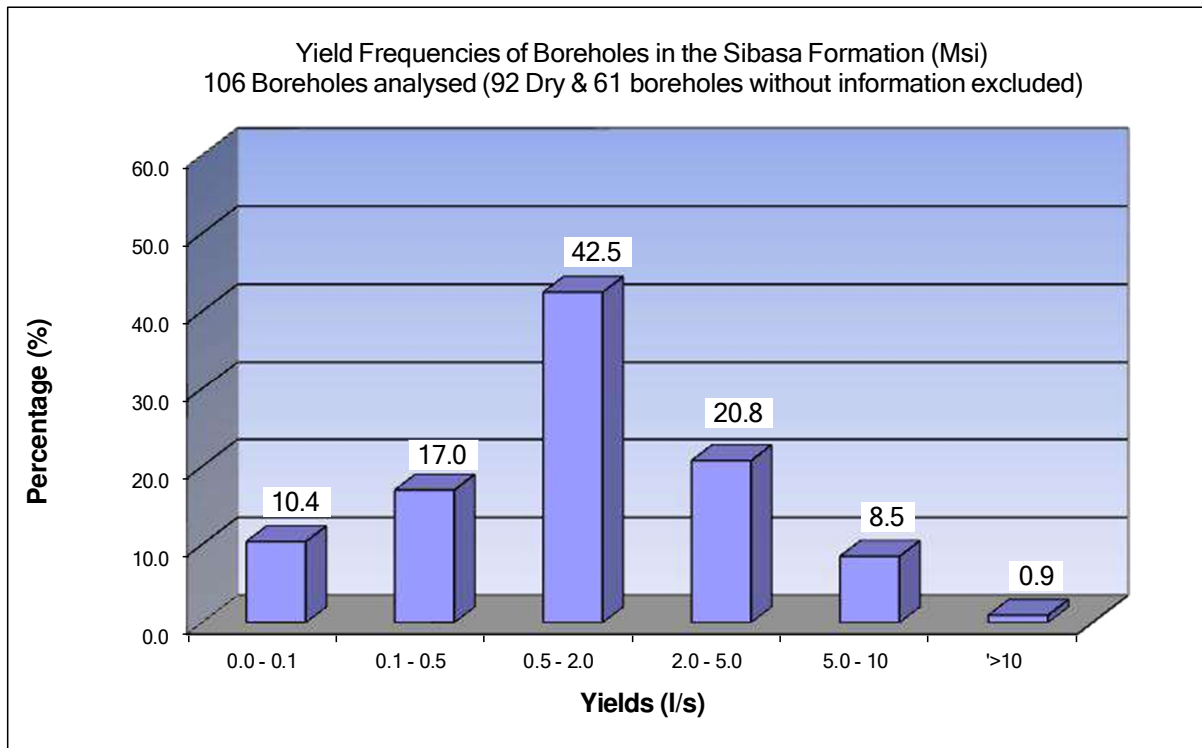


Figure 65: Yield frequency for the intergranular and fractured aquifers of the Sibasa Formation (Msi).

Statistics indicate that 27.4% of successful boreholes yield less than 0.5l/s. A further 42.5% yield between 0.5l/s to 2l/s, while 20.8% yield between 2l/s to 5l/s and 9.4% more than 5l/s, (Figure 65).

The static water level ranges from 0.2 meters below ground level (mbgl) to 56.59mbgl, with a median of 12.27mbgl and an average of 16.82mbgl (based on 44 data points). The maximum borehole recorded depth is 300m, with an average depth of 68.6m, and a median depth of 57m (based on 51 data points). The maximum installation depth is 190m, with an average installation depth of 41.6m (12 data points). The depth of installation can be indicative of water strike depths when compared to the average depth and static water levels of the boreholes.

The maximum recommended daily abstraction recorded is 259.2 cubic meters per day (m<sup>3</sup>/day) and the average is 54.2m<sup>3</sup>/day. The 90th percentile of the daily abstraction is 160.7m<sup>3</sup>/day and the 80th percentile is 82.9m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 29.

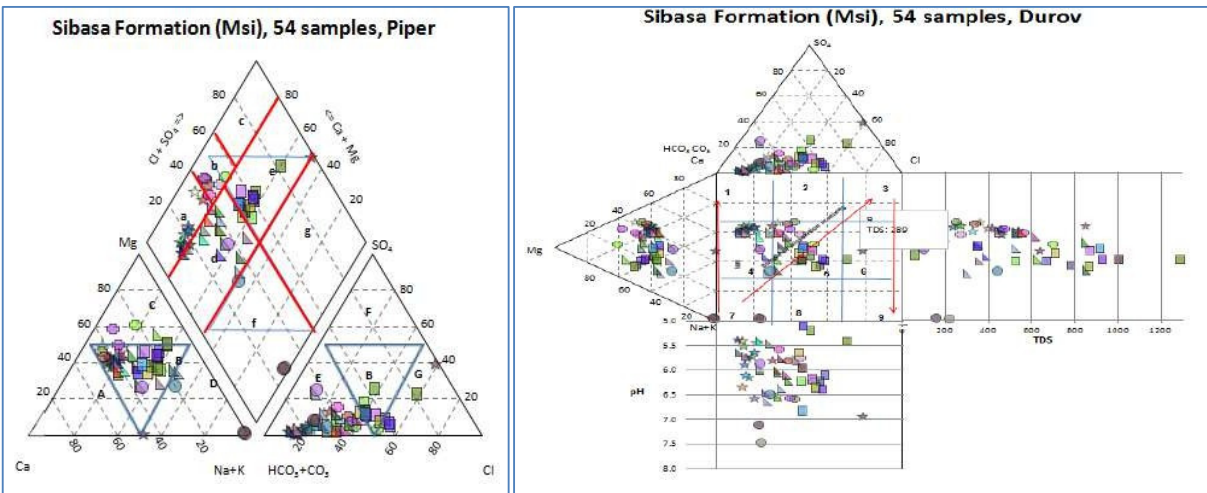


Figure 66: Trilinear diagrams, Piper, and Durov for the Sibasa Formation (Msi), cross-boundary section.

The trilinear Piper diagrams, (Figure 66) facilitate the visualization of water chemistry through the representation of the concentrations of the major cations and anions, allowing for the classification of the major hydrochemical facies. The initial evaluation of chemical dominance is as follows: The first evaluation on the chemical dominance is as follows: Alkali earths > Alkali (94.4%), Weak acidic anions > Strong acidic anions (72.2%); Alkali > Alkali earths (5.6%); Strong acids > Weak acids (27.8%).

The groundwater in the cross-boundary occurs across the unit classifies as:

- Mixed Calcium-Magnesium-Bicarbonate type (68.5%),
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type (14.8%),
- Mixed Calcium-Magnesium-Chloride type (7.4%),
- Magnesium-Bicarbonate type (5.6%),
- Sodium-Chloride type (3.7%).

The trilinear Durov diagram defines hydrochemical processes along with the water type. For the cross-boundary occurrence of the unit it is as follows:

- No dominant anion or cation indicates water exhibiting simple dissolution or mixing (53.7%), plot along the dissolution or mixing line,
- Anion discriminant and Ca dominant frequently indicates recharge in lava, otherwise mixed water or water exhibiting simple dissolution. (42.6%)
- Anion discriminate and Na dominant, indicates probable mixing or uncommon dissolution influences (3.7%),
- Some samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 57: Chemical statistics for the Sibasa Formation (Msi).

Element / Parameter	Statistics Drawn from a population of 107 data points for the Sibasa Formation (Soutpansberg Group) (Msi).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	103	6.51	9.97	7.98	8.01	7.34	8.01	8.58	0.55	6.9%	
Electrical Conductivity (mS/m EC)	106	4.4	376.0	53.2	96.8	30.2	90.0	169.4	58.4	60.3%	
Total Dissolved Salts (mg/l TDS)	98	28.0	1748.9	384.0	689.8	232.0	655.6	1136.1	361.4	52.4%	
Calcium (mg/l Ca)	97	0.50	213.45	12.22	55.96	10.20	54.30	97.34	35.94	64.2%	
Magnesium (mg/l Mg)	97	0.17	165.35	6.48	50.44	4.66	40.20	96.81	34.30	68.0%	
Sodium (mg/l Na)	96	3.70	220.06	30.51	66.38	12.60	52.73	129.35	49.21	74.1%	
Potassium (mg/l K)	96	0.15	25.20	0.64	3.07	0.26	2.07	7.13	3.83	125.0%	
Chloride (mg/l Cl)	99	3.80	642.75	25.04	86.97	10.60	56.80	189.61	95.54	109.9%	
Sulphate (mg/l SO <sub>4</sub> )	96	2.00	233.80	9.07	30.27	4.60	15.27	69.11	38.34	126.7%	
Total Alkalinity (mg/l) CaCO <sub>3</sub> )	85	10.30	537.60	155.35	297.88	107.32	329.80	478.64	134.34	45.1%	
Nitrate (mg/l N)	106	0.02	70.79	0.18	9.07	0.08	2.16	23.51	12.53	138.2%	
Fluoride (mg/l F)	103	0.05	1.16	0.21	0.30	0.12	0.24	0.50	0.19	62.9%	
Silicon as Si	97	4.27	49.05	20.23	26.35	12.28	26.33	37.83	9.61	36.5%	
Iron (Fe)	41	0.003	0.550	0.009	0.052	0.003	0.011	0.080	0.11	205.5%	
Manganese (Mn)	41	0.001	0.346	0.002	0.022	0.001	0.003	0.050	0.06	260.5%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	96	0.003	1.600	0.009	0.073	0.003	0.013	0.117	0.22	297.3%	
ZAR	96	0.25	17.54	0.97	1.91	0.47	1.36	3.18	2.42	126.6%	
LSI	84	Langelier Saturation Index (LSI)			Slightly Scaling		59.5%		Highly Scaling		0.0%
		Highly corrosive			3.6%		Slightly corrosive		7.1%		Balanced Corrosion

Table 57 provides a summary of the physical properties, major anions, cations, and some minor elements. Where the coefficient of variation exceeds 100%, the 90th percentile, maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality for the unit in terms of Electrical conductivity (EC) is ideal to good (81.1%) of a moderate quality in 17.9% and unacceptable only in 0.9% (values above 370mS/m) of the analysis. The Total Dissolved Solids (TDS) levels are acceptable in 93.9% of the samples, (TDS ≤ 1200mg/l).

An evaluation of the major cations and anions from 107 samples indicates elevated concentrations of Nitrate (N >20mg/l) in 15.1% and Chloride (Cl > 600mg/l) in 1% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water is slightly to highly corrosive (10.7%); in predominantly slightly scaling (59.5%) and balanced (29.8%). The ZAR index indicates that 89.6% of the water is of a fair quality for irrigation (ZAR < 3).

In the Blouberg area, the unit consists of rugged, inaccessible terrain. To the east (Buysdorp to Louis Trichardt), the unit forms mountainous terrain with some diluted plains at the foot of the Soutpansberg Mountain Range. Large sections of this area are used for farming, while some rural villages are also present. The northern part of Louis Trichardt is underlain by this unit. Groundwater is primarily used for livestock and domestic consumption.

### 7.2.3.5 NEBO GRANITE (Mn)

The Lebowa Granite Suite comprises all the granite rocks of the Bushveld Complex. It includes several granite types ranging from very coarse-grained to fine-grained, though these variations have not been separated on the map sheet. Within the map sheet the Lebowa Suite is represented by the Nebo Granite, which occurs in two distinct areas. The first is within the central-western section of the map sheet where it overlays the Villa Nora Gabbro-Anorthosite. It forms a sheet-like body of unknown thickness and is in general coarse-grained although varying, homogenous and pinkish with small occurrences of a porphyritic variety, (Council of Geoscience). This occurrence is part of an outcrop that extent into the Lephallale map sheet.

A second occurrence is located in the central part of the map sheet, forming a narrow strip that extends from the Seepabana Perennial River in the north southward into the adjacent Modimolle map sheet.

The cross-boundary occurrence (Polokwane and Lephallale) has a small portion that falls within the Lephallale map, (see inset map Figure 76). The characterization of this outcrop for the Lephallale Brochure was conducted using both sets of data. The reasons were as follows: no data points were available within the Lephallale map sheet boundary, the hydrogeological setting is the same and the outcrop is connected, see Figure 68 for the yield diagram and Figure 70 for the Piper and Durov diagram for the cross-boundary outcrop.

A separate characterization was conducted for the central section of the unit (Seepabana Perennial River / Matlana to Mokopane) within the Polokwane map sheet. Figure 69 show the results for the yield diagram and Figure 71, the results for the Piper and Durov diagram.

The two outcrops of the Nebo Granite within the Polokwane map sheet covers approximately 3.23% of the total map area.

In 53.2% of the water samples, at least one element exceeds the maximum allowed limits for domestic use. For this unit the anion of concern is Fluoride followed by Nitrate that exceeds the maximum allowable concentration for domestic use in 24.7% of the available samples.

The yield frequency diagram, (Figure 68) gives an indication of the expected yield of the boreholes. For 71.7% of the successful boreholes the maximum yield is less than 2l/s and in 28.3% of the boreholes the yield exceeds 2l/s.

For domestic use, elevated Fluoride and Nitrate concentration that exceeds the maximum allowable limits is of concern within the Nebo Granite groundwater resource unit.

*Table 58: Fluoride and Nitrate concentrations within the adjacent 1:250 000 map sheets.*

Map Sheet	Fluoride (F >1.5mg/l) (% unacceptable)	Nitrate (N >10mg/l) (% unacceptable)
Thabazimbi	26.5%	11.8%
Lephallale	68.2%	28%
Modimole	45.5%	13.3%
Polokwane	39.2%	17.9%

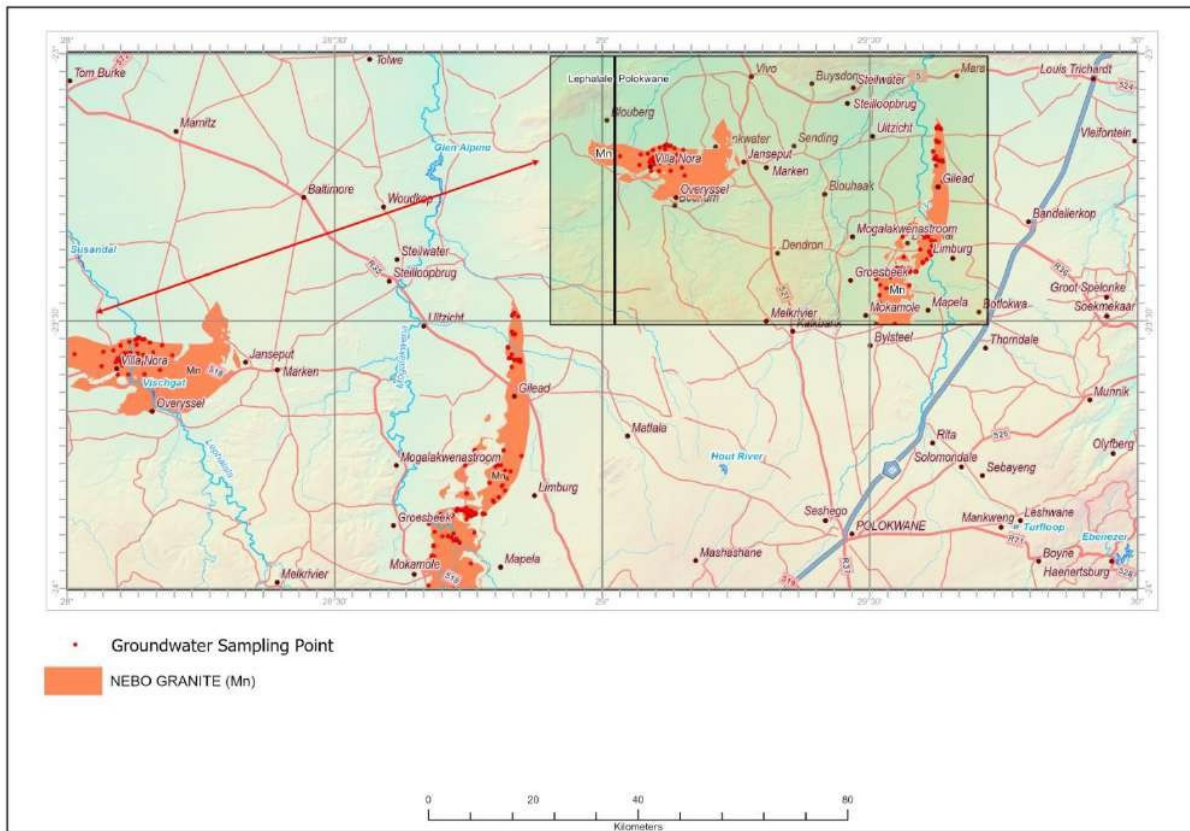


Figure 67: Geographical distribution of the Nebo Granite (Mn) and the associated groundwater data points

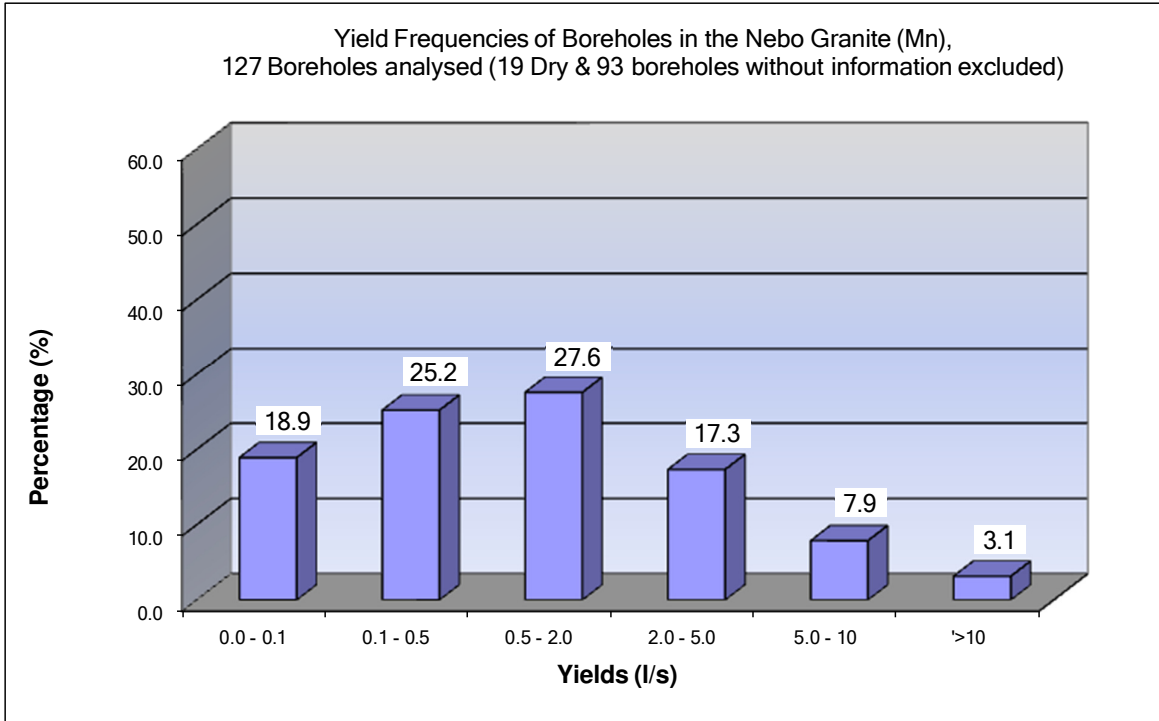


Figure 68: Yield frequency for the intergranular and fractured aquifers of the Nebo Granite (Mn), cross-boundary section.

Figure 68 illustrates the maximum yield distribution for the cross-boundary outcrop of the unit spanning the Polokwane and Lephalale map sheets. Statistics indicate that 71.7% of successful boreholes yield less than 2l/s, while 17.3% of the boreholes yield between 2l/s to 5l/s. Only 11% of the boreholes yield more than 5l/s.

For the same cross-boundary outcrop, static water levels range from 0.5 meters below ground level (mbgl) to 37.07mbgl, with a median of 5mbgl and an average static water level of 7mbgl, (based on 43 data points). The recorded maximum borehole depth is 154m, with an average depth of 58m and a median depth of 60m (63 data points). The maximum installation depth is 82.8m, and the average is 46m (33 data points). The installation depth, when compared with the average borehole depths and static water levels, provides insight into potential water strike depths.

The maximum recorded recommended daily abstraction is 256 cubic meters per day (m<sup>3</sup>/day), with an average of 50.6m<sup>3</sup>/day and a 90th percentile abstraction volume calculated as 141.4m<sup>3</sup>/day. Records indicated that 33 boreholes were subjected to pump testing within the cross-boundary outcrop.

The above statistics are for the unit that falls on the cross-boundary occurrence (thus central-east on the Lephalale map sheet and central-west on the Polokwane map sheet). Therefore, both data sets were used for the characterization; 100% of the chemical analysis and 95.3% of the yield data fall within the adjacent Polokwane map area.

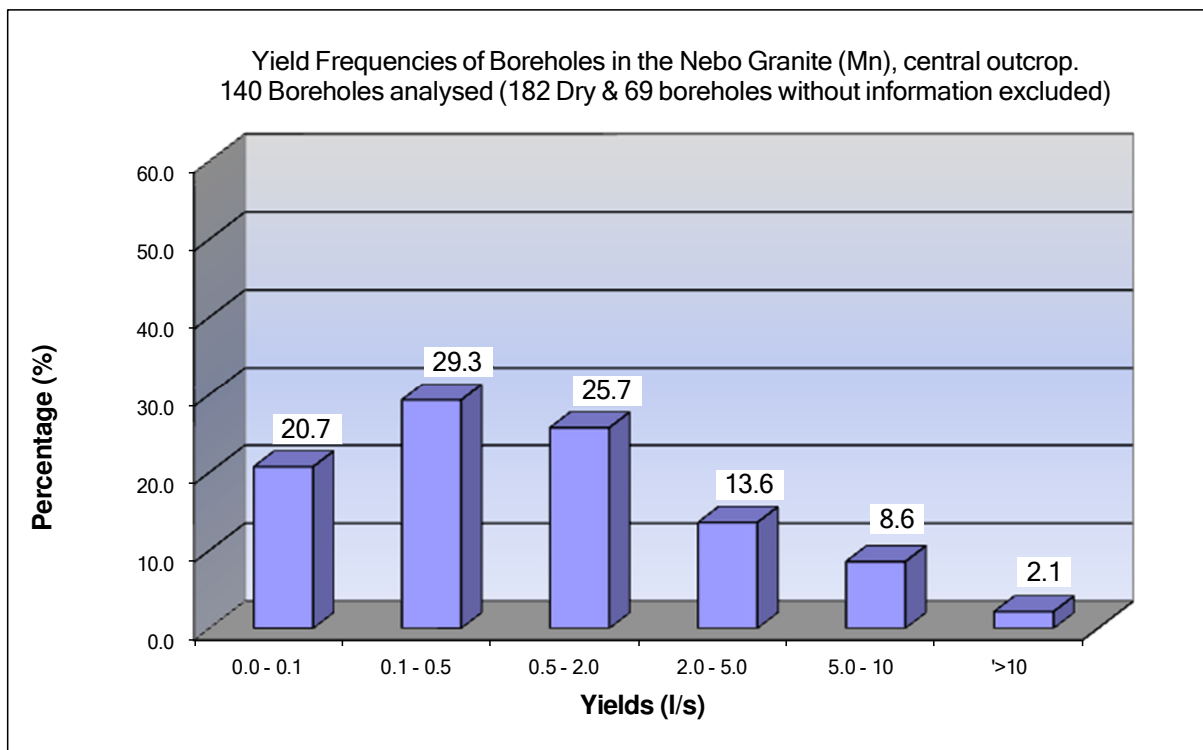


Figure 69: Yield frequency for the intergranular and fractured aquifers of the Nebo Granite (Mn), central outcrop.

Figure 69 illustrates the maximum yield distribution for the central outcrop within the Polokwane map sheet. The yield distribution pattern closely resembles that of Figure 68, which represents data from the cross-boundary occurrence (Polokwane and Lephalale). Statistics indicate that 75.7% of successful boreholes yield less than 2l/s and 13.6% yield in the range 2l/s to 5l/s, with only 10.7% of the boreholes yielding more than 5l/s.

For the central outcrop, the static water levels range from 1.21 meters below ground level (mbgl) to 60mbgl, with a median of 8.61mbgl, and an average of 12.01mbgl (based on 100 data points). The maximum recorded borehole depth is 500m, with an average depth of 73.3m and a median depth of 66.1m (128 data points). The maximum installation depth is 115m, while the average installation depth is 37.6m (70 data points). Comparing these values with average borehole depths and static water levels provide insight into potential water strike depths.

The maximum recorded recommended daily abstraction is 691.2 cubic meters per day (m<sup>3</sup>/day), with an average of 54.9m<sup>3</sup>/day and a 90th percentile abstraction volume of 63m<sup>3</sup>/day. A total of 70 boreholes were subjected to pump testing within the groundwater resource unit.

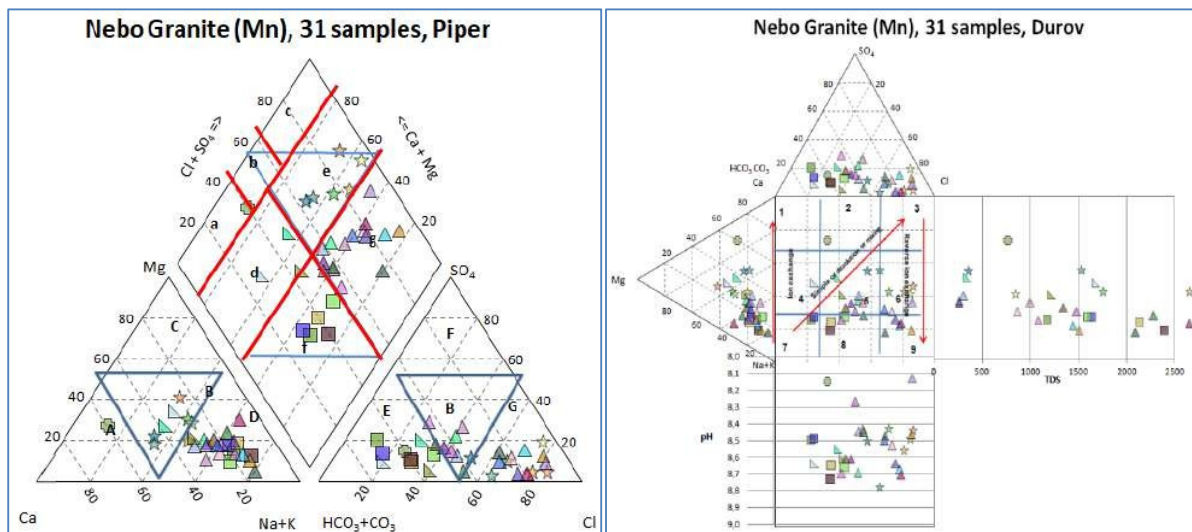


Figure 70: Trilinear diagrams, Piper, and Durov for the Nebo Granite (Mn), cross-boundary section.

The trilinear Piper diagram, (Figure 70) represents the cross-boundary occurrence between the Polokwane and Lephalale map sheets. It provides a visual representation of water chemistry by illustrating the concentrations of the major cations and anions, allowing for the classification of hydrochemical facies. The first evaluation on the chemical dominance reveals the following trends: Alkali earths > Alkali (32.3%), Weak acidic anions > Strong acidic anions (29%); Alkali > Alkali earths (67.7%); Strong acids > Weak acids (71%).

The groundwater in the cross-boundary occurrence of the unit classifies as:

- Sodium-Chloride type (25.8%),
- Sodium-Mixed-Bicarbonate-Chloride type with prevailing Sulphate in some of the samples (25.8%),
- Mixed Calcium-Magnesium-Chloride type with increased Sodium (19.4%),
- Sodium-Bicarbonate type (16.1%),
- Mixed Calcium-Magnesium-Bicarbonate type with increased Sodium (9.7%),
- Calcium-Bicarbonate type (3.2%).

The trilinear Durov diagram defines hydrochemical processes along with the water type. For the cross-boundary occurrence of the unit it is as follows:

- No dominant anion or cation indicates water exhibiting simple dissolution or mixing (32.3%), plot along the dissolution or mixing line,
- Anion discriminate and Na dominant, indicates probable mixing or uncommon dissolution influences (22.6%),
- Cl is the dominant anion and Na the dominant cation, indicative that the groundwater relates to reverse ion exchange of Na-Cl waters (16.1%),
- Cl and Na dominant, frequently indicative of end-point gradient waters through Dissolution (16.1%),
- Cl and Na dominant, reverse ion exchange of Na-Cl waters (6.5%),

- The water type is dominated by Ca and  $\text{HCO}_3$ , Na not significant, thus some recharge of fresh water (3.2%),
- Anion discriminant and Ca dominant, mixed water or water exhibiting simple dissolution. (3.2%),
- Some samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

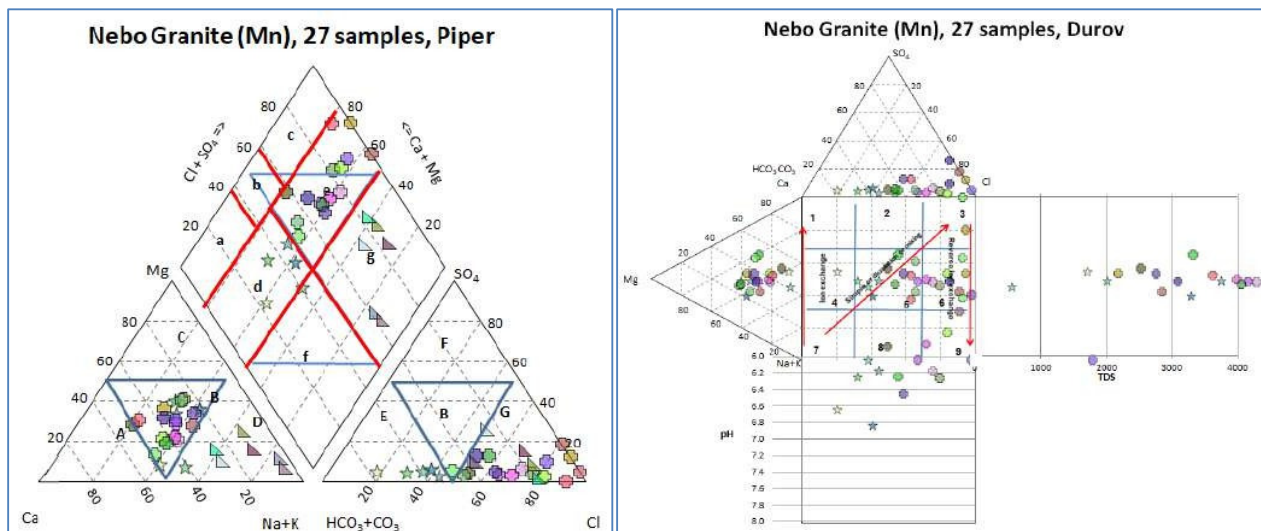


Figure 71: Trilinear diagrams, Piper, and Durov for the Nebo Granite (Mn), central section.

Figure 78 represents the second granite outcrop (south-to-north linear section, Seepabana Perennial River to Mokopane) located within the central Polokwane map sheet.

The initial evaluation of ionic dominance reveals the following trends: Alkali earths > Alkali (77.8%), Weak acidic anions > Strong acidic anions (14.8%); Alkali > Alkali earths (22.2%); Strong acids > Weak acids (85.2%).

The groundwater in the centre occurrence of the unit classifies as:

- Sodium-Chloride type (22.2%),
- Mixed Calcium-Magnesium-Chloride type with increased Sodium (51.9%),
- Mixed Calcium-Magnesium-Bicarbonate type with increased Sodium (18.5%),
- Sodium-Bicarbonate type (3.7%),
- Mixed Calcium-Magnesium-Bicarbonate-Chlorite type with increased Sodium (3.7%),

The trilinear Durov diagram defines hydrochemical processes along with the water type. For the center occurrence of the unit, it is as follows:

- No dominant anion or cation indicates water exhibiting simple dissolution or mixing (48.2%), plot along the dissolution or mixing line,
- Anion discriminates and Na dominant, indicates probable mixing or uncommon dissolution influences (33.3%),
- Cl is the dominant anion and Na the dominant cation, indicative that the groundwater relates to reverse ion exchange of Na-Cl waters (7.4%),
- Cl and Na dominant, frequently indicative of end-point gradient waters through Dissolution (7.4%),
- Anion discriminates and Ca dominant indicating mixed water or water exhibiting simple dissolution (3.7%),

Table 59: Chemical statistics for the Nebo Granite (Mn), all units Polokwane and Lephalale map.

Element / Parameter	Statistics Drawn from a population of 179 data points for the Nebo Granite (Mn). All data from the Lephalale and Polokwane map sheets were used.										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	178	6.28	8.60	7.82	7.85	7.14	7.98	8.30	0.47	5.9%	
Electrical Conductivity (mS/m EC)	177	13.50	964.00	78.62	145.88	42.66	105.60	297.80	129.04	88.5%	
Total Dissolved Salts (mg/l TDS)	170	102.00	5605.00	550.19	981.50	284.95	786.17	1987.65	819.91	83.5%	
Calcium (mg/l Ca)	173	0.50	342.40	29.45	72.51	23.56	61.80	131.50	52.05	71.8%	
Magnesium (mg/l Mg)	173	2.68	259.60	17.20	42.83	6.40	33.30	86.45	43.49	101.5%	
Sodium (mg/l Na)	173	11.20	1280.10	66.05	156.70	30.70	105.31	300.30	176.40	112.6%	
Potassium (mg/l K)	173	0.15	49.12	1.54	5.64	0.70	2.49	14.13	8.75	155.1%	
Chloride (mg/l Cl)	178	5.30	2124.20	58.76	237.66	21.39	122.81	499.43	328.02	138.0%	
Sulphate (mg/l SO <sub>4</sub> )	174	1.73	236.00	13.70	39.38	6.03	27.58	91.97	42.12	106.9%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	151	15.20	900.70	160.54	279.25	75.50	252.38	486.65	171.20	61.3%	
Nitrate (mg/l N)	170	0.01	174.70	0.24	17.44	0.11	9.44	49.06	27.22	156.1%	
Fluoride (mg/l F)	173	0.01	10.07	0.38	2.05	0.33	1.64	4.11	1.78	87.0%	
Silicon as Si	156	1.73	48.75	16.96	25.42	10.44	25.86	39.30	11.11	43.7%	
Iron (Fe)	85	0.003	2.600	0.008	0.059	0.003	0.010	0.050	0.28	482.2%	
Manganese (Mn)	56	0.006	1.046	0.023	0.120	0.010	0.050	0.273	0.18	151.4%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	147	0.005	0.800	0.018	0.055	0.009	0.020	0.058	0.14	260.9%	
ZAR	173	0.36	22.16	2.04	3.63	1.12	2.66	7.46	3.37	93.0%	
LSI	143	Langelier Saturation Index (LSI)			Slightly Scaling		61.5%		Highly Scaling		0.0%
		Highly corrosive			0.0%		Slightly corrosive		9.8%		Balanced Corrosion

Table 59 provides a summary of the physical properties, major anions, cations, and some minor elements for all occurrences of the unit across both the Polokwane and Lephalale map sheets (including both the cross-boundary and Matlala-Mokopane outcrops). In cases where the coefficient of variation in the summary table exceeds 100%, the 90th percentile, maximum value, and standard deviation offer insight into the extent of variability.

An evaluation of 179 data points indicates that the overall water quality is ideal to good (69.7%); marginal (24.2%) and unacceptable in 6.2% of the analysis in terms of the Electrical conductivity (EC) with values ranging between 13.5 and 964mS/m. The 90<sup>th</sup> percentile is 297.8mS/m.

The Total Dissolved Solids (TDS) is acceptable in 75.9% of the samples, (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 179 samples, indicates elevated concentrations of Fluoride (F > 1.5mg/l) in 53.2%; Nitrate (N > 20mg/l) in 24.7%; Chloride (Cl > 600mg/l) in 8.4%; Sodium (Na > 400mg/l) in 5.8%; Magnesium (Mg > 200mg/l) in 2.3% and Calcium (Ca > 300) in 0.6% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water is slightly corrosive (9.8%); predominantly slightly scaling (61.5%) and balanced (28.7%). The ZAR index indicates that 56% of the water is of a fair quality for irrigation (ZAR < 3).

Numerous villages fall within the Matlala-Mokopane section of the Nebo Granite outcrop, with Bakenberg being the best known among them. In the past, groundwater development projects in the area failed due to the low groundwater potential of Nebo Granite. As part of the implementation of the Mogalakwena Groundwater Master Plan, the focus for groundwater development shifted to the establishment of well fields in high-potential areas. To supply the Bakenberg area, a regional well field (Kabeane) was developed, targeting a diabase sill within the Waterberg sedimentary rocks, located approximately 12 km west of Bakenberg (WSM Leshika, 2016).

A large section of the central outcrop of this unit falls within the Bellevue Nature Reserve.

Within the cross-boundary occurrence, groundwater supplies one rural village. In the rest of the unit game, livestock watering, and rural farmsteads dominate the groundwater use. In a section of the unit (Overysse), irrigation fields were developed along the Lephalala River (Palala River). The probability is

that surface water as well as shallow wells situated within the riverbed, are utilised as a water source for irrigation. No groundwater sources are on record within this area or within the immediate vicinity.

Structural lineaments include diabase dykes and one major east-west fault zone that transects this unit. An evaluation based on coordinates shows four boreholes that are located near the fault zone as depicted on the geological map, these boreholes are however reported dry. Future groundwater development may target this fault using geophysical methods to determine the potential thereof.

### **7.2.3.6 VILLA NORA GABBRO-ANORTHOSITE (Vv)**

The Rustenburg Layered Suite represents the mafic phase of the Bushveld Igneous Complex (BIC). Within the Polokwane map sheet (central-west) and the adjacent Lephalale map sheet (central-east), the Bushveld Complex is believed to form a separate intrusion known as the Villa Nora Compartment. This compartment appears to have no direct connection to the main Bushveld outcrop northeast of Mokopane, which falls within the Polokwane geological map sheet area (Council of Geoscience).

The Villa Nora Gabbro, considered part of the northern limb of the Rustenburg Layered Suite (RLS), is largely concealed beneath a cover of younger rocks from the Waterberg Supergroup, with exposures mainly along the eastern edge of the limb and near Villa Nora itself. The intrusion comprises gabbro, anorthosite, ferrogabbro, norite, and minor olivine diorite. These lithologies are interpreted to belong to the Upper Zone and, in part, the Main Zone of the Bushveld Igneous Complex (BIC).

The olivine diorite, which appears at the base of the succession, shares mineralogical similarities to that found in the Mokopane (formerly Potgietersrus) limb. A distinguishing feature of the Villa Nora occurrence is the presence of narrow, elongated bodies of apatite-bearing magnetite, which are largely concordant with the igneous layering of the host rock

Within the Polokwane map sheet, the outcrop accounts for approximately 80% of its total occurrence, with the remaining 20% falling within the Lephalale map sheet. The section of the unit within the Polokwane map sheet represents approximately 1.17% of its total areal extent. Given that the occurrences across both sheets form part of a continuous geological unit with identical hydrogeological settings, all available groundwater data for the outcrop from both areas were combined for the characterization, (inset map, Figure 72).

The yield frequency diagram, (Figure 73), provides an overview of borehole yields. For 63.4% of the successful boreholes, the maximum yield is less than 2l/s and 36.6% yield more than 2l/s.

Regarding water quality, 66.7% of the water samples exceed the maximum allowed limits for domestic use. The primary concern in this unit is the presence of elevated Nitrate concentrations followed by the anion Fluoride that exceeds the maximum allowable limit for domestic use in 12.1% of the analysis.

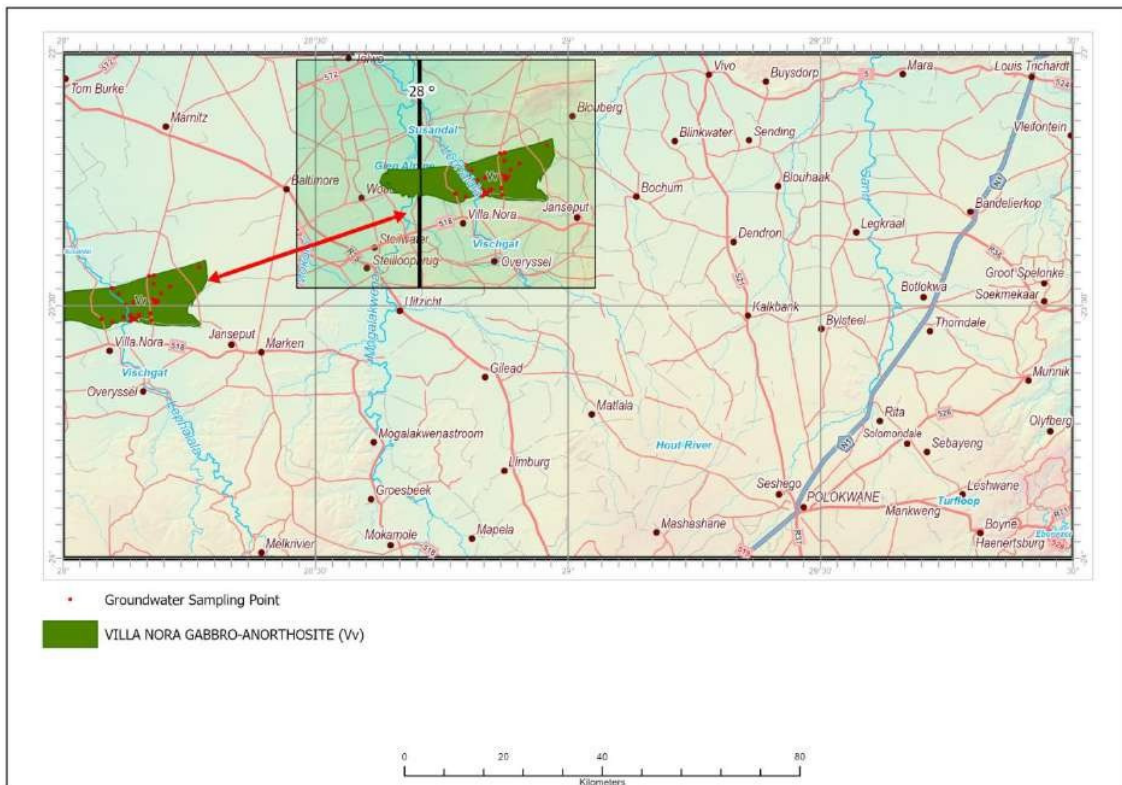


Figure 72: Geographical distribution of the Villa Nora Gabbro-Anorthosite (Vv) and the associated groundwater data points

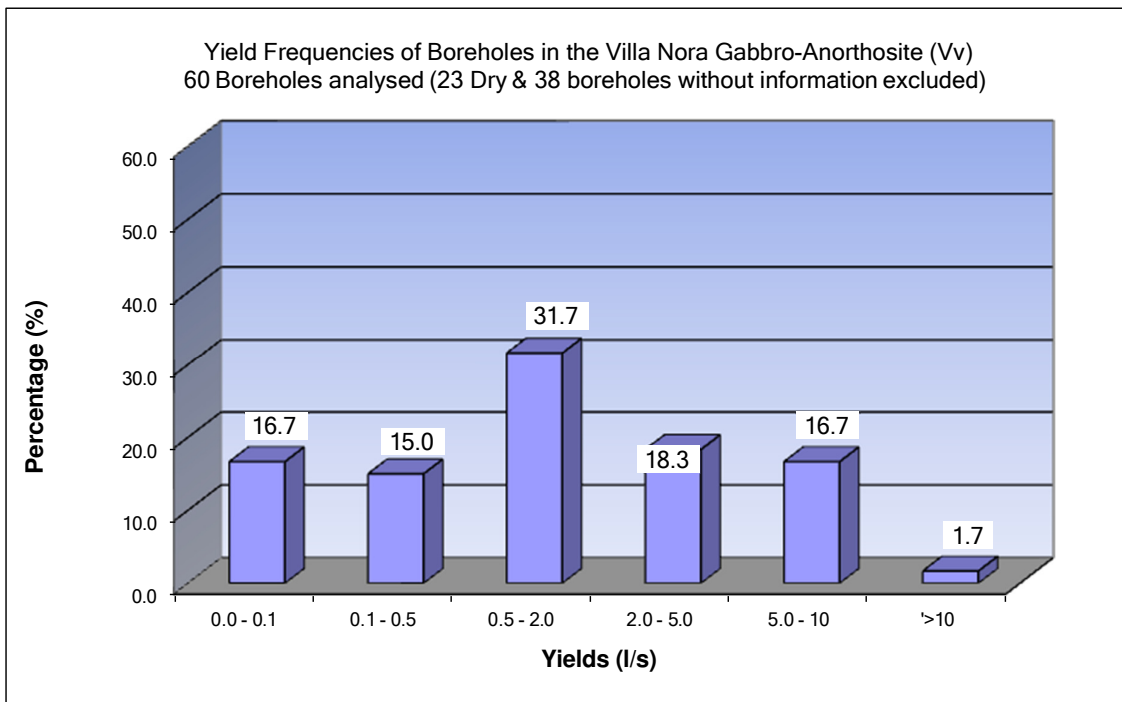


Figure 73: Yield frequency for the intergranular and fractured aquifers of the Villa Nora Gabbro-Anorthosite (Vv).

The statistical analysis of 60 borehole records, (Figure 73) reveals the following distribution of borehole yields:

- 31.7% of the successful boreholes yield between 0.001ℓ/s and 0.5ℓ/s, thus suitable for small households.
- 31.7% have yields between 0.5ℓ/s and 2ℓ/s.
- 18.3% yield between 2ℓ/s and 5ℓ/s.
- 18.4% have yields exceeding 5ℓ/s, of which only 1.7% report maximum yields greater than 10ℓ/s.

The static water levels range from 1.25 meters below ground level (mbgl) to 23.7mbgl, with a median of 8.78mbgl and an average static water level of 9.69mbgl (based on 20 data points). The maximum depth recorded is 217m, with an average depth of 52.5m and a median depth of 41.9m (24 data points). The maximum installation depth is 55m, with an average of 32.2m (12 data points). Comparing the depth of installation to average borehole depth and static water levels can provide insights into water strike depths.

The maximum recommended daily abstraction on record is 345.6 cubic meters per day (m<sup>3</sup>/day), with an average of 100.9m<sup>3</sup>/day, the 90th percentile for daily abstraction is 245.7m<sup>3</sup>/day, and the 80th percentile is 191.8m<sup>3</sup>/day. The total number of boreholes subjected to pump testing in this unit on record is 20.

The above statistics are for the outcrop that spans the cross-boundary occurrence, (the central-west portion of the Polokwane map sheet and the central-east portion of the Lephalale map sheet). As a result, both data sets were used for the characterization. Notably, 100% of the chemical analysis and 88.5% of the yield data fall within the Polokwane map area."

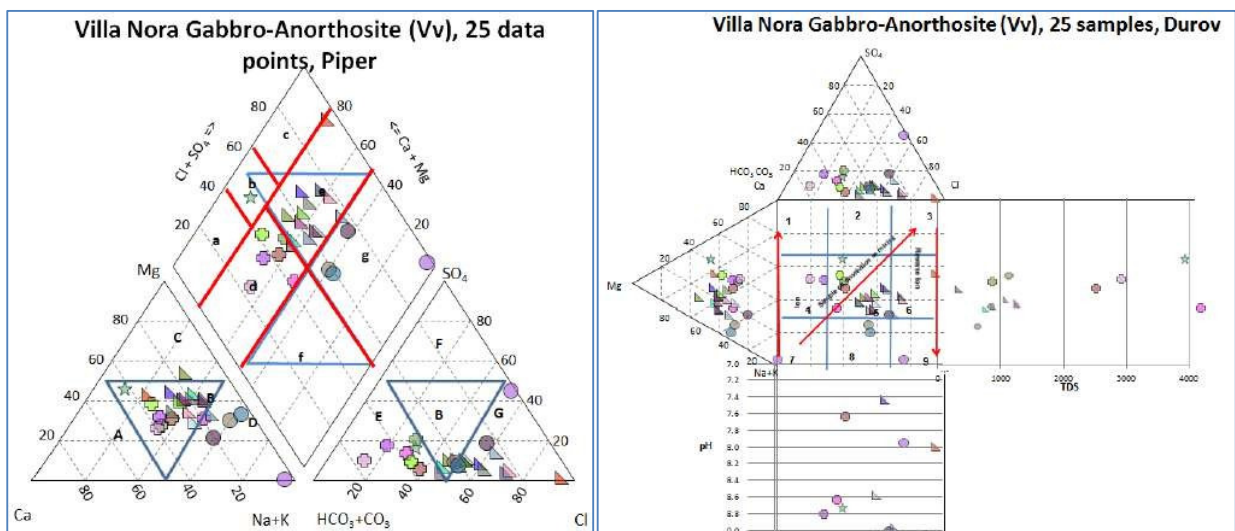


Figure 74: Trilinear diagrams, Piper and Durov for the Villa Nora Gabbro-Anorthosite (Vv).

The trilinear Piper diagram, (Figure 74) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (84%), Weak acidic anions > Strong acidic anions (26%); Alkali > Alkali earths (16%); Strong acids > Weak acids (74%).

The groundwater in this unit classifies as:

- Mixed Calcium-Magnesium-Chloride type (32%);
- Mixed Calcium-Magnesium-Bicarbonate type (28%);
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type (20%);
- Sodium-Chloride type (16%);
- Magnesium-Bicarbonate-Chloride type (4%);

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- No dominant anion or cation, indicates water exhibiting simple dissolution or mixing (60%), plot along the dissolution or mixing line,
- Anion discriminate and Na dominant, indicates probable mixing or uncommon dissolution influences (12%),
- Cl is the dominant anion and Na the dominant cation, indicative that the groundwater relates to reverse ion exchange of Na-Cl waters (12%),
- Anion discriminant and Ca dominant, mixed water or water exhibiting simple dissolution. (8%),
- Cl and Na dominant, reverse ion exchange of Na-Cl waters (4%),
- Cl and Na dominant, frequently indicative of end-point gradient waters through Dissolution (4%),
- Some samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 60: Chemical statistics for the Villa Nora Gabbro-Anorthosite (Vv).

Element / Parameter	Statistics Drawn from a population of 34 data points for the Villa Nora Gabbro (Vv).									
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation
pH	34	7.20	8.91	8.02	8.04	7.49	8.06	8.51	0.38	4.7%
Electrical Conductivity (mS/m EC)	34	21.1	703.0	117.3	164.9	83.6	154.7	224.8	111.7	67.7%
Total Dissolved Salts (mg/l TDS)	32	134.1	4072.0	829.6	1161.9	672.7	1121.0	1560.7	657.7	56.6%
Calcium (mg/l Ca)	33	10.8	511.6	45.4	80.6	24.8	70.9	109.8	83.7	103.7%
Magnesium (mg/l Mg)	33	1.30	388.80	21.93	74.31	24.29	62.20	105.80	65.39	88.0%
Sodium (mg/l Na)	33	13.3	397.0	91.4	154.2	58.2	149.8	270.8	89.9	58.3%
Potassium (mg/l K)	33	0.15	7.48	1.22	2.71	0.81	2.05	5.84	2.09	77.1%
Chloride (mg/l Cl)	34	12.1	2226.9	85.7	256.4	42.9	165.4	445.1	377.8	147.3%
Sulphate (mg/l SO <sub>4</sub> )	34	10.92	394.40	34.22	65.04	19.99	37.34	122.00	85.91	132.1%
Total Alkalinity (mg/l CaCO <sub>3</sub> )	29	35.9	533.9	239.7	346.2	263.5	349.6	470.0	110.1	31.8%
Nitrate (mg/l N)	33	0.04	95.00	1.08	27.81	1.84	25.48	48.01	20.81	74.8%
Fluoride (mg/l F)	33	0.14	3.58	0.55	0.94	0.36	0.60	1.78	0.84	89.3%
Silicon as Si	31	10.42	46.75	30.13	33.77	24.77	36.66	40.23	8.34	24.7%
Iron (Fe)	11	0.005	0.266	0.014	0.049	0.006	0.023	0.050	0.07	152.9%
Manganese (Mn)	24	0.001	0.210	0.002	0.019	0.001	0.002	0.049	0.04	230.5%
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	29	0.009	0.800	0.020	0.071	0.011	0.023	0.126	0.16	221.5%
ZAR	33	0.56	27.74	2.26	3.66	1.53	3.03	5.12	4.51	123.1%
LSI	28	Langelier Saturation Index (LSI)		Slightly Scaling		78.6%		Highly Scaling		0.0%
		Highly corrosive		0.0%		Slightly corrosive		7.1%		Balanced Corrosion

Table 60 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality is ideal to good (47.1%), marginal (50%) and unacceptable in 2.9% of the analysis in terms of the Electrical conductivity (EC) with values ranging between 21.1 and 703mS/m. The 90<sup>th</sup> percentile is 224.8mS/m.

The Total Dissolved Solids (TDS) is acceptable in 62.5% of the samples, (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 34 samples indicates elevated concentrations of Nitrate (N >20mg/l) in 66.7%; Fluoride (F >1.5mg/l) in 12.1%; Chloride (Cl > 600mg/l) in 5.9%; Calcium (Ca > 300) in 3% and Magnesium (Mg > 200mg/l) in 3% of the analysis.

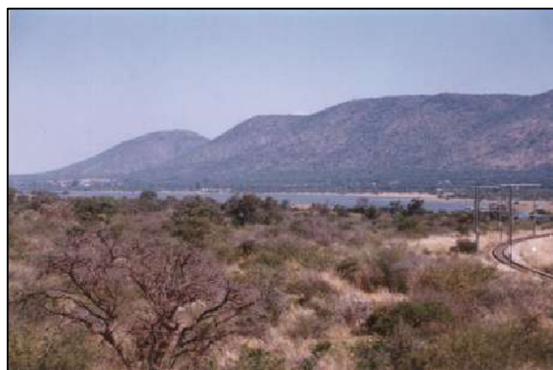
The Langelier Saturation Index (LSI) indicates that the water is predominantly slightly scaling (78.6%); slightly corrosive (7.1%) and balanced (14.3%). The ZAR index indicates that 45.5% of the water is of a fair quality for irrigation (ZAR < 3).

Land use in the unit consists of approximately 3 rural villages and some livestock and game farms. Water supply for the villages is from regional water supply schemes that is a combination of surface water from the Lephala River and boreholes. The game farms and other livestock farming are dependable on groundwater resources.

### 7.2.3.7

### UNDIFFERENTIATED RUSTENBURG LAYERED SUITE (Vrs)

The mafic rocks of the Bushveld Complex constitute the most voluminous preserved mafic, layered intrusion in the world. They underlie an area of 65,000km<sup>2</sup>, from Zeerust in the west to Burgersfort in the east and from Bethal in the south to Villa Nora in the north. The maximum vertical thickness of the layered rocks approaches 8 km. Some individual layers can be traced for over 150 km along strike. The world's largest ore reserves of platinum-group elements, chromium, and vanadium are being exploited in this intrusion. The associated felsic volcanic rocks are also among the most voluminous known. The various units and limbs of the Bushveld Complex are generally tabular and emplaced slightly discordantly to the Pretoria Group of the Transvaal Supergroup. The Bushveld Complex forms two large occurrences: one situated in the Villa Nora area and another east of the main Waterberg outcrop zone, which trends north to south and is known as the Northern or Potgietersrus limb. Some aspects of the northern limb are discussed under the heading Malmani Subgroup. The Villa Nora occurrence is described in this document as a separate groundwater unit (Villa Nora Gabbro-Anorthosite, Vv). The Complex has been divided into a mafic portion termed the Rustenburg Layered Suite and a felsic portion represented by the Rashoop Granophyre and Lebowa Granite Suites. The Rashoop Granophyre Suite is genetically related to the volcanic rocks of the Rooiberg Group (Walraven, 1982). It covers approximately 0.75% of the total map area.



*Plate 10: Western view of the Nyl River near Moorddrift 289 KR. The mountains in the background comprise of Bushveld Granite with gabbro of the Rustenburg Layered Suite in the foreground (Photograph: WH du Toit).*



*Plate 11: Calcrete veins crisscrossing through mafic rocks of the Rustenburg Layered Suite in a road cutting between Chuniespoort and Burgersfort (Photograph: WH du Toit).*



*Plate 12: Eastern view of the Critical Zone of the Rustenburg Layered Suite outcropping in the foreground with the Pretoria Group dominating the background (Photograph: WH du Toit).*

The yield frequency diagram, (Figure 76), gives an indication of the expected yield of the boreholes. It shows that 59.6% of the successful boreholes yield less than 2l/s and 40.4% yield more than 2l/s.

In 29.4% of the water samples at least one element exceeds the maximum allowed limit for domestic use. In this unit Nitrate is the most problematic anion followed by Fluoride and then Chloride. Magnesium is the most problematic cation followed by Sodium and Calcium.

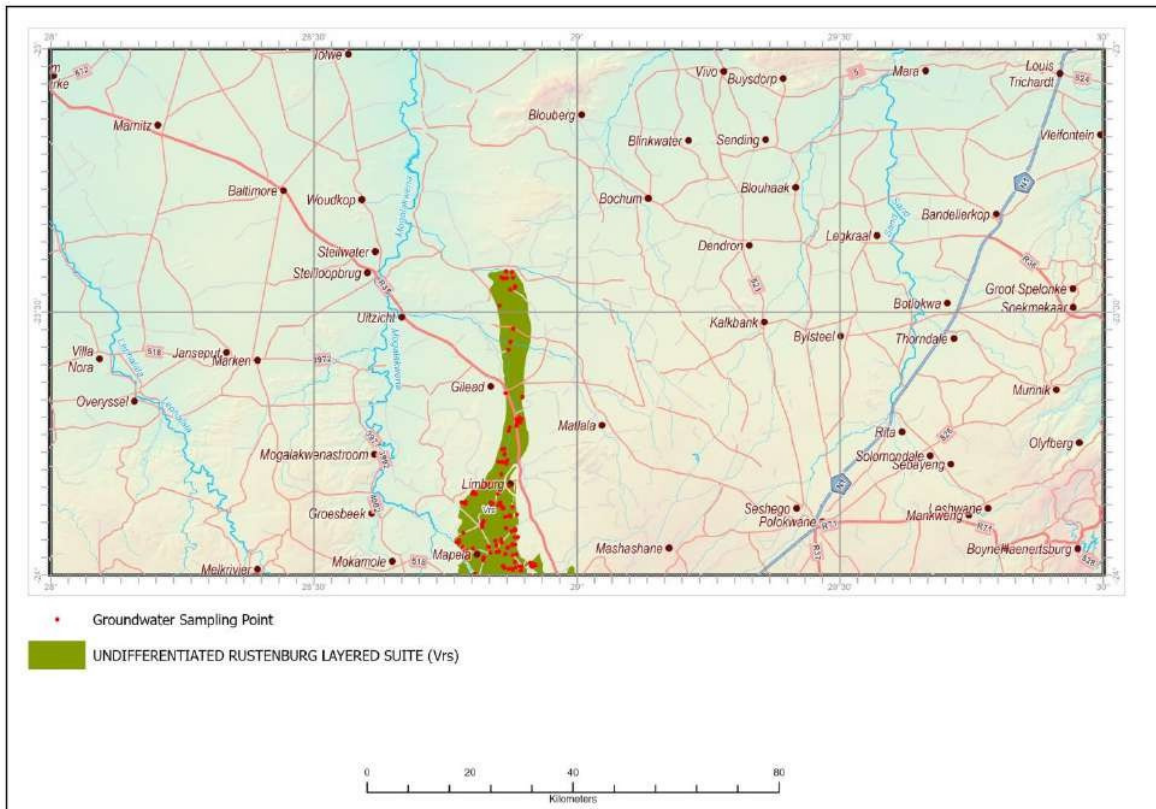


Figure 75: Geographical distribution of the Undifferentiated Rustenburg Layered Suite (Vrs) and the associated groundwater data points.

The currently accepted subdivisions and nomenclature of the Rustenburg Layered Suite show that it comprises five zones, all intrusive above the Rooiberg volcanic rocks:

- **Upper Zone:** Sub-Zone C: Diorite; Sub-Zone B: Gabbronorite; Sub-Zone A: Gabbronorite. The Molendraai Formation represents the Upper Zone.
- **Main Zone:** Upper Sub-Main Zone; Lower Sub-Main Zone. The Mapela Formation represents the Main Zone.
- **Critical Zone:** Upper Subdivision: Norite, Anorthosite, Pyroxenite; Lower Subdivision: Pyroxenite.
- **Lower Zone:** Upper Pyroxenite Subzone; Harzburgite Subzone; Lower Pyroxenite Subzone.
- **Marginal Zone:** Norite.

(Source: The South African Geology, 2006, edited by Johnson M.R., Anhaeusser C.R., and Thomas R.J.)

In the western and far western limbs, the Rustenburg Layered Suite is generally concordant with the Magaliesberg Formation. In the eastern limb, emplacement occurred at the same stratigraphic level north of Steelpoort, but further south the intrusion transgressed upwards. Near Stoffberg, the upper part of the Pretoria Group and the Dullstroom Formation are preserved beneath the layered suite, and predominantly felsic volcanic rocks occur in the roof, (Button, 1976). In the northern limb, emplacement occurred at the level of the Magaliesberg Formation south of Mokopane (Potgietersrus), but the contact transgresses

downward when traced to the north, such that ultimately the mafic rocks adjoin against Archaean granitic gneiss (White, 1994).

The groundwater potential is generally good, with 40.3% of successful boreholes yielding more than 2l/s, (Figure 76). In the Mokopane (Potgietersrus) area, groundwater occurs in deeply weathered and fractured mafic rocks. Due to the relatively high permeability of the weathered and fractured rock, these basins can form extremely good aquifers. Water is also obtained in fault and associated shear or fracture zones, contact zones, and dyke contacts.

As part of the hydrogeological baseline study done by Golder Associates Africa (Pty) Ltd in 2012 for Platreef Mine, 41 boreholes were drilled targeting various geological features in the Rustenburg Layered Suite. Although the study is predominantly in the section of the northern limb that falls just to the south of the Polokwane map sheet boundary the findings are relevant for the unit when employing a scientific approach for groundwater studies. The findings were as follows:

- Drilling depths range from 44m to 200m and final air-lift yields ranging from 0.1l/s to 13l/s,
- Ten boreholes have significant air-lift yields (> 5l/s), mainly associated with near surface (< 45mbgl) fractured norite bedrock and occurrence of granite inclusions in the western part of the RLS,
- Weathering depths range from 5m to 45m, i.e., representing a fractured and weathered aquifer type,
- Groundwater mostly occurs in weathered and fractured bedrock at shallow depth (<45mbgl),
- Water interceptions in the weathered bedrock aquifer range from 12m to 20m, yielding 0.1l/s to 1.0l/s,
- Water interceptions in the near surface fractured bedrock (20mbgl to 42mbgl), underlying the weathered aquifer yield 1.0l/s to 13l/s,
- Water strikes in fractured bedrock at depth (>45mbgl) are minor and range from 0.1l/s to 0.2l/s, and
- Water strikes at RLS/ Macalacaskop dyke contact zones ranged from 1.0l/s to 2l/s at depths <45mbgl.

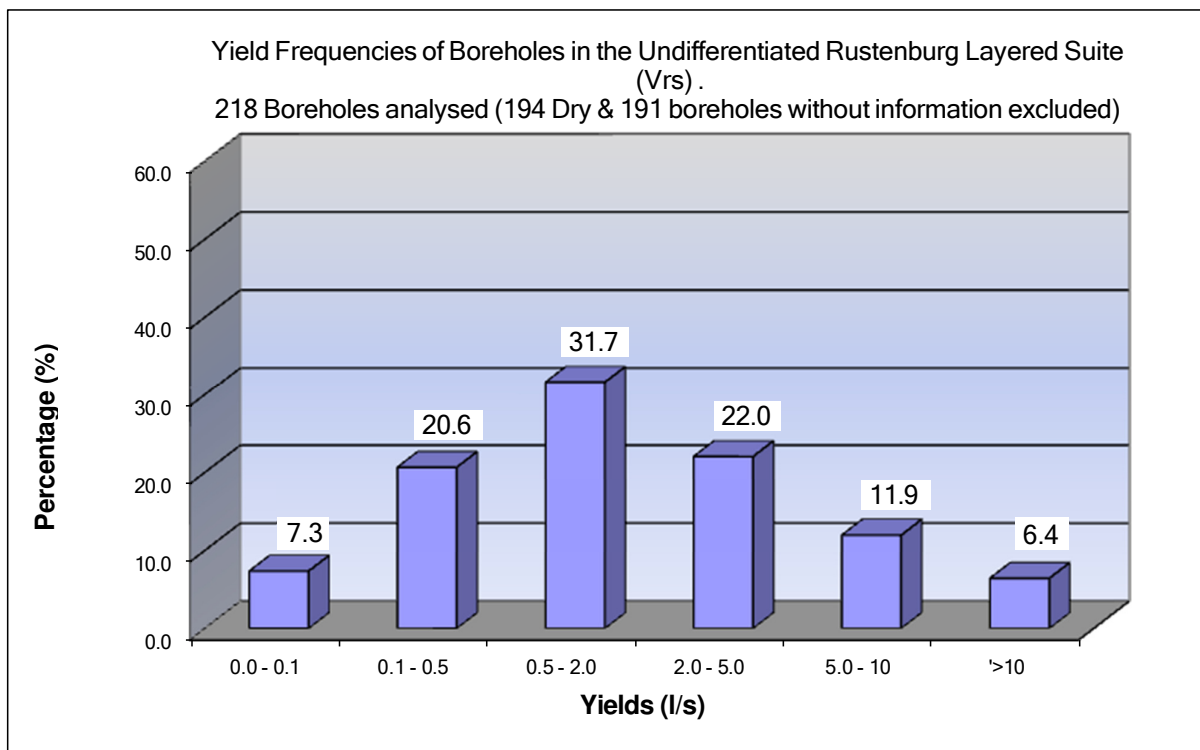


Figure 76: Yield frequency for the intergranular and fractured aquifers of the Undifferentiated Rustenburg Layered Suite (Vrs).

The statistical analysis of 218 borehole records, (Figure 76) indicates that 27.9% of the successful boreholes' yields are suitable for small households (>0.001l/s to 0.5l/s). A further 31.7% of the boreholes

have yields between 0.5l/s and 2l/s, with 22% between 2l/s and 5l/s and 18.3% of the boreholes yielding more than 5l/s.

The static water level ranges from 0.18 meters below ground level (mbgl) to 34.5mbgl, with a median of 14.8mbgl and an average of 16.23mbgl (based on 169 data points). The maximum depth recorded is 236m, the average depth is 59.9m and the median depth is 58.4m (261 data points). The maximum installation depth is 64.5m, with an average installation depth of 31.7m, (138 data points). The depth of installation can be indicative of water strike depths if compared to the average depth and static water levels of the boreholes.

The maximum recommended daily abstraction on record is 691.2 cubic meters per day (m<sup>3</sup>/day), with an average abstraction of 81.3m<sup>3</sup>/day. The 90th percentile of the daily abstraction is 198.7m<sup>3</sup>/day and the 80th percentile is 112.3m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 141.

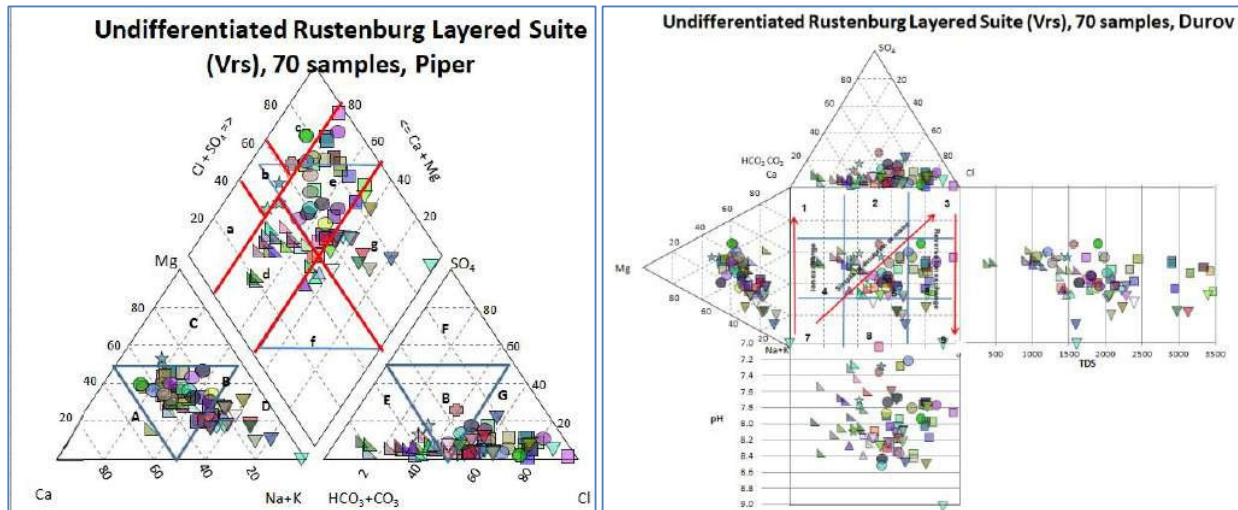


Figure 77: Trilinear diagrams, Piper and Durov for the Undifferentiated Rustenburg Layered Suite (Vrs).

The trilinear Piper diagram, (Figure 77) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (76%), Weak acidic anions > Strong acidic anions (32%); Alkali > Alkali earths (24%); Strong acids > Weak acids (68%).

The second evaluation was on the water type:

- Mixed Calcium-Magnesium-Chloride type (42.9%),
- Mixed-Calcium-Magnesium-Bicarbonate type (28.6%),
- Sodium-Chloride type (20%),
- Sodium-Bicarbonate type (5.7%),
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type (1.4%),
- Magnesium-Chloride type (1.4%),

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- No dominant anion or cation indicates fresh recent recharge water exhibiting simple dissolution or mixing (70.7%), points plot along the dissolution or mixing line,
- Anion discriminates and Na dominant, indicates probable mixing or uncommon dissolution influences (14.7%),
- Anion discriminant and Ca dominant, mixed water or water exhibiting simple dissolution. (6.7),
- Cl is the dominant anion and Na the dominant cation, indicative that the groundwater relates to reverse ion exchange of Na-Cl waters (5.3%),
- Cl and Na dominant is indicating end-point gradient water through dissolution (2.7%),

- The high TDS is some of the samples that may be indicative of long residence times in the aquifer allowing reactions to be fairly complete.

Table 61: Chemical statistics for the Undifferentiated Rustenburg Layered Suite (Vrs).

Element / Parameter	Statistics Drawn from a population of 146 data points for the Undifferentiated Rustenburg Layered Suite (Vrs)										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	143	6.98	9.02	7.81	7.83	7.24	7.84	8.35	0.42	5.3%	
Electrical Conductivity (mS/m EC)	143	22.4	757.0	126.0	164.0	85.0	150.0	263.0	93.2	56.8%	
Total Dissolved Salts (mg/l TDS)	142	7.4	4920.5	485.9	1116.1	565.9	1023.6	1639.8	601.2	53.9%	
Calcium (mg/l Ca)	140	4.61	402.00	62.90	90.40	43.47	78.20	152.00	53.26	58.9%	
Magnesium (mg/l Mg)	140	0.56	254.80	26.64	69.07	27.12	57.75	134.72	49.25	71.3%	
Sodium (mg/l Na)	140	1.99	725.00	68.85	149.74	46.70	124.10	289.54	105.87	70.7%	
Potassium (mg/l K)	140	0.10	56.45	2.73	6.52	1.53	5.27	11.33	6.35	97.3%	
Chloride (mg/l Cl)	143	6.39	1730.00	83.51	237.49	46.79	177.94	518.24	238.05	100.2%	
Sulphate (mg/l SO <sub>4</sub> )	143	3.45	403.00	23.38	60.67	10.95	36.08	114.85	67.25	110.9%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	117	27.90	772.11	284.17	364.75	229.30	359.00	504.98	128.51	35.2%	
Nitrate (mg/l N)	143	0.02	73.44	0.71	16.14	0.89	11.76	34.96	14.83	91.9%	
Fluoride (mg/l F)	140	0.05	6.36	0.34	0.79	0.16	0.47	1.54	0.92	116.5%	
Silicon as Si	120	0.98	62.40	20.30	32.18	22.03	34.09	39.73	9.66	30.0%	
Iron (Fe)	62	0.005	0.900	0.012	0.044	0.007	0.011	0.050	0.13	287.4%	
Manganese (Mn)	33	0.006	0.629	0.011	0.043	0.008	0.010	0.095	0.11	256.4%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	112	0.000	1.020	0.018	0.053	0.009	0.023	0.054	0.14	269.5%	
ZAR	140	0.05	33.83	1.49	3.34	0.93	2.27	5.77	3.57	106.8%	
LSI	119	Langelier Saturation Index (LSI)			Slightly Scaling		71.4%		Highly Scaling		0.0%
		Highly corrosive		0.0%	Slightly corrosive		0.0%	Balanced Corrosion		28.6%	

Table 61 provides a summary of the physical properties, major anions, cations, as well as some minor elements in the groundwater samples. Where the coefficient of variation exceeds 100%, the 90th percentile, maximum value, and standard deviation are useful indicators of potential issues.

In terms of electrical conductivity (EC), the water quality is ideal to good (49.7%); marginal (46.2%) and unacceptable in 4.2% of the samples; it varies between 22.4 and 757mS/m. The 90<sup>th</sup> percentile is 263mS/m. The Total Dissolved Solids (TDS) is acceptable in 66.2% of the samples (TDS ≤ 1200mg/l).

The evaluation of the major cations and anions in 146 samples indicates elevated concentrations of Nitrate (N >20mg/l) in 29.4%; Fluoride (F >1.5mg/l) in 10.7%; Chloride (Cl > 600mg/l) in 5.6%; Magnesium (Mg > 200mg/l) in 4.3%; Calcium (Ca > 300) in 1.4% and Sodium (Na > 400mg/l) in 1.4% of the samples.

The Langelier Saturation Index (LSI) indicates that the water is predominantly slightly scaling (71.4%) and balanced (28.6%) of the analysis. The ZAR index indicates that 57.1% of the water is of a fair quality for irrigation (ZAR < 3).

The unit supports a mix of economic activities including Platinum mines, rural villages and farms. The rural villages obtain groundwater from within the unit as well as from outside the unit.

### 7.2.3.8 UNDIFFERENTIATED PRETORIA GROUP (Vpg)

The Undifferentiated Pretoria Group of the Transvaal Supergroup appears on the western side of the map close to the Lephalale boundary as two small elongated polygons caught up between granite in the south and the Villa Nora Gabbro-Anorthosite in the north, (Figure 78). The unit constitute approximately 0.03% of the total map area. The rocks on either side of the unit represent the felsic and the mafic phase of the Bushveld Igneous Complex (BIC). The average width of the unit is 400m to 500m and consists of metamorphic rock types, viz. quartzite, hornfels and marble.

The geological processes (metamorphism) and setting (sedimentary and carbonate rich rocks that represent the older floor and intruded by rocks of the BIC) for this unit is similar to conditions along the northern limb of the BIC. Along sections of the northern limb, the contact between rocks of the Transvaal Supergroup, (sedimentary and carbonate rich rocks) and rocks of the Rustenburg Layered Suite, (mafic to ultra mafic rocks), alterations of the original rocks occur due to contact metamorphism. Detailed studies that included core drilling were done in the Mokopane area for the platinum mines and the findings regarding the alteration of the original rock may apply to the unit near Villa Nora.

The findings were as follows: Metamorphism related to the Bushveld Igneous Complex (BIC) influenced rocks of the Transvaal Supergroup (Pretoria and Chuniespoort Groups) along the contact with the northern limb of the BIC. Along this contact the zone between the sedimentary and intrusive rocks varies from sharp to transitional. Intercalated zones of sedimentary rocks and magmatic units persist over centimeters to hundreds of meters. The degree of metamorphism, metasomatism and/or melting of the assimilated sedimentary clasts varies according to the sedimentary rock type and the magmatic unit that intruded into the sediment. Lithological variants in the 'Footwall Assimilation Zone' includes intensely metamorphosed, dolomitic (now calc-silicate and marble) and alumino-silicate (now hornfels), (Grobler, et al. 2018).

The quartzite occurring within Undifferentiated Pretoria Group unit is fine-to coarse-grained and varies in colour from white to brown to bluish. Occasionally, it contains clinopyroxene, hornblende, biotite, chlorite, and magnetite as accessory minerals. Where metamorphism has occurred due to the heat of the Bushveld Complex, the water-bearing properties of the unit may be reduced.

Hornfels are usually very hard, equigranular, and homogeneous, with limited fractures and joints, making them poor aquifers. Marble typically lacks internal layering or bedding, forming large, solid masses that appear homogeneous; as a result, it is also not considered a good aquifer. The water-bearing properties of quartzite depend on fracturing. It can serve as a good aquifer when highly fractured; however, when subjected to contact metamorphism, quartzite can recrystallize into a homogeneous, fine-grained, massive rock, thereby losing pre-existing bedding planes.

Overall, the Pretoria Group has been classified as both intergranular and fractured. In addition, on adjacent maps, it has been intruded on a large scale by diabase in the form of sills and dykes. These diabase intrusions can significantly influence groundwater occurrence.

For the Undifferentiated Pretoria Group groundwater resource unit insufficient data was available for an accurate assessment of the groundwater character.



*Plate 13: A beautiful example of a fault cutting through sediments of the Pretoria Group. Faults are generally good targets for groundwater exploration in Limpopo but can also under certain circumstances act as impermeable barriers to groundwater flow (Photograph: WH du Toit).*

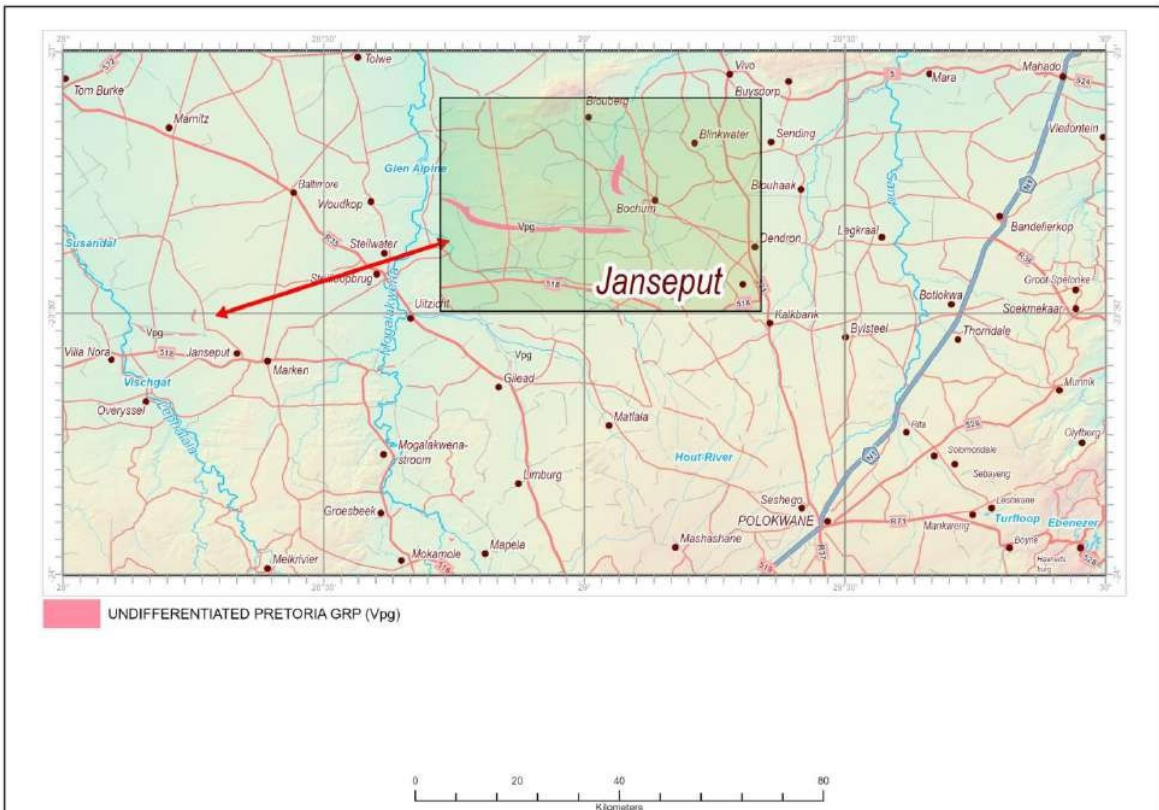


Figure 78: Geographical distribution of the Undifferentiated Pretoria Group (Vpg).

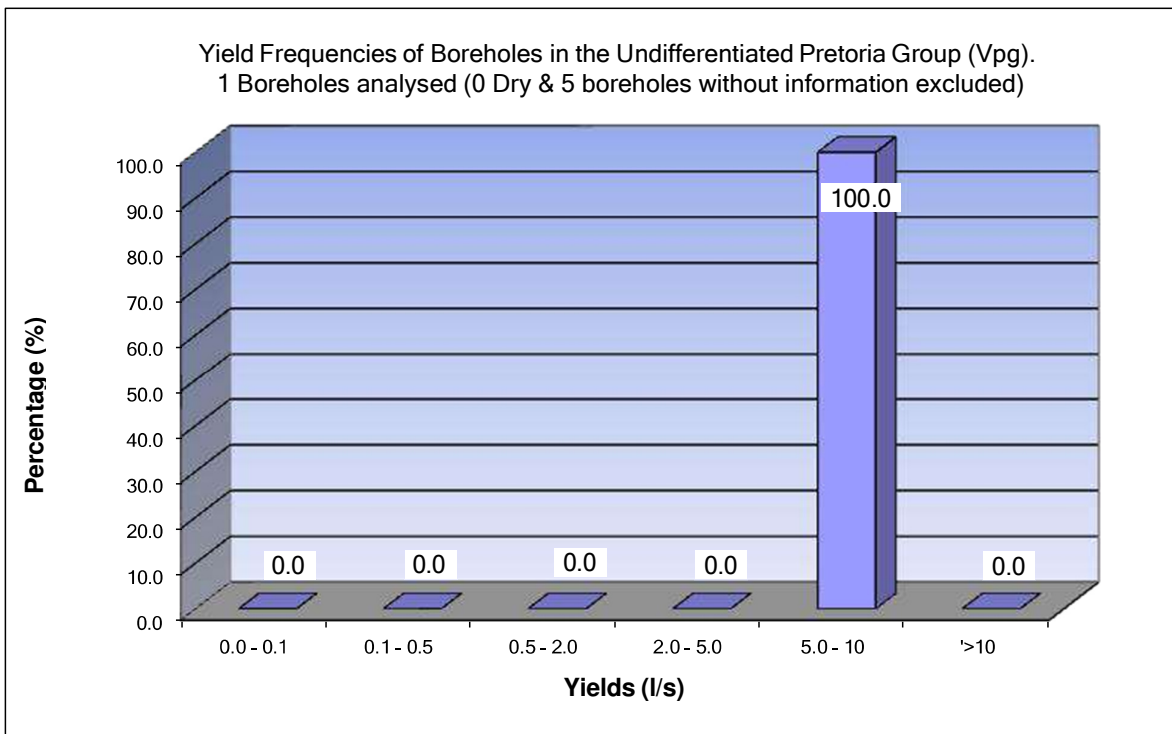


Figure 79: Yield frequency for the fractured aquifers of the Undifferentiated Pretoria Group (Vpg).

Only a single borehole record is available with data, the information available is as follows; the static water level is 1.76 meters below ground level (mbgl); the depth of the borehole is 7m and the available recommended abstraction is 129.6 cubic meters per day (m<sup>3</sup>/day). The borehole is located next to the Lephala River, and the high yield may relate to alluvial deposits.

### **7.2.3.9 MATLALA GRANITE (Vml)**

The Matlala Granite, an intrusive batholith within the Hout River Gneiss, is located approximately 45 km northwest of Polokwane. It occurs as a roughly circular outcrop covering an area of approximately 268 km<sup>2</sup>, which represents about 1.19% of the map area, (Figure 80). The outcrop coincides with rugged mountainous terrain, rising some 600m above the surrounding planes.

The Matlala Granite varies in colour from light grey to pink and red, and in grain size from fine to coarse porphyritic (Brandl, 1986). Van Wyk (1977) identified eight varieties, with the most widespread being a grey and pink, fine-grained biotitic rock of granodioritic composition.

The contact relationships between the Matlala Granite and the surrounding host rocks were investigated as part of a research project conducted by the Department of Water Affairs (DWA), (Du Toit, 2001). Supported by drilling and geochemical data, the study suggests that the Matlala batholith actually consists of three separate intrusions. These intrusions, although mapped as a single unit on the published geological map (Sheet 2328), have been locally named by Du Toit (2001) as:

- Matlala Granite - the largest and most extensive body,
- Tibane Granite - located immediately north of the main Matlala outcrop, and
- Chloe Granite - a dyke-like feature situated northeast of the Matlala body.

In this document the three granitic intrusions are grouped together and discussed as the Matlala Granite groundwater resource unit.

The yield frequency diagram, (Figure 81), gives an indication of the expected yield of the boreholes drilled into the Matlala Granite. It shows that 68.8% of the successful boreholes yield less than 2ℓ/s and 31.3% yield more than 2ℓ/s.

In terms of groundwater chemistry, 34.7% of the water samples have one element that exceeds the maximum allowed limits for domestic use. For this unit, the anions of concern are Fluoride followed by a high percentage (31.4%) of the sources with elevated Nitrate concentrations that exceeds the maximum allowable limit for domestic use.

Similar to the Moletsi Granite, drilling results suggest the Matlala Granite to have the characteristics of a weathered and fractured, semi-confined to confined aquifer. It also varies in saturated thickness from 1m to 70m (confirmed by drilling) along the different geophysical traverses surveyed across the contact. Well-fractured remnant roof sections appear to be the most important host of the aquifer in the area, whereas the contact between the granite and the host rock, (Hout River Gneiss), itself has been indicated by drilling as poor targets for groundwater exploration. Water is mostly intercepted in the transitional zone between the weathered and solid rock. Diabase dyke contacts were also finding to be potential targets but due to limited storage may not be sustainable during periods of low recharge.

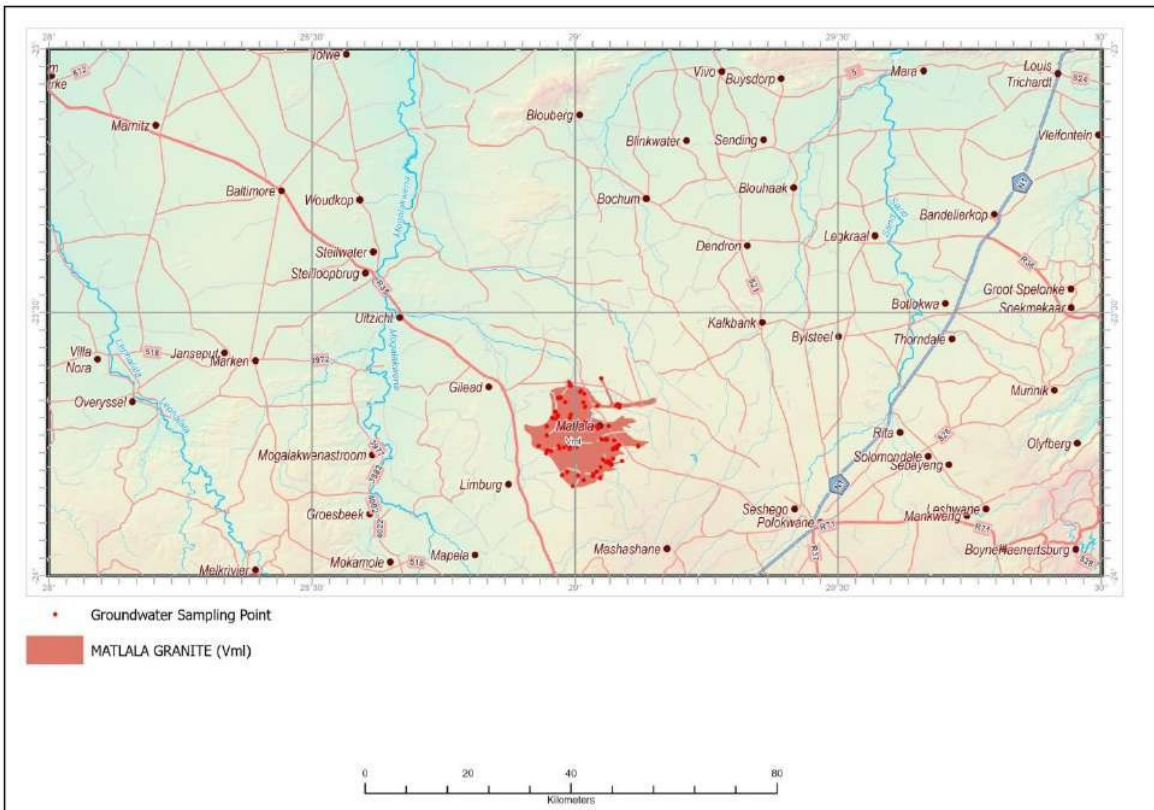


Figure 80: Geographical distribution of the Matlala Granite (Vml) and the associated groundwater data points.

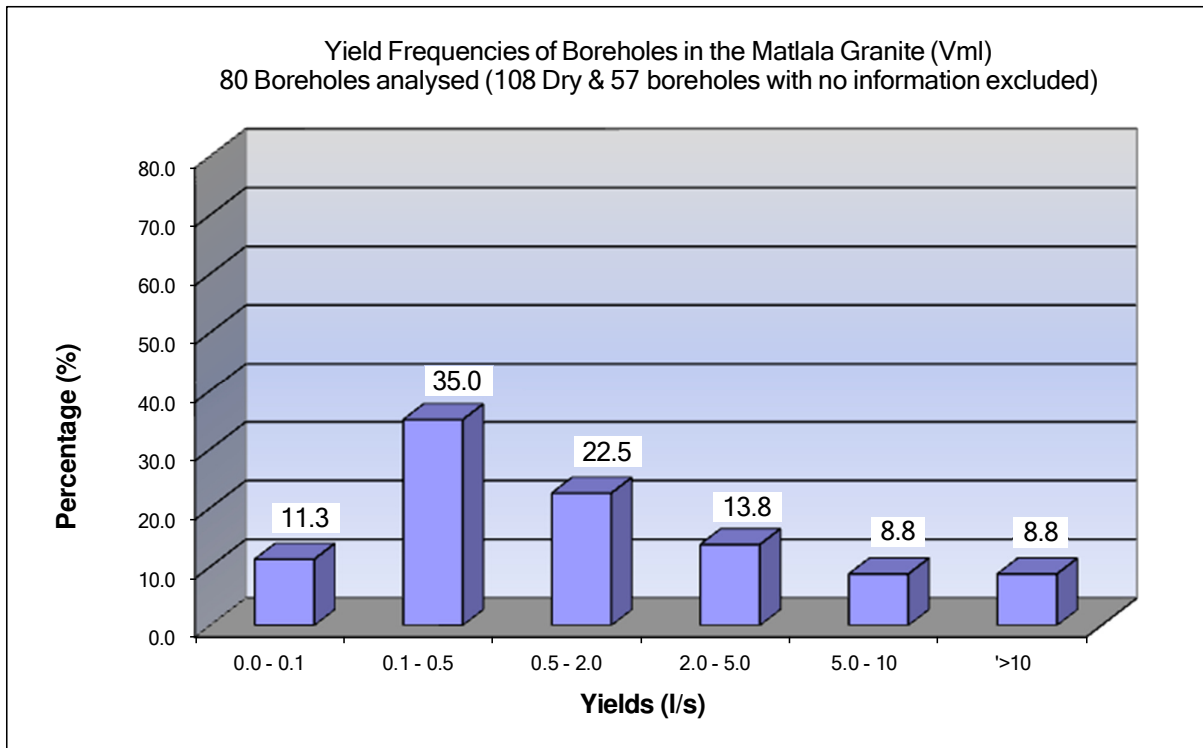


Figure 81: Yield frequency for fractured aquifers of the Matlala Granite (Vml).

The statistical analysis of 80 borehole records, (Figure 81) indicates that 46.3% of the successful borehole's yields are suitable for small households (>0.001ℓ/s to 0.5ℓ/s). Additionally, 22.5% of the boreholes have yields between 0.5ℓ/s and 2ℓ/s, with 13.8% of the boreholes yielding between 2ℓ/s and 5ℓ/s and 17.6% yielding more than 5ℓ/s.

The static water level ranges from 1.26 meters below ground level (mbgl) to 49.96mbgl, with a median of 8.21mbgl and an average of 10.80mbgl (based on 74 data points). The maximum depth recorded is 204m, with an average of 75.8m and a median depth of 68.8m (154 data points). The maximum installation depth is 80m and the average is 34m, (62 data points). The depth of installation can be indicative of water strike depths if compared to the average depth and static water levels of the boreholes.

The maximum recommended daily abstraction on record is 432 cubic meters per day (m<sup>3</sup>/day) and the average is 68.9m<sup>3</sup>/day. The 90th percentile for daily abstraction is 172.8m<sup>3</sup>/day and the 80th percentile is 101.9m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 62.

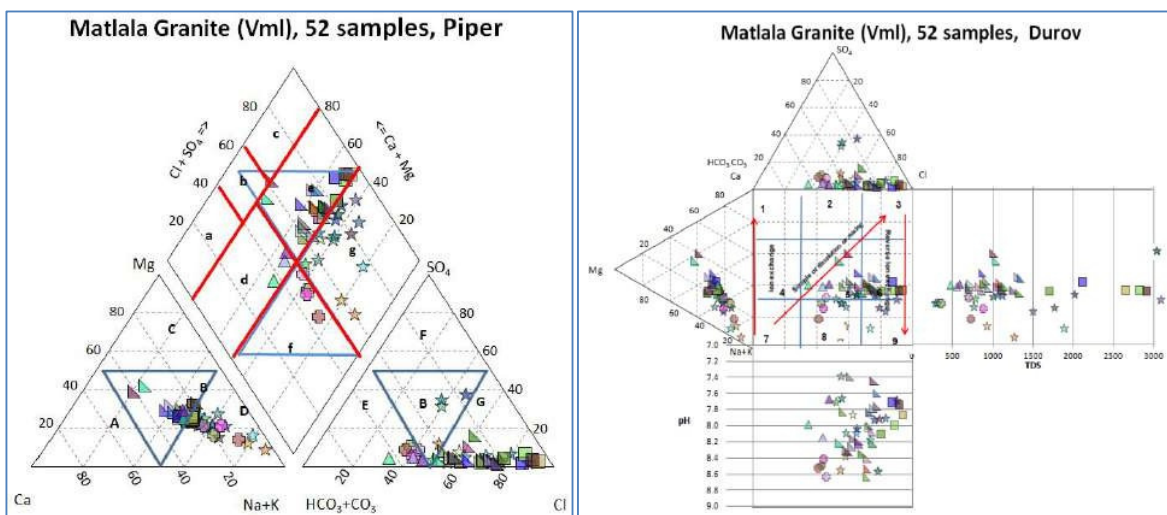


Figure 82: Trilinear diagrams, Piper, and Durov for the Matlala Granite (Vml) data points.

The trilinear Piper diagram, (Figure 82) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (57.7%), Weak acidic anions > Strong acidic anions (19.2%); Alkali > Alkali earths (42.3%); Strong acids > Weak acids (80.8%).

The groundwater in this unit classifies as:

- Mixed Calcium-Magnesium-Chloride type with increased Sodium (51.8%);
- Sodium-Chloride type (23.1%),
- Sodium-Bicarbonate type (13.5%);
- Mixed Calcium-Magnesium-Bicarbonate type with increased Sodium (5.8%);
- Sodium-Bicarbonate-Chloride type with prevailing Sulphate (5.8%).

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- No dominant anion or cation indicates water exhibiting simple dissolution or mixing (32.7%), plot along the dissolution or mixing line,
- Anion discriminate and Na dominant, indicate probable mixing or uncommon dissolution influences (26.9%),
- Cl is the dominant anion and Na the dominant cation, indicative that the groundwater is related to reverse ion exchange of Na-Cl waters (19.2%),
- Cl and Na dominant, frequently indicative of end-point gradient waters through Dissolution (15.4%).

- Cl and Na dominant, reverse ion exchange of Na-Cl waters (5.8%),
- Some samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 62: Chemical statistics for the Matlala Granite (Vml).

Element / Parameter	Statistics Drawn from a population of 103 data points for the Matlala Granite (Vml).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	102	6.69	8.64	7.97	7.99	7.49	8.06	8.48	0.40	5.0%	
Electrical Conductivity (mS/m EC)	102	39.2	587.4	116.7	167.5	63.8	129.9	314.1	112.1	66.9%	
Total Dissolved Salts (mg/l TDS)	102	289.2	4114.1	842.2	1130.5	520.9	924.1	2080.3	692.7	61.3%	
Calcium (mg/l Ca)	102	10.4	342.7	47.0	77.0	25.4	62.6	153.6	57.8	75.2%	
Magnesium (mg/l Mg)	102	7.75	221.19	34.07	53.47	19.03	44.59	98.02	41.89	78.3%	
Sodium (mg/l Na)	101	36.1	696.7	123.8	184.5	70.8	144.8	360.4	129.1	0.7	
Potassium (mg/l K)	102	0.90	80.61	5.29	8.91	3.41	6.69	15.77	9.23	103.6%	
Chloride (mg/l Cl)	102	9.50	1912.1	90.9	288.8	35.8	192.6	628.7	351.8	1.2	
Sulphate (mg/l SO <sub>4</sub> )	101	1.56	398.20	16.20	41.42	9.18	23.60	82.58	57.42	138.6%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	95	87.2	628.7	275.0	309.8	217.1	310.2	400.6	95.2	0.3	
Nitrate (mg/l N)	102	0.02	245.92	1.07	20.36	1.21	11.36	36.07	30.35	149.1%	
Fluoride (mg/l F)	101	0.17	5.89	0.64	1.21	0.30	0.90	2.29	0.99	82.3%	
Silicon as Si	97	3.82	64.10	24.60	29.53	17.71	30.98	38.00	9.00	30.5%	
Iron (Fe)	61	0.002	0.880	0.011	0.040	0.005	0.013	0.050	0.11	282.1%	
Manganese (Mn)	54	0.001	1.204	0.003	0.088	0.001	0.005	0.241	0.24	266.7%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	97	0.005	0.800	0.019	0.047	0.010	0.026	0.068	0.11	241.0%	
ZAR	101	1.20	14.71	3.14	4.14	1.64	3.59	7.19	2.38	57.5%	
LSI	95	Langelier Saturation Index (LSI)			Slightly Scaling		69.5%		Highly Scaling		0.0%
		Highly corrosive			0.0%		Slightly corrosive		2.1%		Balanced Corrosion

Table 62 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality is ideal to good (52.9%), marginal (42.2%) and unacceptable, (EC > 370mS/m) in 4.9% of the analysis in terms of the Electrical conductivity (EC) with values ranging between 39.2 and 587.4mS/m. The 90<sup>th</sup> percentile is 314.1mS/m.

The Total Dissolved Solids (TDS) is acceptable in 69.6% of the samples, (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 103 samples indicates elevated concentrations of Fluoride (F > 1.5mg/l) in 34.7%; Nitrate (N > 20mg/l) in 31.4%; Chloride (Cl > 600mg/l) in 11.8%; Sodium (Na > 400mg/l) in 8.9%; Magnesium (Mg > 200mg/l) in 2% and Calcium (Ca > 300) in 1% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water is slightly corrosive (2.1%); predominantly slightly scaling (69.5%) and balanced (28.4%). The ZAR index indicates that 30.7% of the water is of a fair quality for irrigation (ZAR < 3).

The rural villages that occupy the complete unit obtain water from the Bakone Regional Water Scheme. The water supply to the scheme is from groundwater resources.

### 7.2.3.10 SMITSKRAAL GRANITE (Vs)

The Smitskraal Granite is a pink, coarse-grained biotitic rock of granitic composition that forms some minor intrusive stocks between Mogwadi (Dendron) and Gilead, (Figure 83). Fine-grained or porphyritic varieties do occur locally. Not much is known about its geohydrological properties nor did the search for information on this intrusion yield any results

The unit covers approximately 0.36% of the total areal extent.

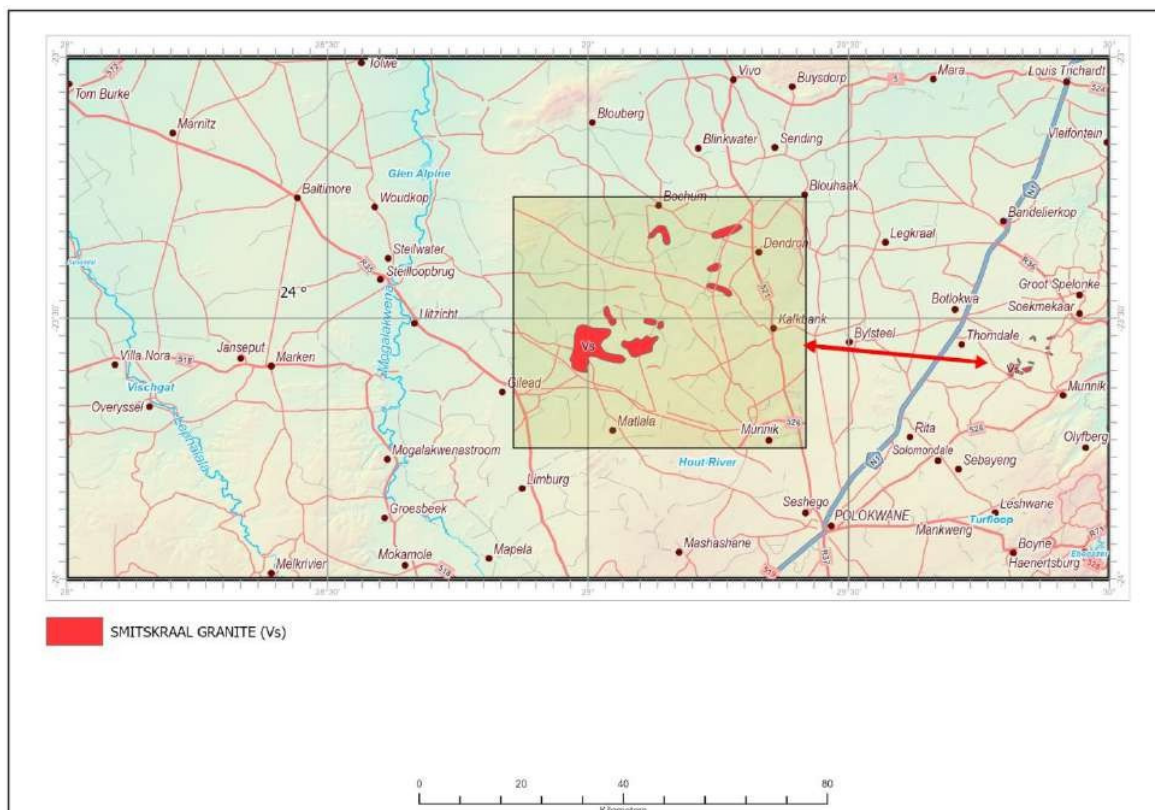


Figure 83: Geographical distribution of the Smitskraal Granite (Vs).

There is no data available on the maximum yield, borehole depth, pump testing data, static water level or water chemistry for this unit, a proper characterization could therefore not be done. It is however expected that the groundwater conditions will be more or less the same as with other granitic intrusions.

### 7.2.3.11 PALMIETFONTEIN GRANITE (Vpf)

The Palmietfontein pluton in the Limpopo province is Proterozoic calc-alkaline granite which intruded into the Southern Marginal Zone of the Limpopo Mobile Belt. This granite forms scattered stock-like intrusions as well as locally occurring dykes and sheets. It is a light grey, medium-grained rock of ademellitic to granitic composition which consists of quartz, feldspar, plagioclase, muscovite and minor biotite.

The Palmietfontein Granite occurs as a few scattered outcrops north of Bandelierskop, (Figure 84). The section of the unit within the Polokwane map sheet covers approximately 0.01% of the total areal extent. No data could be obtained regarding maximum yields, pump test data or drilled depths.

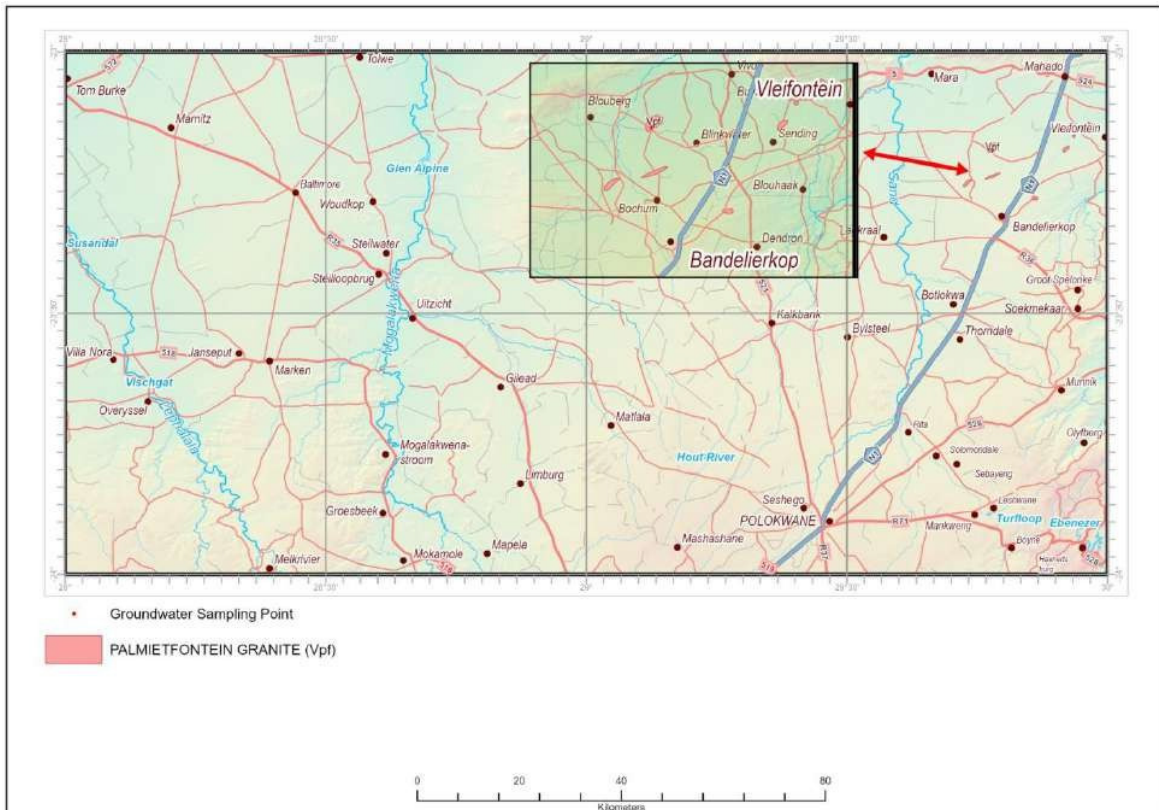


Figure 84: Geographical distribution of the Palmietfontein Granite (Vpf) and the associated groundwater sampling point.

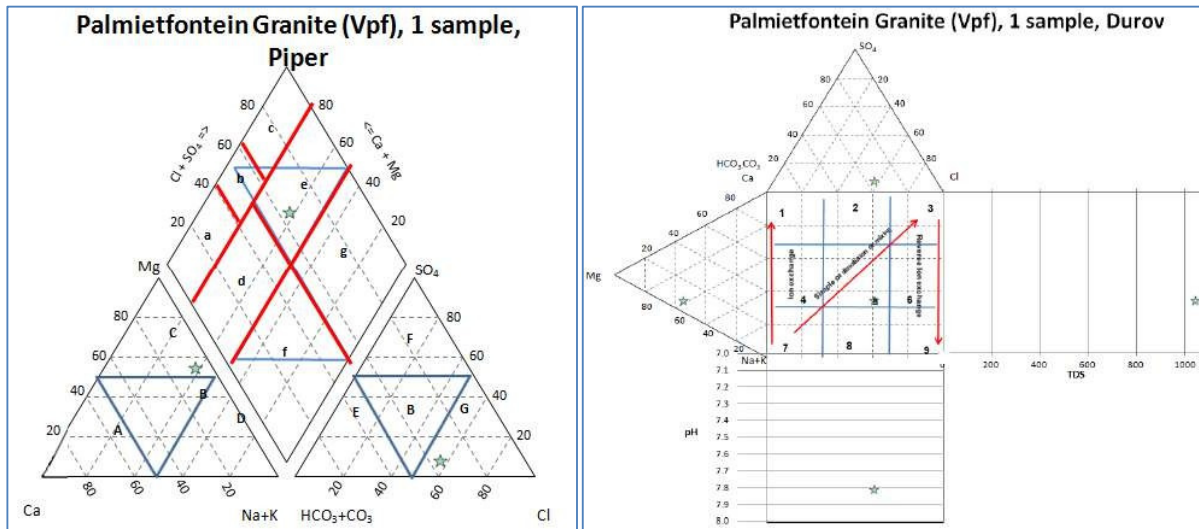


Figure 85: Trilinear diagrams, Piper, and Durov for the Palmietfontein Granite (Vpf) data points.

The trilinear Piper diagram, (Figure 63) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (100%), Weak acidic anions > Strong acidic anions (0%); Alkali > Alkali earths (0%); Strong acids > Weak acids (100%).

The groundwater in this unit is classified as a Magnesium-Chloride type.

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- No dominant anion or cation indicates water exhibiting simple dissolution or mixing (100%).

Table 63: Chemical statistics for the Palmietfontein Granite (Vpf).

Element / Parameter	Statistics Drawn from a population of 1 data point for the Palmietfontein Granite (Vpf).									
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation
pH	1	7.80	7.80	7.80	7.80	7.80	7.80	7.80		
Electrical Conductivity (mS/m EC)	1	176.00	176.00	176.00	176.00	176.00	176.00	176.00		
Total Dissolved Salts (mg/l TDS)	1	1141.00	1141.00	1141.00	1141.00	1141.00	1141.00	1141.00		
Calcium (mg/l Ca)	1	25.60	25.60	25.60	25.60	25.60	25.60	25.60		
Magnesium (mg/l Mg)	1	117.60	117.60	117.60	117.60	117.60	117.60	117.60		
Sodium (mg/l Na)	1	148.10	148.10	148.10	148.10	148.10	148.10	148.10		
Potassium (mg/l K)	1	10.68	10.68	10.68	10.68	10.68	10.68	10.68		
Chloride (mg/l Cl)	1	251.90	251.90	251.90	251.90	251.90	251.90	251.90		
Sulphate (mg/l SO <sub>4</sub> )	1	46.90	46.90	46.90	46.90	46.90	46.90	46.90		
Total Alkalinity (mg/l) CaCO <sub>3</sub>	1	442.60	442.60	442.60	442.60	442.60	442.60	442.60		
Nitrate (mg/l N)	1	0.02	0.02	0.02	0.02	0.02	0.02	0.02		
Fluoride (mg/l F)	1	0.11	0.11	0.11	0.11	0.11	0.11	0.11		
Silicon as Si	1	17.21	17.21	17.21	17.21	17.21	17.21	17.21		
Iron (Fe)	1	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		
Manganese (Mn)	1	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	1	0.005	0.005	0.005	0.005	0.005	0.005	0.005		
ZAR	1	2.75	2.75	2.75	2.75	2.75	2.75	2.75		
LSI	1	Langelier Saturation Index (LSI)			Slightly Scaling	0.0%	Highly Scaling	0.0%		
		Highly corrosive	0.0%	Slightly corrosive	0.0%	Balanced Corrosion	100.0%			

Table 63 gives a summary of the physical properties, the major anions, cations, and some of the minor elements of one chemical analysis. The overall water quality is marginal in terms of the Electrical conductivity (EC).

The Total Dissolved Solids (TDS) is acceptable, (TDS ≤ 1200mg/l). The Langelier Saturation Index (LSI) indicates that the water is predominantly balanced... The ZAR index indicates that the water is of a fair quality for irrigation (ZAR < 3).

### 7.2.3.12 UNNAMED GRANITE ROCKS (Vz)

This unnamed unit occurs near Haenertsburg in the eastern sector of the map sheet and consists of a leucocratic, whitish, medium-to coarse-grained granite as well as syenite. The mineral biotite occurs as a very minor constituent of the granite, (Explanation booklet, and geological map sheet 2328 page 18). The groundwater resource unit covers approximately 0.41% of the total map area.

The unit is not considered a major aquifer; groundwater is obtained from springs and boreholes for domestic purposes. Surface water stored in numerous small dams erected along the valleys, is utilized for gardens and small irrigation schemes. The rainfall in this area is adequate to sustain the springs but groundwater use from boreholes is expected to increase due to the increasing development of small holdings especially in the Haenertsburg area. The Boyne Shear zone (not indicated on the map) in the western part of the unit is the most important lineament within the unit that can be targeted for groundwater development. Other lineaments are predominantly diabase dykes trending north-east. Groundwater targets in this area are deep sediment accumulation and weathering along the valleys, the transitional zones between weathered basins and fresh bedrock, and the contact/metamorphism zone along diabase intrusions. The latter is expected to give varying success as the contact zone between diabase, and the host rock can be fused together with no visible fracturing. An example of such a phenomenon can be seen in the pool below the Debengeni falls, (just outside map area). The unweathered, unfractured nature of the bedrock, small unfractured criss-crossing pegmatite veins cut by movement and folding, mylonite, and the shallow sheet like fractures most probably related to stress relief, can be observed here.

The yield frequency diagram, (Figure 87), gives an indication of the expected yield of the boreholes. It shows that 58.8% of the successful boreholes yield less than 2l/s and 41.1% yields more than 2l/s.

In 18.2% of the water samples, at least one element exceeds the maximum allowed limits for domestic use. For this unit the anion of concern is Nitrate. People collect water from open streams in the area near Haenertsburg and sell it next to the main road throughout the year.

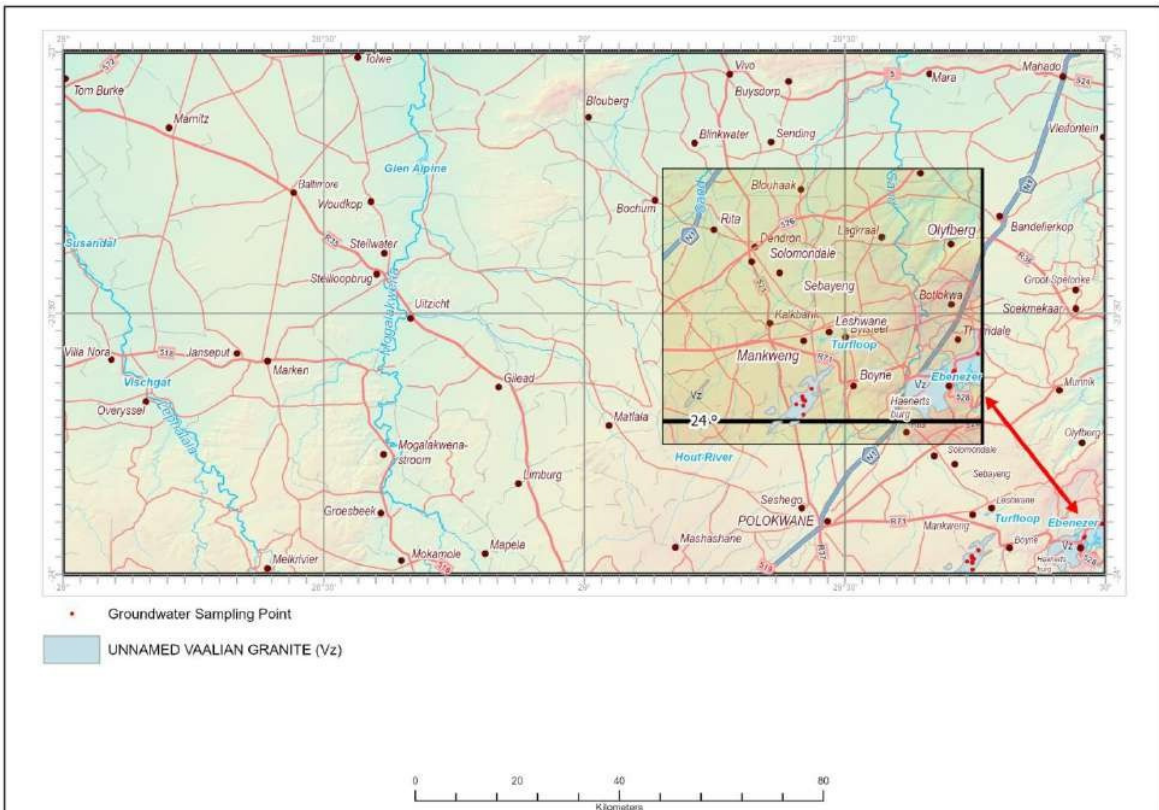


Figure 86: Geographical distribution of the Unnamed Granite Rocks (Vz) and associated groundwater data points.

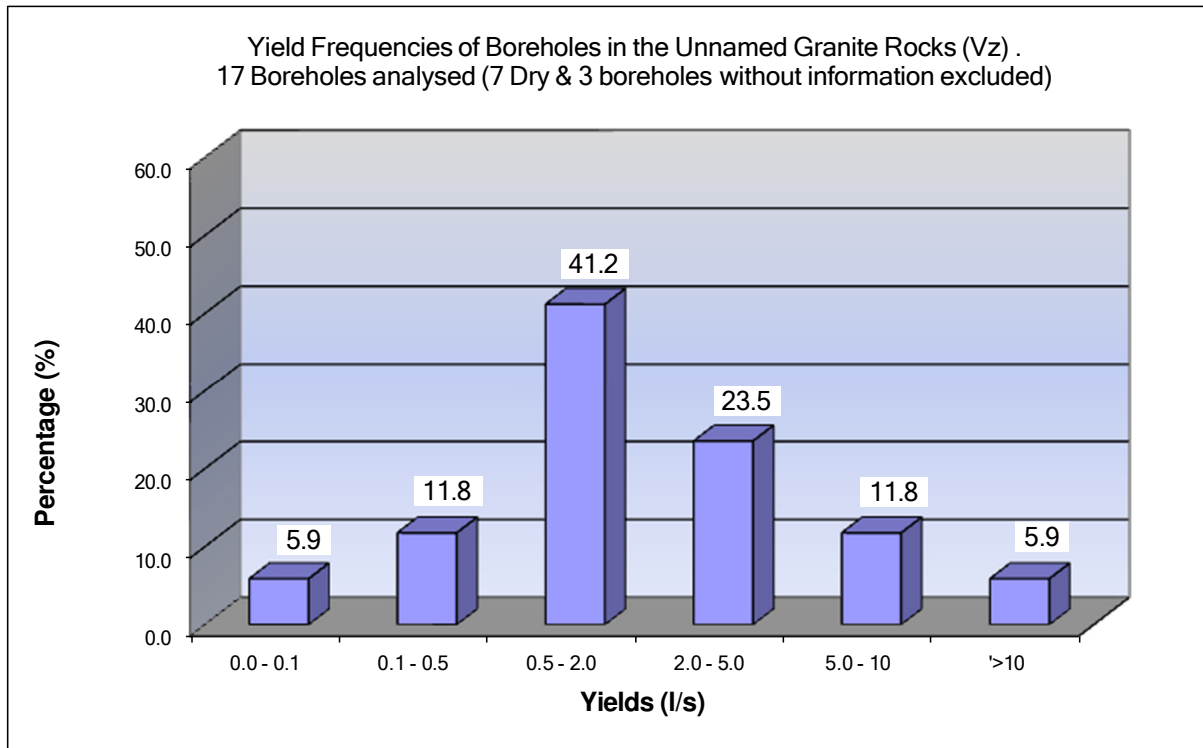


Figure 87: Yield frequency for fractured aquifers of the Unnamed Granite Rocks (Vz).

The statistical analysis of 17 borehole records, (Figure 87) indicates that 17.6% of successful boreholes have yields suitable for small households (>0.001ℓ/s to 0.5ℓ/s). Additionally, 41.2% of boreholes yield between 0.5ℓ/s and 2ℓ/s, with 23.5% yielding between 2ℓ/s and 5ℓ/s and 17.7% yielding more that 5ℓ/s.

The static water level ranges from 1.8 meters below ground level (mbgl) to 56mbgl, with a median of 26.6mbgl and an average of 25.82mbgl (based on 17 data points). The maximum depth recorded is 161m, with an average of 77.5m and a median of 66.6m (12 data points). The maximum installation depth is 95m and the average is 54.5m (11 data points). The depth of installation can be indicative of water strike depths if compared to the average depth and static water levels of the boreholes. The maximum recommended daily abstraction on record is 216 cubic meters per day (m<sup>3</sup>/day) and the average is 61.8m<sup>3</sup>/day. The 90th percentile for daily abstraction is 172.8m<sup>3</sup>/day and the 80th percentile is 155.52m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 11.

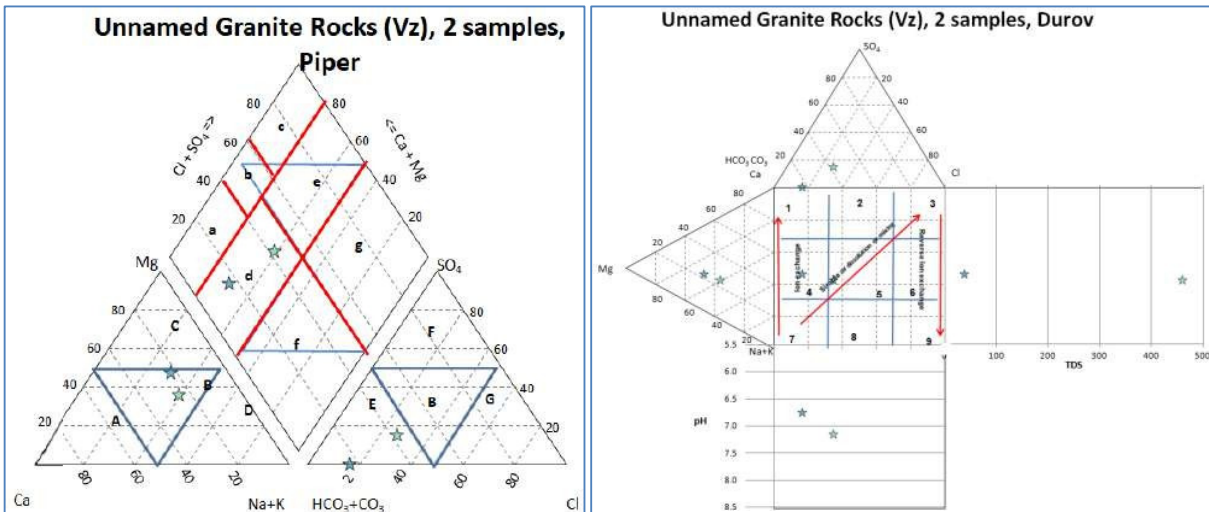


Figure 88: Trilinear diagrams, Piper, and Durov for the Unnamed Granite Rocks (Vz).

The trilinear Piper diagram, (Figure 88) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (100%), Weak acidic anions > Strong acidic anions (100%); Alkali >Alkali earths (0%); Strong acids > Weak acids (0%).

The groundwater in this unit classifies as:

- Mixed Calcium-Magnesium-Bicarbonate type with increased Sodium (100%).

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- No dominant anion or cation indicates water exhibiting simple dissolution or mixing (100%), plot along the dissolution or mixing line,

Table 64: Chemical statistics for the Unnamed Granite Rocks (Vz).

Element / Parameter	Statistics Drawn from a population of 11 data points for the Unnamed Granite Rocks (Vz).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	11	6.5	7.7	7.0	7.1	6.8	7.0	7.3	0.3	4.3%	
Electrical Conductivity (mS/m EC)	11	5.6	107.1	25.8	58.7	15.1	70.0	92.1	35.9	61.1%	
Total Dissolved Salts (mg/l TDS)	11	36.4	696.0	171.8	382.9	113.0	455.0	601.0	231.6	60.5%	
Calcium (mg/l Ca)	11	2.2	91.6	13.8	36.0	11.9	41.1	51.6	24.3	67.4%	
Magnesium (mg/l Mg)	11	2.9	47.1	12.2	25.8	6.2	31.4	45.8	15.9	61.4%	
Sodium (mg/l Na)	11	2.7	112.8	13.0	52.8	7.3	61.4	101.2	40.7	77.1%	
Potassium (mg/l K)	11	1.0	6.7	1.6	2.3	1.1	1.5	5.5	1.9	83.1%	
Chloride (mg/l Cl)	11	1.7	81.9	9.6	31.8	4.9	33.5	56.0	23.6	74.4%	
Sulphate (mg/l SO <sub>4</sub> )	11	0.1	33.4	1.1	14.7	1.5	17.5	29.5	11.7	79.4%	
Total Alkalinity (mg/l) CaCO <sub>3</sub>	2	24.8	229.0	44.8	126.9	45.2	126.9	208.6	144.4	113.8%	
Nitrate (mg/l N)	11	1.4	22.0	5.0	10.2	2.0	8.9	20.1	7.0	68.4%	
Fluoride (mg/l F)	11	0.10	0.39	0.16	0.22	0.10	0.14	0.36	0.13	57.2%	
Silicon as Si	9	13.5	53.9	19.6	23.3	13.7	18.9	32.4	12.6	53.9%	
Iron (Fe)	10	0.010	0.020	0.011	0.011	0.010	0.010	0.011	0.00	28.7%	
Manganese (Mn)	10	0.002	0.020	0.008	0.012	0.009	0.010	0.020	0.01	48.5%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	9	0.018	0.050	0.042	0.046	0.044	0.050	0.050	0.01	22.9%	
ZAR	11	0.28	2.84	0.75	1.48	0.36	1.66	2.68	0.99	67.1%	
LSI	2	Langelier Saturation Index (LSI)			Slightly Scaling		0.0%		Highly Scaling		0.0%
		Highly corrosive		50.0%	Slightly corrosive		50.0%	Balanced Corrosion		0.0%	

Table 64 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality is ideal to good in all the analysis in terms of the Electrical conductivity (EC) with values ranging between 5.6 and 107.1mS/m.

The Total Dissolved Solids (TDS) is acceptable in 100% of the samples, (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 11 samples indicates elevated concentrations of Nitrate (N >20mg/l) in 18.2% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water is slightly (50%) to highly corrosive (50%). The ZAR index indicates that 100% of the water is of a fair quality for irrigation (ZAR < 3).

Haenertsburg is the largest town within the unit, it is known for tourism and forestry that support the economy of the area.

### 7.2.3.13 UTRECHT GRANITE (Vut)

The Utrecht Granite, which forms a circular stock-like body approximately 55km west of Polokwane, is a fine-grained, pink biotitic rock of granodioritic composition. The groundwater resource unit covers an area of about 12.8km<sup>2</sup> or 0.06% of the map area, (Figure 89). It can be described as a weathered and fractured, semi-confined to confined granitic aquifer. Indications are that it has a low potential for groundwater exploration. No remnant roof sections were found to be present, although numerous gneiss inclusions have been intercepted during drilling. Drilling revealed the contact between the Utrecht Granite and host rock to be very poor targets for groundwater development. In the few successful boreholes drilled in the granite, water was mostly intercepted in fractures and transitional zones between weathered and solid granite (Du Toit, 2001).

The yield frequency diagram, (Figure 90), gives an indication of the expected yield of the boreholes. It shows that 90% of successful boreholes yield less than 2ℓ/s and 10% yields more than 2ℓ/s.

In 45.5% of the water samples, at least one element exceeds the maximum allowed limits for domestic use. For this unit the problematic anion is Nitrate followed by a low percentage (9.1%) of the sources with elevated Fluoride concentrations.

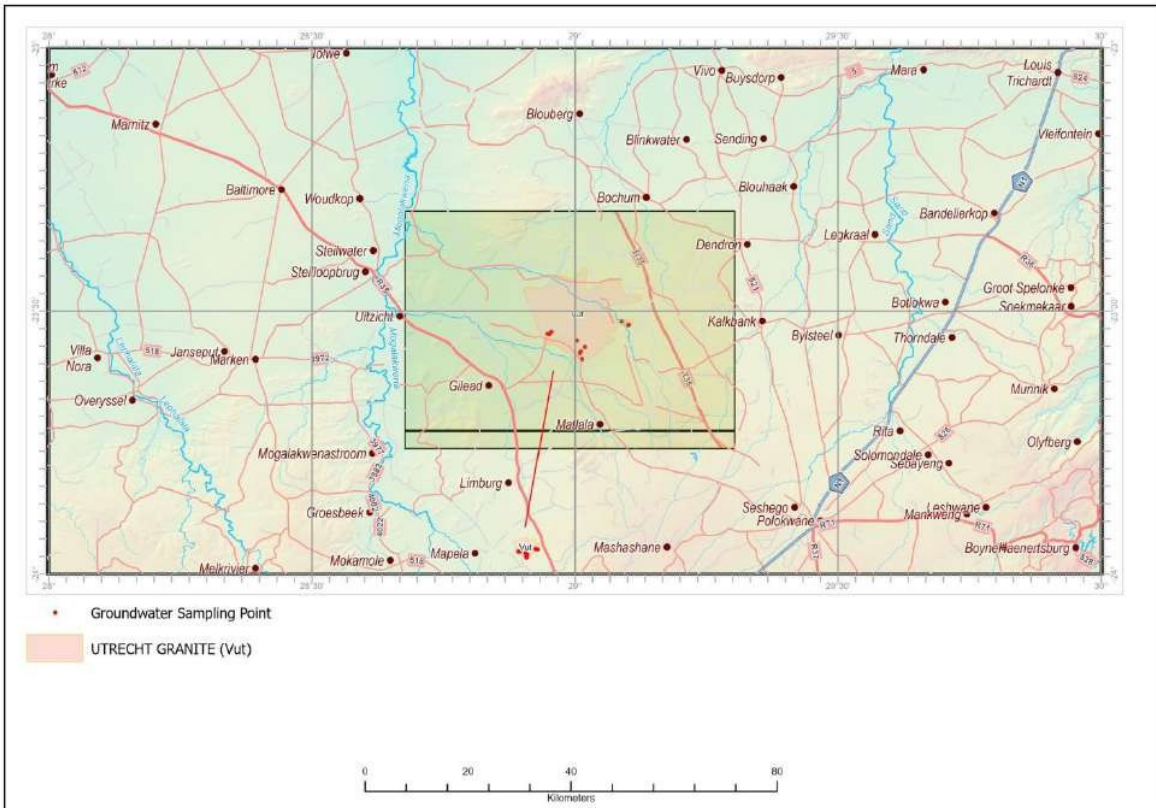


Figure 89: Geographical distribution of the Utrecht Granite (Vut) and the associated groundwater data points.

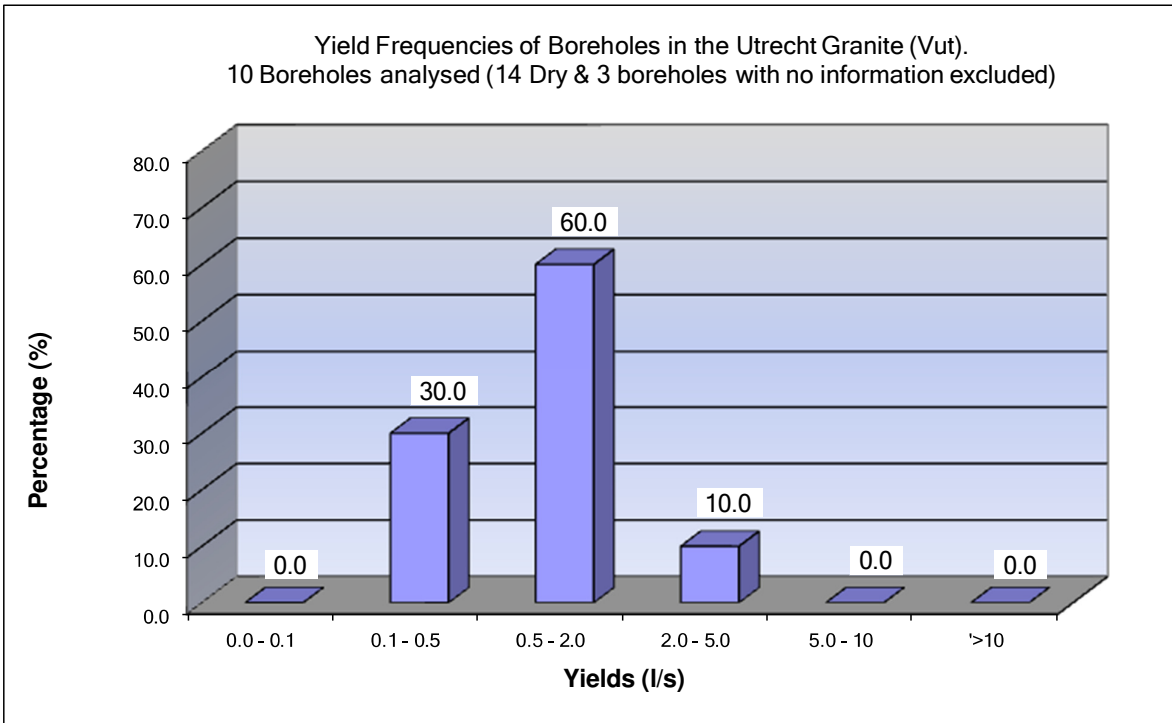


Figure 90: Yield frequency for fractured aquifers of the Utrecht Granite (Vut)

The statistical analysis of 10 borehole records, (Figure 90) indicates that 30% of successful boreholes have yields suitable for small households (>0.001l/s to 0.5l/s). Additionally, 60% of boreholes have yields between 0.5l/s and 2l/s, with 10% yielding between 2l/s and 5l/s.

The static water level ranges from 10.25 meters below ground level (mbgl) to 47.22mbgl, with a median of 20.9mbgl, and an average of 24.23mbgl (based on 21 data points). The maximum depth recorded is 162m, the average is 128.9m, and the median is 138m (19 data points). The installation depth is between 35.3m and 38.9m, (2 data points) and the recommended daily abstraction is between 4.3 cubic meters per day (m<sup>3</sup>/day) and 6m<sup>3</sup>/day, (based on 2 data points).

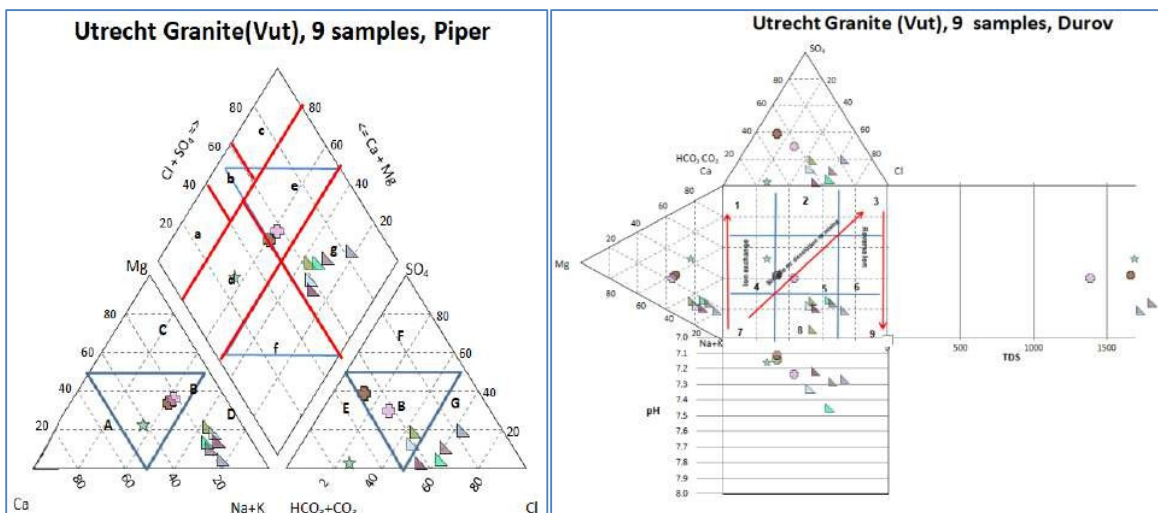


Figure 91: Trilinear diagrams, Piper, and Durov for the Utrecht Granite (Vut) data points.

The trilinear Piper diagram, (Figure 91) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The

initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (40%), Weak acidic anions > Strong acidic anions (10%); Alkali > Alkali earths (60%); Strong acids > Weak acids (90%).

The groundwater in this unit classifies as:

- Sodium-Chloride type (40%),
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type with increased Sodium and Sulphate (30%),
- Sodium-Bicarbonate-Chloride type (20%),
- Mixed Calcium-Magnesium-Bicarbonate type with increased Sodium (10%).

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- Cl is the dominant anion and Na the dominant cation, indicative that the groundwater is related to reverse ion exchange of Na-Cl waters (55.6%),
- No dominant anion or cation indicates water exhibiting simple dissolution or mixing (22.2%), plot along the dissolution or mixing line,
- SO<sub>4</sub> dominates, or anion discriminant and Ca dominant, frequently indicates recharge in gypsiferous deposits, otherwise mixed water or water exhibiting simple dissolution. (11.1%)
- Cl and Na dominant, frequently indicative of end-point gradient waters through Dissolution (11.1%).
- Some samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 65: Chemical statistics for the Utrecht Granite (Vut).

Element / Parameter	Statistics Drawn from a population of 11 data points for the Utrecht Granite (Vut).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	11	7.93	8.44	8.21	8.21	8.10	8.22	8.34	0.14	1.7%	
Electrical Conductivity (mS/m EC)	11	68.50	215.00	106.88	125.78	73.00	115.40	186.00	53.16	42.3%	
Total Dissolved Salts (mg/l TDS)	11	572.0	1739.0	856.9	962.9	686.0	748.0	1346.8	372.2	38.7%	
Calcium (mg/l Ca)	11	31.70	92.30	45.33	49.52	35.30	45.00	72.80	17.84	36.0%	
Magnesium (mg/l Mg)	11	6.00	41.70	22.12	31.13	13.80	36.70	40.96	11.81	37.9%	
Sodium (mg/l Na)	11	65.60	373.60	131.54	186.43	69.70	192.10	306.10	104.28	55.9%	
Potassium (mg/l K)	11	1.05	5.16	2.17	2.83	1.06	3.02	5.02	1.40	49.3%	
Chloride (mg/l Cl)	11	24.00	413.20	68.99	151.74	24.40	179.75	253.80	118.30	78.0%	
Sulphate (mg/l SO <sub>4</sub> )	11	8.30	103.05	34.53	62.76	16.20	67.76	97.00	33.17	52.8%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	11	149.3	617.0	303.7	358.7	235.4	386.9	551.4	146.3	40.8%	
Nitrate (mg/l N)	11	0.05	39.98	0.41	13.03	0.44	4.18	32.49	14.67	112.7%	
Fluoride (mg/l F)	11	0.26	2.37	0.50	0.73	0.31	0.59	1.03	0.60	82.8%	
Silicon as Si	11	3.1	34.6	12.1	20.2	8.9	21.8	34.5	11.1	54.7%	
Iron (Fe)	2	0.000	0.012	0.000	0.006	0.001	0.006	0.011	0.008	139.1%	
Manganese (Mn)	2	0.006	0.010	0.008	0.008	0.006	0.008	0.010	0.003	35.4%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	11	0.008	0.084	0.018	0.025	0.014	0.019	0.027	0.020	82.6%	
ZAR	11	1.81	8.26	3.68	5.17	1.98	5.96	8.16	2.63	50.9%	
LSI	11	Langelier Saturation Index (LSI)			Slightly Scaling		90.9%		Highly Scaling		0.0%
		Highly corrosive		0.0%	Slightly corrosive		0.0%	Balanced Corrosion		9.1%	

Table 65 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality is ideal to good (63.6%) and marginal, (EC < 370mS/m), in 36.4% of the analysis in terms of the Electrical conductivity (EC) with values ranging between 68.5 and 215mS/m. The 90<sup>th</sup> percentile is 186mS/m.

The Total Dissolved Solids (TDS) is acceptable in 72.7% of the samples, (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 11 samples indicates elevated concentrations of Nitrate (N >20mg/l) in 45.5% and Fluoride (F >1.5mg/l) in 9.1% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water is predominantly slightly scaling (90.9%) and balanced (9.1%). The ZAR index indicates that 36.4% of the water is of a fair quality for irrigation (ZAR < 3).

The Anglo American Platinum, Mogalakwena Complex mine tailings dam occupies the lower laying area next to the mountain. The rural settlement that previously occupied the area around the mountain was re-located. No groundwater is abstracted from the unit.

### 7.2.3.14 TURFLOOP GRANITE (Rt-Vt)

This granite which is a major batholithic intrusion flanks the southern edge of the Pietersburg Group forming numerous isolated hills. It is a medium- to coarse-grained, grey to pinkish biotitic rock of adamellite to granodioritic composition and contains orthoclase, microcline, quartz, sodic plagioclase, and biotite with sphene and zircon as accessories. The unit covers approximately 2.84% of the map area and is restricted to the south-eastern section of the map area. Although the unit cross over to the Modimolle map sheet, each map was characterized with the data that falls within the particular map sheet. This was done as each map had sufficient points to characterize. The findings on the hydrogeological character for the unit on both map sheets were very similar.

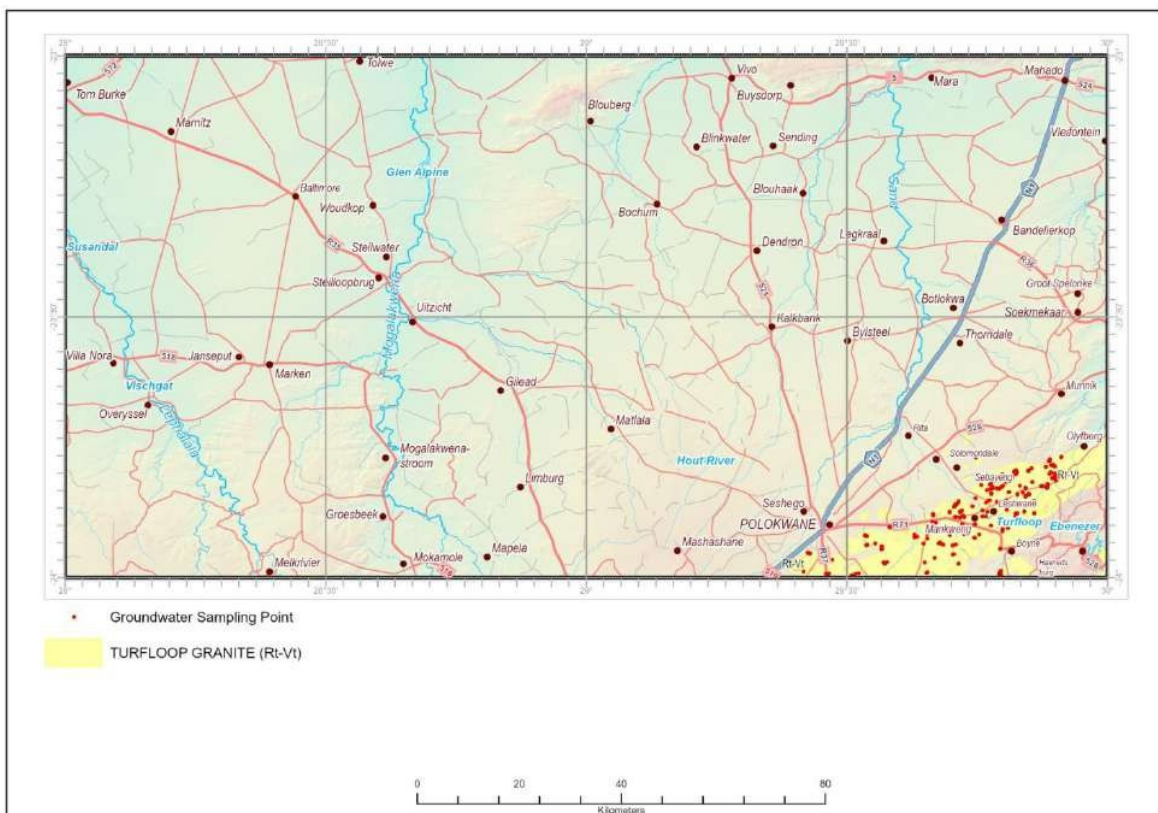


Figure 97: Geographical distribution for the intergranular and fractured aquifers of the Turfloop Granite (Rt-Vt) and the associated groundwater data points

Similar to most of the granite intrusions in the map area, the potential of the Turfloop Granite is generally low with 70.9% of the successful boreholes yielding < 2l/s and 29.1% yielding more than 2l/s, (Figure 92).

In 19% of the water samples, at least one element exceeds the maximum allowed limits for domestic use. For this unit the anion of concern is Fluoride followed by a low percentage (10.4%) of the sources with Nitrate concentrations that exceeds the maximum allowable limit for human consumption.

The higher yielding boreholes especially the 4.7% boreholes yielding more than 5l/s usually relate to the Boyne shear zone or deep weathering and transported sediment within low laying areas. Water also occurs in weathered and fracture zones or occasionally in minor fractures related to dyke intrusions.

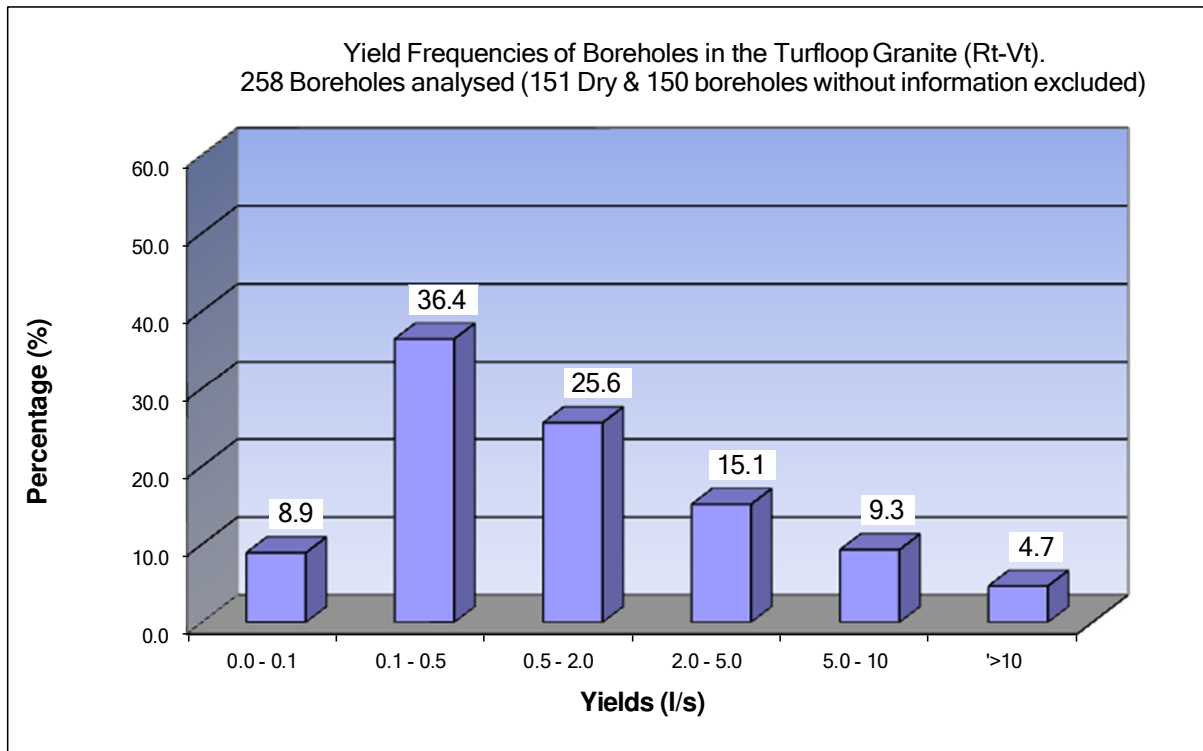


Figure 92: Yield frequency for fractured aquifers of the Turfloop Granite (Rt-Vt)

The statistical analysis of 258 borehole records, Figure 92 indicates that 45.3% of successful boreholes have yields suitable for small households (>0.001l/s to 0.5l/s). Additionally, 25.6% of boreholes have yields between 0.5l/s and 2l/s, with 15.1% yielding between 2l/s and 5l/s and 14% of boreholes yielding more that 5l/s.

The static water level ranges from 0.73 meters below ground level (mbgl) to 49.96mbgl, with a median of 11mbgl and an average of 12.59mbgl, (based on 158 data points). The maximum depth recorded is 204.4m, with an average depth of 66.8m and a median depth of 60m, (259 data points). The maximum installation depth is 126m, with an average installation depth of 43.6m, (10 data points). The depth of installation can be indicative of water strike depths if compared to the average depth and static water levels of the boreholes. The maximum recommended daily abstraction on record is 864 cubic meters per day (m<sup>3</sup>/day) and the average is 52.7m<sup>3</sup>/day. The 90<sup>th</sup> percentile of daily abstraction is 129.6m<sup>3</sup>/day and the 80<sup>th</sup> percentile is 81.21m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 129.

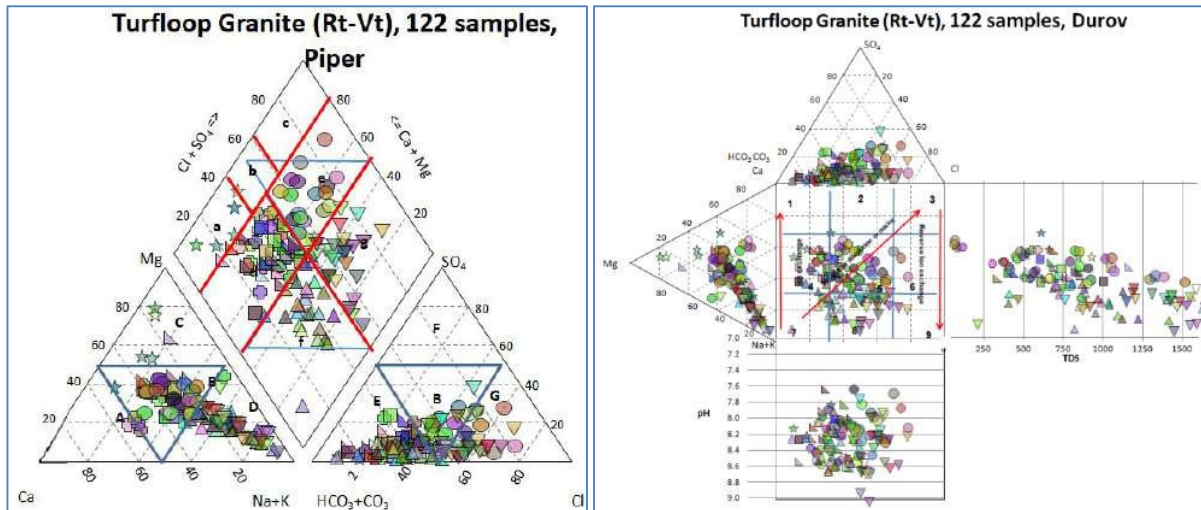


Figure 93: Trilinear diagrams, Piper, and Durov for the Turfloop Granite (Rt-Vt) data points.

The trilinear Piper diagram, (Figure 93) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (57.4%), Weak acidic anions > Strong acidic anions (61.5%); Alkali > Alkali earths (42.6%); Strong acids > Weak acids (38.5%).

The groundwater in this unit classifies as a Mixed Calcium-Magnesium-Bicarbonate-Chloride type

- Mixed Calcium-Magnesium-Bicarbonate type with increased Sodium (42.6%);
- Sodium-Bicarbonate type (20.5%);
- Sodium-Chloride type (16.4%),
- Mixed Calcium-Magnesium-Chloride type with increased Sodium (8.2%);
- Sodium-Bicarbonate-Chloride type (5.7%);
- Magnesium-Bicarbonate type (4.1%);
- Calcium-Bicarbonate type (2.5%)

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- Cl is the dominant anion and Na the dominant cation, indicative that the groundwater is related to reverse ion exchange of Na-Cl waters (46.3%),
- No dominant anion or cation indicates water exhibiting simple dissolution or mixing (27.3%), plot along the dissolution or mixing line,
- Anion discriminant and Ca dominant, frequently indicates recharge in gypsiferous deposits, otherwise mixed water or water exhibiting simple dissolution (19%),
- Cl and Na dominant, reverse ion exchange of Na-Cl waters (3.3%),
- Anion discriminate and Na dominant, indicates probable mixing or uncommon dissolution influences (2.5%),
- Cl and Na dominant, frequently indicative of end-point gradient waters through Dissolution (1.7%),
- Some samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 66: Chemical statistics for the Turfloop Granite (Rt-Vt).

Element / Parameter	Statistics Drawn from a population of 176 data points for Turfloop Granite (Rt-Vt).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	174	6.58	9.05	7.73	7.76	7.12	7.77	8.39	0.47	6.1%	
Electrical Conductivity (mS/m EC)	175	4.26	494.95	61.83	94.64	43.28	84.23	150.99	52.60	55.6%	
Total Dissolved Salts (mg/l TDS)	170	38.37	1731.00	425.34	659.07	310.63	603.80	1068.99	309.31	46.9%	
Calcium (mg/l Ca)	168	1.27	144.24	25.19	42.00	18.90	38.38	70.53	23.95	57.0%	
Magnesium (mg/l Mg)	168	0.50	101.72	14.90	33.27	13.98	29.32	65.33	20.64	62.1%	
Sodium (mg/l Na)	168	2.99	848.64	47.51	116.12	29.07	86.96	221.38	96.43	83.0%	
Potassium (mg/l K)	169	0.03	45.36	1.22	3.88	0.80	2.43	7.16	4.79	123.5%	
Chloride (mg/l Cl)	173	5.00	1195.20	43.44	96.83	22.00	68.80	192.70	112.01	115.7%	
Sulphate (mg/l SO <sub>4</sub> )	169	0.10	392.72	6.41	31.75	4.13	19.80	63.83	41.56	130.9%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	153	16.85	665.90	186.72	290.70	120.97	267.90	481.50	136.90	47.1%	
Nitrate (mg/l N)	173	0.03	77.99	0.62	7.47	0.28	4.43	19.79	10.58	141.7%	
Fluoride (mg/l F)	163	0.10	4.42	0.45	0.88	0.20	0.68	1.75	0.70	79.1%	
Silicon as Si	153	1.49	40.20	19.05	24.16	15.90	24.03	33.88	7.29	30.2%	
Iron (Fe)	110	0.005	0.508	0.012	0.032	0.007	0.012	0.050	0.06	194.4%	
Manganese (Mn)	60	0.006	1.656	0.018	0.092	0.010	0.026	0.113	0.25	270.8%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	149	0.006	0.800	0.023	0.060	0.012	0.029	0.076	0.13	217.3%	
ZAR	165	0.21	15.60	1.80	3.49	0.97	2.75	7.01	2.76	78.9%	
LSI	153	Langelier Saturation Index (LSI)		Slightly Scaling			34.6%		Highly Scaling		0.0%
		Highly corrosive		1.3%	Slightly corrosive		11.8%	Balanced Corrosion		52.3%	

Table 66 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality is ideal to good (89.1%); marginal in (10.3%) and unacceptable, (EC > 360mS/m) in 0.6% of the available analysis in terms of the Electrical conductivity (EC) with values ranging between 4.26 and 494.95mS/m. The 90<sup>th</sup> percentile is 150.99mS/m.

The Total Dissolved Solids (TDS) is acceptable in 66.2% of the samples, (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 176 samples indicates elevated concentrations of Fluoride (F > 1.5mg/l) in 19%; Nitrate (N > 20mg/l) in 10.4%; Chloride (Cl > 600mg/l) in 0.6% and Sodium (Na > 400mg/l) in 0.6% of the analysis

The Langelier Saturation Index (LSI) indicates that the water is slightly to highly corrosive (13.1%); slightly scaling (34.6%) and predominantly balanced (52.3%). The ZAR index indicates that 57.1% of the water is of a fair quality for irrigation (ZAR < 3).

A large section of this unit is covered by rural villages, urban settlement and towns. The water supply is from nine (9) Regional Water Schemes that obtain water from surface sources such as the Ebenezer Dam and numerous groundwater resources. In the eastern section of the unit that falls within the North Eastern Highland Ecoregion, forestry dominates economic activity. The Polokwane Nature Reserve occupies a part of the unit in the west, and the rest is occupied by semi-urban small holdings and livestock farming.

### 7.2.3.15 UITLOOP GRANITE (Ru-Vu)

The Uitloop Granite, which forms only one minor outcrop close to the centre southern boundary of the map area, is mineralogically similar to the Lunsklip Granite, but does not contain hornblende. The rock which has an adamellitic composition is medium-to coarse-grained and mainly reddish in colour. It also forms part of the Mashashane Suite (younger intrusion). It contains minerals such as quartz, orthoclase, microcline- perthite, sodic plagioclase and biotite. The rock has an adamellitic composition, is medium- to coarse- grained and mainly reddish in colour. It covers approximately 0.001% (0.199km<sup>2</sup>) of the map area.

No data was available for the groundwater resource unit in terms of maximum yield, borehole depth, static water level, water chemistry or pump testing data. The unit crosses over to the Modimolle map sheet and the reader can consult the Modimolle Brochure for more information on the unit.

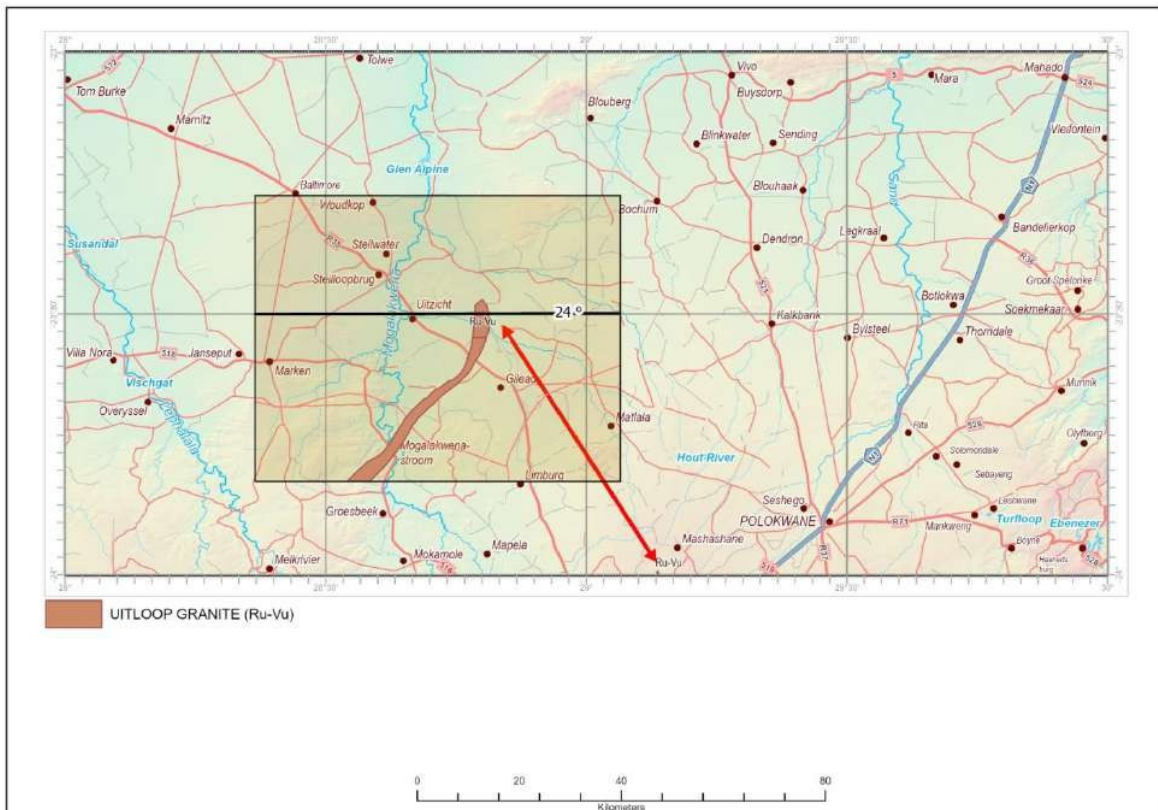


Figure 94: Geographical distribution of the Uitloop Granite (Ru-Vu).

### 7.2.3.16 LUNSKLIP GRANITE (RI-VI)

The Lunsklip Granite occurs northeast of Mokopane (formerly Potgietersrus) and southwest of Polokwane, in the Mashashane area, (Figure 95). It is medium to coarse-grained, pink to pinkish-grey in colour, and its main constituents are quartz, orthoclase, microcline-perthite, sodic plagioclase, hornblende, and biotite. The composition of the granite varies between adamellitic and granodioritic. In places, it has knife-sharp contact with the country rock. The Lunsklip Granite forms the lower part of the Mashashane Suite and underlies approximately 0.63% of the map sheet area. The granitic rocks are less prone to weathering and jointing, and they lack pegmatitic bodies, which are common in the Hout River and Goudplaats Gneiss and contribute extensively to groundwater potential in those units.

The characterization of this unit was based on yield and chemical data from both the Polokwane and Modimolle map sheets, as it is recognized as a single intrusive pluton. Groundwater data within the Polokwane sheet includes 42 boreholes with recorded yields, another 25 that are listed as dry, and 33 with no available yield information. In the Modimolle sheet, groundwater data comprises 35 sources with reported water strikes, while another 8 boreholes without any data on yield. For the chemical evaluation, 51 analyses were available within the Polokwane boundary, and 12 analyses within the Modimolle map boundary. Of these, 29 and 9 samples, respectively, were used for the Piper and Durov diagrams.

From the yield frequency diagram, (Figure 96) indications are that the Lunsklip Granite has a low to moderate groundwater development potential with 84.5% of the successful boreholes yielding less than

2l/s and 15.6% yielding more than 2l/s. This unit is most suitable as a resource for domestic and livestock watering.

In 58.6% of the water samples, at least one element exceeds the maximum allowed limits for domestic use. For this unit the anion of concern is Fluoride followed by a very low percentage (5.1%) of the sources with Nitrate concentrations that exceeds the maximum allowable limit for human consumption.

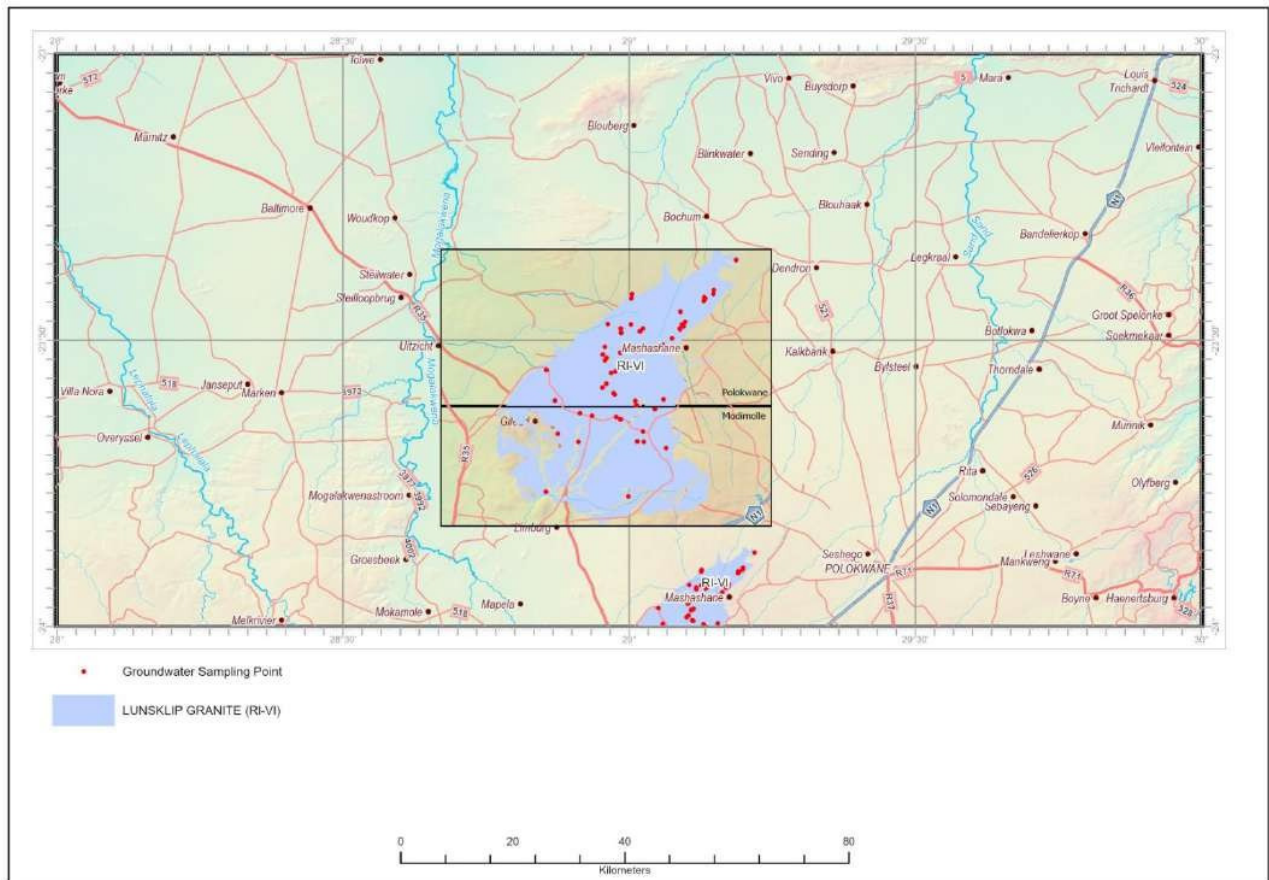


Figure 95: Geographical distribution of the Lunsklip Granite (RI-VI) and the associated groundwater data points.

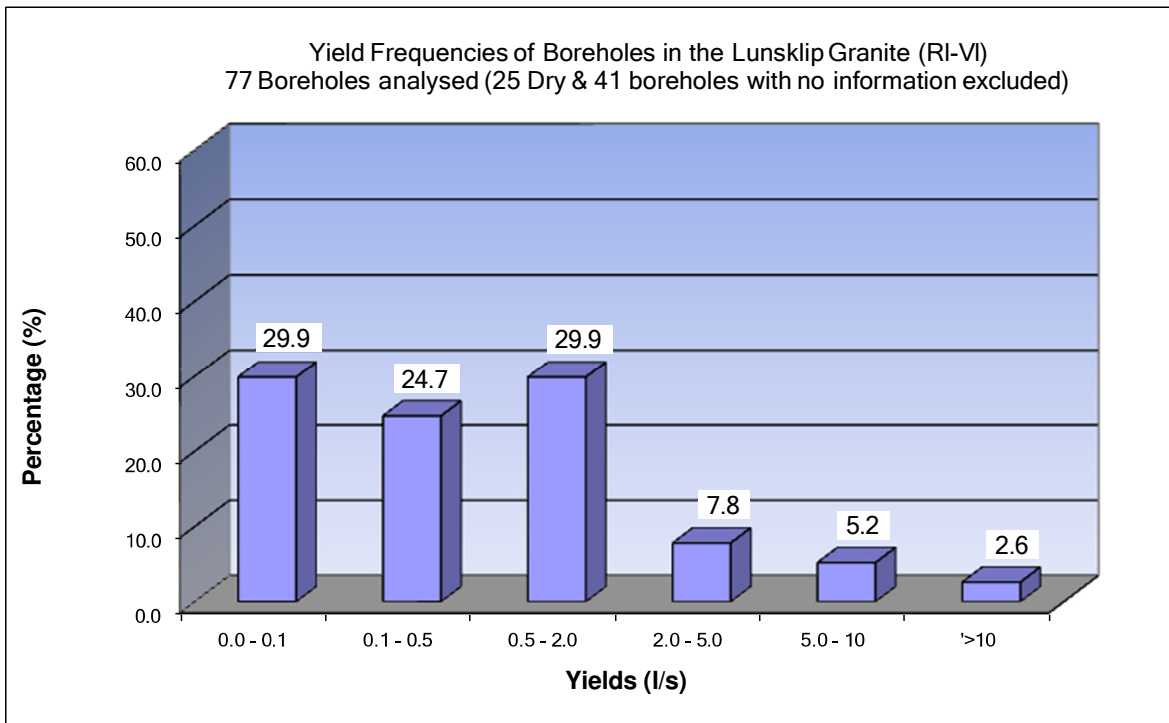


Figure 96: Yield frequency for fractured aquifers of the Lunsklip Granite (RI-VI).

A statistical analysis of 77 borehole records within the Polokwane and Modimolle map sheet boundaries indicates that 54.5% of the maximum borehole yields fall within the 0.1l/s to 0.5l/s range, which is generally suitable for small household use. A total of 29.9% of the boreholes yield between 0.5l/s and 2l/s, 7.8% yield between 2l/s and 5l/s, and only 7.8% of the boreholes have yield exceeding 5l/s, (Figure 96).

The static water level (swl) ranges from 0.26 meters below ground level (mbgl) to 35.38mbgl (one record discarded with a swl of 60mbgl that was identified as a pump drawdown measurement), with a median of 11.62mbgl and an average of 13.68mbgl (based on 77 data points). The maximum depth recorded is 145m, with an average of 75m and a median depth of 72m (61 data points). The maximum installation depth is 100m and the average is 39.7m, (32 data points). The depth of installation can be indicative of water strike depths if compared to the average depth and static water levels of the boreholes. The maximum recommended daily abstraction on record is 432 cubic meters per day (m<sup>3</sup>/day) and the average is 40.9m<sup>3</sup>/day. The 90th percentile of daily abstraction is 84.6m<sup>3</sup>/day and the 80th percentile is 58.75m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 32.

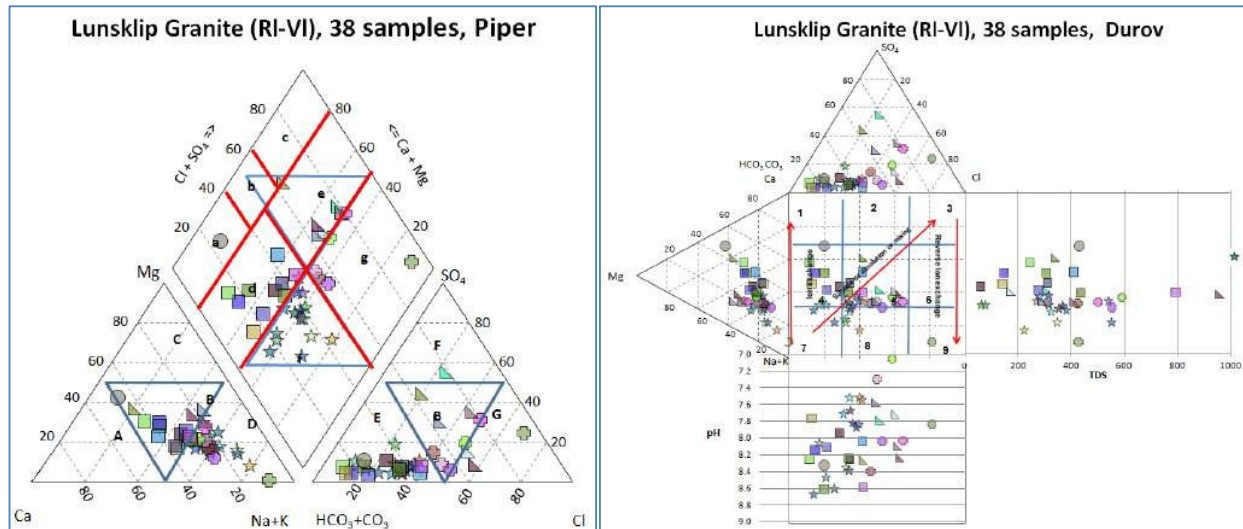


Figure 97: Trilinear diagrams, Piper, and Durov for the Lunsklip Granite (RI-VI) data points.

The trilinear Piper diagram, (Figure 97) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (41.4%), Weak acidic anions > Strong acidic anions (65.5%); Alkali > Alkali earths (58.6%); Strong acids > Weak acids (34.5%).

The groundwater in this unit classifies as:

- Sodium-Bicarbonate type (39.5%);
- Mixed Calcium-Magnesium-Bicarbonate type with increased Sodium (26.3%);
- Sodium-Bicarbonate-Chloride type with increased Sulphate (13.2%);
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type with increased Sodium and Sulphate (7.9%).
- Mixed Calcium-Magnesium-Chloride type with increased Sodium (5.3%);
- Mixed Calcium-Magnesium-Bicarbonate type (2.6%);
- Mixed Calcium-Magnesium-Sulphate (2.6%);
- Sodium-Chloride type (2.6%);

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- No dominant anion or cation indicates water exhibiting simple dissolution or mixing (63.2%), plot along the dissolution or mixing line,
- Cl is the dominant anion and Na the dominant cation, indicative that the groundwater is related to reverse ion exchange of Na-Cl waters (10.5%),
- SO<sub>4</sub> dominates, or Anion discriminant and Ca dominant, Ca and SO<sub>4</sub> dominate, frequently indicates recharge in gypsiferous deposits, otherwise mixed water or water exhibiting simple dissolution (18.4%)
- Cl and Na dominant, reverse ion exchange of Na-Cl waters (5.3%),
- Cl and Na dominant, frequently indicative of end-point gradient waters through Dissolution (2.6%).
- Some samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 67: Chemical statistics for the Lunsklip Granite (RI-VI).

Element / Parameter	Statistics Drawn from a population of 64 data points for Lunsklip Granite (RI-VI).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	59	6.53	8.65	7.79	7.83	6.99	7.91	8.38	0.52	6.7%	
Electrical Conductivity (mS/m EC)	59	8.40	138.00	33.57	47.13	20.14	41.40	82.42	25.21	53.5%	
Total Dissolved Salts (mg/l TDS)	59	56.00	964.00	239.27	334.49	146.80	304.43	555.16	181.07	54.1%	
Calcium (mg/l Ca)	59	3.10	63.00	15.95	25.17	9.01	21.13	48.34	15.22	60.5%	
Magnesium (mg/l Mg)	59	0.50	59.30	6.03	13.17	3.32	10.20	26.43	10.23	77.7%	
Sodium (mg/l Na)	59	5.10	139.90	29.32	50.20	15.65	42.48	109.44	34.64	69.0%	
Potassium (mg/l K)	59	0.39	25.39	1.28	2.81	0.63	1.52	3.80	4.32	153.7%	
Chloride (mg/l Cl)	59	1.50	211.90	13.12	35.65	4.98	21.85	94.46	38.37	107.6%	
Sulphate (mg/l SO <sub>4</sub> )	59	0.70	237.61	5.17	20.44	2.00	8.47	65.08	35.88	175.6%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	55	22.33	342.35	84.48	133.10	38.89	133.10	227.41	78.15	58.7%	
Nitrate (mg/l N)	59	0.05	41.08	1.04	7.96	0.82	6.06	14.95	8.10	101.8%	
Fluoride (mg/l F)	58	0.08	9.23	0.71	1.84	0.30	1.65	3.68	1.49	80.8%	
Silicon as Si	55	5.59	42.90	19.24	21.29	14.15	20.70	28.93	6.34	29.8%	
Iron (Fe)	18	0.006	4.900	0.016	0.493	0.010	0.015	1.262	1.310	265.5%	
Manganese (Mn)	7	0.005	0.064	0.011	0.020	0.006	0.014	0.038	0.020	102.6%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	54	0.005	0.153	0.013	0.024	0.006	0.015	0.040	0.028	117.0%	
ZAR	59	0.32	10.39	1.46	2.12	0.95	1.75	3.40	1.49	70.2%	
LSI	55	Langelier Saturation Index (LSI)			Slightly Scaling		16.4%		Highly Scaling		0.0%
		Highly corrosive		5.5%	Slightly corrosive		30.9%		Balanced Corrosion		47.3%

Table 67 gives a summary of the physical properties, the major anions, cations, and some of the minor elements for the unit. The unit falls on both the Polokwane and Modimolle map sheets and the data from both were used for the summary table. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality is ideal to good in all the available analysis in terms of the Electrical conductivity (EC) with values ranging between 8.4 and 138mS/m.

The Total Dissolved Solids (TDS) is acceptable in 100% of the samples, (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 64 samples indicates elevated concentrations of Fluoride (F >1.5mg/l) in 58.6% and Nitrate (N >20mg/l) in 5.1% of the analysis

The Langelier Saturation Index (LSI) indicates that the water is slightly to highly corrosive (39.6%); slightly scaling (16.3%) and predominantly balanced (44.2%). The ZAR index indicates that 79.6% of the water is of a fair quality for irrigation (ZAR < 3).

Various rural villages occur on the lower lying areas around the mountain formed by the unweathered outcrop. Water for these villages is supplied by the Moletje South Groundwater System. Water supplying this system is a combination of surface water from the Mashashane (Utjane Dam) and groundwater sources.

### 7.2.3.17 MOLETSI GRANITE (Rmo)

This batholith intrusion is located north-west of Polokwane (Pietersburg) depicted as two (2) outcrops on the map sheet, (Figure 98). The groundwater resource unit covers approximately 0.59% of the total map area. The granite is rich in biotite and typically weathers into huge oval boulders. It consists of two varieties, a pink to grey coarse-grained granite which is rimmed by the second described as a grey to pink, medium-grained porphyritic rock. It contains inclusions of banded gneiss and leucocratic granite. Garnets may occasionally be present.



*Plate 14: Xenoliths of gneiss occurring in outcrops of the Moletsi Granite. Studies of the groundwater potential of the Moletsi and other large granite intrusions (Batholiths) revealed that weathered and/or fractured remnant gneissic roof sections are good targets for groundwater development and can occasionally produce yields exceeding 40l/s. These high yields relate to tensional fractures, which developed in the roof during the emplacement of the magma (Photograph: WH du Toit).*

Based on the drilling results of a research project conducted by DWA on the Moletsi Granite, (Du Toit 2001), it can be described as a weathered and fractured semi confined to confined aquifer. It varies in saturated thickness from 1m to 70m (confirmed by drilling) along the different geophysical traverses that were surveyed. The weathering and fracturing are of secondary nature as it only formed after the intrusion of the granite. Well fractured remnant roof sections appear to be the most important host of the aquifer in the area, where as the contact between the granite and the host rock (Hout River Gneiss) itself has been indicated by drilling as poor targets for groundwater exploration. Groundwater is mostly intercepted in the transitional zone between the weathered and solid granite. Drilling has further shown that diabase intrusions, especially their contact zones with the host rock, may also be targeted for successful boreholes. However, these contact zones generally have limited storage and may not be sustainable if not managed properly.

In 36.8% of the water samples, at least one element exceeds the maximum allowed limits for domestic use. For this unit the anion of concern is Fluoride followed by a small percentage (14.9%) of the sources with Nitrate concentrations that exceed the maximum allowed limit for human consumption.

The yield frequency diagram, (Figure 99) gives an indication of the expected yield of the boreholes, 53.5% of the successful boreholes yield less than 2l/s and 46.5% yields more than 2l/s.

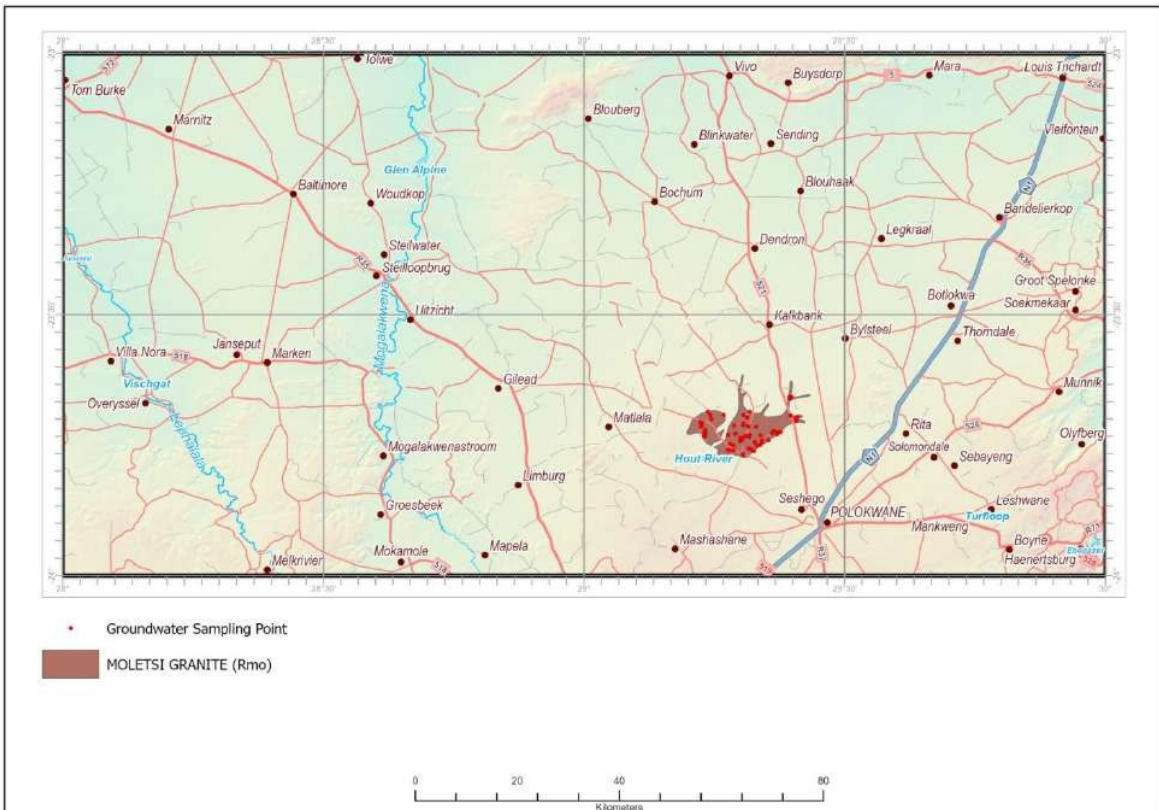


Figure 98: Geographical distribution of the Moletsi Granite (Rmo) and the associated groundwater data points.

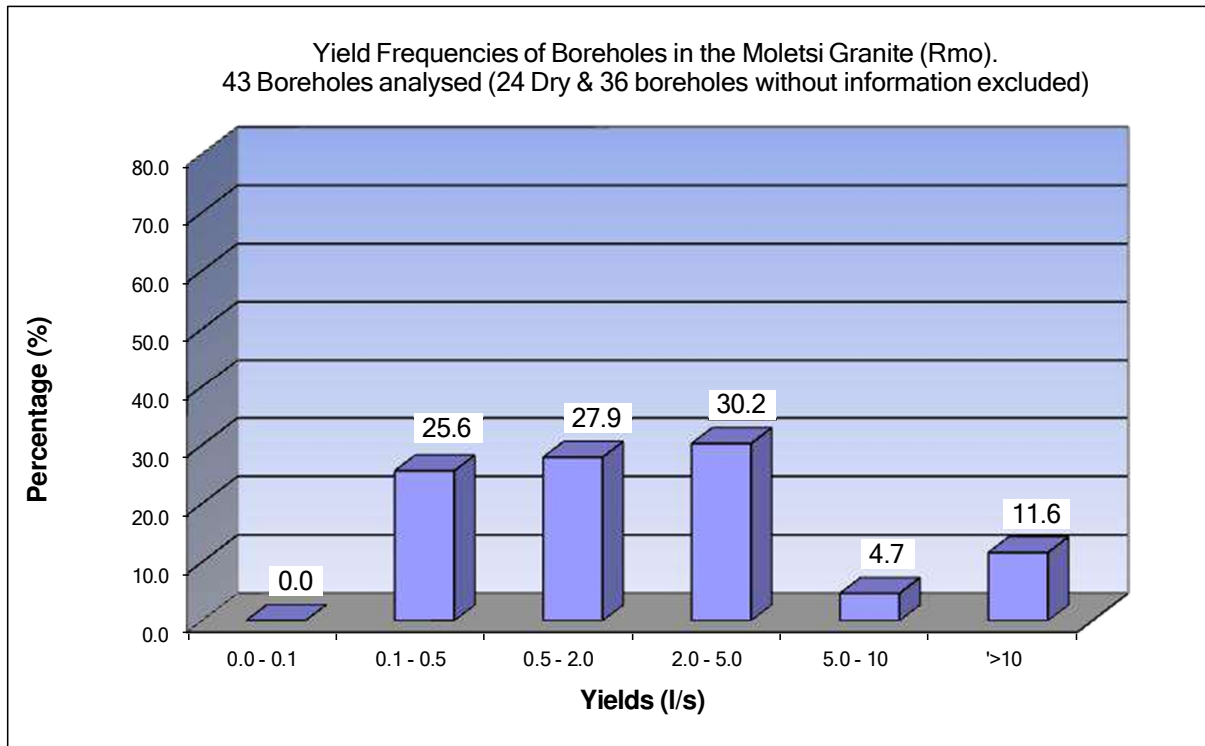


Figure 99: Yield frequency for fractured aquifers of the Moletsi Granite (Rmo)

The statistical analysis of 86 borehole records, (Figure 99) indicates that 25.6% of successful boreholes have yields suitable for small households (>0.001ℓ/s to 0.5ℓ/s). Additionally, 27.9% of boreholes yield between 0.5ℓ/s and 2ℓ/s, with 30.2% yielding between 2ℓ/s and 5ℓ/s and 16.3% of the boreholes with yields exceeding 5ℓ/s.

The static water level ranges from 3.3 meters below ground level (mbgl) to 33.21mbgl, the median is 9.44mbgl and the average is 12.11mbgl (based on 43 data points). The maximum depth recorded is 150m, with an average of 72m and a median depth of 60m (61 data points). The maximum installation depth is 72m and the average is 35.8m, (39 data points). The depth of installation can be indicative of water strike depths if compared to the average depth and static water levels of the boreholes. The maximum recommended daily abstraction on record is 518.4 cubic meters per day (m<sup>3</sup>/day) and the average is 75.9m<sup>3</sup>/day. The 90th percentile of abstraction is 155.5m<sup>3</sup>/day and the 80th percentile is 103.7m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 39.

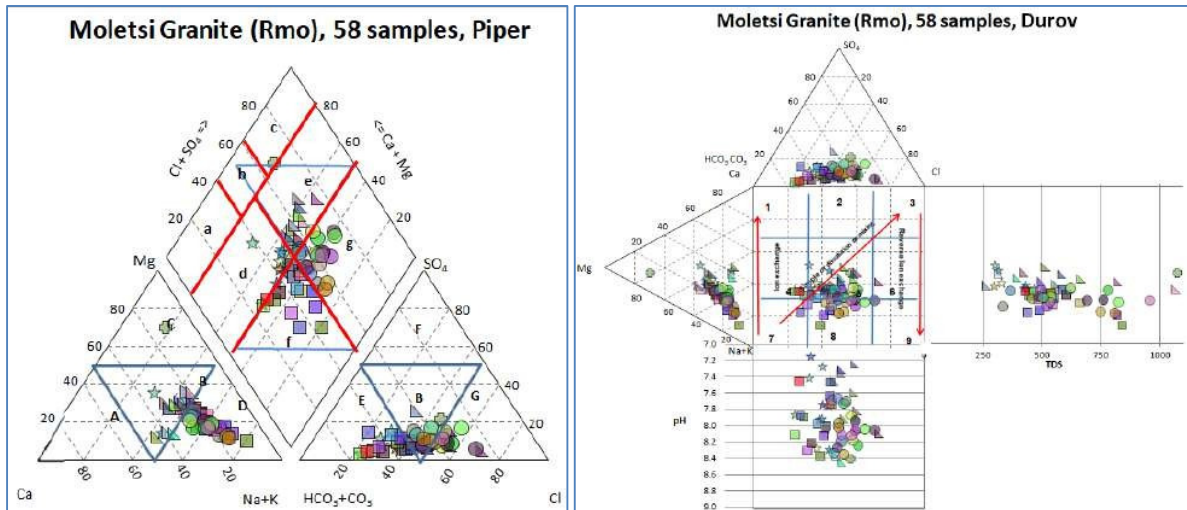


Figure 100: Trilinear diagrams, Piper, and Durov for the Moletsi Granite (Rmo) data points.

The trilinear Piper diagram, (Figure 100) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (39.7%), Weak acidic anions > Strong acidic anions (43.1%); Alkali > Alkali earths (60.3%); Strong acids > Weak acids (56.9%).

The groundwater in this unit classifies as:

- Sodium-Bicarbonate type (25.9%),
- Sodium-Chloride type (19%).
- Mixed Calcium-Magnesium-Bicarbonate type with increased Sodium (17.2%),
- Sodium-Bicarbonate-Chloride type (15.5%),
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type (12.1%),
- Mixed Calcium-Magnesium-Chloride type with increased Sodium (8.6%),
- Magnesium-Bicarbonate-Chloride type (1.7%),

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- No dominant anion or cation indicates water exhibiting simple dissolution or mixing (58.6%), plot along the dissolution or mixing line,
- Cl is the dominant anion and Na the dominant cation, indicative that the groundwater is related to reverse ion exchange of Na-Cl waters (29.3%),
- Anion discriminant and Ca dominant, frequently indicate recharge in gypsiferous deposits, otherwise mixed water or water exhibiting simple dissolution (6.9%),
- Ca and Na dominant, reverse ion exchange of Na-Cl waters (3.4%),

- Anion discriminate and Na dominant, indicates probable mixing or uncommon dissolution influences (1.7%),
- Some samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 68: Chemical statistics for the Moletsli Granite (Rmo).

Element / Parameter	Statistics Drawn from a population of 68 data points for the Moletsli Granite (Rmo)									
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation
pH	68	7.10	8.45	7.87	7.88	7.36	7.95	8.32	0.34	4.4%
Electrical Conductivity (mS/m EC)	68	37.16	476.00	73.38	87.61	46.75	73.48	113.02	56.37	64.3%
Total Dissolved Salts (mg/l TDS)	67	262.68	2076.14	521.88	594.07	351.22	537.48	824.81	260.17	43.8%
Calcium (mg/l Ca)	68	13.55	100.22	31.67	36.58	22.21	33.02	60.42	15.52	42.4%
Magnesium (mg/l Mg)	68	7.37	126.12	17.84	23.11	12.32	18.95	34.04	17.36	75.1%
Sodium (mg/l Na)	68	30.97	332.20	81.47	100.54	53.91	91.20	159.30	49.96	49.7%
Potassium (mg/l K)	68	0.15	28.26	2.31	5.59	2.20	5.25	7.93	3.97	71.0%
Chloride (mg/l Cl)	68	21.38	444.99	57.39	84.97	29.42	67.90	154.74	64.09	75.4%
Sulphate (mg/l SO <sub>4</sub> )	68	5.00	96.78	16.92	23.63	10.16	19.50	40.71	14.95	63.3%
Total Alkalinity (mg/l CaCO <sub>3</sub> )	63	74.71	387.60	187.10	209.97	134.10	199.95	304.83	69.29	33.0%
Nitrate (mg/l N)	67	0.02	50.66	0.92	13.23	3.44	10.09	32.22	10.82	81.8%
Fluoride (mg/l F)	68	0.11	3.50	0.68	1.36	0.31	1.09	3.00	1.00	74.0%
Silicon as Si	65	14.19	53.90	30.67	32.51	23.74	33.84	39.01	6.85	21.1%
Iron (Fe)	26	0.01	0.13	0.01	0.03	0.01	0.01	0.07	0.03	110.8%
Manganese (Mn)	10	0.01	8.00	0.02	0.82	0.01	0.03	0.85	2.52	305.8%
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	64	0.01	0.20	0.02	0.03	0.01	0.03	0.04	0.03	92.2%
ZAR	68	1.05	8.39	2.76	3.30	1.85	3.06	5.25	1.45	43.8%
LSI	63	Langelier Saturation Index (LSI)			Slightly Scaling	27.0%	Highly Scaling		0.0%	
		Highly corrosive	0.0%	Slightly corrosive	9.5%	Balanced Corrosion		63.5%		

Table 68 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality is ideal to good (47.7%), marginal (48.6%) and unacceptable, (EC > 370mS/m), in 1.5% of the analysis in terms of the Electrical conductivity (EC) with values ranging between 37.2 and 476mS/m. The 90<sup>th</sup> percentile is 113mS/m.

The Total Dissolved Solids (TDS) is acceptable in 98.5% of the samples, (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 68 samples indicates elevated concentrations of Fluoride (F > 1.5mg/l) in 36.8% and Nitrate (N > 20mg/l) in 14.9% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water is slightly corrosive (9.6%); slightly scaling (27%) and predominantly balanced (63.5%). The ZAR index indicates that 48.5% of the water is of a fair quality for irrigation (ZAR < 3).

The rural villages that occupy the complete areal extent of the unit obtain water from the Houtriver Regional Water Scheme. The water supply to the scheme is from surface water (Hout River Dam) and groundwater sources within and from outside the unit.

### 7.2.3.18 MATOK GRANITE (Rma)

The Matok Granite occurs in the centre-eastern sector of the map sheet, halfway between Polokwane and Louis Trichardt along the N1 north, (Figure 101). It is a major batholithic intrusion and includes several smaller stocks located north of Rhenosterkoppies. It is characterized by the presence of a mafic and a younger granitic phase. The mafic phase itself can be divided into an older enderbite and a younger charno-enderbite phase. Both are confined mainly to the northern edge of the batholith. The enderbite is typically fine-grained and dark-coloured whereas the charno-enderbite is paler and coarser-grained. Mineralogically both types are similar and are composed of plagioclase and biotite with subordinate augite, hypersthene, orthoclase, and quartz. They differ only in pyroxene content which is less in the charno-enderbite phase. It covers approximately 1.03% of the map sheet.

The yield frequency diagram, (Figure 102), gives an indication of the expected yield of the boreholes. It shows that 60.4% of successful boreholes yield less than 2ℓ/s and 39.6% yields more than 2ℓ/s. Available information indicates that the higher yielding boreholes relate to the Matok Fault Zone and to a lesser degree to diabase dykes.

In 54.3% of the water samples, at least one element exceeds the maximum allowed limits for domestic use. For this unit the anion of concern is Fluoride followed by a high percentage (52.8%) of the sources with elevated Nitrate concentrations that exceed the maximum allowable limit for human consumption.

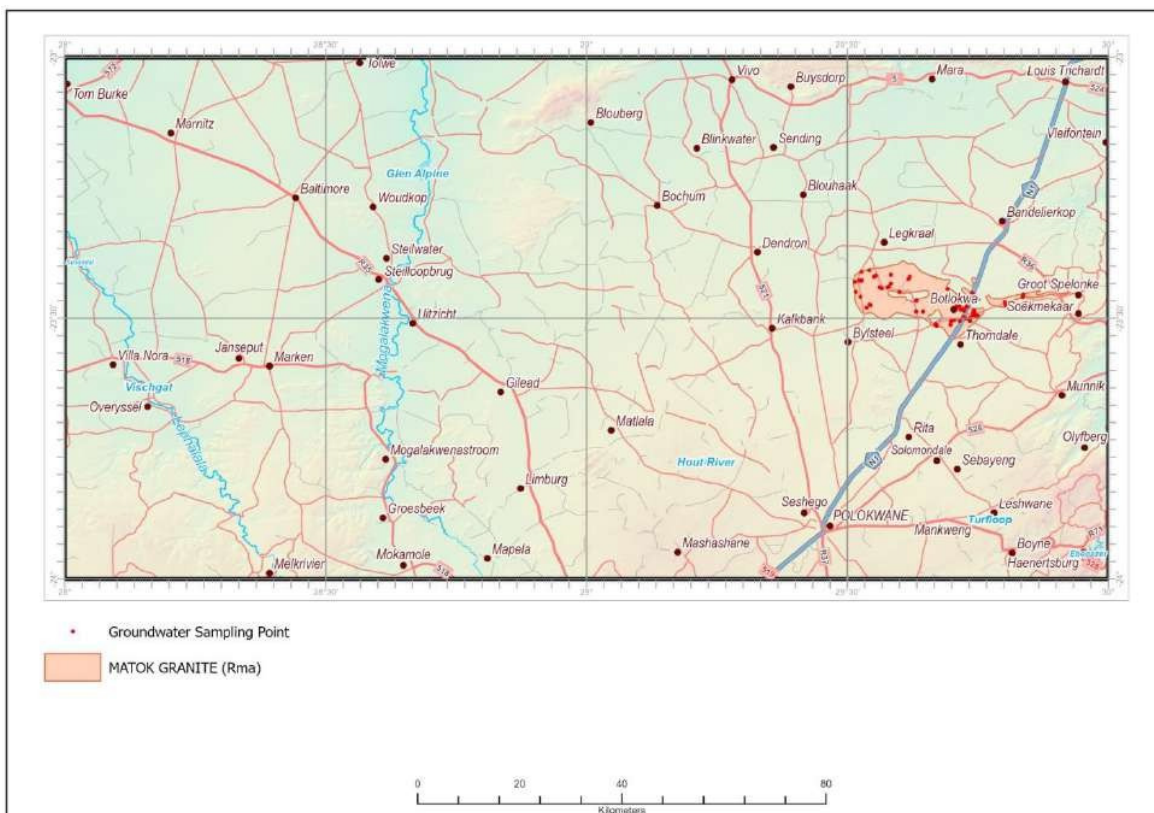


Figure 101: Geographical distribution of the Matok Granite (Rma) and the associated groundwater data points.

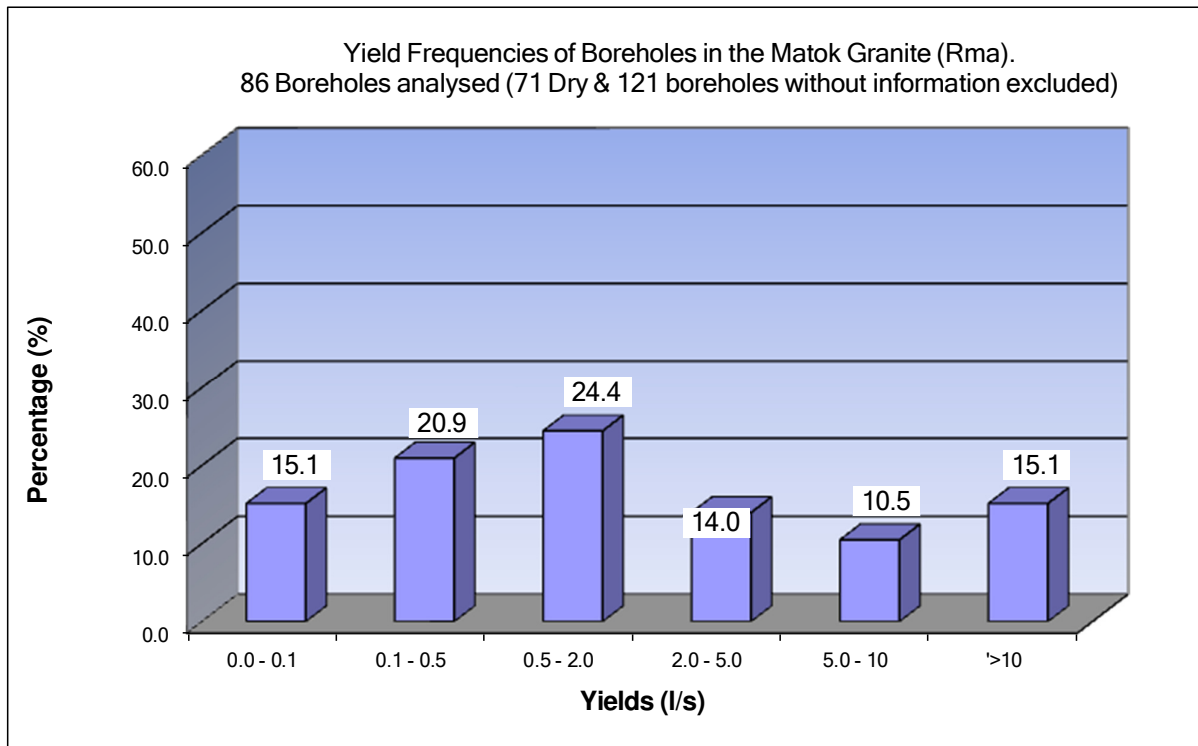


Figure 102: Yield frequency for fractured aquifers of the Matok Granite (Rma)

The statistical analysis of 86 borehole records, (Figure 102) indicates that 36% of successful boreholes have yields suitable for small households (>0.001l/s to 0.5l/s). Additionally, 24.4% of boreholes have yields between 0.5l/s and 2l/s, with 14% yielding between 2l/s and 5l/s and 25.6% with yields that exceed 5l/s.

The static water level ranges from 1.85 meters below ground level (mbgl) to 75.07mbgl, with a median of 9.61mbgl and an average of 12.44mbgl (based on 54 data points). The maximum depth recorded is 150m, with an average depth of 68.58m and a median depth of 61m (86 data points). The maximum installation depth is 102m and the average installation depth is 37m, (48 data points). The depth of installation can be indicative of water strike depths if compared to the average depth and static water levels of the boreholes. The maximum recommended daily abstraction on record is 691.2 cubic meters per day (m<sup>3</sup>/day) and the average is 107.5m<sup>3</sup>/day. The 90th percentile of daily abstraction is 279.9m<sup>3</sup>/day and the 80th percentile is 184.9m<sup>3</sup>/day. The total number of boreholes subjected to pump testing this unit on record is 48.

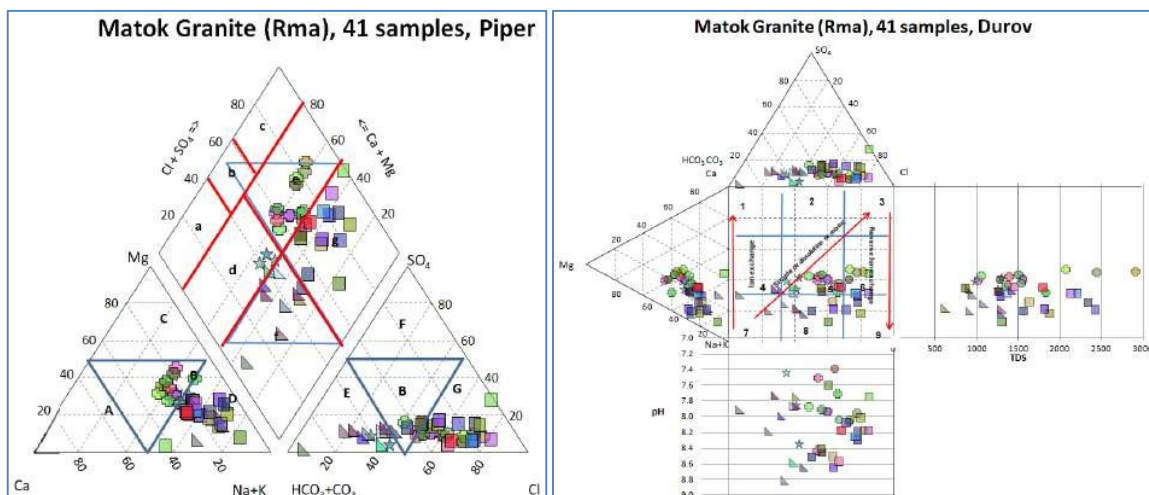


Figure 103: Trilinear diagrams, Piper, and Durov for the Matok Granite (Rma) data points.

The trilinear Piper diagram, (Figure 103) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (39%), Weak acidic anions > Strong acidic anions (31.7%); Alkali > Alkali earths (61%); Strong acids > Weak acids (68.3%).

The groundwater in this unit classifies as:

- Sodium-Bicarbonate type (53.7%),
- Mixed Calcium-Magnesium-Chloride type with increased Sodium (29.3%);
- Sodium-Bicarbonate-Chloride type (7.3%),
- Mixed Calcium-Magnesium-Bicarbonate type with increased Sodium (7.3%);
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type with increased Sodium (2.4%);

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- No dominant anion or cation indicates water exhibiting simple dissolution or mixing (46.3%), plot along the dissolution or mixing line,
- Anion discriminate and Na dominant, indicates probable mixing or uncommon dissolution influences (17.1%),
- Cl is the dominant anion and Na the dominant cation, indicative that the groundwater is related to reverse ion exchange of Na-Cl waters (17.1%),
- Cl and Na dominant, frequently indicative of end-point gradient waters through Dissolution (9.8%).
- Ca and Na dominant, reverse ion exchange of Na-Cl waters (4.9%),
- Anion discriminant and Ca dominant, frequently indicate recharge in gypsiferous deposits, otherwise mixed water or water exhibiting simple dissolution (4.9%),
- Some samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 69: Chemical statistics for the Matok Granite (Rma).

Element / Parameter	Statistics Drawn from a population of 73 data points for the Matok Granite (Rma).									
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation
pH	72	6.71	8.93	7.91	7.94	7.35	7.98	8.54	0.48	6.0%
Electrical Conductivity (mS/m EC)	72	58.22	1607.46	148.78	189.09	102.31	156.50	245.69	184.02	97.3%
Total Dissolved Salts (mg/l TDS)	70	452.11	11947.35	1066.85	1327.53	728.89	1090.50	1730.94	1353.91	102.0%
Calcium (mg/l Ca)	68	13.07	1152.23	53.44	94.68	26.59	71.92	139.76	142.83	150.9%
Magnesium (mg/l Mg)	68	7.52	732.06	41.21	66.52	25.43	51.10	90.76	86.52	130.1%
Sodium (mg/l Na)	68	67.79	1663.66	173.32	219.53	123.29	177.87	307.64	197.77	90.1%
Potassium (mg/l K)	67	2.62	44.54	8.66	12.64	5.21	10.81	25.52	8.86	70.2%
Chloride (mg/l Cl)	70	8.69	5965.55	117.04	328.54	72.45	193.77	532.57	715.59	217.8%
Sulphate (mg/l SO <sub>4</sub> )	70	3.77	1009.12	38.71	80.70	23.98	52.19	112.13	138.57	171.7%
Total Alkalinity (mg/l) CaCO <sub>3</sub>	68	50.66	551.00	274.09	325.04	181.31	341.60	434.30	104.51	32.2%
Nitrate (mg/l N)	72	0.32	106.82	5.72	30.31	3.20	23.33	73.30	25.24	83.3%
Fluoride (mg/l F)	70	0.08	4.30	0.79	1.56	0.49	1.54	2.72	0.87	56.0%
Silicon as Si	65	9.30	48.75	28.29	30.88	20.93	31.00	38.62	7.73	25.0%
Iron (Fe)	30	0.01	0.30	0.01	0.03	0.01	0.01	0.05	0.05	194.4%
Manganese (Mn)	17	0.01	0.45	0.02	0.06	0.01	0.03	0.06	0.10	186.8%
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	62	0.01	0.80	0.02	0.12	0.01	0.03	0.75	0.25	205.5%
ZAR	68	1.88	10.33	3.89	4.46	2.93	3.82	6.96	1.87	41.9%
LSI	66	Langelier Saturation Index (LSI)		Slightly Scaling		69.7%		Highly Scaling		0.0%
		Highly corrosive		0.0%		Slightly corrosive		0.0%		Balanced Corrosion

Table 69 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90<sup>th</sup> percentile, the maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality is ideal to good (47.7%), marginal (48.6%) and unacceptable, (EC > 370mS/m), in 4.2% of the analysis in terms of the Electrical conductivity (EC) with values ranging between 58.2 and 1607.5mS/m. The 90<sup>th</sup> percentile is 245.69mS/m.

The Total Dissolved Solids (TDS) is acceptable in 62.9% of the samples, ( $TDS \leq 1200\text{mg/l}$ ). An evaluation of the major cations and anions from 73 samples indicates elevated concentrations of Fluoride ( $F > 1.5\text{mg/l}$ ) in 54.3%; Nitrate ( $N > 20\text{mg/l}$ ) in 52.8%; Chloride ( $Cl > 600\text{mg/l}$ ) in 5.7%; Sodium ( $Na > 400\text{mg/l}$ ) in 4.4%; Calcium ( $Ca > 300$ ) in 2.9%; Sulphate ( $SO_4 > 600\text{mg/l}$ ) in 2.9% and Magnesium ( $Mg > 200\text{mg/l}$ ) in 1.5% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water is predominantly slightly scaling (69.7%) and balanced (30.3%). The ZAR index indicates that 13.2% of the water is of a fair quality for irrigation ( $ZAR < 3$ ).

Approximately 50% of the units are covered by rural villages that obtain their water from the Botlokwa Groundwater System. The water is from groundwater from resources within the unit as well as from the adjacent groundwater resource units, namely Hout River Gneiss (Rho) and Hout River Gneiss with Xenoliths (Rh<sub>x</sub>). Within the largest section of the remaining area underlain by the unit livestock farming dominates. In the western part of the unit large scale irrigation occurs. The water for irrigation is from this unit but predominantly from the above-mentioned units Rho and Rh<sub>x</sub>.

### **7.2.3.19 HUGOMOND GRANITE (Rhu)**

The Hugomond Granite is a coarse-grained, sometimes porphyritic, grey biotitic rock which occurs as several low barren ridges east-north-east of Mogwadi (Dendron). It is cut by tourmaline-bearing pegmatitic veins having indistinct contacts. It covers approximately 0.02% of the map sheet area. There is no yield or water chemistry data available for this unit, but it is expected to be similar in character to granite intrusions on the map sheet.

A dimension stone quarry is located within the unit. Large scale irrigation was practiced in the past but as water levels decreased in the Dendron area, the areal extent of irrigation fields decreased. All the farms falling within the unit are dependable on groundwater. Water for irrigation was pumped from the adjacent units i.e. Hout River Gneiss (Rho) and Hout River Gneiss with Xenoliths (Rh<sub>x</sub>).

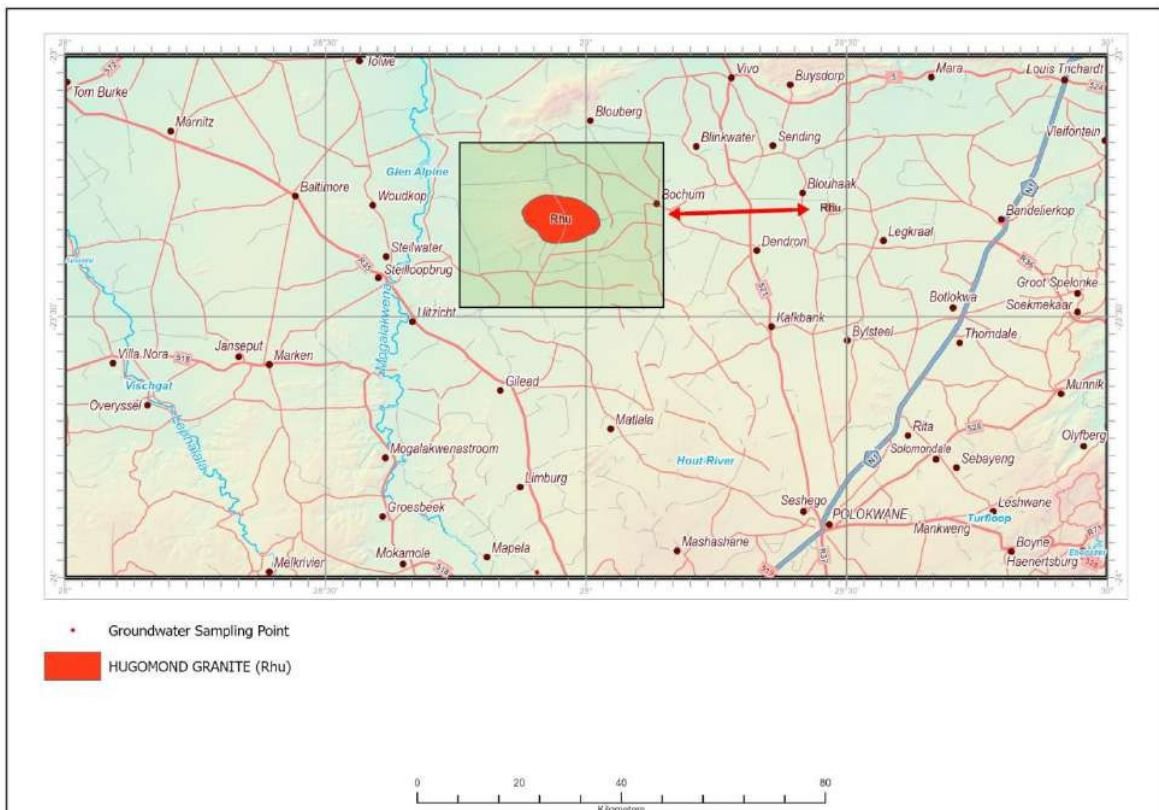


Figure 104: Geographical distribution of the Hugomond Granite (Rhu) and the associated groundwater data points.

### 7.2.3.20 HOUT RIVER GNEISS (Rho)

The Hout River Gneiss comprise a variety of granitoid rocks including leucocratic migmatite, gneiss, pink hornblende biotite gneiss, grey biotite gneiss, and pegmatitic rocks. The unit predominantly underlay flat country and are poorly exposed. Leucocratic pegmatite and gneiss consist typically of dominant quartz-feldspatic layers and thin streaks, mainly of biotite. In the Dendron and Blouberg areas a common variety occur, namely a medium to coarse-grained pinkish grey and pink leucocratic gneiss composed of orthoclase and quartz with minor plagioclase, biotite, and hornblende. The dark minerals usually impart a strong foliation. Muscovite bearing granite and pegmatite occur throughout the Hout River Gneiss but seem to be more prominently developed near the contact with the Pietersburg Group.

The Hout River Gneiss is mostly exposed to ephemeral streams throughout its occurrence in the Polokwane (Pietersburg) area in the south up to the Soutpansberg in the north. As mentioned above a wide variety of granitoid rocks have been grouped under this unit. Various granites and numerous diabase dykes intruded into the unit. The dykes are predominantly trending northwest and northeast. This unit covers approximately 13.86% of the total map sheet and is an important groundwater resource for rural villages, highly populated areas such as Polokwane and Louis Trichardt and agriculture purposes including irrigation and livestock watering. The area is generally flat and covered by sandy soil.

The groundwater potential of the gneisses is generally good with 47.6% of the successful boreholes yielding less than 2l/s and 52.4% more than 2l/s, (Figure 106). A considerable number of boreholes (33.2%), yield more than 5l/s.

In 10.3% of the water samples, at least one element exceeds the maximum allowed limits for domestic use. For this unit the anion of concern is Nitrate followed by a small percentage (4.8%) of the sources with elevated Fluoride concentrations that exceed the maximum allowable limit for human consumption.

High yielding boreholes such as in the Dendron area 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 Louis Trichardt area revealed that the presence of these pegmatites could make a considerable difference in the yield over very short distances. Water is also obtained in deep basins of weathering as well as in the transitional zone between weathered and solid gneiss. Depths of weathering more than 40m are not uncommon which enlarges the storage capacity for groundwater.

Over-utilization of groundwater resources in the Dendron/Vivo area depleted the groundwater to such an extent that the present groundwater-level is already below the average depth of weathered basins in places. This prompted irrigation farmers to drill deeper and abstract water from deeper seated fractures and pegmatites. Many of the fractures intercepted with depth are thought to be related to off-loading. Water occurs also in fault and shear zones and also to a lesser extent along diabase dyke contacts. Some of the wider dykes in the area are sometimes more fractured, fissured or decomposed than the surrounding host rock and therefore act as the preferred pathways for groundwater. As the wider dykes cooled slower than the narrow ones, they are coarser grained and therefore more susceptible to weathering and fracturing (Du Toit, 1986).

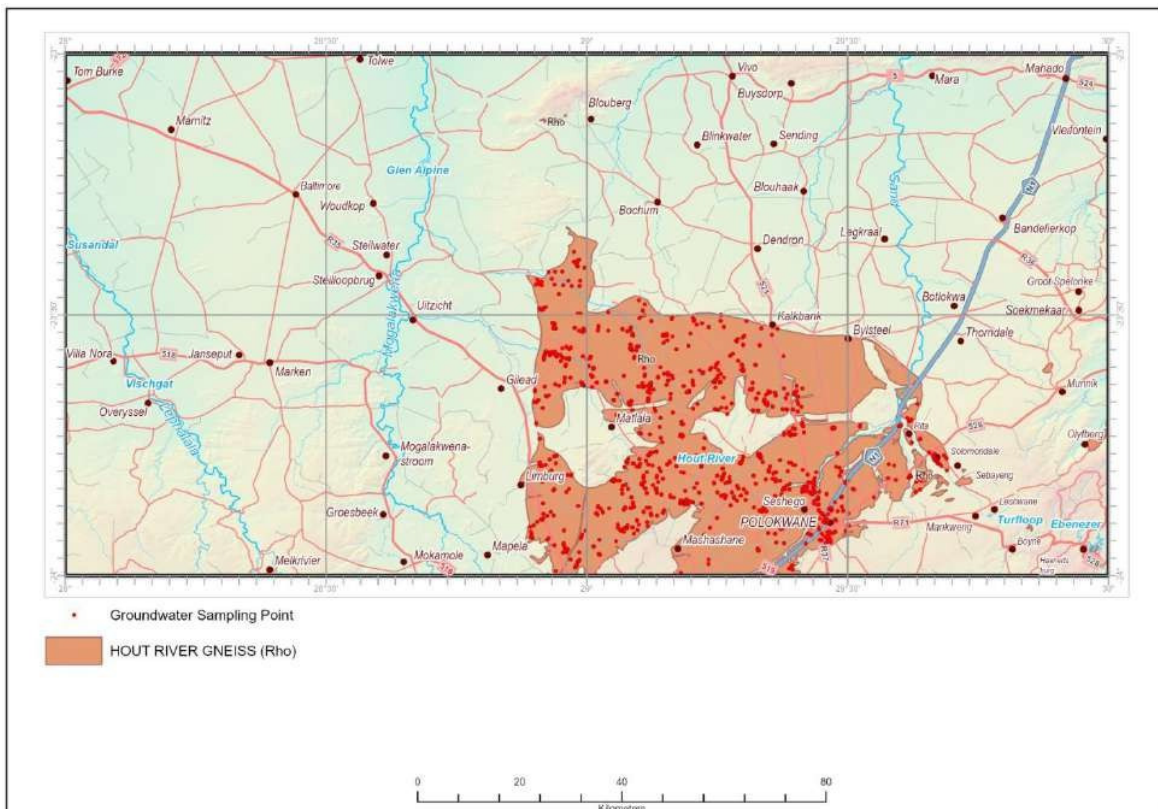
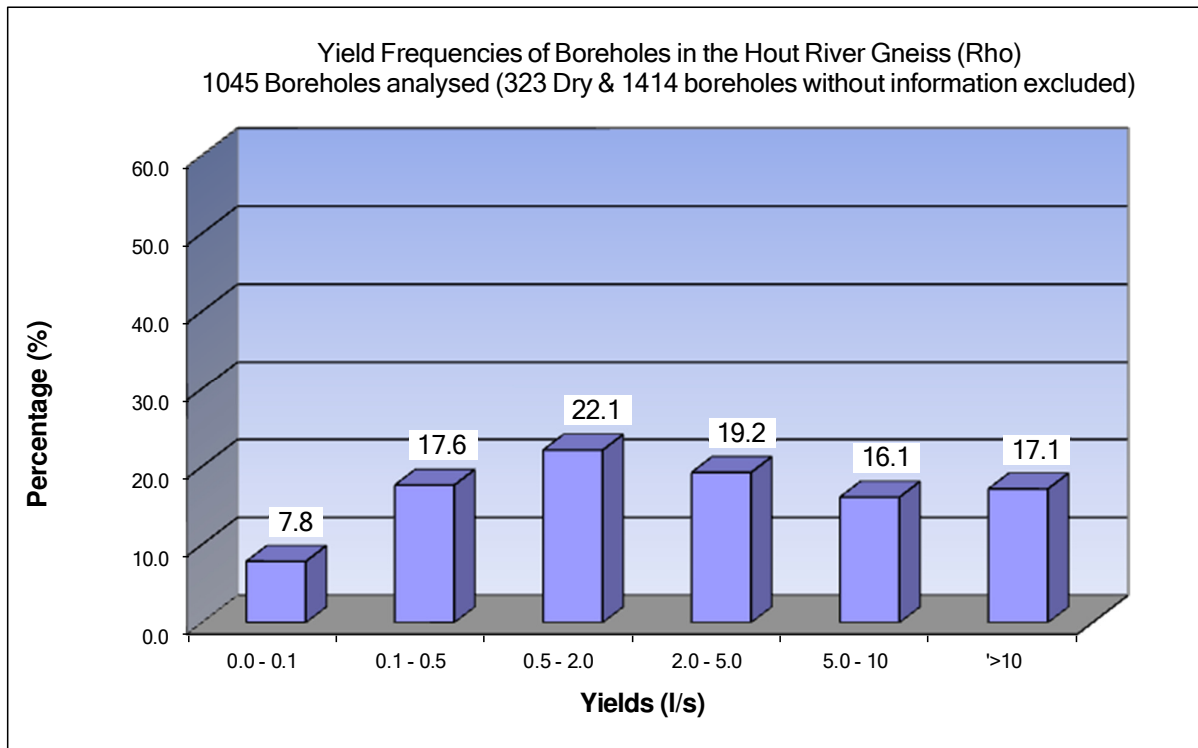


Figure 105: Geographical distribution of the Hout River Gneiss (Rho) and the associated groundwater data points.



*Figure 106: Yield frequency for fractured aquifers of the Hout River Gneiss (Rho)*

The statistical analysis of 1045 borehole records, (Figure 106) indicates that 25.5% of successful boreholes have yields suitable for small households (>0.001l/s to 0.5l/s). A further 22.1% of boreholes yield between 0.5l/s and 2l/s, with 19.2% yielding between 2l/s and 5l/s. In addition, 16.1% of the boreholes yield between 5l/s and 10l/s and 17.1% have yields exceeding 10l/s.

The static water level ranges from 0.6 meters below ground level (mbgl) to 75.3mbgl, with a median of 13.03mbgl, and an average of 15.54mbgl (based on 879 data points). The maximum depth recorded is 250m, with an average of 68.4m, and a median of 61m (1177 data points). The maximum installation depth is 135m and with an average of 38.8m, (643 data points). The depth of installation can be indicative of water strike depths if compared to the average depth and static water levels of the boreholes. The maximum recommended daily abstraction on record is 864 cubic meters per day (m<sup>3</sup>/day) and the average is 114.9m<sup>3</sup>/day. The 90th percentile of daily abstraction is 302.2m<sup>3</sup>/day and the 80th percentile is 172.8m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 647.

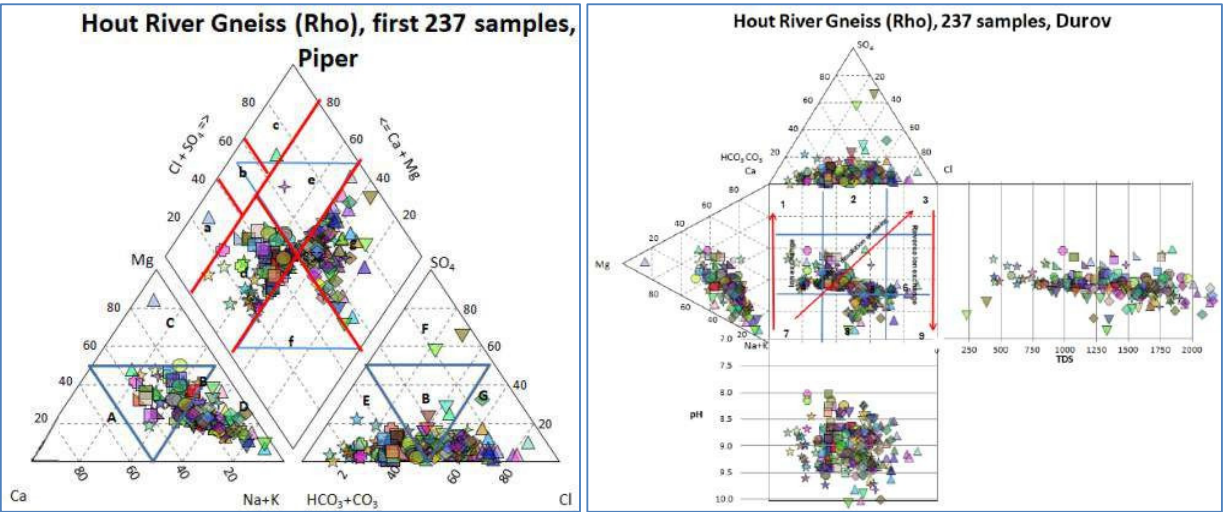


Figure 107: Trilinear diagrams, Piper, and Durov for the Hout River Gneiss (Rho), first 237 data points.

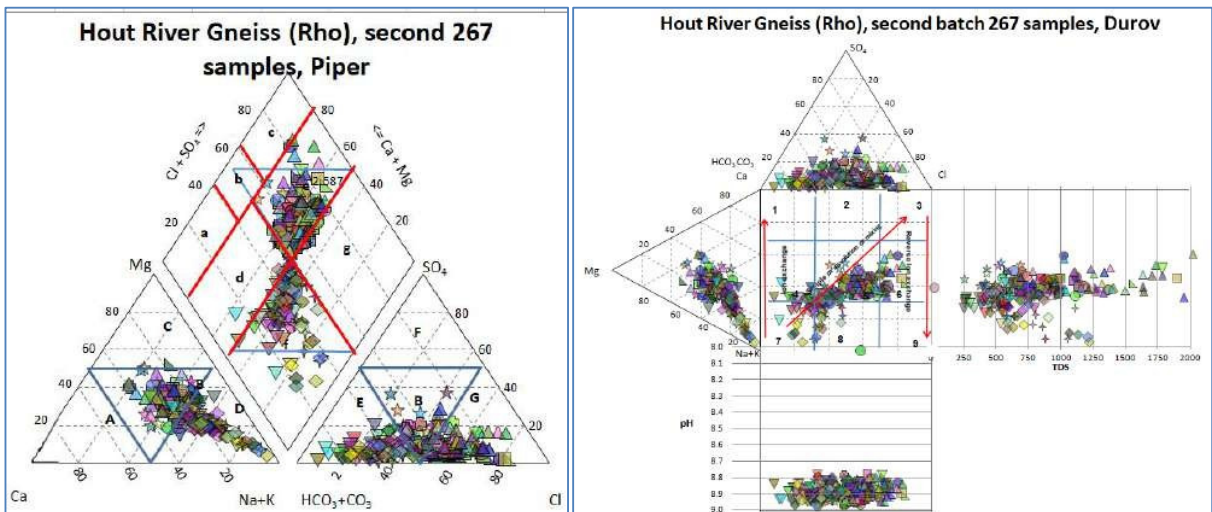


Figure 108: Trilinear diagrams, Piper, and Durov for the Hout River Gneiss (Rho), second batch of 267 data points.

The trilinear Piper diagram, (Figure 107 & Figure 108) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (51.7%), Weak acidic anions > Strong acidic anions (42.7%); Alkali > Alkali earths (48.3%); Strong acids > Weak acids (57.3%).

The groundwater in this unit classifies as:

- Mixed Calcium-Magnesium-Chloride type (21.1%);
- Sodium-Bicarbonate type (20.1%);
- Mixed Calcium-Magnesium-Bicarbonate type (17.5%);
- Sodium-Chloride type (14.9%),
- Sodium-Bicarbonate-Chloride type (12.9%);
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type (12.1%);
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type with increased Sulphate (0.8%);
- Sodium-Sulphate type (0.4%);
- Magnesium-Bicarbonate type (0.2%);

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- No dominant anion or cation indicates water exhibiting simple dissolution or mixing (63.4%), plot along the dissolution or mixing line,
- Cl is the dominant anion and Na the dominant cation, indicative that the groundwater is related to reverse ion exchange of Na-Cl waters (17.3%),
- Anion discriminant and Ca dominant, frequently indicates recharge in gypsiferous deposits, otherwise mixed water or water exhibiting simple dissolution (7.2%),
- Anion discriminate and Na dominant, indicates probable mixing or uncommon dissolution influences (6.4%),
- Cl and Na dominant, reverse ion exchange of Na-Cl waters (4.6%),
- Cl and Na dominant, frequently indicative of end-point gradient waters through Dissolution (1.2%),
- Some samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 70: Chemical statistics for the Hout River Gneiss (Rho).

Element / Parameter	Statistics Drawn from a population of 937 data points for Hout River Gneiss (Rho).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	908	2.60	9.05	7.86	7.90	7.30	7.93	8.41	0.47	5.9%	
Electrical Conductivity (mS/m EC)	908	14.10	470.42	78.16	99.14	50.07	88.29	164.86	52.23	52.7%	
Total Dissolved Salts (mg/l TDS)	902	17.18	3094.50	532.03	701.45	369.06	637.33	1129.90	350.13	49.9%	
Calcium (mg/l Ca)	894	2.70	305.35	32.88	47.05	18.69	40.23	80.96	31.38	66.7%	
Magnesium (mg/l Mg)	892	1.90	186.28	24.50	35.37	14.97	29.43	64.10	23.19	65.6%	
Sodium (mg/l Na)	888	0.01	430.60	7.99	109.94	45.98	93.02	194.97	63.36	57.6%	
Potassium (mg/l K)	882	0.42	155.45	5.52	10.44	3.10	7.89	18.80	11.37	108.9%	
Chloride (mg/l Cl)	909	0.99	1401.37	47.40	117.73	23.28	81.10	233.31	123.97	105.3%	
Sulphate (mg/l SO <sub>4</sub> )	899	0.30	215.60	13.55	28.94	7.30	20.40	61.02	26.45	91.4%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	800	2.00	689.00	196.07	279.21	147.78	271.39	419.03	106.25	38.1%	
Nitrate (mg/l N)	905	0.01	244.21	0.68	10.33	0.63	6.80	20.18	15.37	148.8%	
Fluoride (mg/l F)	893	0.02	4.44	0.31	0.51	0.19	0.36	0.96	0.49	96.3%	
Silicon as Si	819	0.05	101.00	6.66	31.87	19.17	32.71	39.28	11.53	36.2%	
Iron (Fe)	472	0.005	0.691	0.013	0.035	0.006	0.012	0.055	0.07	204.2%	
Manganese (Mn)	246	0.005	0.888	0.013	0.059	0.006	0.011	0.140	0.13	217.9%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	793	0.005	2.550	0.021	0.073	0.010	0.026	0.106	0.18	247.1%	
ZAR	886	0.25	18.92	2.42	3.13	1.53	2.68	4.86	2.00	63.8%	
LSI	798	Langelier Saturation Index (LSI)		Slightly Scaling			44.2%		Highly Scaling		0.0%
		Highly corrosive		0.6%	Slightly corrosive		5.3%	Balanced Corrosion		49.9%	

Table 70 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality is ideal to good (86.6%), marginal (12.7%) and unacceptable, (EC > 370mS/m), in 0.8% of the analysis in terms of the Electrical conductivity (EC) with values ranging between 14.1 and 470.42mS/m. The 90<sup>th</sup> percentile is 164.86mS/m.

The Total Dissolved Solids (TDS) are acceptable in 92.5% of the samples, (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 937 samples indicates elevated concentrations of Nitrate (N > 10mg/l) in 10.3%; Fluoride (F > 1.5mg/l) in 4.8%; Chloride (Cl > 600mg/l) in 1.2%; Sodium (Na > 400mg/l) in 0.3%; Potassium (K > 100mg/l) in 0.2%; Calcium (Ca > 300) in 0.1% and Magnesium (Mg > 200mg/l) in 0.1% of the analysis. The pH value exceeds the maximum allowable limit in one sample; it is acidic.

The Langelier Saturation Index (LSI) indicates that the water is slightly to highly corrosive (5.9); slightly scaling (44.2%) and predominantly balanced (49.9%). The ZAR index indicates that 60.7% of the water is of a fair quality for irrigation (ZAR < 3).

A large section of the unit underlies Polokwane. The unit supply groundwater to various Regional Water Schemes of which some are dependent on groundwater, and some are from a combination of surface and groundwater. Large scale irrigation occurs in the unit.

### **7.2.3.21 HOUT RIVER GNEISS WITH XENOLITHS (Rh<sub>x</sub>)**

The Hout River Gneiss with Xenoliths differs from the Hout River Gneiss mostly due to the presence of inclusions/xenoliths in the former. These inclusions/xenoliths of rocks belonging to the Bandelierskop Complex occur as highly deformed keels within the gneiss. Numerous diabase dykes intruded into this as well as into the Hout River Gneiss unit. The dykes are predominantly trending northwest and northeast. Except for the inclusions, the unit has overall the same characteristics as the Hout River Gneiss. It comprises a variety of granitoid rocks including leucocratic migmatite, gneiss, pink hornblende biotite gneiss, grey biotite gneiss, and pegmatitic rocks. They largely underlay flat country and are poorly exposed. Leucocratic pegmatite and gneiss consist typically of dominant quartzo-feldspathic layers and thin, mainly of biotite, streaks. In the Dendron and Blouberg areas there is a common variety i.e. medium to coarse-grained pinkish grey and pink leucocratic gneiss composed of orthoclase and quartz with minor plagioclase, biotite, and hornblende. The dark minerals usually impart a strong foliation. Muscovite bearing granite and pegmatite occur throughout the Hout River Gneiss but seems to be more prominently developed near the contact with the rocks of the Pietersburg Group.

The Hout River Gneiss with Xenoliths is mostly exposed in ephemeral streams throughout its occurrence in the Polokwane (Pietersburg) area in the south up to the Soutpansberg in the north. As mentioned above, a wide variety of granitoid rocks have been grouped under this unit. This unit covers approximately 13.9% of the total map sheet and is an important groundwater resource for rural villages and agriculture purposes (irrigation and livestock watering). The area is generally flat and covered by sandy soil.

The groundwater potential of the gneisses is generally good with 44.4% of the boreholes yielding less than 2l/s and 55.6% yielding more than 2l/s of which 34.7% yield more than 5l/s, (Figure 110). In 9.6% of the water samples, at least one element exceeds the maximum allowed limits for domestic use. For this unit the anion of concern is Nitrate. The average depth to groundwater level is 29.9 meters below ground level (mbgl) but in high abstraction areas such as Bandelierskop and Dendron it can be more than 60mbgl.

High yielding boreholes such as in the Dendron area appear to be related to the occurrence of pegmatites. Drilling in the Louis Trichardt area revealed that the presence of pegmatites could make a considerable difference in the maximum yield over very short distances. Water is also obtained in deep weathered basins as well as in the transitional zone between weathered and solid gneiss. Depths of weathering exceeding 40m are not uncommon that enlarges the storage capacity for groundwater in areas with a shallow static water table, (< 30mbgl).

Over-utilization of groundwater resources in the Dendron/Vivo area depleted the groundwater to such an extent that the present groundwater level is already below the average depth of weathered basins in places. This prompted irrigation farmers to drill deeper and abstract water from deeper seated fractures and pegmatite. Many of the fractures intercepted with depth are thought to be related to off-loading stress. Water occurs also in fault and shear zones and to a lesser extent along diabase dyke contacts. Some of the wider dykes in the area are sometimes more fractured, fissured or decomposed than the surrounding host rock and act as the preferred pathways for groundwater. As the wider dykes cooled slower than the narrow ones, they are coarser grained and therefore more susceptible to weathering and fracturing (Du Toit, 1986).

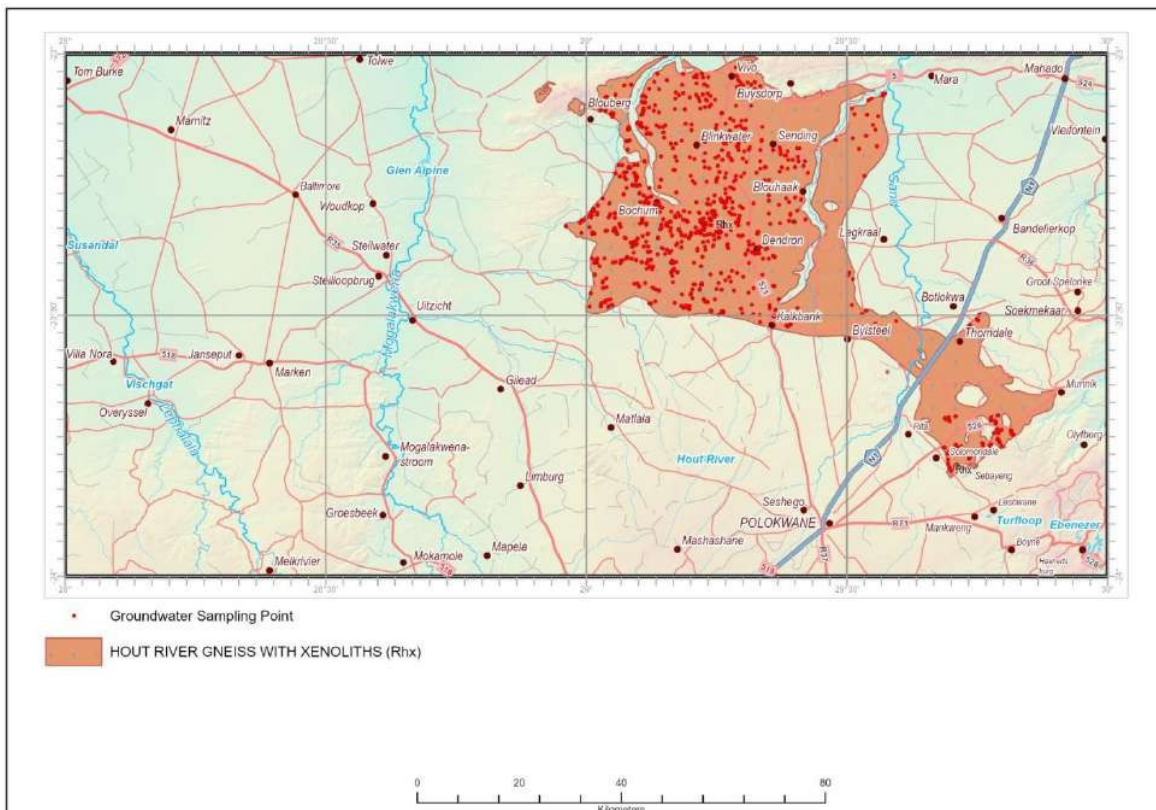


Figure 109: Geographical distribution of the Hout River Gneiss with Xenoliths (RhX) and the associated groundwater data points.

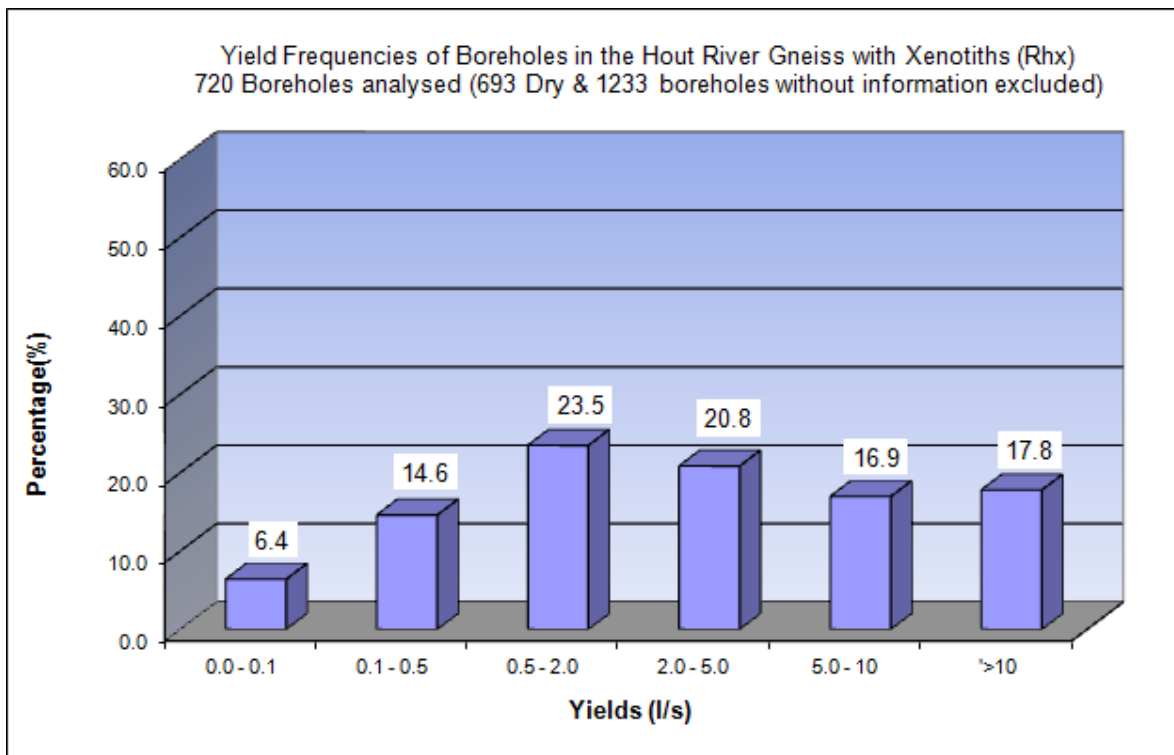


Figure 110: Yield frequency for fractured aquifers of the Hout River Gneiss with Xenoliths (RhX)

The statistical analysis of 720 borehole records, (Figure 110) indicates that 21% of successful boreholes have yields suitable for small households (>0.001ℓ/s to 0.5ℓ/s). Additionally, 23.5% of boreholes yield between 0.5ℓ/s and 2ℓ/s, with 20.8% yielding between 2ℓ/s and 5ℓ/s and 34.7% of the boreholes yielding more that 5ℓ/s.

The static water level ranges from 0.01 meters below ground level (mbgl) to 90.8mbgl, with a median of 25.62mbgl and an average of 29.91mbgl (based on 431 data points). The maximum depth recorded is 300m, with an average of 77m and a median depth of 71m (608 data points). The maximum installation depth is 150m and with an average of 48.7m (329 data points). The depth of installation can be indicative of water strike depths if compared to the average depth and static water levels of the boreholes. The maximum recommended daily abstraction on record is 950 cubic meters per day (m<sup>3</sup>/day) and the average is 165m<sup>3</sup>/day. The 90th percentile of daily abstraction is 432m<sup>3</sup>/day and the 80th percentile is 293.8m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 330.

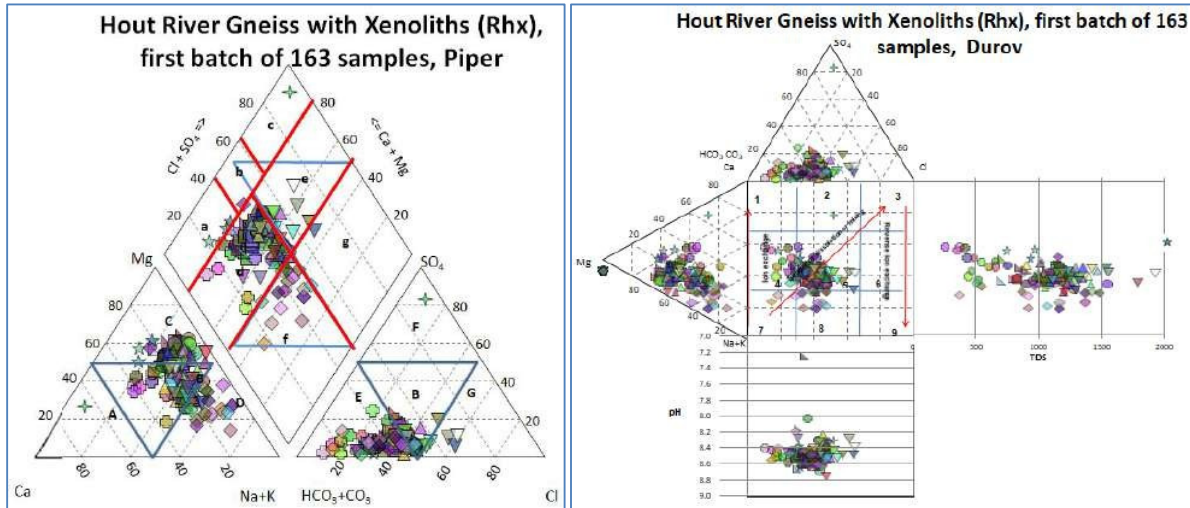


Figure 111: Trilinear diagrams, Piper, and Durov for the Hout River Gneiss with Xenoliths (RhX) first batch of 163 data points.

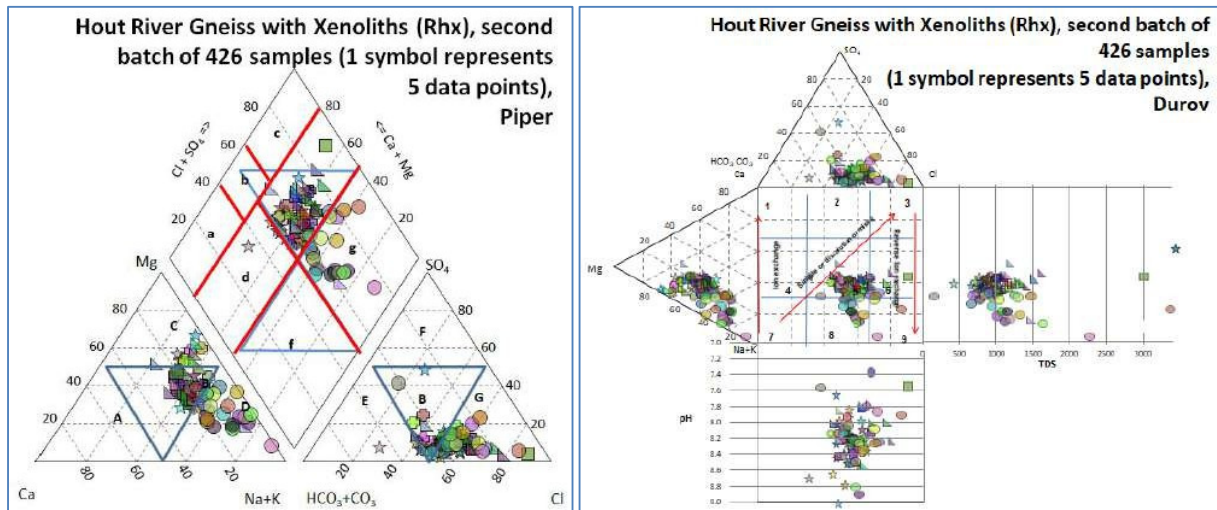


Figure 112: Trilinear diagrams, Piper, and Durov for the Hout River Gneiss with Xenoliths (RhX), second batch of 426 data points.

The trilinear Piper diagram, (Figure 111 & Figure 112) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of

hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (81.6%), Weak acidic anions > Strong acidic anions (27.4%); Alkali > Alkali earths (18.4%); Strong acids > Weak acids (72.6%).

The groundwater in this unit classifies as:

- Mixed Calcium-Magnesium-Chloride type with increased Sodium (38.8%);
- Sodium-Chloride type (14%),
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type with increased Sodium (12.5%);
- Magnesium-Bicarbonate type (11.5%);
- Magnesium-Bicarbonate-Chloride type (9.8%);
- Mixed Calcium-Magnesium-Bicarbonate type (6.1%);
- Sodium-Bicarbonate type (2.7%);
- Mixed Calcium-Magnesium-Bicarbonate type with increased Sodium (2%);
- Magnesium-Chloride type (1.5%),
- Magnesium-Sulphate type (0.5%),
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type with increased Sulphate (0.3%);
- Calcium-Sulphate type (0.3%).

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- No dominant anion or cation indicates water exhibiting simple dissolution or mixing (73.7%), plot along the dissolution or mixing line,
- Cl is the dominant anion and Na the dominant cation, indicative that the groundwater is related to reverse ion exchange of Na-Cl waters (15%),
- SO<sub>4</sub> dominates, or anion discriminant and Ca dominant, Ca and SO<sub>4</sub> dominates, frequently indicates recharge in gypsiferous deposits, otherwise mixed water or water exhibiting simple dissolution may be indicated. (4.2%)
- SO<sub>4</sub> dominates, or anion discriminate and Na dominant, indicates probable mixing or uncommon dissolution influences (3.2%),
- Cl and Na dominant, frequently indicative of end-point gradient waters through Dissolution (3.2%),
- Cl and Na dominant, reverse ion exchange of Na-Cl waters (0.5%),
- HCO<sub>3</sub> and Ca dominant, frequently indicates recharging water in limestone, sandstone, and many other aquifers (0.2%),
- Some samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 71: Chemical statistics for the Hout River Gneiss with Xenoliths (Rhx).

Element / Parameter	Statistics Drawn from a population of 884 data points for Hout River Gneiss with Xenoliths (Rhx).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	880	3.77	9.12	8.06	8.08	7.62	8.14	8.48	0.38	4.7%	
Electrical Conductivity (mS/m EC)	879	4.35	631.63	109.72	136.18	86.76	121.20	196.00	64.33	47.2%	
Total Dissolved Salts (mg/l TDS)	869	147.40	4335.82	868.47	995.38	653.80	923.74	1353.20	413.25	41.5%	
Calcium (mg/l Ca)	854	2.40	601.91	37.30	52.72	22.57	48.15	78.07	36.61	69.4%	
Magnesium (mg/l Mg)	854	4.25	310.40	53.32	69.19	33.84	67.29	98.82	34.44	49.8%	
Sodium (mg/l Na)	852	5.08	813.90	102.27	137.35	74.57	119.26	203.87	85.83	62.5%	
Potassium (mg/l K)	851	0.15	202.96	8.81	13.69	6.76	12.61	20.20	10.64	77.7%	
Chloride (mg/l Cl)	873	3.00	1766.38	102.14	187.68	72.80	149.40	304.11	178.14	94.9%	
Sulphate (mg/l SO <sub>4</sub> )	854	0.60	1619.58	24.87	52.25	17.83	34.98	86.10	88.37	169.1%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	808	25.70	909.00	326.87	366.57	239.61	367.81	475.88	97.33	26.6%	
Nitrate (mg/l N)	872	0.02	130.89	0.96	9.89	0.83	7.26	19.61	11.78	119.1%	
Fluoride (mg/l F)	866	0.02	3.03	0.27	0.37	0.18	0.29	0.61	0.29	79.0%	
Silicon as Si	821	2.15	49.63	24.87	31.87	20.21	34.50	39.88	8.87	27.8%	
Iron (Fe)	213	0.005	0.360	0.012	0.023	0.007	0.012	0.050	0.036	156.9%	
Manganese (Mn)	123	0.005	0.718	0.013	0.054	0.006	0.011	0.129	0.111	204.2%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	785	0.005	0.800	0.016	0.035	0.009	0.019	0.050	0.087	246.2%	
ZAR	852	0.19	22.65	2.37	3.00	1.62	2.68	4.48	1.66	55.3%	
LSI	801	Langelier Saturation Index (LSI)			Slightly Scaling		78.8%		Highly Scaling		0.0%
		Highly corrosive			0.1%		Slightly corrosive		1.2%		Balanced Corrosion

Table 71 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value, and standard deviation will give an indication of the scale of the problem. The overall water quality is good (74.1%), marginal (24.3%) and unacceptable in 1.6% of the analysis in terms of the Electrical conductivity (EC) with values ranging between 4.35 and 631.63mS/m. The 90<sup>th</sup> percentile is 196mS/m.

The Total Dissolved Solids (TDS) is acceptable in 83.2% of the samples, (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 884 samples indicates elevated concentrations of Nitrate (N >20mg/l) in 9.6%; Chloride (Cl > 600mg/l) in 2.6%; Sodium (Na > 400mg/l) in 2%; Fluoride (F >1.5mg/l) in 1.6%; Magnesium (Mg > 200mg/l) in 1.2%; Calcium (Ca > 300) in 0.5%, Sulphate (SO<sub>4</sub> >600mg/l) in 0.5% and Potassium (K > 100mg/l) in 0.2% of the analysis. The pH value exceeds the maximum allowable limit in one sample; it is acidic.

The Langelier Saturation Index (LSI) indicates that the water is slightly to highly corrosive (1.3%); predominantly slightly scaling (78.8%) and balanced (19.9%). The ZAR index indicates that 65% of the water is of a fair quality for irrigation (ZAR < 3).

### **7.2.3.22 UNDIFFERENTIATED MESSINA SUITE (BEIT BRIDGE COMPLEX), (Zms)**

This unit comprises principally metapyroxenite and serpentinite which are intrusive into the Beit Bridge Complex. The meta-pyroxenite is a coarsely crystalline greyish black rock composed of large equigranular grains of pyroxene, mainly hypersthene and minor amphibole, plagioclase, spinel, and magnetite. The serpentinites, which probably represent altered peridotites, are dark green and greyish black rocks in which antigorite, antiphylite, and tremolite can be recognised. The occasional presence of chromite indicates igneous origin. Coarsely crystalline hornblendite is locally associated with serpentinite. Mylonite and various strong sheared rocks related to the Bushveld Igneous Complex (BIC) are included in the Messina Suite. A small occurrence in the northern part of the map sheet is shown in Figure 113.

Within the Polokwane map sheet, the unit extent represents approximately 95% of the total occurrence, with the remaining portion falling within the Lephalale map sheet. The unit occurs in the western-centre section of the Polokwane map sheet and the central-eastern section of the Lephalale map sheet. The section of the unit within the Polokwane map sheet covers approximately 0.87% of the total map area.

It was decided to use all available groundwater data from both map sheets for characterization, as the occurrences on both sheets are within the same area and are physically connected. Therefore, the hydrogeological settings are considered the same, (see inset map, Figure 113). However, the data within the Lephalale map area was limited to one borehole with no available data. Consequently, all data used for the chemical and yield diagrams falls within the Polokwane map sheet.

The groundwater potential of this unit is generally good. Figure 114 represents the yield frequency diagram for the unit that show that 45.9% of the boreholes yield less than 2l/s, while 54.1% yield more than 2l/s, and 27.9% are yielding more than 5l/s.

In 77.5% of the water samples, at least one element exceeds the maximum allowable limits for domestic use. For this unit, the primary concern is the anion Nitrate.



The statistical analysis of 61 borehole records indicates that 32.7% of the successful boreholes have yields that can only be used for small households (>0.001l/s to 0.5l/s). A further 13.1% of the boreholes yield between 0.5l/s and 2l/s, with 26.2% of the boreholes yielding between 2l/s and 5l/s and 27.9% yielding more than 5l/s, (Figure 114).

The static water level ranges from 2.51 meters below ground level (mbgl) to 25.82mbgl, with a median of 10.14mbgl and an average static water level of 11.06mbgl (based on 41 data points). The maximum depth recorded is 130m, with an average depth of 54m and a median depth of 52.5m, (50 data points). The maximum installation depth is 95m and the average is 36.3m, (9 data points). The depth of installation can be indicative of water strike depths if compared to the average depth and static water levels of the boreholes.

The maximum recommended daily abstraction on record is 691.2 cubic meters per day (m<sup>3</sup>/day) and the average is 137.1m<sup>3</sup>/day. The 90th percentile of daily abstraction is 393.6m<sup>3</sup>/day and the 80th percentile is 200.4m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 35.

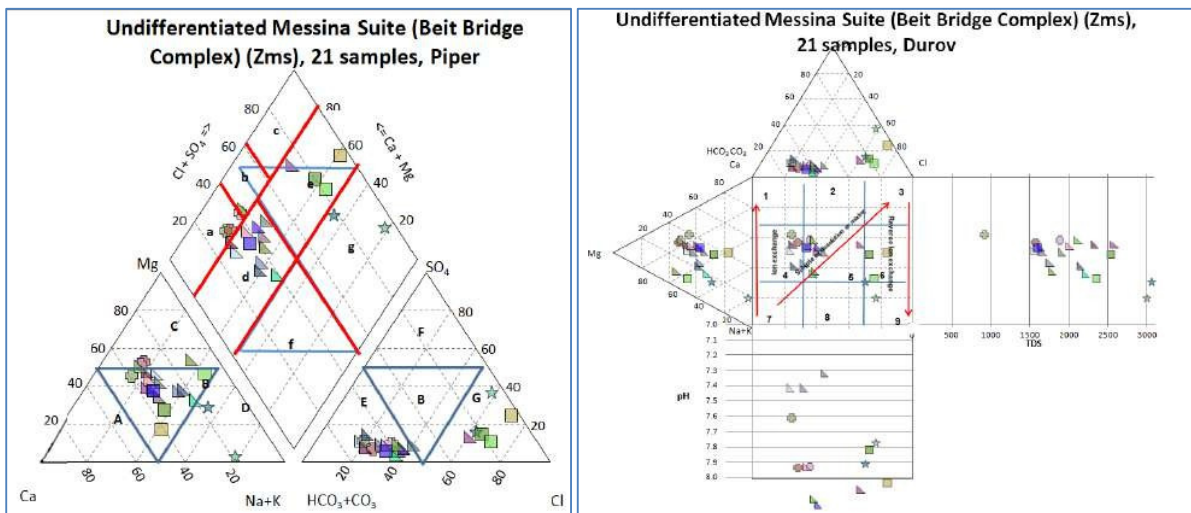


Figure 115: Trilinear diagrams, Piper, and Durov for the Undifferentiated Messina Suite (Beit Bridge Complex), (Zms).

The trilinear Piper diagram, (Figure 115) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (90.5%), Weak acidic anions > Strong acidic anions (71.4%); Alkali > Alkali earths (9.5%); Strong acids > Weak acids (28.6%).

The groundwater in this unit classifies as:

- Mixed-Calcium-Magnesium-Bicarbonate type (61.9%),
- Mixed-Calcium-Magnesium-Chloride type with increasing Sodium (14.3%),
- Sodium-Chloride type (9.5%),
- Magnesium-Bicarbonate type (9.5%),
- Mixed-Calcium-Magnesium-Bicarbonate type with increased Sodium (4.8%).

The high TDS is some of the samples that may be indicative of long residence times in the aquifer allowing reactions to be fairly complete.

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- No dominant anion or cation, indicates water exhibiting simple dissolution or mixing (47.6%), plot along the dissolution or mixing line,

- SO<sub>4</sub> dominates, or anion discriminant and Ca dominant, Ca and SO<sub>4</sub> dominates, frequently indicates recharge in gypsiferous deposits, otherwise mixed water or water exhibiting simple dissolution may be indicated. (28.6%)
- Anion discriminate and Na dominant, indicates probable mixing or uncommon dissolution influences (14.3%),
- Cl and Na dominant, frequently indicative of end-point gradient waters through Dissolution (9.5%),
- Some samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 72: Chemical statistics for the Undifferentiated Messina Suite (Beit Bridge Complex), (Zms).

Element / Parameter	Statistics Drawn from a population of 66 data points for Undifferentiated Messina Suite (Beit Bridge Complex) (Zms).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	65	6.57	8.95	8.00	8.03	7.30	8.03	8.72	0.52	6.5%	
Electrical Conductivity (mS/m EC)	65	41.20	679.00	114.85	135.31	91.10	113.70	189.88	89.03	65.8%	
Total Dissolved Salts (mg/l TDS)	63	415.40	4198.00	863.77	978.62	659.26	881.00	1253.76	539.67	55.1%	
Calcium (mg/l Ca)	63	12.60	417.20	57.96	80.15	40.05	70.20	97.67	62.94	78.5%	
Magnesium (mg/l Mg)	63	8.88	380.50	55.97	71.38	44.90	61.56	93.80	45.75	64.1%	
Sodium (mg/l Na)	63	11.66	477.70	67.69	101.90	37.16	88.68	150.08	76.26	74.8%	
Potassium (mg/l K)	63	1.75	19.90	4.85	5.75	2.84	5.52	7.95	2.58	44.9%	
Chloride (mg/l Cl)	65	15.10	1276.60	62.96	123.22	35.06	68.05	286.10	176.97	143.6%	
Sulphate (mg/l SO <sub>4</sub> )	63	11.98	595.10	28.52	56.88	17.28	28.70	74.51	103.18	181.4%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	54	100.88	567.90	317.27	347.17	236.49	347.70	439.01	86.79	25.0%	
Nitrate (mg/l N)	63	1.01	157.10	12.73	31.13	12.52	27.42	44.66	23.53	75.6%	
Fluoride (mg/l F)	63	0.14	4.50	0.60	0.84	0.37	0.77	1.20	0.58	68.8%	
Silicon as Si	57	11.58	92.90	35.64	40.45	33.82	41.75	45.22	11.57	28.6%	
Iron (Fe)	14	0.010	0.431	0.014	0.049	0.010	0.011	0.070	0.112	227.3%	
Manganese (Mn)	14	0.005	0.440	0.015	0.068	0.010	0.016	0.136	0.116	172.0%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	46	0.009	0.104	0.019	0.025	0.012	0.018	0.043	0.019	75.9%	
ZAR	63	0.38	10.85	1.41	2.09	0.73	1.89	3.48	1.54	73.9%	
LSI	53	Langelier Saturation Index (LSI)			Slightly Scaling		71.7%		Highly Scaling		0.0%
		Highly corrosive			0.0%	Slightly corrosive		0.0%	Balanced Corrosion		28.3%

Table 72 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality is ideal to good 81.5%; marginal in 15.4% and unacceptable, (EC > 370mS/m), in 3.1% of the analysis in terms of the Electrical conductivity (EC) with values between 41.20 and 679mS/m. The 90<sup>th</sup> percentile is 189.88mS/m.

The Total Dissolved Solids (TDS) is acceptable in 87.3% of the samples, (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 66 samples indicates elevated concentrations of Nitrate (N >10mg/l) in 77.8%; Fluoride (F >1.5mg/l) in 6.3%; Calcium (Ca > 300) in 3.2%; Magnesium (Mg > 200mg/l) in 1.6%; Sodium (Na > 400mg/l) in 1.6% and Chloride (Cl > 600mg/l) in 1.5% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water is predominantly slightly scaling (71.7%) and balanced (28.3%). The ZAR index indicates that 84.1% of the water is of a fair quality for irrigation (ZAR < 3).

There are some rural villages within this groundwater unit on the eastern side of the Palala River. Water supply is from the Mmaletswai Regional Water Scheme. Water to these villages is from groundwater and surface / groundwater from shallow wells within the river. Irrigation occurs west of the Palala River; the water resource is most likely surface water from shallow wells within the river. Groundwater is also used to supply water for Game, livestock, and farm homesteads.

### **7.2.3.23 UNDIFFERENTIATED BEIT BRIDGE COMPLEX (Zbc)**

The Beit Bridge Complex is part of the Limpopo Metamorphic Belt which is subdivided into three domains, a Central Zone and two flanking Marginal Zones. They are separated from each other, and from the neighbouring Kaapvaal and Zimbabwe Cratons (Rhodesian Craton), by major shear zones.

The Beit Bridge Complex is restricted to the Central Zone and is a succession of supracrustal gneisses into which mafic and ultramafic rocks (Messina Suite) and granitoid rocks (Alldays Gneiss) were emplaced, (Council of Geoscience).

It is broadly subdivided into the Mount Dowe, Malala Drift and Gumbu Groups. The supracrustal gneisses of the complex which include metaquartzite, amphibolite, marble, and calc-silicate rocks are interpreted to represent mainly a shelf-type sequence.

Due to the lack of outcrop, as the area is extensively covered by sandy soils, the delineation between the Groups is not always possible. The groundwater units are thus divided into the Undifferentiated Beit Bridge Complex, Malala Drift and Mount Dowe Groups. The Gumbu Group do not have any outcrops within the map area. The Gumbu Group comprises marble together with associated calc-silicate rocks. Minor intercalations include amphibolite, metaquartzite and garnetiferous. The rocks of the Gumbu Group usually form positive topographic features often covered by surface limestone. The unit is extensively overlain by tertiary-quadernary sediments as indicated on the 1:250 000 geological map sheet 2328, these surface sediments does not have aquifer characteristics and were ignored.

The undifferentiated Beit Bridge Complex aquifer unit consists of the rocks of all three groups as well as rocks of the Messina Suite and Alldays Gneiss except where outcrop occurs that is assigned to one of the groups as indicated on the geological map sheet. These outcrops are assigned and described as separate groundwater resource units. The Undifferentiated Beit Bridge Complex groundwater resource unit underlay approximately 6.37% of the total map area.

Although the unit cross over to the Lephalale map sheet area, the characterization for each map was done separately as sufficient data was available on both map sheets for proper characterization. The findings are that the maximum yield and chemical characteristics are similar for the unit in both map sheets.

The groundwater potential of the groundwater resource unit is poor with 76.3% (Figure 117) of boreholes yielding less than 2ℓ/s and 23.7% yielding more than 2ℓ/s.

In 52% of the water samples, at least one element exceeds the maximum allowed limits for domestic use. For this unit, the primary concern is the anion Nitrate.

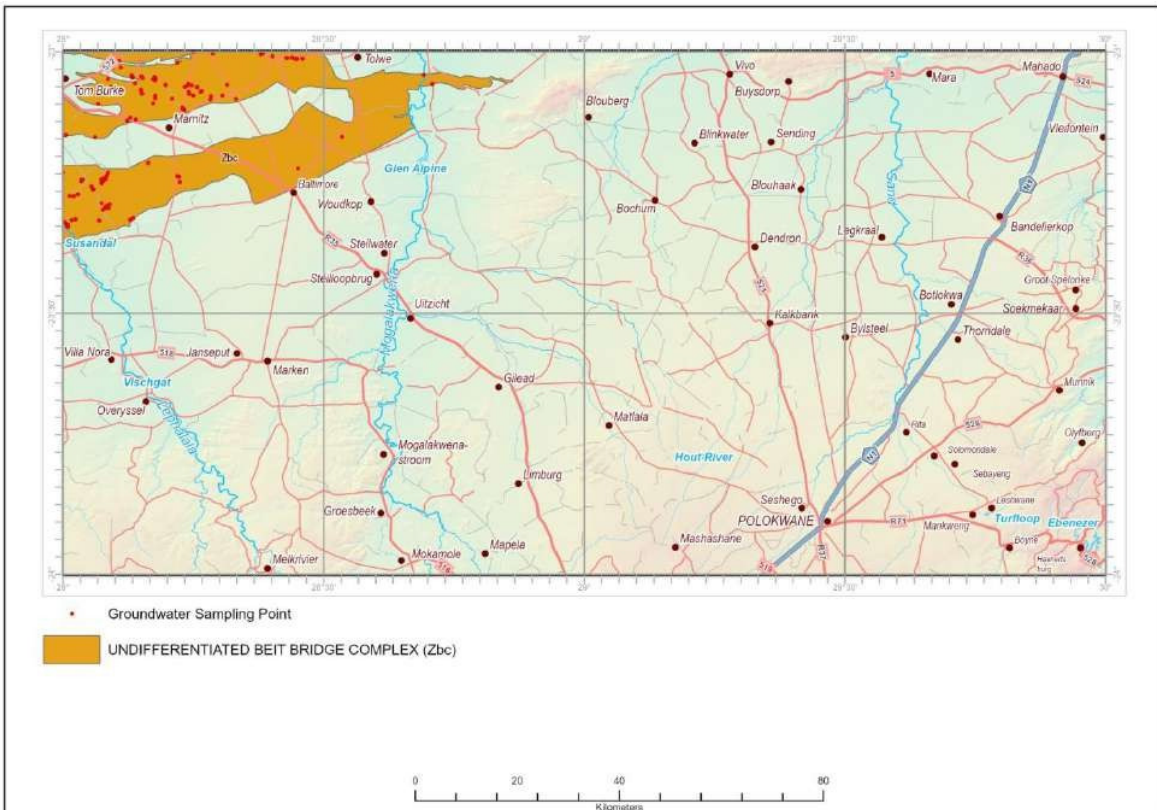


Figure 116: Geographical distribution of the Undifferentiated Beit Bridge Complex (Zbc) and associated groundwater data points.

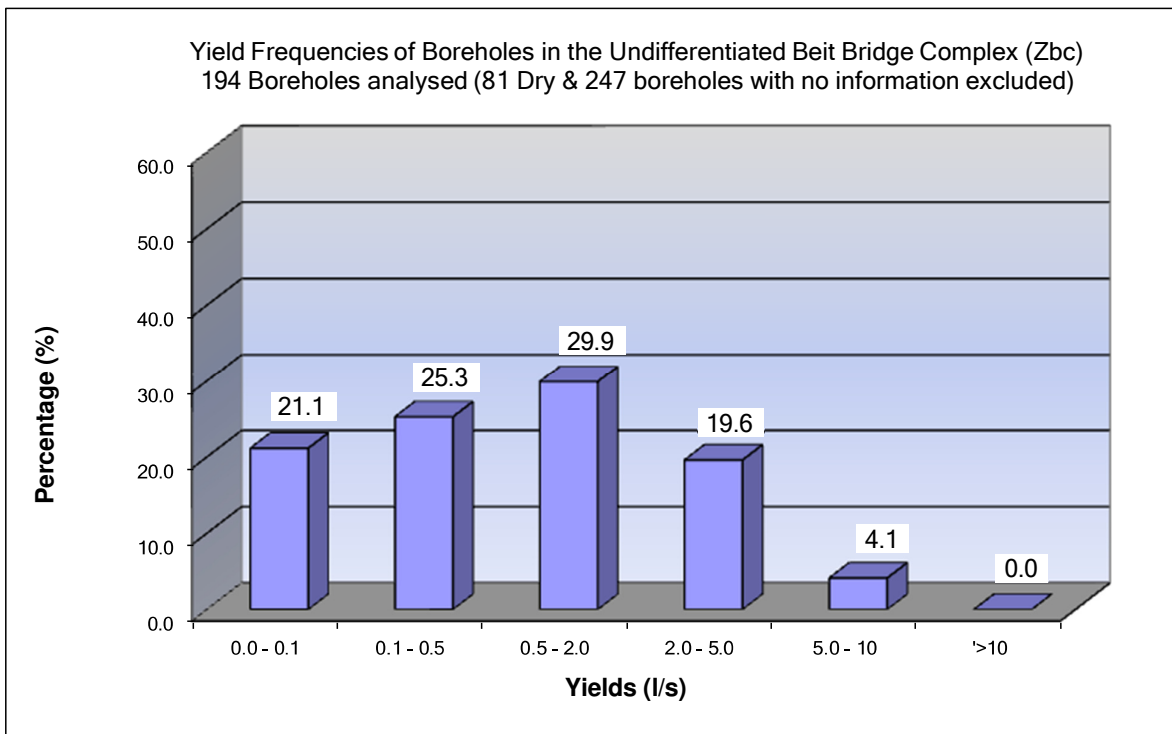


Figure 117: Yield frequency for the intergranular and fractured aquifers of the Undifferentiated Beit Bridge Complex (Zbc).

The statistical analysis of 194 borehole records, (Figure 117) indicates that 46.4% of successful boreholes have yields suitable for small households (>0.001ℓ/s to 0.5ℓ/s). A further 29.9% of boreholes yield between 0.5ℓ/s and 2ℓ/s, while 19.6% are yielding between 2ℓ/s and 5ℓ/s and 4.1% of the boreholes yield more than 5ℓ/s.

The static water level ranges from 3.99 meters below ground level (mbgl) to 62mbgl, with a median of 34.55mbgl and an average static water level of 34.82mbgl (based on 55 data points). The maximum depth recorded is 200m, with an average depth of 75.8m and a median depth of 67.8m (104 data points). The maximum installation depth is 100m and the average is 50.9m (25 data points). The depth of installation can be indicative of water strike depths if compared to the average depth and static water levels of the boreholes.

The maximum recommended daily abstraction on record is 328.3 cubic meters per day (m<sup>3</sup>/day) and the average is 44.2m<sup>3</sup>/day. The 90th percentile of daily abstraction was calculated as 86.8m<sup>3</sup>/day and the 80th percentile is 69m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 26.

Groundwater occurs mainly in faults and associated shear zones as well as fractured contact zones between mafic and acidic rocks as well as dyke contact zones. The Complex has in general a low groundwater potential. Higher yielding boreholes (yield > 2ℓ/s) occurs over the whole unit and could not be correlated with any fault zones or diabase dykes as depicted on the geological map sheet for the area.

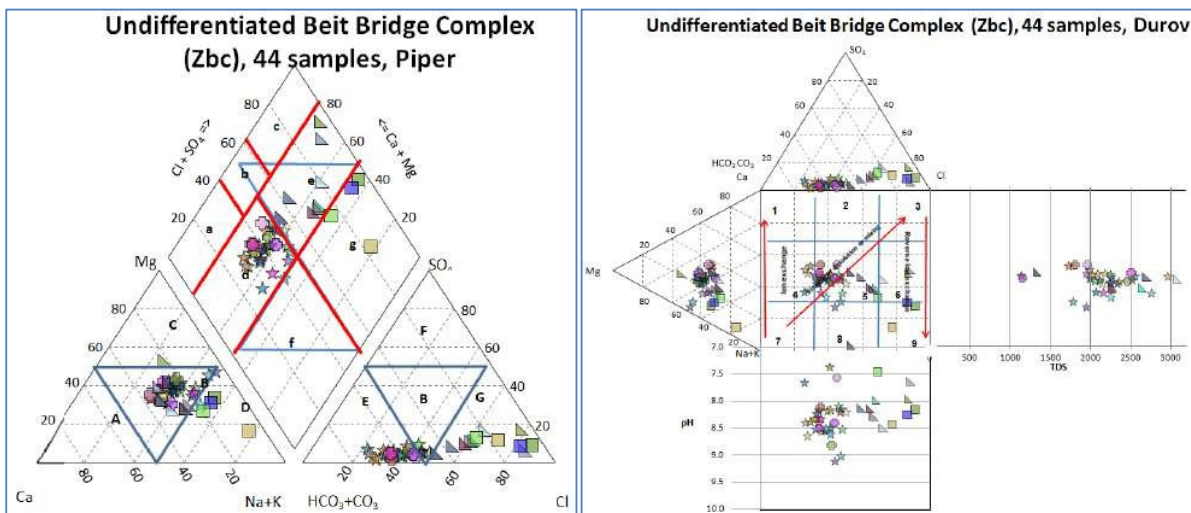


Figure 118: Trilinear diagrams, Piper, and Durov for the Undifferentiated Beit Bridge Complex (Zbc).

The trilinear Piper diagram, (Figure 118) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (90.9%), Weak acidic anions > Strong acidic anions (70.5%); Alkali > Alkali earths (9.1%); Strong acids > Weak acids (29.5%).

The groundwater in this unit classifies as:

- Mixed Calcium-Magnesium-Bicarbonate type with increasing Sodium (63.6%),
- Mixed Calcium-Magnesium-Chloride type with increased Sodium (18.2%),
- Sodium-Chloride type with (9.1%),
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type with increasing Sodium (6.8%),
- Magnesium-Chloride type (2.3%).

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- No dominant anion or cation indicates fresh recent recharge water exhibiting simple dissolution or mixing (70.5%), plot along the dissolution or mixing line,

- Cl and Na dominate; frequently indicate endpoint down gradient waters through dissolution (9.1%),
- SO<sub>4</sub> dominates, or anion discriminant and Ca dominant, frequently indicates recharged water in gypsiferous deposits or mixed water or water exhibiting simple dissolution (9.1%),
- Anion discriminant and Na dominate indicative of possible mixing or uncommon dissolution influences (6.8%),
- Cl dominant anion and Na dominant cation, indicative of reverse ion exchange of Na-Cl waters (4.5%),
- Some samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 73: Chemical statistics for the Undifferentiated Beit Bridge Complex (Zbc)

Element / Parameter	Statistics Drawn from a population of 130 data points for Undifferentiated Beit Bridge Complex (Zbc).									
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation
pH	129	6.58	9.08	8.04	8.07	7.40	8.13	8.51	0.46	5.7%
Electrical Conductivity (mS/m EC)	129	28.00	662.00	113.80	161.02	77.18	107.70	323.00	120.94	75.1%
Total Dissolved Salts (mg/l TDS)	126	186.00	4511.0	843.85	1105.30	568.00	847.00	1991.00	706.03	63.9%
Calcium (mg/l Ca)	122	7.50	384.70	58.92	82.45	45.94	62.70	121.15	63.66	77.2%
Magnesium (mg/l Mg)	122	16.60	363.30	54.97	76.90	35.60	56.30	146.80	59.99	78.0%
Sodium (mg/l Na)	122	36.60	582.20	88.90	122.16	57.72	92.18	175.14	97.14	79.5%
Potassium (mg/l K)	122	1.91	69.70	8.09	11.29	5.07	9.28	17.72	9.15	81.0%
Chloride (mg/l Cl)	129	20.50	1865.00	85.19	224.34	46.18	90.40	584.35	324.29	144.6%
Sulphate (mg/l SO <sub>4</sub> )	123	2.80	426.00	15.08	40.22	8.26	16.80	104.16	62.86	156.3%
Total Alkalinity (mg/l CaCO <sub>3</sub> )	110	36.60	559.20	282.42	323.33	217.96	322.94	412.35	85.09	26.3%
Nitrate (mg/l N)	125	0.05	218.53	2.15	31.82	5.56	21.25	62.36	35.97	113.0%
Fluoride (mg/l F)	124	0.04	4.00	0.51	0.86	0.33	0.83	1.31	0.58	66.5%
Silicon as Si	113	1.44	54.05	28.42	37.49	22.91	39.53	47.96	10.19	27.2%
Iron (Fe)	16	0.005	0.086	0.017	0.036	0.008	0.035	0.073	0.026	71.8%
Manganese (Mn)	18	0.006	0.880	0.019	0.141	0.009	0.050	0.323	0.214	152.6%
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	101	0.005	0.800	0.010	0.022	0.006	0.010	0.030	0.079	355.9%
ZAR	122	0.75	12.17	1.93	2.37	1.40	1.99	3.24	1.61	68.1%
LSI	110	Langelier Saturation Index (LSI)			Slightly Scaling	78.2%	Highly Scaling		0.0%	
		Highly corrosive	0.0%	Slightly corrosive	1.8%	Balanced Corrosion		20.0%		

Table 73 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90<sup>th</sup> percentile, the maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality is ideal to good (69%), marginal in (24%) and unacceptable in 7% of the analysis in terms of the Electrical conductivity (EC) with values ranging between 28 and 662mS/m. The 90<sup>th</sup> percentile is 323mS/m.

The Total Dissolved Solids (TDS) is acceptable in 76.2% of the samples, (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 130 samples indicates elevated concentrations of Nitrate (N > 20mg/l) in 52%; Chloride (Cl > 600mg/l) in 10.1%; Magnesium (Mg > 200mg/l) in 5.7%; Fluoride (F > 1.5mg/l) in 4.8%; Sodium (Na > 400mg/l) in 3.3% and Calcium (Ca > 300) in 2.5% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water is slightly corrosive (1.8%); predominantly slightly scaling (78.2%) and balanced (20%). The ZAR index indicates that 84.4% of the water is of a fair quality for irrigation (ZAR < 3).

The water abstracted supply people in rural farmsteads and lodges; the water is also abstracted for livestock and game watering. Large scale irrigation is in the south-western-centre section of the unit and west of the Lephalala River.

Various rural villages are predominantly along and east of the Lephalala River. These villages obtain water from the Witpoort Regional Water Scheme and the Ga-Seleka Regional Water Scheme that uses a combination of groundwater and surface water.

### 7.2.3.24 UNDIFFERENTIATED MALALA DRIFT GROUP (Zma).

The Undifferentiated Malala Drift Group underlies extensive parts of the Central Zone of the Limpopo Mobile Belt and consists predominantly of leucocratic quartz-feldspathic gneisses (leuco-gneiss), metaquartzite, pink granitoid hornblende gneiss, felsic granulite, metapelite, amphibolite or mafic granulite, and marble or calc-silicate rocks, which occur as subordinate intercalations. Leucocratic quartz-feldspathic gneiss is the most abundant rock type in the Central Zone and estimated to comprise approximately 50% of the gneisses present, (Brandl, 1996).

The gneiss consists of quartz, K-feldspar, and sodic plagioclase, with minor amounts of garnet, biotite, and sphene. The garnet, which is reddish-brown in colour, may be locally absent. Due to extensive soil and sandy overburden, exposures are poor, leading to part of the unit being included in the Undifferentiated Beit Bridge Complex.

Within the Polokwane map sheet, the unit accounts for approximately 90% of its total occurrence, with the remaining portion falling within the Lephalale map sheet boundary. The unit is located in the north-western part of the Polokwane map sheet and the north-eastern part of the Lephalale map sheet, with outcrops in the Tom Bourke/Marnitz and Dwaalboom/Makoppa areas.

The section of the unit within the Polokwane map sheet covers approximately 2.3% of the total areal extent.

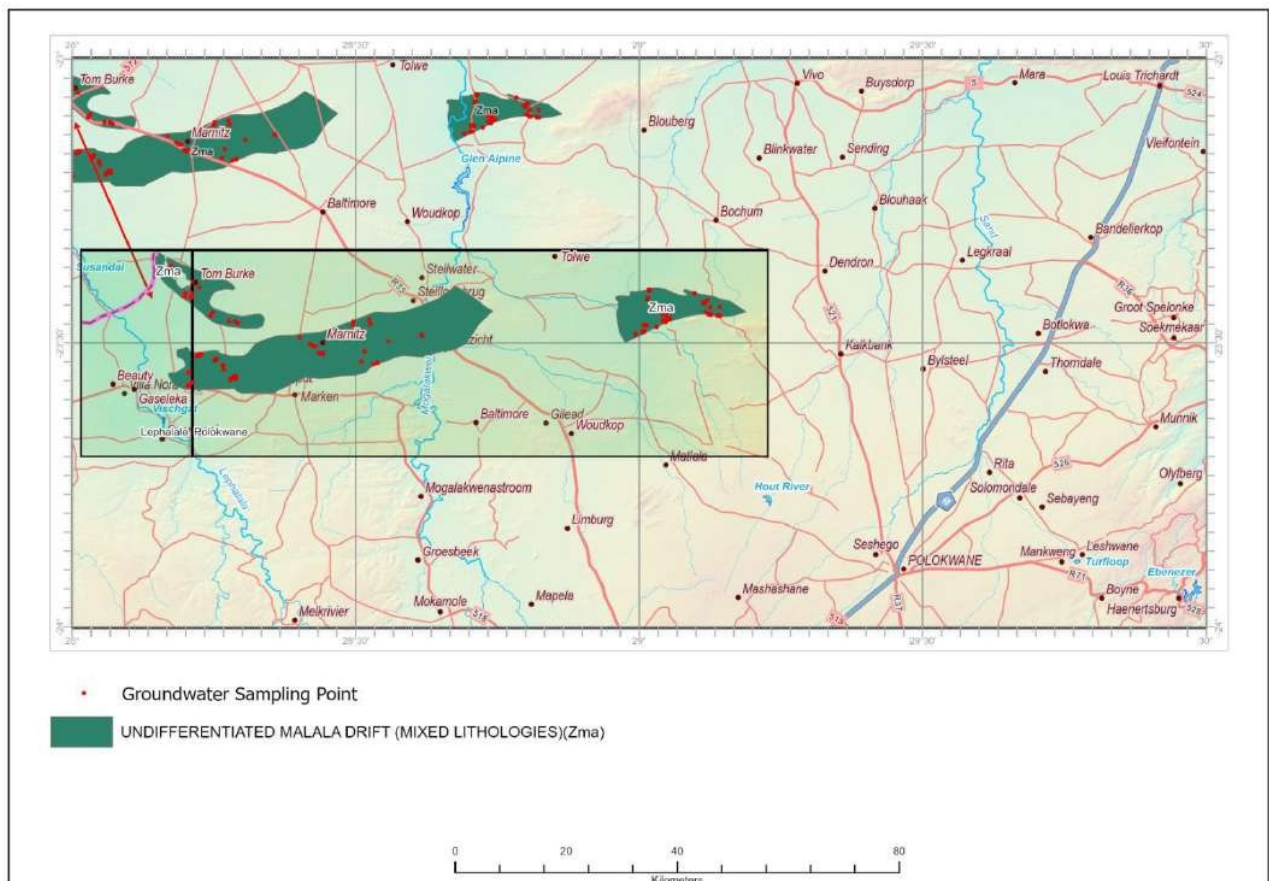


Figure 119: Geographical distribution of the Malala Drift Group (Zma) and associated groundwater sampling points.

It was decided to use all available groundwater data from both map sheets for characterization, as the occurrences on both sheets are within the same area and are physically connected. Therefore, the hydrogeological settings are considered the same, (see inset map, Figure 119).

The groundwater potential of the groundwater resource unit is poor to moderate with 60.7% of boreholes yielding less than 2l/s and 39.3% yielding more than 2l/s, (Figure 120).

In 41.3% of the water samples, at least one element exceeds the maximum allowed limits for domestic use. For this unit, the primary concern is the anion Nitrate.

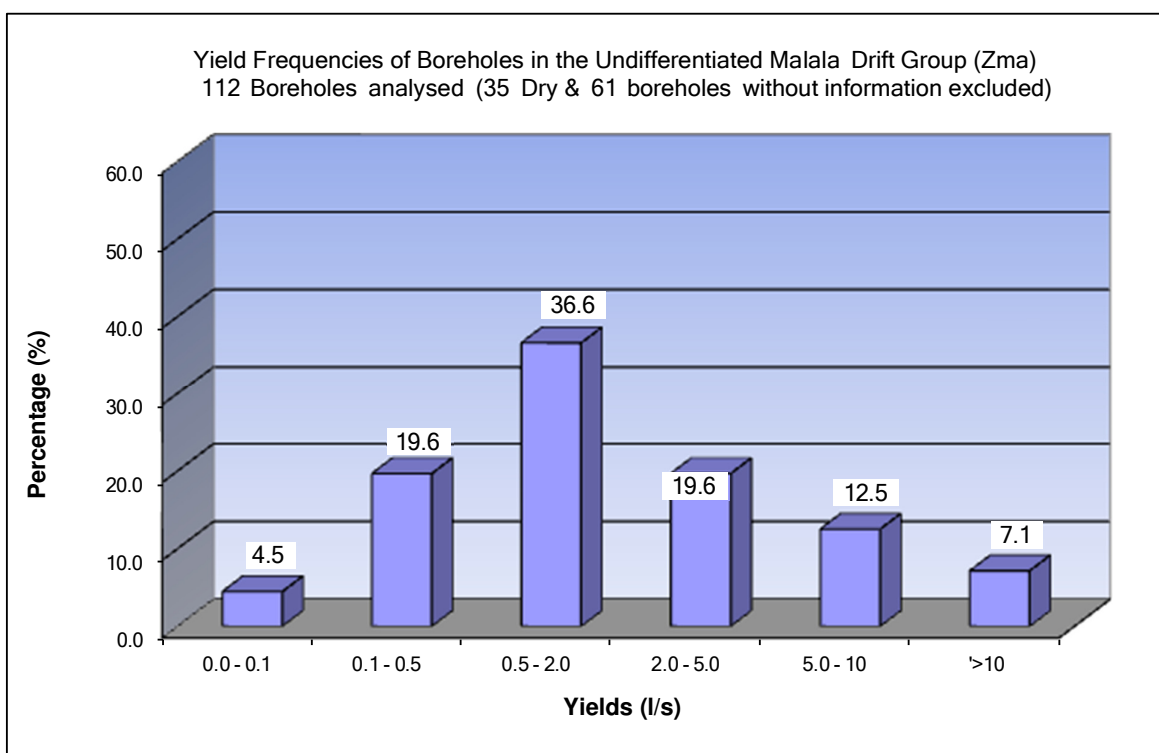


Figure 120: Yield frequency for the intergranular and fractured aquifers of the Undifferentiated Malala Drift Group (Zma).

Statistics indicate that 36.6% of successful boreholes yield between 0.5l/s to 2l/s. Additionally 21.1% yield less than 0.5l/s, with 19.6% yielding between 2l/s to 5l/s and another 19.6% yield more than 5l/s, (Figure 120).

The static water level ranges from 2.46 meters below ground level (mbgl) to 49.13mbgl, with a median of 15.16mbgl and an average static water level of 16.89mbgl (based on 48 data points). The maximum depth recorded is 179.70m, with an average depth of 74.76m and a median depth of 63.0m (70 data points). The maximum installation depth is 100m and an average installation depth of 36.37m (45 data points).

The maximum recommended daily abstraction on record is 561.6 cubic meters per day (m<sup>3</sup>/day). The 80<sup>th</sup> percentile for recommended daily abstraction is 198.7m<sup>3</sup>/day and the average daily abstraction volume is 107.9m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 45.

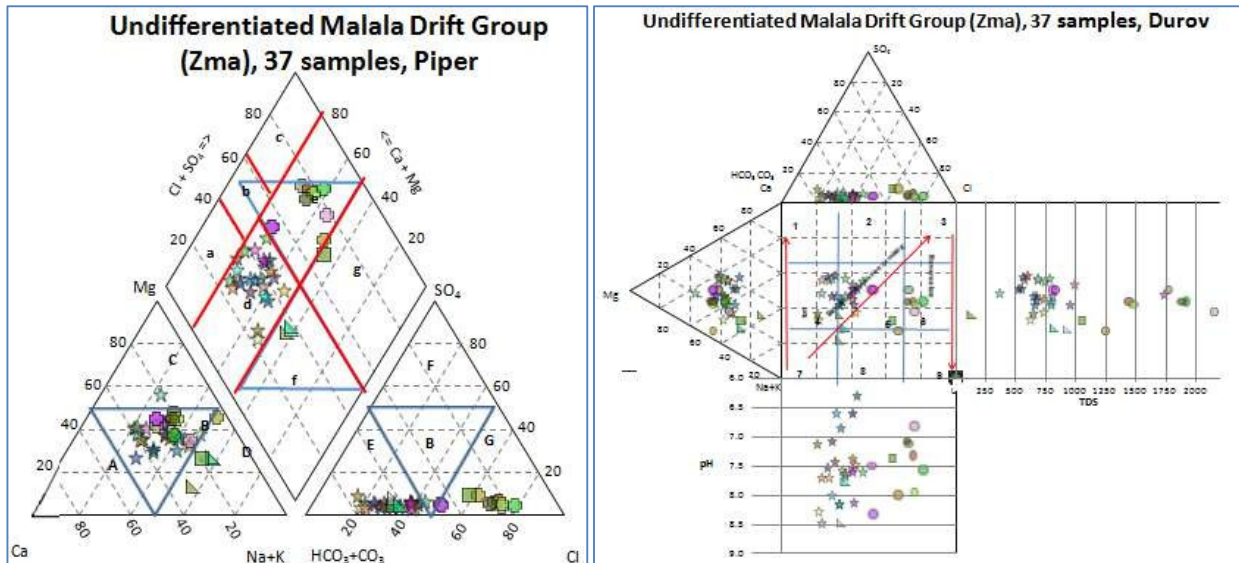


Figure 121: Trilinear diagrams, Piper and Durov for the Undifferentiated Malala Drift Group (Zma), 37 data points.

The trilinear Piper diagram, (Figure 121) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (89.2%), Weak acidic anions > Strong acidic anions (73%); Alkali > Alkali earths (10.8%); Strong acids > Weak acids (27%).

The second evaluation was on the water type:

- Mixed Calcium-Magnesium-Bicarbonate type with increasing Sodium (62.2%),
- Mixed Calcium-Magnesium-Chloride type with increasing Sodium (24.3%),
- Sodium-Bicarbonate type (8.1%),
- Magnesium-Bicarbonate-Chloride type (2.7%),
- Sodium-Chloride type with (2.7%).

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- No dominant anion or cation indicates fresh recent recharged water exhibiting simple dissolution or mixing (51.4%), plot along the dissolution or mixing line,
- $\text{SO}_4$  dominates, or anion discriminant and Ca dominant, frequently indicates recharged water in gypsiferous deposits or mixed water or water exhibiting simple dissolution (24.3%),
- Anion discriminant and Na dominate indicative of possible mixing or uncommon dissolution influences (16.2%),
- Cl dominant anion and Na dominant cation, indicative of reverse ion exchange of Na-Cl waters (8.1%),
- Some samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 74: Chemical statistics for the Undifferentiated Malala Drift Group (Zma).

Element / Parameter	Statistics Drawn from a population of 83 data points for the Undifferentiated Malala Drift Group (Zma).									
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation
pH	82	6.36	8.65	7.81	7.84	7.21	7.98	8.40	0.49	6.2%
Electrical Conductivity (mS/m EC)	81	17.3	360.8	110.2	154.6	77.2	114.9	305.0	85.7	55.4%
Total Dissolved Salts (mg/l TDS)	81	114.0	2557.2	787.8	1090.4	582.0	874.3	1927.0	538.3	49.4%
Calcium (mg/l Ca)	75	11.46	228.32	60.85	86.89	38.36	75.10	147.28	44.47	51.2%
Magnesium (mg/l Mg)	76	3.26	178.30	47.44	79.69	34.70	56.97	148.05	46.42	58.3%
Sodium (mg/l Na)	77	21.40	373.80	84.68	116.41	51.28	93.83	233.59	72.37	62.2%
Potassium (mg/l K)	76	0.23	24.01	1.98	6.39	0.82	5.34	12.30	5.32	83.3%
Chloride (mg/l Cl)	82	13.80	789.09	73.71	182.06	32.11	91.53	471.82	199.74	109.7%
Sulphate (mg/l SO <sub>4</sub> )	77	1.40	149.00	15.23	34.59	8.82	20.29	74.44	31.13	90.0%
Total Alkalinity (mg/l CaCO <sub>3</sub> )	67	79.48	818.00	326.85	369.07	242.61	350.10	462.16	130.39	35.3%
Nitrate (mg/l N)	80	0.02	233.63	1.32	32.28	3.13	18.43	92.88	40.43	125.3%
Fluoride (mg/l F)	80	0.04	1.65	0.43	0.70	0.27	0.69	1.17	0.35	50.3%
Silicon as Si	74	18.66	53.92	35.84	37.26	28.86	37.09	45.34	6.81	18.3%
Iron (Fe)	34	0.002	0.881	0.007	0.040	0.003	0.010	0.050	0.149	374.0%
Manganese (Mn)	33	0.001	0.590	0.002	0.038	0.001	0.004	0.058	0.112	296.0%
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	72	0.003	0.800	0.016	0.056	0.008	0.025	0.077	0.132	237.4%
ZAR	76	0.66	5.17	1.83	2.19	1.21	1.91	4.03	1.00	45.4%
LSI	67	Langelier Saturation Index (LSI)		Slightly Scaling		77.6%		Highly Scaling		0.0%
		Highly corrosive		0.0%		Slightly corrosive		1.5%		Balanced Corrosion

Table 74 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value and standard deviation will give an indication of the extent of the problem. The overall water quality is ideal to good, (61.7%) and marginal is 38.3 of the analysis with Electrical conductivity (EC) values varying between 17.3 and 360.8mS/m. The 90<sup>th</sup> percentile is 305mS/m.

The Total Dissolved Solids (TDS) is acceptable in 65.4% of the samples, (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 83 samples indicates elevated concentrations of Nitrate (N >10mg/l) in 41.3%; Chloride (Cl > 600mg/l) in 6.1% and Fluoride (F >1.5mg/l) in 2.5% and of the analysis.

The Langelier Saturation Index (LSI) indicates that the water is slightly corrosive (1.5%); predominantly slightly scaling (77.6%) and balanced (20.9%). The ZAR index indicates that 80.3% of the water is of a fair quality for irrigation (ZAR < 3).

Water supply is for farmsteads, livestock, and game. Marnitz and Tom Burke towns that fall within this unit are supplied from groundwater sources. Irrigation occurs within the unit in the north-west near and along the Lephala River. The water for irrigation as well as the few rural villages is from the river as well as from boreholes.

### 7.2.3.25 MOUNT DOWE GROUP (Zmd)

The Mount Dowe Group, probably at the base of the Beit Bridge Complex, consists of metaquartzites and magnetite quartzite with minor intercalations of garnetiferous leuco-gneiss, amphibolite, and mafic granulite. The topographically prominent metaquartzite is a coarse-grained, whitish to grey rock consisting chiefly of large interlocking grains of strained quartz. Minor local constituents include green fuchsite mica, sillemantite, dark-green tourmaline, rutile, pyrite, biotite, pyroxene, and hornblende. Magnetite quartzite is a medium-to fine-grained dark-grey to black rock having a distinctly glistening appearance. It consists of alternating layers of quartz-rich and magnetite/hematite-rich material which reflect original bedding.

The unit covers approximately 0.22% of the map area and occurs in the north-eastern section of the map sheet, (Figure 123). Although limited data is available, it indicates that the groundwater potential of the groundwater resource unit is poor with around 81% of all the available boreholes yielding less than 2l/s, (Figure 123). The unit cross over to the Lephalale map sheet, but as no data was available, all the data used for the characterization originates from data that falls within the Polokwane map sheet.

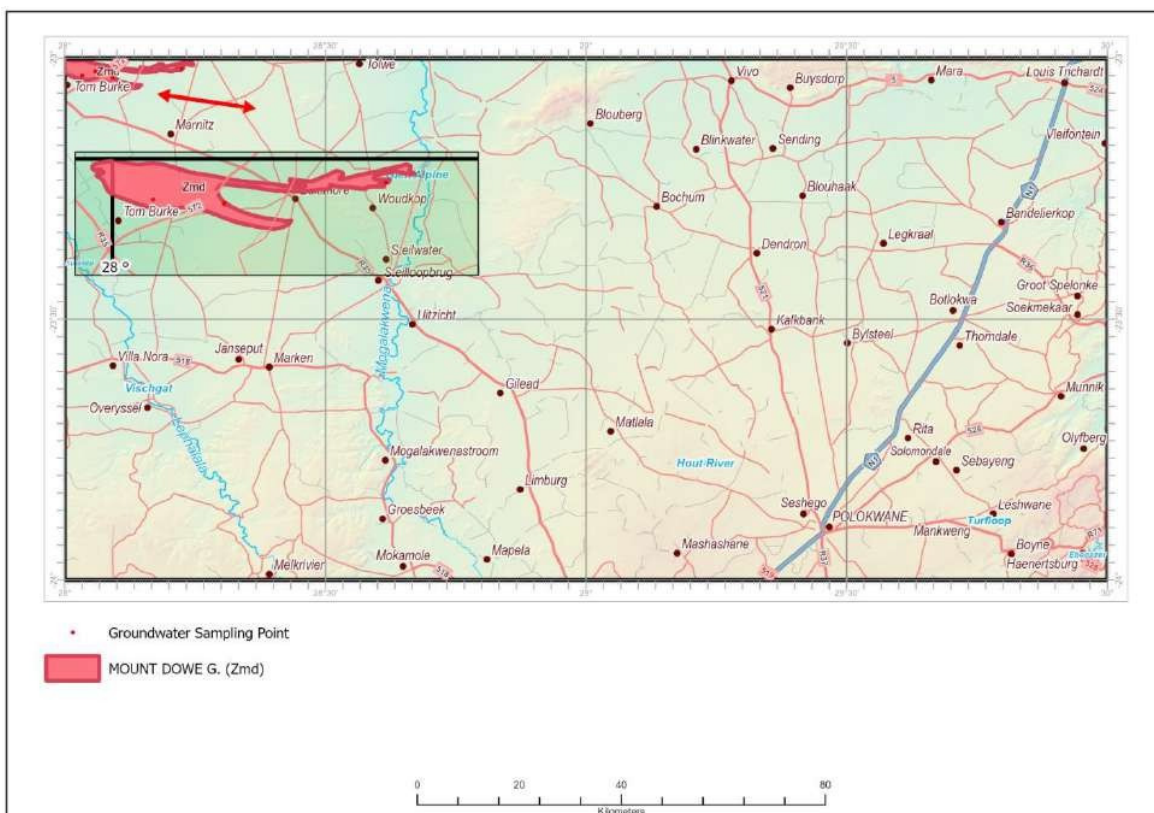


Figure 122: Geographical distribution of the Mount Dowe (Zmd) and the associated groundwater sampling points.

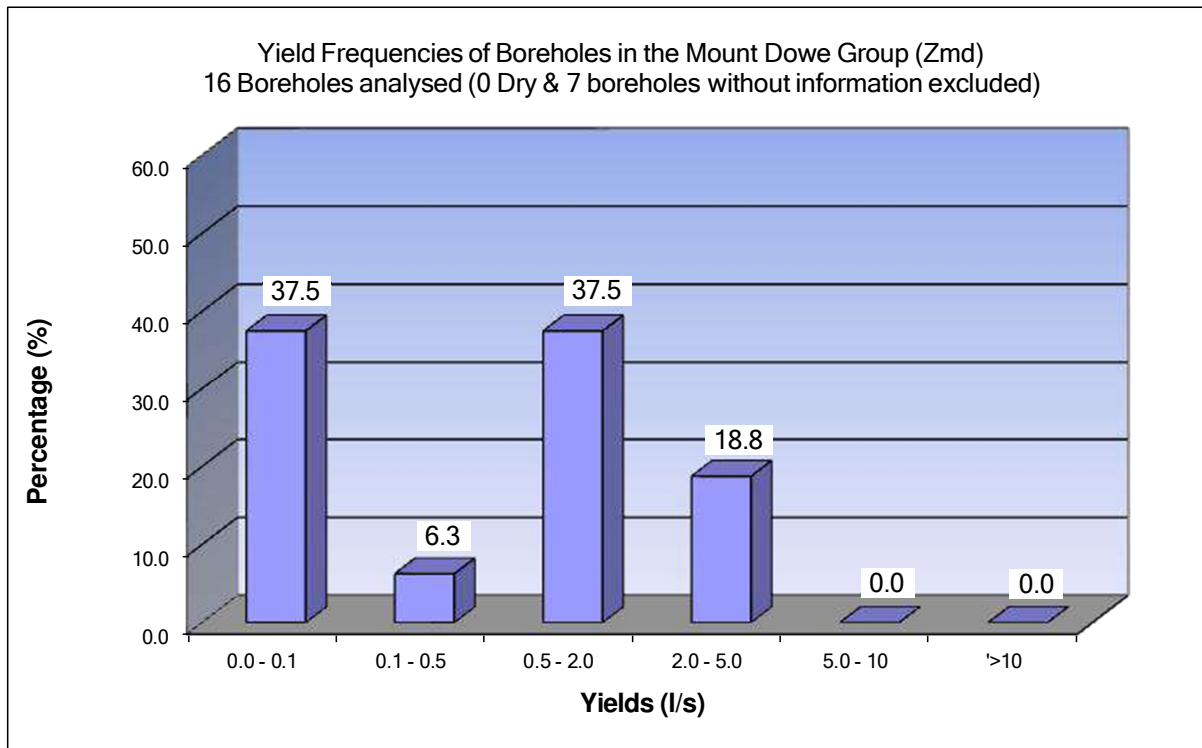


Figure 123: Yield frequency for the fractured aquifers of the Mount Dowe Group (Zmd).

The statistical analysis of 16 borehole records, (Figure 123) indicates that 43.8% of successful boreholes have yields suitable for small households (>0.001l/s to 0.5l/s). In addition, 37.5% of the boreholes have yields between 0.5l/s and 2l/s and 18.8% between 2l/s and 5l/s. None of the boreholes yields more than 5l/s. Fault zones occur within the unit that can be targeted in the search for groundwater.

No information was available on static water levels, borehole depth, abstraction and pump testing data.

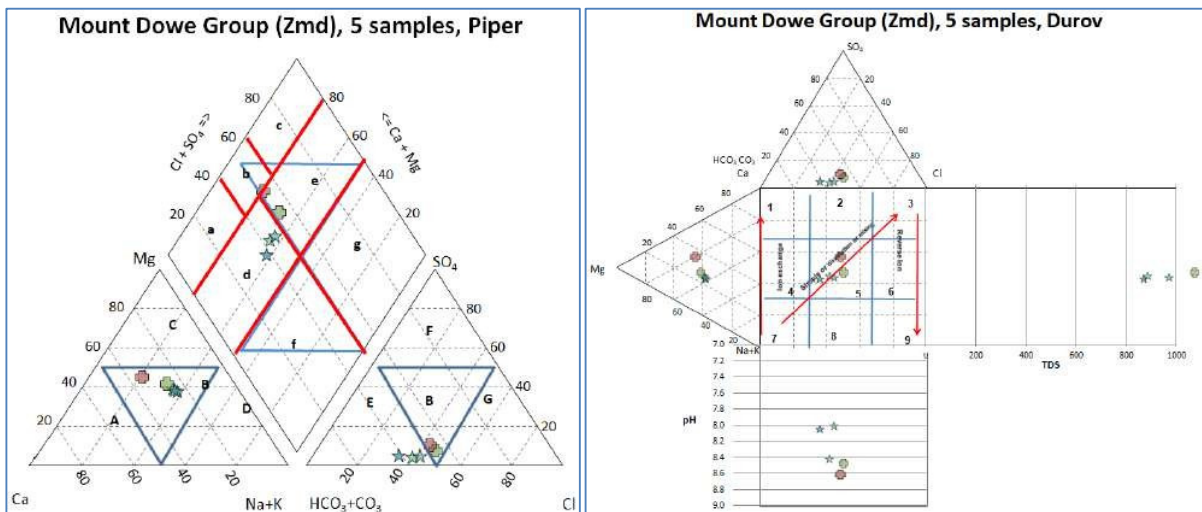


Figure 124: Trilinear diagrams, Piper and Durov for the Mount Dowe Group (Zmd), 5 data points.

The trilinear Piper diagram, (Figure 124) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (100%), Weak acidic anions > Strong acidic anions (60%); Alkali > Alkali earths (0%); Strong acids > Weak acids (40%).

The second evaluation was on the water type:

- Mixed Calcium-Magnesium-Bicarbonate type (60%),
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type (40%).

The trilinear Durov diagram defines the hydrochemical processes along with the water type;

- No dominant anion or cation indicates fresh recent recharge water exhibiting simple dissolution or mixing (100%), plot along the dissolution or mixing line.

Table 75: Chemical statistics for the Mount Dowe Group (Zma).

Element / Parameter	Statistics Drawn from a population of 5 data points for Mount Dowe Group (Zmd)										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	5	7.98	8.60	8.29	8.29	8.00	8.40	8.54	0.27	3.3%	
Electrical Conductivity (mS/m EC)	5	91.73	146.00	111.85	114.80	96.62	106.80	137.80	21.22	18.5%	
Total Dissolved Salts (mg/l TDS)	5	784.13	1055.00	884.38	895.73	790.08	873.51	1019.80	114.84	12.8%	
Calcium (mg/l Ca)	5	50.93	104.40	64.32	68.67	52.64	59.94	91.80	21.60	31.5%	
Magnesium (mg/l Mg)	5	48.37	83.00	59.32	61.72	49.86	55.61	77.60	14.33	23.2%	
Sodium (mg/l Na)	5	69.50	95.40	84.57	85.68	75.38	84.96	94.97	10.41	12.2%	
Potassium (mg/l K)	5	3.82	11.39	7.75	9.15	6.05	10.48	11.09	3.06	33.5%	
Chloride (mg/l Cl)	5	74.04	155.70	104.65	112.61	79.99	107.63	148.14	33.60	29.8%	
Sulphate (mg/l SO <sub>4</sub> )	5	13.20	48.10	19.50	24.54	14.12	16.20	40.74	14.68	59.8%	
Total Alkalinity (mg/l) CaCO <sub>3</sub>	5	361.30	474.90	394.84	398.32	369.98	385.83	439.56	44.06	11.1%	
Nitrate (mg/l N)	5	2.34	19.09	6.12	10.29	3.74	11.86	16.38	6.46	62.8%	
Fluoride (mg/l F)	5	0.57	1.00	0.79	0.82	0.65	0.78	1.00	0.18	21.7%	
Silicon as Si	5	17.50	47.51	29.70	35.63	19.11	44.28	47.43	14.83	41.6%	
Iron (Fe)	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0%	
Manganese (Mn)	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	5	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.00	64.0%	
ZAR	5	1.23	2.11	1.78	1.85	1.51	1.95	2.08	0.35	19.1%	
LSI	5	Langelier Saturation Index (LSI)			Slightly Scaling		100.0%		Highly Scaling		0.0%
		Highly corrosive		0.0%	Slightly corrosive		0.0%	Balanced Corrosion		0.0%	

Table 75 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90<sup>th</sup> percentile, the maximum value and standard deviation will give an indication of the extent of the problem. The overall water quality is ideal to good in all the available analysis with Electrical conductivity (EC) values varying between 91.73 and 146mS/m.

The Total Dissolved Solids (TDS) is acceptable in all the samples, (TDS ≤ 1200mg/l). The Langelier Saturation Index (LSI) indicates that the water is slightly scaling. The ZAR index indicates that all the water analysed for this unit is of a fair quality for irrigation (ZAR < 3).

Water supply is for farmsteads, livestock, and game. Irrigation occurs within the unit in the north-west section of the unit near and along the Lephala River. The water for irrigation is from the river as well as from boreholes.

### 7.2.3.26 UNDIFFERENTIATED BANDELIERKOP COMPLEX (Zbk)

The Undifferentiated Bandelierkop Complex constitutes a typical greenstone belt succession of meta-sedimentary and meta-volcanic rocks. It has been sub-divided into ultramafic, mafic, and phyllitic rock units plus meta-quartzite, magnetite, metapelite, calc-silicate rocks and marble. It comprises 5 units on the 1:500 000 geological map series, map sheet 2328 Pietersburg i.e. Zbc, Zbp, Zbq, Zbm, and Zbu. This unit occurs mainly as numerous small scattered clusters within the Goudplaats and Hout River Gneisses in an area bounded in the west by longitude 29° (Bochum) and in the east by longitude 30° (map boundary). The southern boundary is latitude 23,5° (Matok) and the northern boundary latitude is 23.13° (Louis Trichardt). Due to their number and size, they have mostly been incorporated into the above-mentioned gneisses and are therefore not indicated on the map. A small occurrence within the Matok Granite could not be incorporated and is thus depicted separately as representing the Bandelierkop Complex groundwater resource unit. The occurrences within the Palala shear zone are also indicated, (Figure 125). The unit covers approximately 0.16% of the map area.

The complex is part of the southern marginal zone of the Limpopo Mobile Belt and the rocks have been subjected to granulite-facies metamorphism. These rocks occur now as highly deformed keels surrounded by the Goudplaats and Hout River Gneisses (Explanatory booklet 2328).

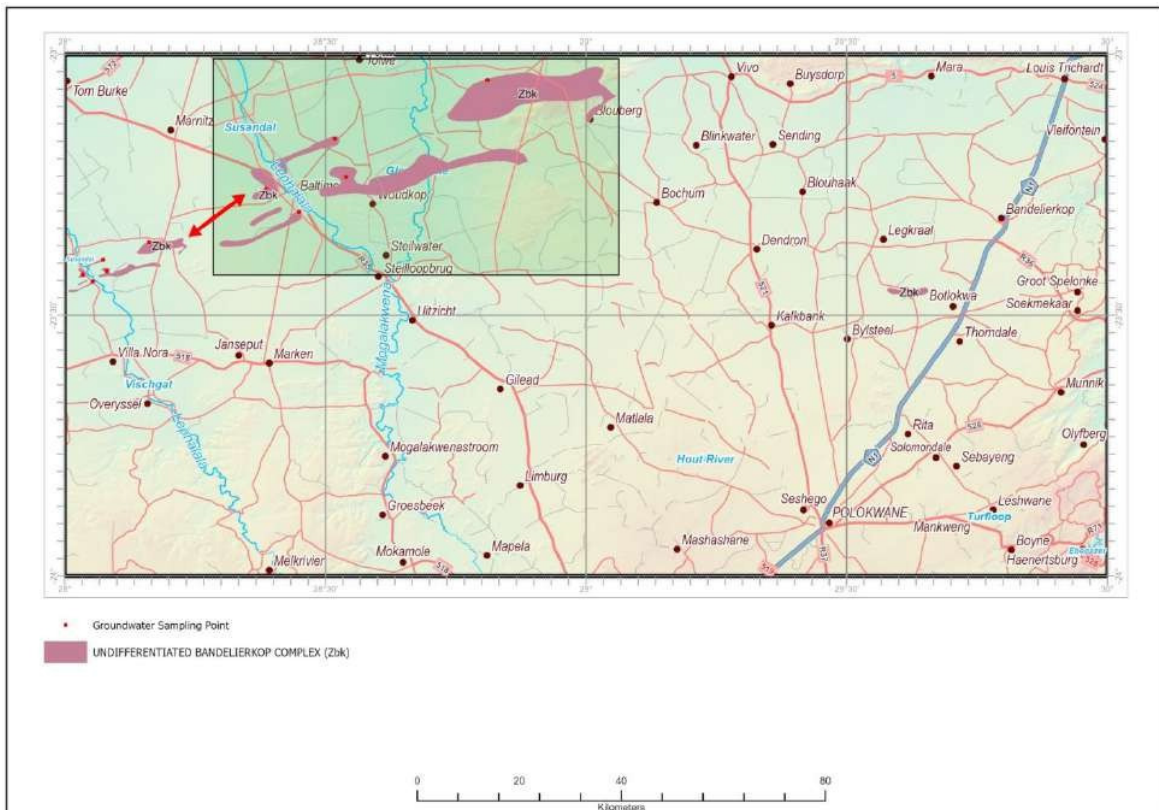


Figure 125: Geographical distribution of the Undifferentiated Bandelierkop Complex (Zbk) and the associated groundwater data points

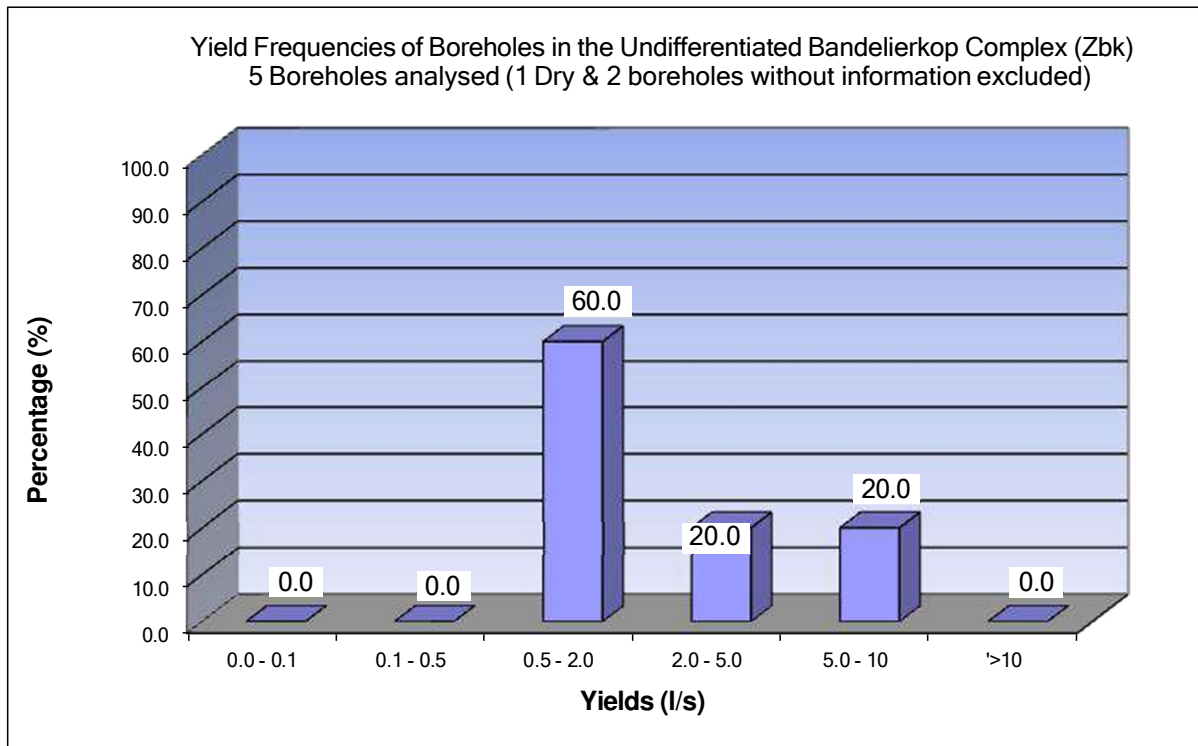


Figure 126: Yield frequency for the fractured aquifers of the Undifferentiated Bandelierkop Complex (Zbk).

The statistical analysis of 5 borehole records, (Figure 126) indicates that 60% of successful boreholes have yields between 0.5l/s and 2l/s, with 20% between 2l/s and 5l/s and 20% yielding between 5l/s to 10l/s.

The static water level ranges from 5.1 meters below ground level (mbgl) to 16.61mbgl, with a median of 12.42mbgl and an average static water level of 12.46mbgl, (based on 5 data points). The maximum depth recorded is 120m, with an average depth of 63.4m and a median depth of 65.3m, (6 data points). The maximum installation depth is 63m and the average installation depth is 37.2m, (5 data points). The depth of installation can be indicative of water strike depths if compared to the average depth and static water levels of the boreholes.

The maximum recommended daily abstraction on record is 86.4 cubic meters per day (m<sup>3</sup>/day) and the average is 23.6m<sup>3</sup>/day. The 90th percentile of daily abstraction is 57m<sup>3</sup>/day and the 80th percentile is 27.6m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 5.

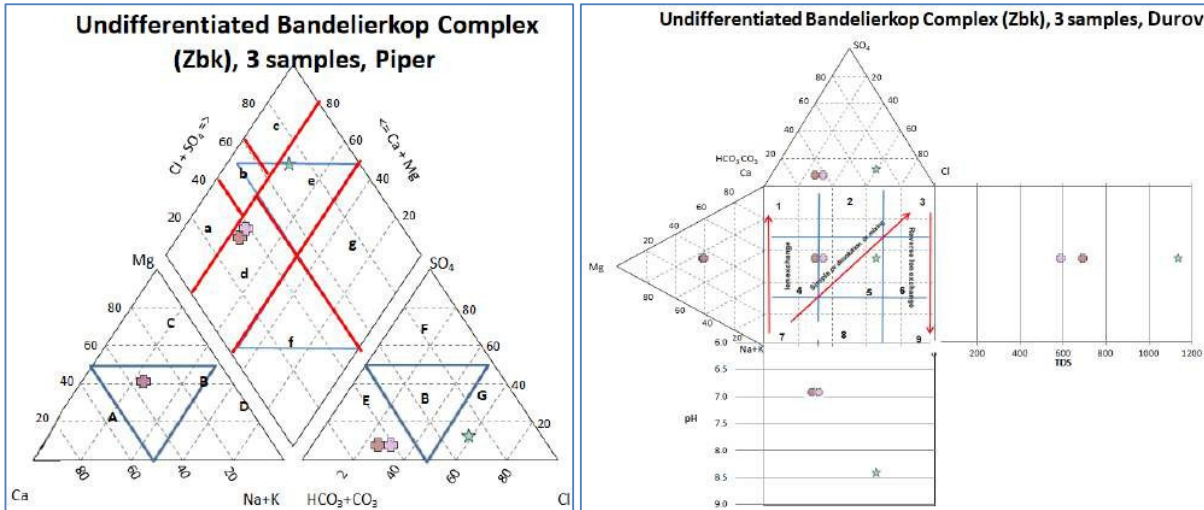


Figure 127: Trilinear diagrams, Piper, and Durov for the Undifferentiated Bandelierkop Complex (Zbk).

The trilinear Piper diagram, (Figure 127) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (100%), Weak acidic anions > Strong acidic anions (66.7%); Alkali > Alkali earths (0%); Strong acids > Weak acids (33.3%).

The second evaluation was on the water type:

- Mixed Calcium-Magnesium-Bicarbonate type (66.7%),
- Mixed Calcium-Magnesium-Chloride type (33.3%).

The trilinear Durov diagram defines hydrochemical processes along with the water type. The interpretation is as follows:

- No dominant anion or cation, plots along the dissolution line can be attributed to fresh resent recharge water exhibiting simple dissolution or mixing (75%),
- $\text{SO}_4$  dominates, or anion discriminant and Ca dominant, frequently indicates recharged water in gypsiferous deposits or mixed water or water exhibiting simple dissolution (25%).

Table 76: Chemical statistics for the Undifferentiated Bandelierkop Complex (Zbk).

Element / Parameter	Statistics Drawn from a population of 5 data points for the Undifferentiated Bandelierkop Complex (Zbk).									
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation
pH	5	6.90	8.57	7.64	7.70	6.90	7.79	8.48	0.79	10.2%
Electrical Conductivity (mS/m EC)	5	73.80	144.63	100.86	106.17	80.44	106.40	133.02	26.76	25.2%
Total Dissolved Salts (mg/l TDS)	4	587.60	1139.59	776.11	826.20	618.80	788.80	1063.52	242.79	29.4%
Calcium (mg/l Ca)	5	45.58	108.06	71.18	77.10	55.53	76.40	98.83	22.69	29.4%
Magnesium (mg/l Mg)	5	50.49	80.40	66.45	68.40	55.12	71.20	79.38	12.27	17.9%
Sodium (mg/l Na)	5	30.40	82.61	50.00	55.97	37.01	54.07	75.89	19.66	35.1%
Potassium (mg/l K)	5	1.56	5.87	2.94	3.86	1.79	4.22	5.73	1.95	50.6%
Chloride (mg/l Cl)	5	56.80	226.79	75.76	99.89	57.16	61.20	174.85	72.88	73.0%
Sulphate (mg/l SO <sub>4</sub> )	5	14.85	68.71	24.04	31.07	17.60	23.76	51.75	21.47	69.1%
Total Alkalinity (mg/l CaCO <sub>3</sub> )	5	246.40	421.00	314.78	324.72	269.04	305.21	391.80	64.80	20.0%
Nitrate (mg/l N)	4	9.00	70.75	17.73	31.52	10.65	23.16	59.07	27.91	88.5%
Fluoride (mg/l F)	4	0.31	0.94	0.57	0.69	0.42	0.75	0.91	0.28	40.4%
Silicon as Si	5	39.72	63.24	45.99	47.24	40.55	43.84	56.99	9.40	19.9%
Iron (Fe)	2	0.011	0.013	0.012	0.012	0.011	0.012	0.013	0.001	11.1%
Manganese (Mn)	4	0.001	0.020	0.003	0.011	0.002	0.011	0.020	0.011	97.0%
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	2	0.010	0.030	0.015	0.020	0.012	0.020	0.028	0.014	70.1%
ZAR	5	0.58	1.48	1.00	1.12	0.75	1.20	1.42	0.35	31.0%
LSI	4	Langelier Saturation Index (LSI)			Slightly Scaling	50.0%	Highly Scaling	0.0%		
		Highly corrosive	0.0%	Slightly corrosive	0.0%	Balanced Corrosion	50.0%			

Table 76 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90th percentile, the maximum value and standard deviation will give an indication on the extent of the problem. The overall water quality in terms of the Electrical conductivity (EC) is ideal to good in all the available analysis. The values range from 73.8mS/m to 144.63mS/m.

The Total Dissolved Solids (TDS) is acceptable in all the available analysis (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 5 samples show elevated concentrations of Nitrate (N > 10mg/l) in 50% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water may be slightly scaling and balanced (50/50). The ZAR index indicates that all the boreholes with chemical data in this unit are of a fair quality for irrigation (ZAR < 3).

Groundwater is mainly abstracted for game, livestock watering and domestic purposes in the areas indicated on the inset map, (Figure 126). Large scale irrigation occurs west of the Lephalala River. Various rural villages are supplied by the Mmaletswai Regional Water Scheme. The water scheme as well as the irrigation fields obtain water from boreholes and surface water from the Lephalala River. Major fault zones occur in the region that supplies the bulk of groundwater.

Water is used mainly for farming (livestock and irrigation) in the units that occur as scattered Xenoliths within the Hout River Gneiss. The Hout River Gneiss aquifer is however the major source of groundwater and abstraction linked to the unit is minimal.

### 7.2.3.27 UNDIFFERENTIATED PIETERSBURG GROUP (MOSTLY MOTHIBA FORMATION) (Zpg)

This group, a typical Archaean greenstone belt, occurs as two belts and as scattered xenoliths enveloped in granitoid rocks. The southern belt stretches from the south-west near Ysterberg (Mokopane) in an east-north-eastern direction toward Duiwelskloof, (Figure 128). Six formations (not shown separately on the map) have been distinguished within the group, of which the Mothiba, Eersteling, Zandriverspoort, and Vrischgewaagd Formations are recognized in the Polokwane map sheet area.

The groundwater resource unit consists of these four formations, but only the **Mothiba Formation** is noteworthy in terms of groundwater potential. The Mothiba Formation comprises ultramafic metavolcanics, talc-chlorite, amphibole-chlorite schist, talc schist, serpentinite, amphibolite with thinly interbedded banded ironstone, and ferruginous quartzite.

The Zandriverspoort Formation is not connected to the main outcrop and forms conspicuous ridges known as the Rhenosterkoppies, located approximately 25 km north-east of Polokwane. It consists of mafic metavolcanic rocks, intercalated magnetite quartzite, minor metaquartzite, quartz-sericite schist, and calc-silicate rocks. Based on lithological characteristics, it is considered a lateral equivalent of the Eersteling Formation, (SACS, 1980). The Eersteling Formation consists of scattered xenoliths of amphibolite in the extreme south-eastern part of the map area.

This unit covers approximately 1.09% of the mapping area. Groundwater occurs mainly in faults and associated shear zones (e.g., the Ysterberg shear fault), lithological contacts, dyke contacts, and fractured lavas, quartzite, and schist. The Eersteling and Zandriverspoort Formations generally have low groundwater potential, although some high-yielding boreholes have been reported, particularly in areas where the Sandrivierspoort Formation is fractured at the contact zone with the Hout River Gneiss.

Deep weathering, ranging from 18 meters to 48 meters, occurs in the Mothiba Formation. However, its weathered basins are extremely poor aquifers due to very low permeability, likely caused by excessive clay formation from weathering processes. Water is exclusively obtained from fissures and fractures below the weathered zone. Fissures and fractures in the Pietersburg Group mainly originate from folding, faulting, assimilation, metamorphism, and the intrusion of granitic batholiths, diabase dykes, and other tectonic forces.

Although the group has limited storage capacity, 58.6% of borehole yields in the greenstones exceed 2l/s, (Figure 129). However, over-exploitation can lead to borehole failure, as observed in the Dalmada smallholdings north-east of Polokwane (Pietersburg). The unit cross over to the Modimolle map sheet, but as each map sheet had sufficient data, the data used for the characterization was not combined. The maximum yields for the two units have a similar trend, but for the Modimolle data set, the Mixed Calcium-Magnesium-Bicarbonate type dominates with no Sodium-Chloride types identified.

In 13.2% of the water samples, at least one element exceeds the maximum allowed limit for domestic use. For this unit, the concerning cation is nitrate.

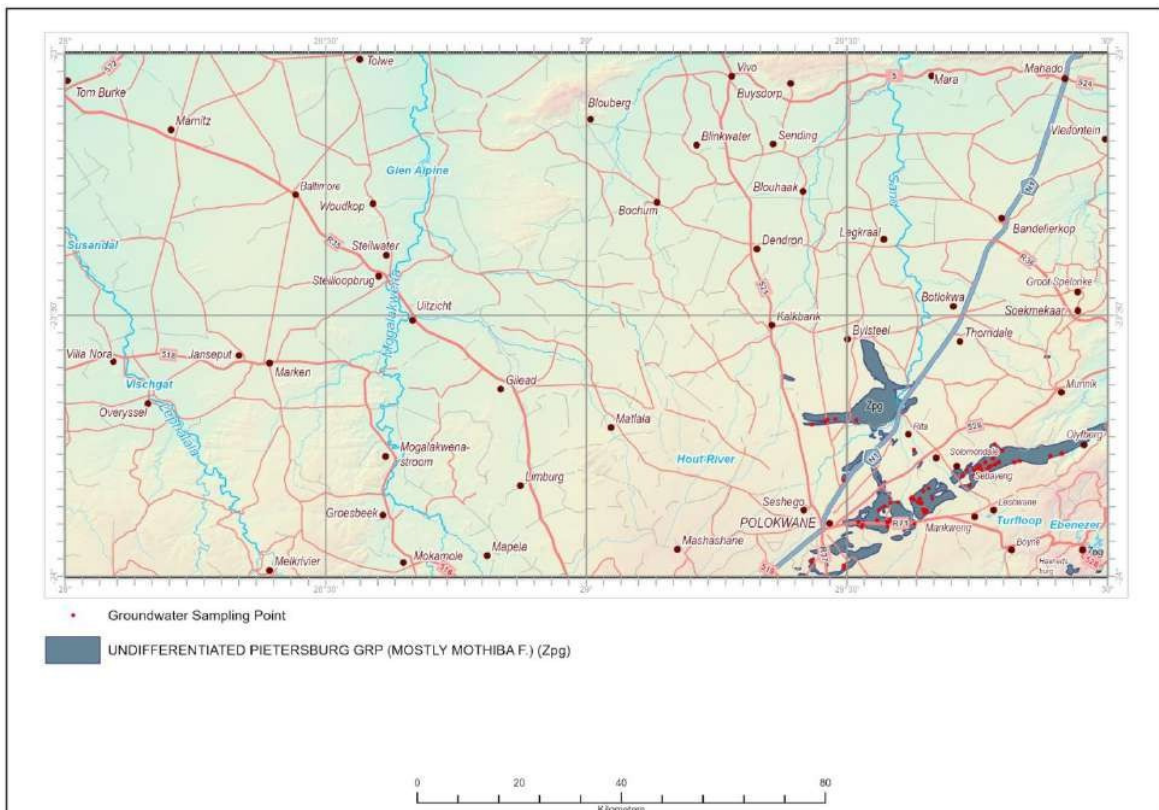


Figure 128: Geographical distribution of the Undifferentiated Pietersburg Group, (Mostly Mothiba Formation), (Zpg) and the associated groundwater data points.



Plate 15: View of Ysterberg on the right comprising banded ironstone of the Pietersburg Group. The mountain on the left consists of sediments of the Transvaal Sequence with the Ysterberg fault running along the valley between them. The Ysterberg fault, which is of pre-Transvaal age, was re-activated on various occasions until after deposition of the Transvaal Sequence. It has a lateral displacement of about 9km (Photograph: WH Du Toit)

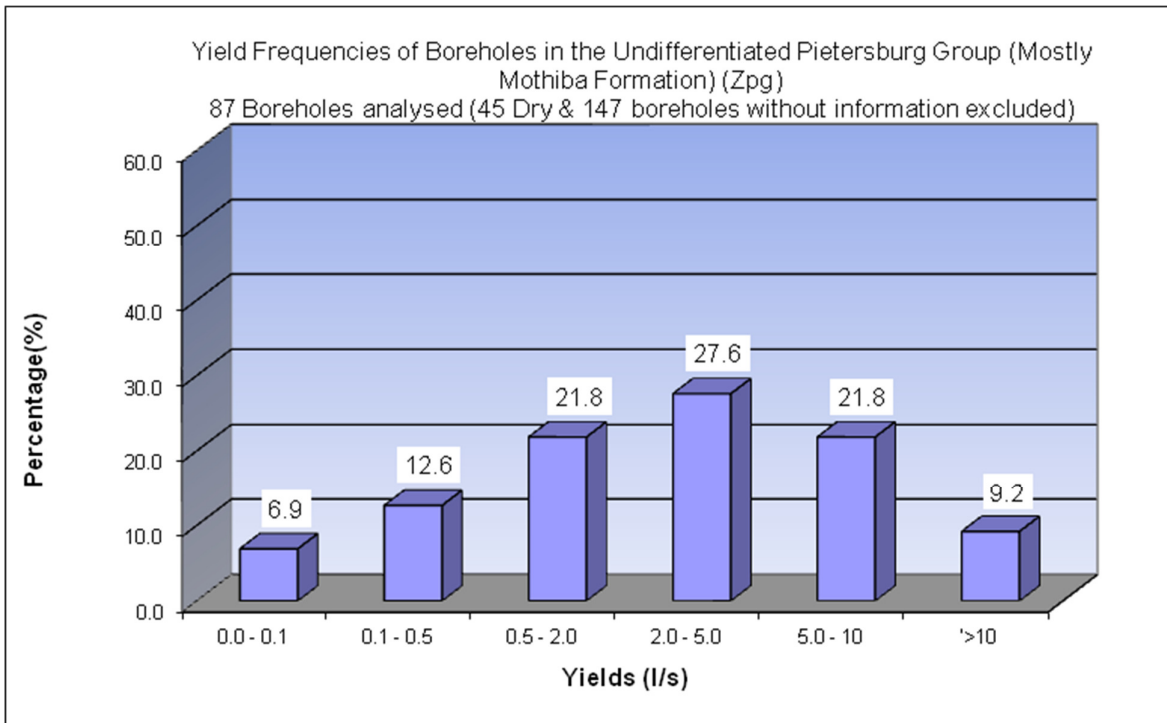


Figure 129: Yield frequency for the intergranular and fractured aquifers of the Undifferentiated Pietersburg Group, (Mostly Mothiba Formation), (Zpg).

The statistical analysis of 87 borehole records, (Figure 129) indicates that 19.5% of successful boreholes yield between >0.001l/s and 0.5l/s, making them suitable for small households. Additionally, 21.8% of boreholes have yields between 0.5l/s and 2l/s, with 27.6% yielding between 2l/s and 5l/s, and 31% yields more than 5l/s.

The static water level ranges from 1.34 meters below ground level (mbgl) to 78.48mbgl, with a median of 14.53mbgl and an average of 18.26mbgl, (based on 71 data points). The maximum borehole depth recorded is 201m, with an average depth of 67.6m and a median depth of 62.5m, (82 data points). The maximum installation depth recorded is 100m, with an average installation depth of 38.3m, (54 data points). The depth of installation can provide an indication of water strike depths when compared to the average depth and static water levels of the boreholes.

The maximum recommended daily abstraction recorded is 552.9 cubic meters per day (m<sup>3</sup>/day), with an average of 106.9m<sup>3</sup>/day. The 90<sup>th</sup> percentile for daily abstraction is 231.7m<sup>3</sup>/day, while the 80<sup>th</sup> percentile is 166m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 54.

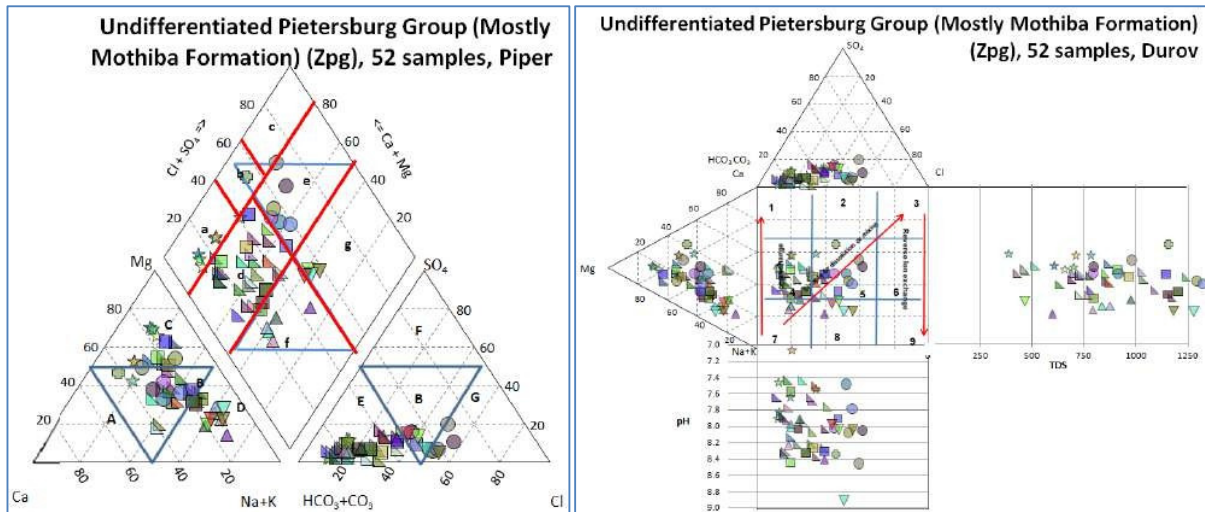


Figure 130: Trilinear diagrams, Piper and Durov for the Undifferentiated Pietersburg Group (Zpg).

The trilinear Piper diagram, (Figure 130) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (82.7%), Weak acidic anions > Strong acidic anions (79.8%); Alkali > Alkali earths (17.3%); Strong acids > Weak acids (20.2%).

The groundwater in this unit classifies as:

- Mixed Calcium-Magnesium-Bicarbonate type with increased Sodium (44.3%),
- Magnesium-Bicarbonate type (21.2%),
- Mixed Calcium-Magnesium-Chloride type with increased Sodium (9.6%),
- Sodium-Bicarbonate type (9.6%),
- Sodium-Bicarbonate-Chloride type (5.8%),
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type (3.8%),
- Mixed Calcium-Magnesium-Bicarbonate type (1.9%),
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type with increased Sodium (1.9%),
- Sodium-Chloride type (1.9%).

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- $\text{SO}_4$  dominates, or anion discriminant and Ca dominant, frequently indicates recharged water in gypsiferous deposits or mixed water or water exhibiting simple dissolution (48.1%).
- No dominant anion or cation, indicates water exhibiting simple dissolution or mixing (34.6%), plot along the dissolution or mixing line,
- Cl and Na dominant, reverse ion exchange of Na-Cl waters (7.7%),
- Cl dominant anion and Na dominant cation, indicate that the groundwater is related to reverse ion exchange of Na-Cl waters (9.6%),
- Some samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 77: Chemical statistics for the Undifferentiated Pietersburg Group (Mostly Mothiba Formation) (Zpg).

Element / Parameter	Statistics Drawn from a population of 78 data points for Undifferentiated Pietersburg Group (Mostly Mothiba Formation) (Zpg)										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	77	6.80	8.90	7.89	7.91	7.41	7.95	8.36	0.40	5.0%	
Electrical Conductivity (mS/m EC)	77	41.98	191.50	79.53	88.06	54.21	86.30	129.12	29.69	33.7%	
Total Dissolved Salts (mg/l TDS)	74	277.21	1213.80	569.29	631.67	380.96	603.53	889.60	202.21	32.0%	
Calcium (mg/l Ca)	75	15.72	95.77	34.26	39.59	23.18	38.30	60.04	15.71	39.7%	
Magnesium (mg/l Mg)	75	9.49	127.72	35.69	46.00	22.87	43.80	72.45	21.34	46.4%	
Sodium (mg/l Na)	75	10.20	324.69	49.74	81.03	23.23	67.34	149.29	55.80	68.9%	
Potassium (mg/l K)	75	0.15	18.22	2.88	7.11	1.71	6.50	13.96	4.53	63.6%	
Chloride (mg/l Cl)	77	8.51	204.60	29.79	53.62	15.70	38.42	122.96	45.37	84.6%	
Sulphate (mg/l SO <sub>4</sub> )	74	1.78	93.54	13.09	23.70	6.50	19.11	47.91	17.91	75.6%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	70	90.00	563.00	286.60	325.81	188.47	327.32	453.05	104.73	32.1%	
Nitrate (mg/l N)	76	0.04	39.06	0.91	9.83	1.28	8.21	21.93	8.29	84.3%	
Fluoride (mg/l F)	72	0.10	1.61	0.30	0.49	0.15	0.38	0.98	0.37	75.3%	
Silicon as Si	72	3.03	67.40	22.49	30.39	16.57	31.69	37.98	11.04	36.3%	
Iron (Fe)	44	0.005	0.192	0.013	0.025	0.008	0.013	0.053	0.03	136.4%	
Manganese (Mn)	26	0.006	0.300	0.012	0.043	0.006	0.010	0.100	0.07	164.9%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	70	0.006	0.800	0.021	0.070	0.012	0.028	0.076	0.16	234.0%	
ZAR	75	0.23	10.32	1.28	2.21	0.59	1.81	4.32	1.64	74.0%	
LSI	70	Langelier Saturation Index (LSI)		Slightly Scaling			42.9%		Highly Scaling		0.0%
		Highly corrosive		0.0%	Slightly corrosive		0.0%	Balanced Corrosion		57.1%	

Table 77 gives a summary that includes the physical properties, major anions, cations, and some minor elements. Where the coefficient of variation exceeds 100%, the 90<sup>th</sup> percentile, maximum value, and standard deviation provide an indication of the scale of the issue.

Overall, water quality is classified as ideal to good in 96.1% of the analyses, while 3.9% of the samples are marginal based on Electrical Conductivity (EC). EC values range from 41.98 to 191.50mS/m, with a 90<sup>th</sup> percentile value of 129.12 mS/m.

Total Dissolved Solids (TDS) levels are within acceptable limits (TDS ≤ 1200 mg/L) in 98.6% of the samples. An analysis of major cations and anions from 78 samples indicates elevated nitrate concentrations (N > 20 mg/L) in 13.2% of the samples and elevated fluoride levels (F > 1.5 mg/L) in 2.8% of the samples.

The Langelier Saturation Index (LSI) suggests that the water is slightly scaling in 42.9% of the cases and predominantly balanced in 57.1%. The ZAR index indicates that 76% of the water is of fair quality for irrigation (ZAR < 3).

There are a significant number of rural villages within this unit, which are supplied by Regional Water Schemes, drawing water from both the Ebenezer Dam and groundwater resources.

### 7.2.3.28 GOUDPLAATS GNEISS (Zgo)

For the 1:250 000 hydrogeological map sheet the Goudplaats Gneiss was divided into two units, the first groundwater resource unit as described in this section is without older rock inclusions (Xenoliths) and the second as described as a separate unit is with the older rock inclusions. It consists of gneiss, layered gneiss, migmatite and accompanying leuco-granite. Due to extended sandy soil cover, outcrops are mostly visible in ephemeral stream beds. The gneiss can be large unfoliated masses or can exhibit alternating bands of melanocratic and leucocratic material. This unit is believed to have formed the basement to the Bandelierkop Complex and the Pietersburg Group. Regarding the oldest rock in the area, the unit is mainly confined to the centre-eastern part of the map sheet, (Figure 131). It has been intruded by various granites and numerous diabase and dolerite dykes with a predominantly northeast to southwest strike. The unit covers approximately 0.18% of the total map area.

The groundwater potential of the Goudplaats Gneiss is moderate to good. From the yield diagram, 25.6% of successful boreholes yield less than 2l/s and 74.4% more than 2l/s. A considerable number of boreholes (53.8%) have maximum yields exceeding 5l/s, (Figure 132).

In 18.2% of the water samples, at least one element exceeds the maximum allowed limits for domestic use. For this unit the anion of concern is Nitrate followed by a small percentage (13.6%) of the sources with elevated Fluoride concentrations that exceed the maximum allowable limit for human consumption.

Geophysical methods have been successfully employed in the search for groundwater within this unit. Groundwater targets usually include deep weathering and fracturing, faults, pegmatite zones and secondary fracturing associated with dyke intrusions. The success rate increases in areas where genesis exhibits foliation and pegmatitisation.

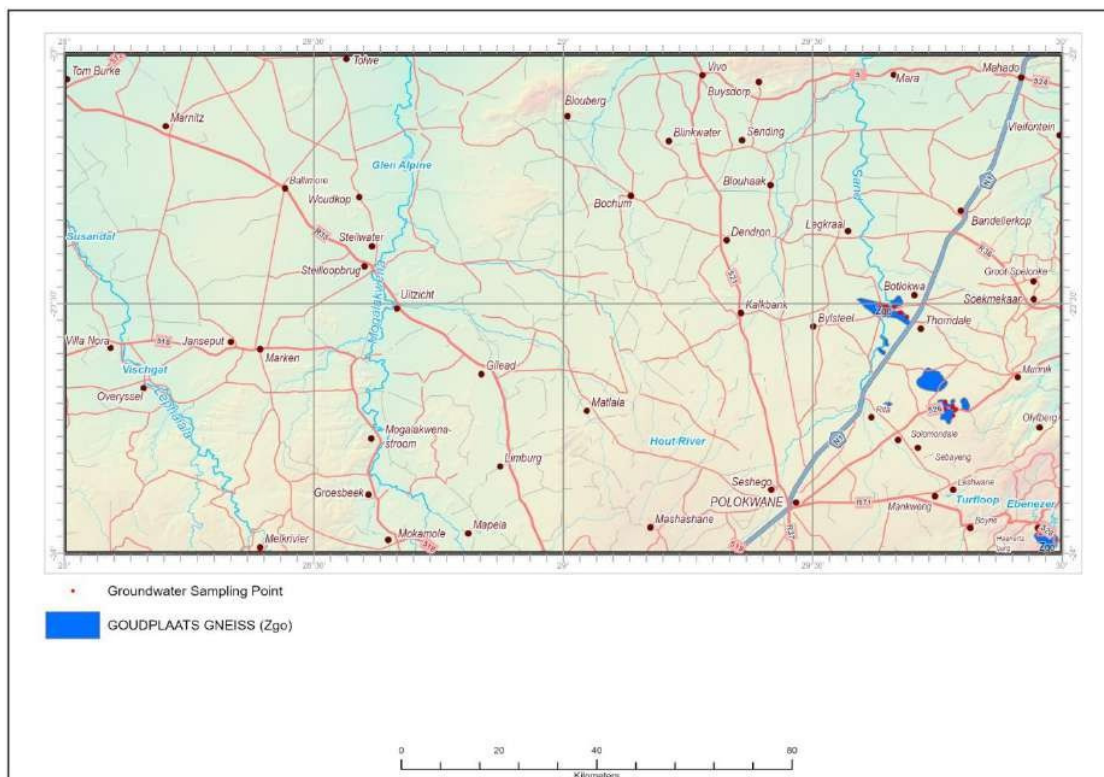


Figure 131: Geographical distribution of the Goudplaats Gneiss (Zgo) and the associated groundwater data points.

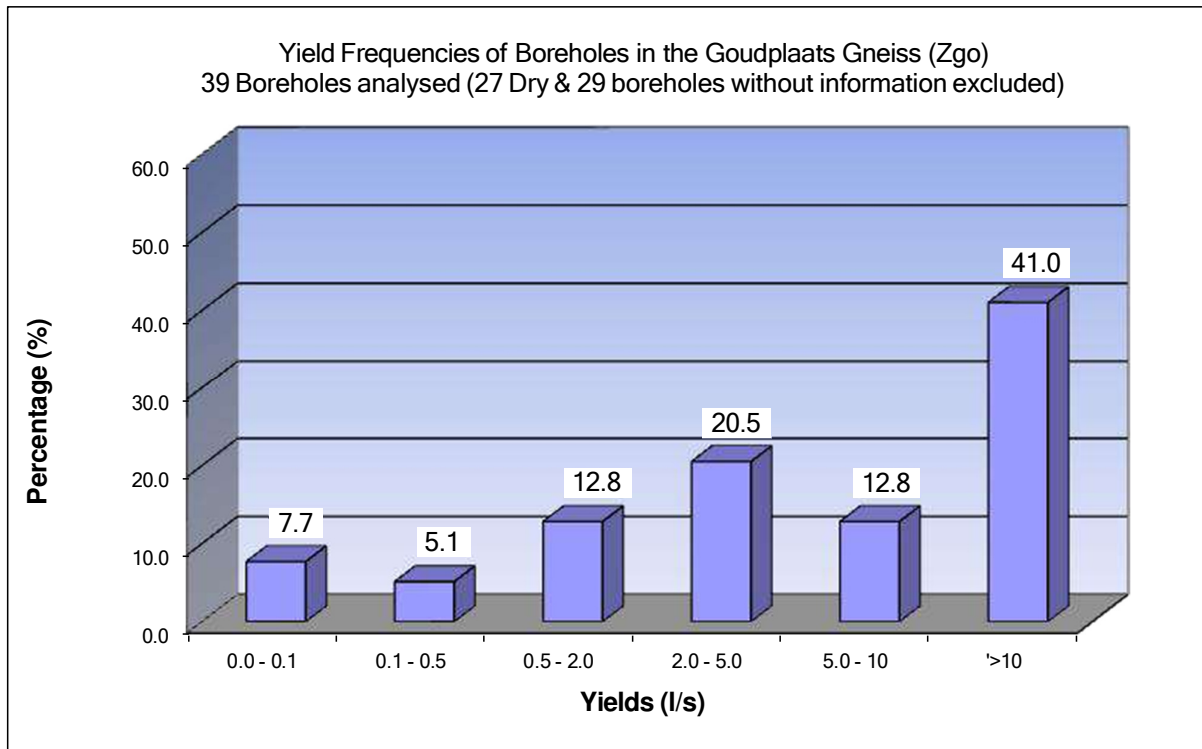


Figure 132: Yield frequency for fractured aquifers of the Goudplaats Gneiss (Zgo).

The statistical analysis of 39 borehole records, (Figure 132) indicates that 12.8% of successful boreholes have yields suitable for small households (>0.001l/s to 0.5l/s). In addition 12.8% of boreholes have yields between 0.5l/s and 2l/s, with 20.5% yielding between 2l/s and 5l/s and 12.8% yielding between 5l/s and 10l/s. A high number (41%) of the boreholes yield more than 10l/s. Due to the limited data the percentages may be different but it is known that the Goudplaats Gneiss represent one of the best aquifers within the map sheet.

The static water level ranges from 1.16 meters below ground level (mbgl) to 27.65mbgl, with a median of 8.03mbgl and an average of 9.11mbgl, (based on 18 data points). The maximum depth recorded is 131m, with an average of 61.4m and a median of 60m, (44 data points). The maximum installation depth is 67m and with an average of 33.6m, (15 data points). The depth of installation can be indicative of water strike depths if compared to the average depth and static water levels of the boreholes.

The maximum recommended daily abstraction on record is 518.4 cubic meters per day (m<sup>3</sup>/day) and the average is 147.4m<sup>3</sup>/day. The 90<sup>th</sup> percentile of daily abstraction is 328.3m<sup>3</sup>/day and the 80<sup>th</sup> percentile is 233.3m<sup>3</sup>/day. The total number of boreholes subjected to pump testing within this unit on record is 15.

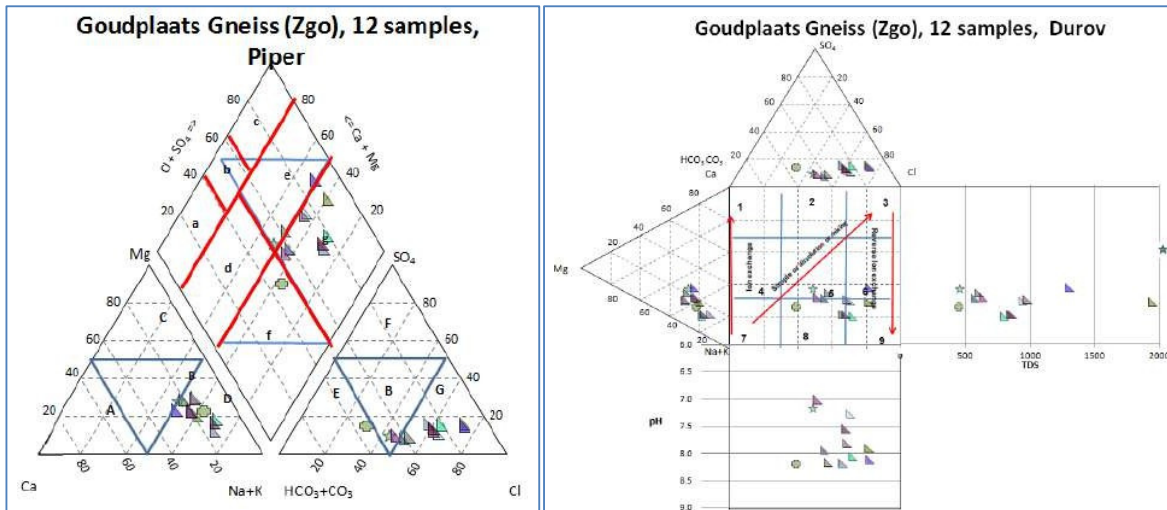


Figure 133: Trilinear diagrams, Piper, and Durov for the Goudplaats Gneiss (Zgo).

The trilinear Piper diagram, (Figure 133) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (8.3%), Weak acidic anions > Strong acidic anions (8.3%); Alkali > Alkali earths (91.7%); Strong acids > Weak acids (91.7%).

The groundwater in this unit classifies as:

- Sodium-Chloride type (75.1%),
- Sodium-Bicarbonate type (8.3%);
- Sodium-Bicarbonate-Chloride type (8.3%);
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type with increased Sulphate (8.3%);

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- No dominant anion or cation indicates water exhibiting simple dissolution or mixing (33.3%), plot along the dissolution or mixing line,
- Cl is the dominant anion and Na the dominant cation, indicative that the groundwater is related to reverse ion exchange of Na-Cl waters (33.3%),
- Cl and Na dominant, frequently indicative of end-point gradient waters through Dissolution (25%),
- Anion discriminates and Na dominant, indicates probable mixing or uncommon dissolution influences (8.3%),
- Some samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 78: Chemical statistics for the Goudplaats Gneiss (Zgo).

Element / Parameter	Statistics Drawn from a population of 22 data points for Goudplaats Gneiss (Zgo).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	22	7.26	8.45	7.99	8.01	7.58	7.99	8.43	0.35	4.4%	
Electrical Conductivity (mS/m EC)	22	66.00	466.05	129.03	162.93	82.42	133.35	234.95	92.63	56.9%	
Total Dissolved Salts (mg/l TDS)	22	530.00	2929.22	919.50	1104.20	642.42	930.96	1562.31	560.77	50.8%	
Calcium (mg/l Ca)	20	27.50	174.12	49.72	61.04	33.60	51.23	81.46	38.01	62.3%	
Magnesium (mg/l Mg)	20	22.40	112.39	38.69	46.39	27.26	37.95	82.51	24.12	52.0%	
Sodium (mg/l Na)	20	87.62	643.20	159.77	214.04	97.21	165.47	345.91	135.39	63.3%	
Potassium (mg/l K)	20	6.43	21.21	10.63	11.70	7.91	11.17	17.79	3.90	33.3%	
Chloride (mg/l Cl)	22	40.08	1070.52	125.32	256.56	60.45	153.78	490.67	246.91	96.2%	
Sulphate (mg/l SO <sub>4</sub> )	22	27.28	312.79	52.78	80.01	31.93	46.45	123.51	66.48	83.1%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	20	179.29	446.70	309.98	332.18	212.52	334.85	442.20	83.29	25.1%	
Nitrate (mg/l N)	22	2.55	44.39	7.36	13.02	3.88	10.10	24.18	10.63	81.6%	
Fluoride (mg/l F)	22	0.21	1.81	0.50	0.79	0.30	0.47	1.53	0.53	66.4%	
Silicon as Si	20	6.05	39.98	26.49	31.49	25.81	33.20	37.74	7.35	23.3%	
Iron (Fe)	11	0.006	0.096	0.014	0.032	0.010	0.012	0.073	0.03	99.2%	
Manganese (Mn)	8	0.009	1.259	0.020	0.184	0.010	0.031	0.427	0.43	235.8%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	22	0.012	0.800	0.030	0.119	0.015	0.038	0.240	0.23	191.4%	
ZAR	20	2.12	9.34	4.15	4.94	2.92	4.46	8.12	2.16	43.8%	
LSI	20	Langelier Saturation Index (LSI)			Slightly Scaling		65.0%		Highly Scaling		0.0%
		Highly corrosive			0.0%		Slightly corrosive		0.0%		Balanced Corrosion

Table 78 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90<sup>th</sup> percentile, the maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality is ideal to good (59.1%), marginal (36.4%) and unacceptable, (EC > 370mS/m), in 4.5% of the analysis in terms of the Electrical conductivity (EC) with values ranging between 66 and 466.05mS/m. The 90<sup>th</sup> percentile is 234.95mS/m.

The Total Dissolved Solids (TDS) is acceptable in 59.1% of the samples, (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 22 samples indicates elevated concentrations of Nitrate (N > 10mg/l) in 18.2%; Fluoride (F > 1.5mg/l) in 13.6%; Chloride (Cl > 600mg/l) in 9.1% and Sodium (Na > 400mg/l) in 5% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water is predominantly slightly scaling (65%) and balanced (35%). The ZAR index indicates that 20% of the water is of a fair quality for irrigation (ZAR < 3).

The water usage within the unit is described in the next groundwater resource unit namely Goudplaats Gneiss with Xenoliths.



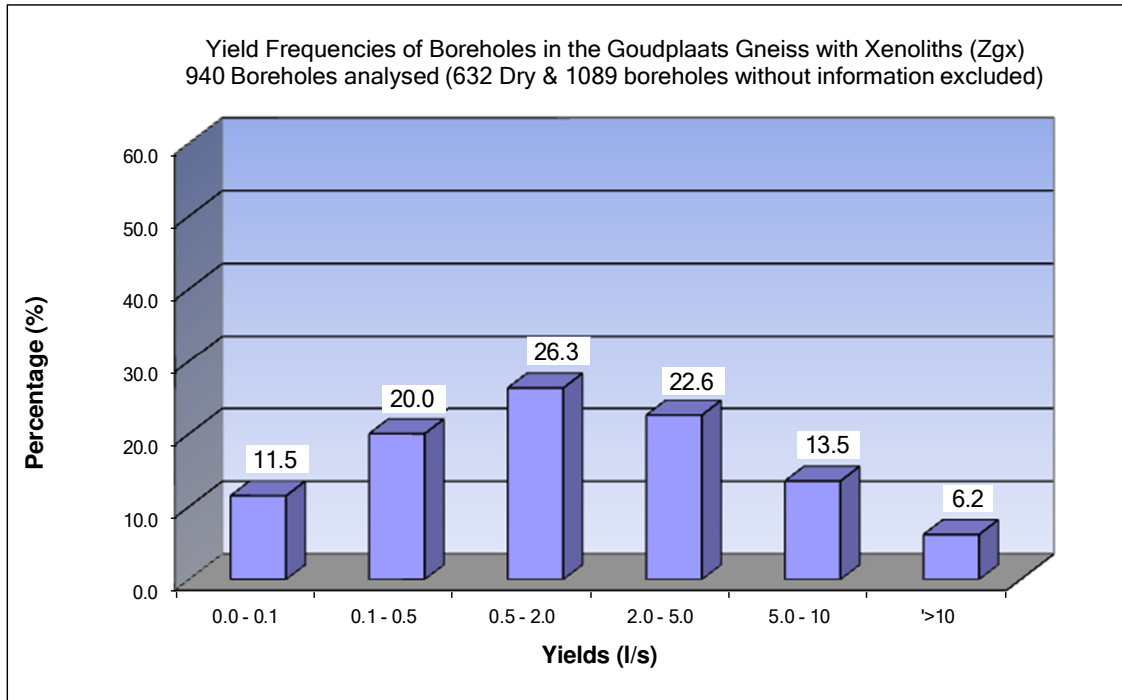


Figure 135: Yield frequency for fractured aquifers of the Goudplaats Gneiss with Xenoliths (Zgx).

The statistical analysis of 940 borehole records, (Figure 135) indicates that 31.5% of successful boreholes have yields suitable for small households (>0.001l/s to 0.5l/s). Additionally, 26.3% of boreholes have yields between 0.5l/s and 2l/s, with 22.6% between 2l/s and 5l/s and 19.7% yielding more that 5l/s.

The static water level ranges from artesian to 89.93 meters below ground level (mbgl), with a median of 20.53mbgl and an average of 21.93mbgl, (based on 342 data points). The maximum depth recorded is 204m, with an average depth of 65.9m and a median depth of 61.3m, (514 data points). The maximum installation depth is 120m and with an average installation depth of 41.8m, (264 data points). The depth of installation can be indicative of water strike depths if compared to the average depth and static water levels of the boreholes. The maximum recommended daily abstraction on record is 864 cubic meters per day (m<sup>3</sup>/day) and an average of 98.7m<sup>3</sup>/day. The 90th percentile of daily abstraction is 252.3m<sup>3</sup>/day and the 80th percentile is 172.8m<sup>3</sup>/day. The total number of boreholes tested in this unit on record is 265.

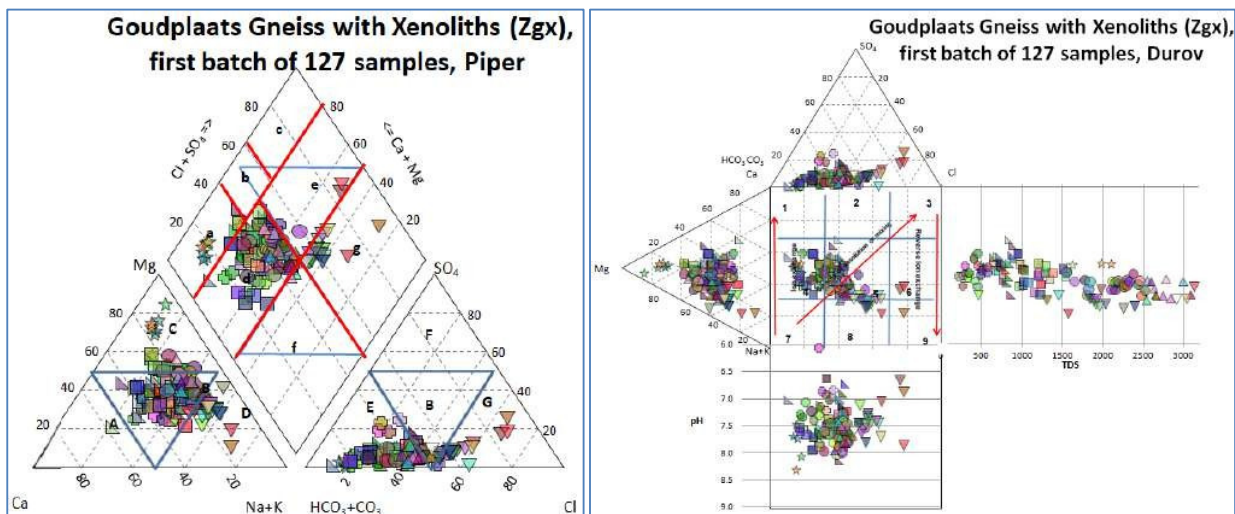


Figure 136: Trilinear diagrams, Piper, and Durov for the Goudplaats Gneiss with Xenoliths (Zgx), first batch of 127 data points.

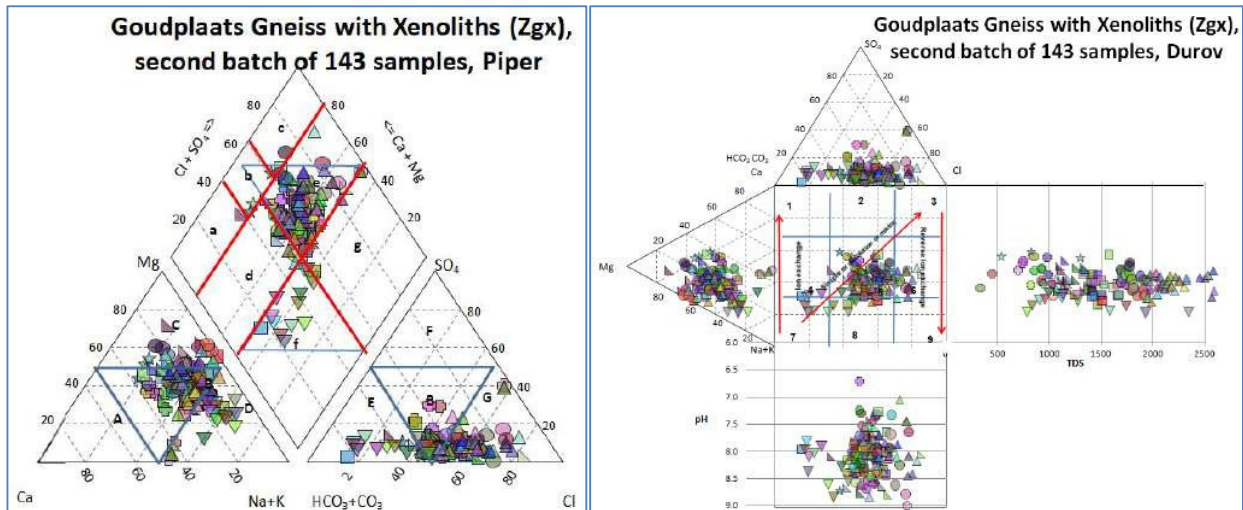


Figure 137: Trilinear diagrams, Piper, and Durov for the Goudplaats Gneiss with Xenoliths (Zgx), second batch of 143 data points.

The trilinear Piper diagram, (Figure 136 & Figure 137) facilitates the visualization of water chemistry by representing the concentrations of major cations and anions, allowing for the classification of hydrochemical facies. The initial evaluation of chemical dominance is as follows: Alkali earths > Alkali (88%), Weak acidic anions > Strong acidic anions (45.1%); Alkali > Alkali earths (12%); Strong acids > Weak acids (54.9%).

The groundwater in this unit classifies as:

- Mixed Calcium-Magnesium-Bicarbonate type with increased Sodium (33%),
- Mixed Calcium-Magnesium-Chloride type with increased Sodium (23.6%),
- Mixed Calcium-Magnesium-Bicarbonate-Chloride type with increased Sodium (16.1%),
- Sodium-Chloride type (11.2%),
- Magnesium-Chloride type (6.7%),
- Magnesium-Bicarbonate type (6.4%),
- Magnesium-Bicarbonate-Chloride type (1.1%),
- Sodium-Bicarbonate-Chloride type (0.7%),
- Calcium-Bicarbonate type (0.4%),
- Mixed Calcium-Magnesium-Chloride type (0.4%),
- Mixed Calcium-Magnesium-Bicarbonate type (0.4%).

The trilinear Durov diagram defines the hydrochemical processes along with the water type:

- No dominant anion or cation indicates water exhibiting simple dissolution or mixing (79%), plot along the dissolution or mixing line,
- Cl is the dominant anion and Na the dominant cation, indicative that the groundwater is related to reverse ion exchange of Na-Cl waters (8.2%),
- Anion discriminates and Na dominant, indicates probable mixing or uncommon dissolution influences (5.2%),
- SO<sub>4</sub> dominates, or anion discriminant and Ca dominant, frequently indicates recharge in gypsiferous deposits, otherwise mixed water or water exhibiting simple dissolution. (4.1%)
- Cl and Na dominant, reverse ion exchange of Na-Cl waters (2.2%),
- Cl and Na dominant, frequently indicative of end-point gradient waters through Dissolution (1.1%),
- Some samples exhibit high TDS values that may be indicative of long residence times in the aquifer allowing reactions to be complete.

Table 79: Chemical statistics for the Goudplaats Gneiss with Xenoliths (Zgx).

Element / Parameter	Statistics Drawn from a population of 647 data points for Goudplaats Gneiss with Xenoliths (Zgx).										
	Total samples	Minimum Value	Maximum Value	Harmonic mean value	Arithmetic mean Value	10 <sup>th</sup> percentile	50 <sup>th</sup> percentile (median)	90 <sup>th</sup> percentile	Standard Deviation	Coefficient of Variation	
pH	621	6.00	9.19	7.91	7.94	7.28	8.00	8.47	0.45	5.7%	
Electrical Conductivity (mS/m EC)	642	11.90	517.00	75.69	117.76	40.25	113.90	189.88	67.43	57.3%	
Total Dissolved Salts (mg/l TDS)	596	72.00	3442.00	545.78	852.98	302.96	847.35	1346.58	465.89	54.6%	
Calcium (mg/l Ca)	608	1.00	355.01	30.67	52.73	17.29	48.20	88.02	35.05	66.5%	
Magnesium (mg/l Mg)	607	1.50	294.82	30.33	64.35	15.92	61.64	116.01	40.69	63.2%	
Sodium (mg/l Na)	590	5.79	848.80	53.68	103.59	20.82	100.99	179.53	72.19	69.7%	
Potassium (mg/l K)	583	0.01	65.51	2.36	7.04	1.90	6.09	12.60	5.42	77.0%	
Chloride (mg/l Cl)	616	1.90	1214.10	46.53	140.87	20.16	112.33	290.25	140.55	99.8%	
Sulphate (mg/l SO <sub>4</sub> )	606	0.13	711.27	7.59	38.24	4.60	27.46	66.59	60.63	158.6%	
Total Alkalinity (mg/l CaCO <sub>3</sub> )	573	19.80	2825.00	224.43	333.10	129.46	330.58	521.13	179.40	53.9%	
Nitrate (mg/l N)	633	0.01	150.30	0.51	14.48	0.42	8.63	38.09	17.91	123.7%	
Fluoride (mg/l F)	618	0.02	3.30	0.21	0.34	0.11	0.26	0.62	0.29	86.3%	
Silicon as Si	572	1.82	80.00	23.18	27.77	16.95	27.37	38.81	8.78	31.6%	
Iron (Fe)	232	0.005	0.730	0.012	0.028	0.006	0.012	0.050	0.07	241.9%	
Manganese (Mn)	120	0.005	0.910	0.014	0.061	0.006	0.020	0.171	0.13	208.9%	
Ortho Phosphate as Phosphorus as PO <sub>4</sub>	546	0.005	0.800	0.017	0.069	0.008	0.020	0.116	0.16	234.2%	
ZAR	590	0.30	14.13	1.57	2.21	0.84	2.14	3.61	1.20	54.5%	
LSI	552	Langelier Saturation Index (LSI)			Slightly Scaling		57.4%		Highly Scaling		0.0%
		Highly corrosive		0.5%	Slightly corrosive		10.5%	Balanced Corrosion		31.5%	

Table 79 gives a summary of the physical properties, the major anions, cations, and some of the minor elements. Where the coefficient of variation is above 100%, the 90<sup>th</sup> percentile, the maximum value and standard deviation will give an indication of the scale of the problem. The overall water quality is ideal to good (70.7%), marginal (28.3%) and unacceptable, (EC > 370mS/m) in 0.9% of the analysis in terms of the Electrical conductivity (EC) with values ranging between 11.9 and 517mS/m. The 90<sup>th</sup> percentile is 189.88Ms/m.

The Total Dissolved Solids (TDS) is acceptable in 79.4% of the samples, (TDS ≤ 1200mg/l). An evaluation of the major cations and anions from 647 samples indicates elevated concentrations of Nitrate (N >20mg/l) in 25.3%; Fluoride (F >1.5mg/l) in 1.5%; Chloride (Cl > 600mg/l) in 1.6% Magnesium (Mg > 200mg/l) in 0.7%; Sodium (Na > 400mg/l) in 0.7%; Calcium (Ca > 300) in 0.3% and Sulphate (SO<sub>4</sub> >600mg/l) in 0.3% of the analysis.

The Langelier Saturation Index (LSI) indicates that the water is slightly to highly corrosive (11%), predominantly slightly scaling (57.4%) and balanced (31.5%). The ZAR index indicates that 79.5% of the water is of a fair quality for irrigation (ZAR < 3).

There are a significant number of rural villages and towns within this groundwater unit, such as Louis Trichardt, Bandelierkop, Morebeng (Soekmekaar) and Ga-Sekgopo. Water to these villages is from groundwater and in some instances a combination of groundwater and surface water. The rural villages and the larger towns are supplied by Regional Water Schemes. Sections within the unit are used for irrigation while the rest is livestock or game farming or a combination of all. The Makado Air Force Base falls within the unit and in terms of groundwater known due to a large spillage of jet fuel that required re- habilitation of the aquifer around the base. In the south-eastern section within the Ecoregion North Eastern Highland, forestry dominates economic activity.

## **8. SPRINGS AND ARTESIAN BOREHOLES**

### **8.1 Hot Springs**

Of the 90 (Kent, 1968) known hot springs in the Republic of South Africa, no hot springs occurs on the 1:250 000 Polokwane hydrogeological map sheet.

### **8.2 Cold Springs**

Springs are natural exit points where groundwater emerges from an aquifer and flows across the surface as surface water. Interflow, on the other hand, refers to the lateral movement of water within the unsaturated (vadose) zone, which eventually returns to the surface or enters a stream, (Wikipedia).

Both processes occur in the Soutpansberg Mountain and North Eastern Highland Ecoregions, where they contribute to the water supply of upper catchment streams and tributaries of major rivers. Springs and interflow can be either perennial (flowing year-round) or intermittent (flowing only during the rainy season).

Several geological conditions can lead to spring formation, but in the Polokwane map sheet area, two factors are the most likely causes. Within the Soutpansberg Mountain and North Eastern Highland Ecoregions, springs typically form where fractures or joints in low-permeability rocks intersect the land surface, allowing groundwater to flow out. A total of 18 registered springs are located within or influenced by these regions.

One such registered spring (ID number 2) at Machachaans 708 LS is most likely a contact spring. Contact springs form at boundaries between permeable and impermeable rock layers. When water-bearing, permeable rocks lie above an impermeable layer, groundwater accumulates and emerges at the surface where these layers intersect.

The Soutpansberg Mountain is also known for its water-retaining mosses. These bryophytes have unique structural characteristics that enable them to retain moisture, helping sustain the flow of springs and streams, particularly during dry periods.

Table 80: List of springs within the Polokwane map sheet.

Id number	Name	Longitude	Latitude	Registered Volume m <sup>3</sup> /annum	Farm name and number	Ecoregion	Groundwater Resource Unit
7	Spring	29.50621	-23.08623	16800	Goedgedacht 49LS	Limpopo Plain but near Soutpansberg	Hout River Gneiss with Xenoliths (Rh <sub>x</sub> )
1	Spring	28.51770	-23.34011	13800	Roodebosspuit 379LR	Limpopo Plain	Kransberg Subgroup (Mkr) / Diabase intrusions (N-Za)
2	Spring	29.15352	-23.92504	18000	Machachaans 709LS	Northern Plateau	Lunsklip Granite (Rl-VI)
4	Spring	29.40739	-23.05896	12800	Bulsdorp 37LS	Soutpansberg	Sibasa Formation (Soutpansberg Group) (Msi) / Diabase intrusions (N-Za)
5	Spring	29.43917	-23.03389	43200	Bergplaats 40LS	Soutpansberg	Wylliespoort Formation (Mwp)
6	Spring	29.44653	-23.02950	3600	Bergplaats 40LS	Soutpansberg	Wylliespoort Formation (Mwp)
8	Spring	29.81993	-23.06222	9282	Nooitgedacht 290LS	Limpopo Plain but near Soutpansberg	Goudplaats Gneiss with Xenoliths (Zgx)
9	Spring	29.83472	-23.00833	11000	Goevernements Belooning 260LS	Soutpansberg	Sibasa Formation (Soutpansberg Group) (Msi)
10	Spring	29.90059	-23.82392	9734	Zaagkuil 928LS	North Eastern Highlands	Turfloop Granite (Rt-VI)
11	Unknown	29.91667	-23.92778	80000	Rustfontein 1030LS	North Eastern Highlands	Goudplaats Gneiss with Xenoliths (Zgx)
12	Unknown	29.92083	-23.90833	40000	Klipspruit 1028LS	North Eastern Highlands	Goudplaats Gneiss with Xenoliths (Zgx)
13	Spring	29.92500	-23.85833	14200	Lunsklip 995LS	North Eastern Highlands	Goudplaats Gneiss with Xenoliths (Zgx)
14	Spring	29.96944	-23.06389	93030	Vygeboomsdrift 283LS	Lowveld but near outpansberg	Goudplaats Gneiss with Xenoliths (Zgx)
15	Spring	29.99867	-23.73475	25000	Welgevonden 886LS	North Eastern Highlands	Unnamed Granite Rocks (Vz)
16	Spring	30.00972	-23.92472	6000	Driehoek 626LT	North Eastern Highlands	Unnamed Granite Rocks (Vz)
17	No name	30.01070	-23.86530	7070	Onderhoek 595LT	North Eastern Highlands	Goudplaats Gneiss with Xenoliths (Zgx)
18	Groundwater	30.02564	-23.89956	2000	Paardeplaats 623LT	North Eastern Highlands	Goudplaats Gneiss with Xenoliths (Zgx)
19	Spring	30.02564	-23.89956	2000	Paardeplaats 623LT	North Eastern Highlands	Goudplaats Gneiss with Xenoliths (Zgx)
20	Spring	30.02950	-23.84982	12000	Rooihoogte 596LT	North Eastern Highlands	Unnamed Granite Rocks (Vz)
H19S0242	Spring-West	29.38889	-23.05000	28200	Bulsdorp 37LS	Soutpansberg	Wylliespoort Formation (Mwp)
				447716			

### 8.3 Artesian boreholes

The definition of an artesian borehole is a borehole that penetrated a confined aquifer in which the Piezometric surface is above ground level. This will result in water being discharged from the borehole without being pumped. The definition of a confined aquifer is a water bearing formation in which the groundwater is isolated from the atmosphere at the point of discharge by impermeable geologic formations thus a confined groundwater is generally subject to pressure greater than atmospheric, (DWS Groundwater Dictionary). In addition to the above, the confined water bearing formation must be exposed to recharge at some distance away, and the formation needs to be permeable to enable the flow of the water within the aquifer from the recharged area to the outlet point. The Piezometric pressure or hydraulic head at the point of recharge that will be represented by the static water level needs to be at a higher altitude than the surface area at the discharge point. Artesian conditions that include outflow or the rate of outflow at a borehole may be seasonal due to the Piezometric pressure head at the recharge point being lowered by drought. To explain to a layman, it can be best illustrated by using a bend pipe with one end higher than the other; when water is added to the higher point it will flow out at the lower point at a yield equal to inflow. In a geological context the pipe is filled with material with small openings and cracks. The dominant forces that will determine the outflow rate and volume are inflow volume, hydraulic pressure, (difference in height), as well as permeability, (connection between openings).

From the evaluation of static water levels available for the map sheet a total of 8 Artesian boreholes were identified. The information obtained from the National Groundwater Archive (NGA). A list of artesian boreholes is as follows:

Table 81: List of artesian boreholes within the Polokwane map sheet.

Borehole Number	Farm name	Farm number	Area or village name	Longitude	Latitude	Borehole Depth (m)	Blow yield (l/s)	Static water level	Lithostratigraphy	Rock type	Current status
H03-1589	STERKWATER	LPLR668	STERKWATER	28.62991	-23.53691	204.4	3.4	-0.09	Kransberg Subgroup	Sedimentary	unknown
H03-1590	STERKWATER	LPLR668	STERKWATER	28.63076	-23.53510	180.0	3.0	-0.23	Kransberg Subgroup	Sedimentary	unknown
H11-2266	ONTBYT	LPLR329	DRIEKOPPIES	28.69947	-23.25301	235.8	7.0	-0.06	Kransberg Subgroup	Sedimentary	unknown
H03-1533	SCHRIKFORTEIN	LPLR715	MAGAGAMATALA	28.59274	-23.71628	7.6	1.9	-0.30	Makgabeng Formation	Sedimentary	unknown
H03-2766	SCHRIKFORTEIN	LPLR715	GA-TSHABA	28.59052	-23.71226	70.9	0.8	-0.01	Makgabeng Formation	Sedimentary	unknown
H03-3782	STEIL LOOP	LPLR403	REBONE	28.61478	-23.44408	0.8	0.2	-0.10	Makgabeng Formation	Sedimentary	unknown
H04-1448	KIRSTENSPRUIT	LPLR351	KIRSTENSPRUIT	28.75785	-23.31424	74.3	4.0	-0.33	Makgabeng Formation	Sedimentary	unknown
H16-0342	ZOEKMAKAAR	LPLS778	SOEKMEKAAR	29.94182	-23.50004	65.8	2.2	-0.01	Goudplaats Gneiss with Xenoliths	Metamorphic	unknown

Note: Negative water levels are typed in the groundwater database for artesian boreholes. It usually represents the casing height or outflow point on the casing or plinth.

The hydrogeological conditions associated with artesian boreholes for sedimentary rocks are in most cases related to diabase sills where the lower contact zone was punctured during drilling. The borehole within the metamorphic rock may relate to the high rainfall within the area and topography combined with a diabase sill, (lower contact).

## 9. GROUNDWATER RELATED MATTERS

### 9.1 The National Water Act (Act 108 1998)

The **National Water Act** (Act 108 of 1998) replaces the old Water Act (Act 56 of 1956). Water resources are now recognised as a scarce and unevenly distributed national assets. The most important implications to groundwater users are 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 and Sanitation is the custodian** (trustee) of water resources on behalf of the National Government, with the responsibility to provide a framework for the protection, to promote equitable access to water, to facilitate social and economic development, to protect aquatic and associated ecosystems and their biological diversity, and management of water resources for the country. It must be managed in an integrated manner according to the principles of the Act (sustainability, equity, and efficiency). It must also meet international obligations.

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 (WUAs) 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) that is similar to some extent 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. In 2016 the

minister of Water and Sanitation approved the establishment of 9 CMAs, due to the complicity DWS had to develop documents for the establishment of these CMAs. CMAs will be representative of and facilitate the involvement of communities and other stakeholders in decision making.

At present the Department of Water and Sanitation is responsible for administering all aspects of the Act on the Minister's behalf. As regional CMA's (19 CMAs are planned) and other local water management institutions are established the Department will delegate or assign water resource management responsibilities to these institutions over time. 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's 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. Other users who are not falling under Schedule 1 must register their use or apply for a license. 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.

### 9.1.1 Water user registration and licenses

Licensing of water use is compulsory reserving the right to the minister of DWS to publish a notice in the Government Gazette requiring all existing and potential water users except Schedule 1 users to apply for licenses. The application for a Water User's License does not differentiate between users of surface or groundwater. The notice is revised on a 5-year basis and published in the Government Gazette.

**Schedule 1** users are relatively low water users such as reasonable domestic household supplies, non-commercial small gardens, livestock watering for subsistence use, (not feeding pens), storing and using run-off water from a roof, emergencies e.g., firefighting, recreation e.g., swimming, angling.

- The use is not excessive in relation to the available source and needs of other users.
- A Catchment Management Agency (CMA) may limit the taking of water in terms of Schedule 1 (Schedule 3(2) (e) of the Act.
- Water users in this category can commence with their activities without informing the Department.

**Continuation of existing lawful use:** Existing Lawful Water Use (ELU) means the use of water authorization by or under any law that took place at any time for a period of two years before the commencement of the NWA, 1998. An Existing Lawful Water Use, with any conditions attached, is recognised but may continue only to the extent that it is not limited, prohibited, or terminated by this Act.

- No license is required to continue with Existing Lawful Water Use until a responsible authority requires a person claiming such an entitlement to apply for a license.
- If a license is issued it becomes the source of authority for water use.
- If a license is not granted the use is no longer permissible.
- This authorization requires a registration with the Department in other words these users must inform DWS of their usage and DWS 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 on 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.

- This authorization requires registration with the Department prior to exercising the water use(s).

**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 following table was obtained from the E-WULAAS web site at: <https://www.dws.gov.za/ewulaas/WUA.aspx>

The following activities constitute water uses and require authorization in terms of Section 21 of the NWA:

*Table 82: The following activities constitute water uses and require authorization in terms of Section 21 of the NWA:*

Water Use	Example
Section 21 (a) Taking water from a water resource.	Abstracting water from a river or borehole for the following purposes: - domestic use - irrigation - watering of livestock - industrial - mining - water bottling, etc.
Section 21 (b) Storing water.	Raw water containment facilities constructed in-stream and in off-channel dams.
Section 21 (c) Impeding or diverting the flow of water in a watercourse.	Construction of structures/facilities within surface water resources, e.g. weirs, bridges, pipelines, etc.
Section 21 (d) Engaging in a stream flow reduction activity.	Plantation of forestry species (Eucalyptus, Pine and Wattle).
Section 21 (e) Engaging in a controlled activity identified as such in section 37(1) or declared under section 28(1) of the NWA.	Irrigation with water containing waste, artificial recharge of aquifer, modification of atmospheric precipitation and in-stream power generation activities.
Section 21 (f) Discharging waste or water containing waste into a water resource.	Discharging of water containing waste into a surface water resource, e.g. discharging treated effluent into a river or a wetland.
Section 21 (g) Disposing of waste in a manner which may detrimentally impact on a water resource.	Disposal of effluent into a water containment facility, dust suppression and stockpiles.
Section 21 (h) Disposing of waste in a manner which contains waster from or which has been heated in any industrial or power generation process.	Discarding of industrial/power generation waste water or water which has been heated.
Section 21 (i) Altering the bed, banks, courses or characteristics of a watercourse.	Construction of structures/facilities within surface water resources, e.g. weirs, bridges, pipelines, etc. Introduction of unnatural characteristic to the resource.
Section 21 (j) Removing, discharging or disposing of water found underground if it is necessary of the efficient continuation of an activity or for the safety of the people.	Extraction of water from underground workings for safe continuation of activities.
Section 21 (k) Using water for recreational purpose.	The use of surface water resources for fishing, boating, etc.

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 licenses will be issued with conditions to ensure that the water use authorized by the license 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.

### 9.1.2 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 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 25 liters/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.

### 9.1.3 Resource Directed Measures

The National Water Act of 1998 places an emphasis on the protection of water resources for their sustainable utilisation. This is reflected in the subsequent development of Resource Directed Measures (RDM) by The Department of Water and Sanitation, which consists of three important aspects, namely: classification of each major resource unit, setting the reserve; and determination of resource quality objectives. 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.

The framework to achieve this objective of protecting water resources while optimising their utilisation in a sustainable and equitable manner is provided in the National Water Resource Strategy (NWRS)

The NWRS adopts two complementary strategies to achieve this balance:

- Resource Directed Measures (RDM) that undertake to protect water resources by setting goals and objectives for the desired condition of water resources in aquatic ecosystems,
- Source Directed Controls (SDC) specify criteria for controlling water resource use activities and their impact on aquatic ecosystems.

The core of the RDM, and the basis of water resource management in South Africa, is the determination of a Management Class (MC). The MC is defined in terms of the resource quality that must be maintained.

Resource quality: includes the water quantity and quality, as well as the “character and condition of in- stream and riparian habitats, and the characteristics, condition and distribution of the aquatic biota” (DWAF 2003).

Management Classes are determined using the Water Resource Classification System (WRCS). The overall objective of the WRCS is to classify water resources in terms of:

- Class I (minimally used),
- Class II (moderately used),
- Class III (heavily used)

Based on the MC for each significant water resource, the Reserve, and the resource quality objectives (RQOs) for that resource are prescribed.

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 DWS is responsible to set the reserve. Basic human needs are set at 25 liters/person/day, and the ecological reserve is determined by investigation groundwater/surface interactions. Management of the resource units will be an ongoing process with emphasis on pollution prevention, emergency spillage and rehabilitation, monitoring of quality and quality, monitoring abstraction and compliance of licensed water users. Availability and demand must be managed in an integrated manner to maintain the resource quality objectives.

### 9.1.4 Monitoring

Monitoring, recording, assessing and dissemination of information on water resources are critically important for achieving the objectives of the act. According to DWS' records there are currently 212 monitoring stations falling within the 1:250 000 Polokwane map of which 68 are active and equipped with electrical data loggers, (Figure 138). The DWS is responsible to set up National water monitoring systems that will facilitate the continued and coordinated monitoring of various aspects of water resources. This is achieved by collecting relevant information and data through established procedures and mechanisms from a variety of sources. These include organs of state, water management institutions, and water users. Monitoring aspects such as quantity, quality, use, and rehabilitation are some of the important ones. As part of the water user license, users can be required to supply information on abstraction, water levels, and quality on a time frequency negotiated between DWS and the license 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.

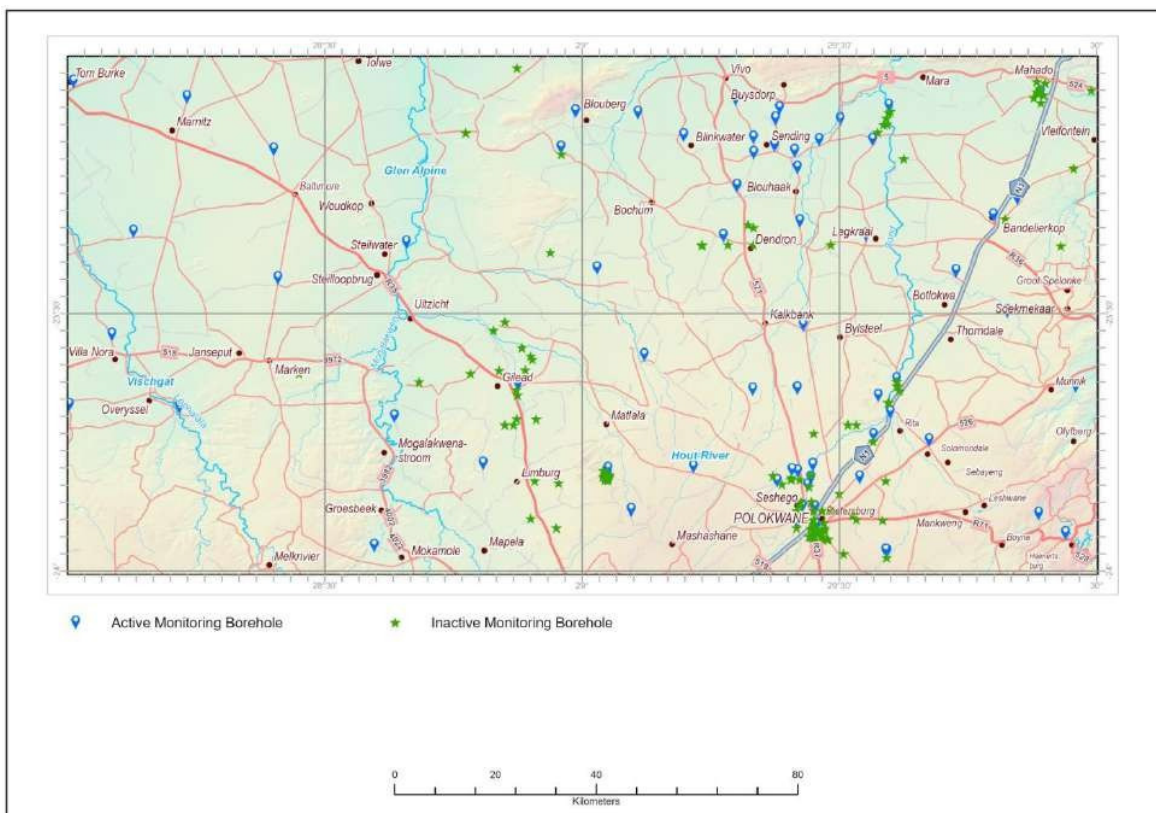


Figure 138: DWS monitoring boreholes.

Table 83: Active DWS monitoring boreholes.

Location	Station Number	Borehole number	Latitude	Longitude	Status	Monitoring Status	Date start	Monitoring equipment
George	A4N0504	M21-0654	-23.6913	28.00321	In use	Active	20080424	Electr Data Logger
Van Wyksfontein Ptn. Tom Burke	A5N0012	M03-3759	-23.064	28.0112	In use	Active	20080220	Electr Data Logger
Pic Van teneriffe ptn. Setateng	A5N0016	M21-0573	-23.555	28.08613	In use	Active	20130909	Electr Data Logger
Haakdoomkuil Ptn. Kitty	A5N0009	M21-0592	-23.355	28.12796	In use	Active	20060628	Electr Data Logger
Weltevreden	A5N0013	M03-3768	-23.6948	28.21757	In use	Active	20080221	Electr Data Logger
Kildare	A5N0018	M03-3975	-23.0943	28.23185	In use	Active	20120523	Electr Data Logger
Bonteberg	A6N0580	M03-3709	-23.1958	28.40044	In use	Active	20071120	Electr Data Logger
Goedgelegen	A6N0598	M03-3767	-23.4456	28.40861	In use	Active	20080206	Electr Data Logger
Klipfontein Ptn. Mmotlana	A6N0588	M03-3672	-23.965	28.59611	In use	Active	20070130	Electr Data Logger
Nelly ptn. Ga-Malope	A6N0604	M03-3855	-23.7138	28.63518	In use	Active	20130909	Electr Data Logger
Duren	A6N0578	M03-2545	-23.3762	28.65835	In use	Active	19960711	Electr Data Logger
Vlakfontein	A6N0597	M03-3770	-23.8054	28.80758	In use	Active	20080717	Electr Data Logger
Gilead	A6N0584	M03-3657	-23.6511	28.87556	In use	Active	20061207	Electr Data Logger
Udney Ptn. Sekiding	A7N0648	M11-2100	-23.1919	28.95889	In use	Active	20050118	Electr Data Logger
Beauley	A7N0634	M11-1223	-23.1215	28.9872	In use	Active	20041201	Electr Data Logger
Ga-Manhodi Ptn. Burgwal	A6N0605	M04-2554	-23.4262	29.02878	In use	Active	20130909	Electr Data Logger
Matalas Location	A6N0623	M04-2268	-23.8238	29.0492	In use	Active	20071019	Electr Data Logger
Matalas Location	A6N0612	M04-1457	-23.8149	29.05034	In use	Active	20071018	Electr Data Logger
Glen Roy Ptn. Glen Roy	A6N0599	M04-1562	-23.8954	29.09528	In use	Active	20070905	Electr Data Logger
Dikgomong ptn. Innes	A7N0659	M11-2606	-23.1244	29.1082	In use	Active	20130909	Electr Data Logger
Graafreinet Ptn. Rapitsi	A6N0586	M04-2261	-23.5946	29.12097	In use	Active	20060309	Electr Data Logger
Engelberg	A7N0670	M11-2679	-23.1682	29.19724	In use	Active	20131112	Electr Data Logger
Vaalkop Ptn. Doornspruit	A7N0635	M04-2262	-23.8118	29.21614	In use	Active	20060309	Electr Data Logger
Boomzien Dendron	A7N0524	M11-2314	-23.3634	29.27445	In use	Active	19650910	Electr Data Logger
Schoonveld	A7N0665	M19-0396	-23.098	29.29836	In use	Active	20160330	Electr Data Logger
Baviaanspoort	A7N0674	M11-2677	-23.2662	29.30081	In use	Active	20131016	Electr Data Logger
Kroon	A7N0672	M19-0463	-23.1725	29.33295	In use	Active	20131112	Electr Data Logger
York	A7N0667	M19-0395	-23.2024	29.33336	In use	Active	20160330	Electr Data Logger
York	A7N0668	M19-0460	-23.1875	29.37366	In use	Active	20130920	Electr Data Logger
Kaalbult	A7N0644	M19-0729	-23.1356	29.37553	In use	Active	20070601	Electr Data Logger
Vaalwater Ptn. Seshego	A7N0637	M14-2241	-23.8389	29.37878	In use	Active	20050714	Electr Data Logger
Buishoek	A7N0669	M19-0458	-23.1153	29.38345	In use	Active	20130807	Electr Data Logger
Pilgrimshoop Ptn. Palmietgat Kleinhoewes	A7N0655	M16-1942	-23.8179	29.40771	In use	Active	20080611	Electr Data Logger
Doorndraai	A7N0664	M19-0394	-23.1984	29.41282	In use	Active	20160330	Electr Data Logger
Sterkloop	A7N0549	M16-1827	-23.9223	29.41739	In use	Active	19711105	Electr Data Logger
Makibelo-Malietzies Ptn. Makibelo	A7N0661	M04-2597	-23.6594	29.41792	In use	Active	20120205	Electr Data Logger
Altenberg	A7N0662	M11-2635	-23.2311	29.41807	In use	Active	20160330	Electr Data Logger
Pilgrimshoop	A7N0642	M16-1851	-23.8203	29.41861	In use	Active	20071110	Electr Data Logger
Tommy	A7N0666	M11-2634	-23.3349	29.42289	In use	Active	20160330	Electr Data Logger
Sterkloop	A7N0538	M16-0255	-23.8879	29.42789	In use	Active	19731112	Electr Data Logger
Springforbi	A7N0641	M11-2406	-23.5365	29.42947	In use	Active	20070627	Electr Data Logger
Doornkraal	A7N0029	M16-1149	-23.8473	29.43837	In use	Active	19850415	Electr Data Logger
Doornkraal	A7N0586	M16-1140	-23.833	29.44412	In use	Active	19770126	Electr Data Logger
Doornbult	A7N0646	M16-1850	-23.808	29.44812	In use	Active	20061010	Electr Data Logger
Sterkloop	A7N0647	M16-1819	-23.8892	29.45157	In use	Active	20060810	Electr Data Logger
Sterkloop	A7N0539	M16-1826	-23.9228	29.45344	In use	Active	19731113	Electr Data Logger
De Droom	A7N0673	M19-0461	-23.1771	29.46045	In use	Active	20131007	Electr Data Logger
Sterkloop	A7N0636	M16-1552	-23.9354	29.46545	In use	Active	20050225	Electr Data Logger
Sodon	A7N0671	M19-0456	-23.1368	29.50139	In use	Active	20130619	Electr Data Logger
Tweefontein	A7N0525	M16-1825	-23.8324	29.53941	In use	Active	19750507	Electr Data Logger
Legkraal	A7N0643	M11-2408	-23.3607	29.55139	In use	Active	20070516	Electr Data Logger
Arras	A7N0663	M19-0399	-23.1763	29.56415	In use	Active	20160330	Electr Data Logger
Papkuil	A7N0654	M16-1920	-23.75	29.56596	In use	Active	20080416	Electr Data Logger
Zandrivierspoort Ptn. Zandrivierspoort	A7N0629	M16-1852	-23.6736	29.57551	In use	Active	20061019	Electr Data Logger
Matjeskraal	A7N0632	M16-1689	-23.9743	29.5899	In use	Active	20050620	Electr Data Logger
Matjeskraal	A7N0631	M16-1553	-23.9754	29.5923	In use	Active	20050315	Electr Data Logger
Lorgensry Ptn. Mara Navorsing Station	A7N0019	M19-0276	-23.1104	29.59566	In use	Active	19830517	Electr Data Logger
Zandrivierspoort	A7N0653	M16-1919	-23.7054	29.59846	In use	Active	20080311	Electr Data Logger
Roodewal	A7N0041	M16-1823	-23.6414	29.61102	In use	Active	19890920	Electr Data Logger
Kalkfontein Ptn. Sebayeng	A7N0633	M16-1789	-23.7602	29.67412	In use	Active	20060313	Electr Data Logger
Ga-Phasha ptn. The Grange	A7N0656	M16-0289	-23.4317	29.72625	In use	Active	20100920	Electr Data Logger
Banerlierkop	A7N0657	M19-0386	-23.3233	29.79917	In use	Active	20130909	Electr Data Logger
Ramagoep Ptn. Eistleben	A7N0638	M16-1818	-23.5097	29.82634	In use	Active	20060812	Electr Data Logger
Beschuitkuil	A9N0019	M19-0387	-23.2908	29.84556	In use	Active	20130909	Electr Data Logger
Spitskop	B5N0068	M16-0295	-23.9029	29.8869	In use	Active	20031001	Electr Data Logger
Ledig	A7N0593	M19-0278	-23.0847	29.8907	In use	Active	19930810	Electr Data Logger
Haenertsburg Town And Townlands Ptn. Haenertsburg	B8N0502	M09-0248	-23.9406	29.93923	In use	Active	20070208	Electr Data Logger
Segops Location Ptn. Seggopo	B8N0520	M09-0133	-23.6549	29.9591	In use	Active	20050208	Electr Data Logger

## 9.2 Groundwater recharge, storage, and movement

Vegter (1995) states that groundwater recharge primarily depends on rainfall. He defines recharge as the process of water absorption and addition to the saturated zone. In the Polokwane map sheet area, groundwater recharge is influenced by effective rainfall, which refers to the portion of rainfall that infiltrates to the saturated zone after losses due to evaporation, transpiration, runoff, and interception. Recharge may also occur from rivers or dams with controlling factors such as open fracture zones and the infiltration potential of the bedding material underlying the surface water bodies. The infiltration potential will be influenced by various aspects such as the type of underlying material, the absence or presence of hard pan surfaces, duration of surface water availability, grain size and distribution.

The map area is generally classified as a "dry" region with frequent droughts. There are a few perennial rivers available to enable continuous recharge, making groundwater recharge a seasonal occurrence, which is primarily during the rainy season when rivers flow. In some cases, groundwater is lost to rivers through seepage and springs, which contribute to base flow. However, depending on local conditions, dams, particularly earth dams, can significantly contribute to groundwater recharge, especially those within the Sand River. Groundwater level responses to rainfall events may exhibit a time lag due to the time required for percolation through the unsaturated zone before reaching the saturated zone.

Some irrigation farmers irrigate from earth dams, which are supplied by boreholes. Recharge through leakage may be occurring from earth dams if not properly sealed. A small percentage of irrigation water is not absorbed by plants and may return to the aquifer. Where artificial recharge from earth dams is planned, various favorable conditions must be present such as that sufficient sub-surface storage must be available. In suitable locations, a localized elevated water table may develop under the recharge area, migrating slowly through preferential pathways into the rest of the aquifer as the system is not entirely closed, (semi confined aquifer). The water table is a subdued replica of the topography that may inhibit the lateral expansion of the recharge mound that is being built up below the recharged zone and must therefore be considered for artificial recharge projects. Natural recharge is controlled by several factors, including rainfall intensity and frequency, vegetation cover, soil type, topography, slope, geology, and depth to the water table, among others.

Surface water percolates through the unsaturated weathered zone into the saturated zone, where all available pore spaces and fractures are filled with water. Structural features such as faults, fractures, joints, and bedding planes often serves as conduits for groundwater movement rather than storage. In dolomitic formations, structural features such as fractures enhance the percolation of water that may result to the formation of large cavities due to solution processes. Solution cavities significantly increase the storage capacity in dolomite as fresh dolomite is fine-grained and dense with minimal storage capacity.

Unconfined aquifer storage occurs in unconsolidated alluvial deposits along rivers and in the weathered zone in certain areas. Specific yield (indication of storage capacity in unconfined or primary aquifers), is defined as the volume of water that will drain under gravity from a saturated rock of unit volume and is typically expressed as a percentage of the total volume. The volume of water stored in the weathered zone and alluvial deposits decreases with the decrease in the static water level.

In solid rock, water is stored within micro pores and fractures. Igneous and metamorphic rocks generally provide limited storage, whereas sedimentary rocks typically offer greater storage capacity. It is important to note that borehole yield is a function of an aquifer's permeability rather than an indication of the total volume of water in storage or its long-term sustainability. The sustainability of groundwater extraction is determined through the interpretation of scientifically conducted borehole pumping tests.

Groundwater in the Polokwane map sheet area generally flows in the same direction as surface water. The groundwater table often mirrors topography, causing groundwater divides to approximately align with surface water divides. However, extensive groundwater abstraction can alter the natural flow pattern by creating a cone of depression around extraction points. Once pumping ceases, natural groundwater flow is restored as water levels recover.

Vegter (1995) produced a recharge map for the Water Research Commission covering the whole of South Africa. The four 1:250 000 maps covering the 1:500 000 Polokwane Hydrogeological map, were cut from the Vegter recharge map (1995) and pasted into this document, (Figure 139). The recharge-related numbers obtained on the Vegter map for Polokwane, was used to determine the estimated mean annual recharge for the Polokwane map sheet.

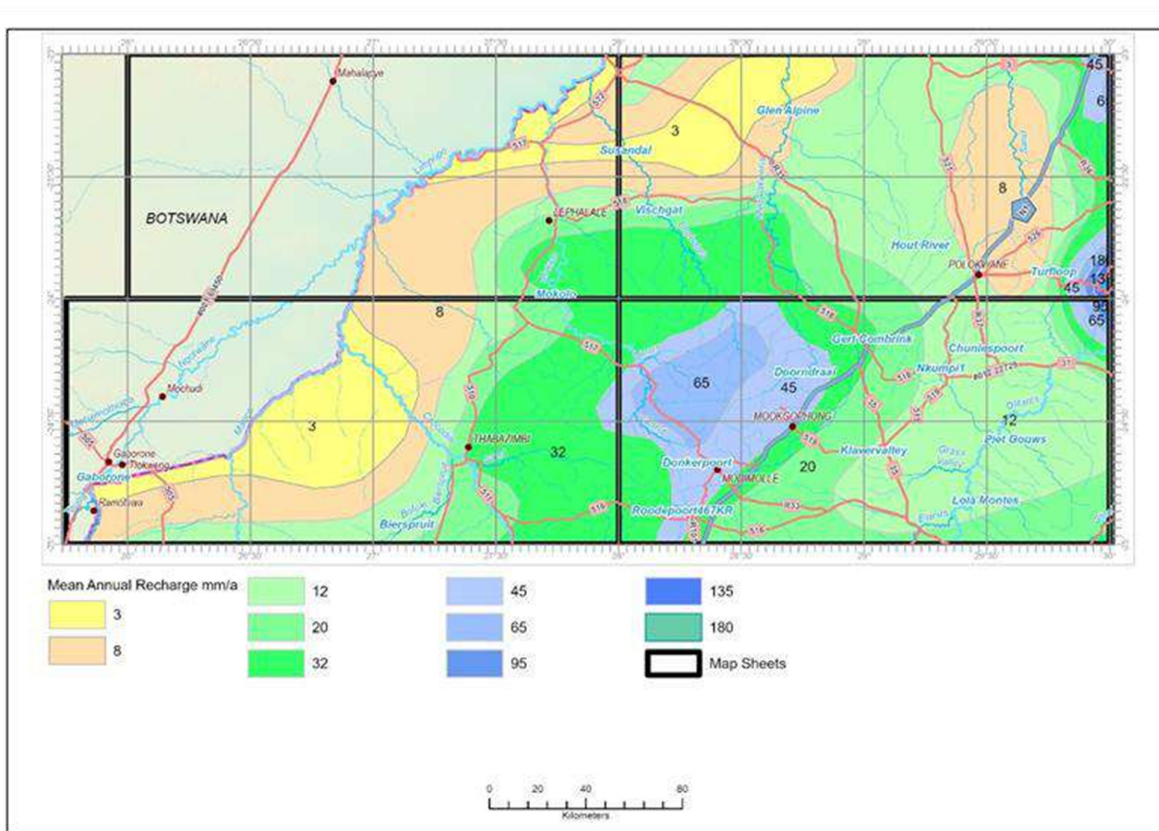


Figure 139: Mean annual recharge in mm for the four, 1:250 000 maps that is the upgrade for the 1:500 000 Polokwane hydrogeological map (after Vegter, 1995). Polokwane map area is at the top right.

Vegter divided the Polokwane map into 14 mean recharge zones, each with an allocated mean annual recharge value in millimeters (mm). Although the recharge is expressed quantitatively, it should be seen as depicting broad trends rather than laying claim to accurate regional recharge figures, (Vegter, 1995). However, these values were used to calculate the mean annual recharge volume for each zone. The volume for each zone was added to determine the total mean annual recharge volume for the Polokwane map, which amounts to 357.433 million cubic meters per annum (357.433Mm<sup>3</sup>/annum), (Table 84).

Another approach to estimating recharge is by utilizing data from the Department of Water and Sanitation's (DWS) GRAII project. However, in a 2024 email, DWS stated that the GRAII data has not been verified, and its use is not recommended without special permission.

Table 84: Mean annual recharge calculated for the 1:250 000 Polokwane map (after Vegter, 1995).

Recharge in zone (mm/annum)	Recharge in zone (m/annum)	Zone area (km <sup>2</sup> )	Zone area (m <sup>2</sup> )	Recharge in zone (m <sup>3</sup> )	Recharge in zone (Mm <sup>3</sup> /annum)
12	0.012	8147.420	8147420000	97769040.00	97.769
20	0.020	2323.554	2323554000	46471080.00	46.471
32	0.032	3446.756	3446756000	110296192.00	110.296
8	0.008	2238.482	2238482000	17907856.00	17.908
45	0.045	240.697	240697200	10831374.00	10.831
65	0.065	68.550	68550000	4455750.00	4.456
3	0.003	2319.126	2319126000	6957378.00	6.957
8	0.008	3370.882	3370882000	26967056.00	26.967
45	0.045	168.416	168416000	7578720.00	7.579
65	0.065	102.193	102192700	6642525.50	6.643
95	0.095	81.473	81473310	7739964.45	7.740
135	0.135	75.654	75653860	10213271.10	10.213
180	0.180	13.033	13033320	2345997.60	2.346
45	0.045	27.934	27933610	1257012.45	1.257
		<b>22624.170</b>			<b>357.433</b>

Specialist hydrogeological reports accompanying e-WULAAS in the Polokwane area were made available by DWS. The groundwater data were abstracted from these reports and used as additional information to compile the brochure and the relevant sections for the map such as median yield and chemical data. In relation to recharge the mining applications typically estimate recharge using numerical groundwater models, while smaller applications, such as farms, rely on localized recharge calculations or published values. These calculations are often based on the Chloride mass balance method; Vegter's recharge values, Harvest Potential values, the GRAII dataset, or a combination of the above. In addition to these methods, other techniques that can be used to estimate recharge include the water balance approach, the water table fluctuation method, Darcy's Law, isotopic tracer studies, and soil moisture balance assessments. Each method varies in applicability depending on data availability, scale, and site-specific hydrogeological conditions.

An alternative method for determining annual recharge or rather "safe abstraction," as referred to in the document, is the Harvest Potential approach proposed by A. Seymour and P. Seward (1995). Similar to Vegter's method, the Polokwane map area was divided into several safe abstraction zones. These zones have a minimum and a maximum volume (similar to the GRAII set that refers to the minimum and maximum volume as 'dry' and 'wet' to take into consideration seasonal fluctuations in rainfall). Table 87 represent the minimum and maximum volume (m<sup>3</sup>/km<sup>2</sup>/annum) that can be safely abstracted without depleting the aquifer. These values were used to calculate a minimum and maximum total annual volume for the Polokwane map sheet. In practice the average total annual volume for an area is mostly used.

### 9.3 Borehole siting

Table 85 depicts the different geophysical survey techniques / methods that were used in the past in the search for geological features that might relate to the occurrence of groundwater. The choice of technique / method for each of the different hydrogeological resource units is based on the proven track records of the application in each unit. This relates to the geological and hydrogeological setting and the expected groundwater target in each unit. The instruments / technique / method used must be as such to detect natural differences in the subsoil. The data obtained must be interpreted to identify and evaluate geological features e.g. dykes, deep-weathered / fracture zones, fault zones, joints, contact zones etc. that are known to relate to groundwater occurrences in each unit.

The table can be used as guidance because technology is evolving at a rapid rate with new instruments / techniques / methods becoming available.

Table 85: Geophysical survey techniques that can be employed in each resource unit.

GROUP/FORMATION	HYDRO-GEOLOGICAL UNIT	CATEGORY	1a	1b	2a	2b	3	4	5
Tertiary - Quaternary alluvial deposits	Q	A	***	***	**			**	**
Undifferentiated Karoo Sediments	C-Tr	B	*	**	**	**	***		*
Swartrant Formation	Psr	B	*	**	**	**	***		*
Wellington Formation	C-Pwe	B	*	**	**	**	***		*
Vaalwater Formation	Mva	D	*	**	**	**	***		*
Cleremont Formation	Mcl	B	*	**	**	**	***		*
Kransberg Subgroup	Mkr	B	*	**	**	**	***		*
Blouberg Formation	Mbb	B	*	**	**	**	***		*
Makgabeng Formation	Mma	B	*	**	**	**	***		*
Setlaole Formation	Mse	B	*	**	**	**	***		*
Koedoesrand Formation	Mko	B	*	**	**	**	***		*
Wylliespoort Formation	Mwp	B	*	**	**	**	***		*
Undifferentiated Rooiberg Group	Vrb	B	*	**	**	**	***		*
Wolkberg Group	Vwo	B	*	**	**	**	***		*
Malmani Subgroup	Vma	C	*	**	**	**	***	***	*
Letaba Formation	Jle	D	*	**	**	**	***		*
Diabase	N-Za	D	*	**	***	**	***		*
Palala Granite	Mpa	D	*	**	***	**	***		*
Sibasa Formation	Msi	D	*	**	***	**	***		*
Nebo Granite	Mn	D	*	**	***	**	***		*
Nora Gabbro-Anorthosite	Vv	D	*	**	***	**	***		*
Undifferentiated Rustenburg Layered Suite	Vrs	D	*	**	***	**	***		*
Undifferentiated Pretoria Group	Vpg	D	*	**	***	**	***		*
Matlala Granite	Vml	D	**	**	***	**	***		*
Smitskraal Granite	Vs	D	**	**	***	**	***		*
Palmietfontein Granite	Vpg	D	**	**	***	**	***		*
Unnamed Granite Rocks	Vz	D	**	**	***	**	***		*
Utrecht Granite	Vut	D	**	**	***	**	***		*
Turfloop Granite	Rt-Vt	D	**	**	***	**	***		*
Uitloop Granite	Ru-Vu	D	**	**	***	**	***		*
Lunsklip Granite	RI-VI	D	**	**	***	**	***		*
Moletsi Granite	Rmo	D	**	**	***	**	***		*
Matok Granite	Rma	D	**	**	***	**	***		*
Hugomond Granite	Rhu	D	**	**	***	**	***		*
Hout River Gneiss	Rho	D	**	**	***	**	***		*
Hout River Gneiss with	Rhx	D	**	**	***	**	***		*

GROUP/FORMATION	HYDRO- GEOLOGICAL UNIT	CATEGORY	1a	1b	2a	2b	3	4	5
Xenoliths									
Undifferentiated Messina Suite	Zms	D	**	**	***	**	***		*
Undifferentiated Beit Bridge Complex	Zbc	D	**	**	***	**	***		*
Undifferentiated Malala Drift Group	Zma	D	**	**	***	**	***		*
Mount Dowe Group	Zmd	D	**	**	***	**	***		*
Undifferentiated Bandelierkop Complex	Zbk	D	**	**	***	**	***		*
Undifferentiated Pietersburg Group	Zpg	D	**	**	***	**	***		*
Goudplaats Gneiss	Zgo	D	**	**	***	**	***		*
Goudplaats Gneiss with Xenoliths	Zgx	D	**	**	***	**	***		*

**The general geophysical methods are listed as follows:**

- 1a Electrical Resistivity
- 1b Electrical Resistivity - profiling
- 2a Electromagnetic - EM-34
- 2b Electromagnetic - Genie SE / Stratagem / Max-Min Slingram
- 3 Magnetic
- 4 Gravity
- 5 Seismic

**The rating for its successful application is as follows:**

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

Geological targets associated with groundwater occurrence are described for most hydrogeological units in Chapter 7. The success of identifying these targets is enhanced by incorporating additional scientific tools such as aerial photographs, LANDSAT images, Terra ASTER satellite imagery, geological and hydrogeological maps, existing data for the area, and aeromagnetic surveys. Experienced geohydrologists also consider visible indicators such as vegetation patterns, topography, soil variations, and other surface features during field surveys. The value of a geohydrologist's expertise, particularly their understanding of geology and data interpretation techniques, cannot be overstated.

While geophysical methods are widely used in groundwater exploration, the use of these methods does not always guarantee successful water strikes (boreholes with water). This is not due to flaws in the instruments themselves since they are based on well-established natural laws, but rather to incorrect interpretations, influences on the response of the instruments not taken in account or natural subsurface conditions that is not favorable for groundwater. For example, when targeting a diabase dyke, differences in magnetic susceptibility between the host rock and the dyke can often produce a detectable anomaly. However, if the contact zone is fused together without secondary fracturing, the borehole may yield no water despite the correct identification of the geological target.

Other factors that influence the effectiveness of geophysical methods include limitations in the area available for surveys, (such as small yards), where no discernible geological features associated with groundwater occurrence are present. Additionally, man-made interferences, such as power lines and other

infrastructure, are often unavoidable in urban or semi-urban environments. These interferences can lead to incorrect data interpretation, as anomalies may not be related to natural geological phenomena, thereby reducing the effectiveness of the instruments. A further concern is the growing use of inexpensive, unverified instruments operated by individuals lacking the necessary geological or geophysical expertise. This trend further undermines the reliability of geophysical surveys.

#### 9.4 Groundwater management

The new Water Act states that the **Minister of the Department of Water and Sanitation 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. It must be managed in an integrated manner according to the principles of the Act (sustainability, equity, and efficiency).

To manage water resources at a local level Catchment Managing Agencies (CMAs) and Water User Associations (WUAs) must be established that operate under the framework of the NWS and DWS guidelines. The CMA is responsible for a water allocation plan within their catchments and a Catchment Water Strategy (CWS) that is like 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 and Sanitation is responsible** for administering all aspects of the Act on the Minister's behalf as no CMA's or WUA is yet in operation within the map area.

Over-exploitation of groundwater resources can be prevented and controlled through sound groundwater management practices.

Part of the license requirements can be that water users must monitor abstraction and quality at all levels that includes local authorities, such as Polokwane, Mokopane, and Louis Trichardt Local Municipalities; Mining, such as Anglo American Platinum - Mogalakwena Mine, Ivanplats Platreef Mine and Doornhoek Gold Mine; Industries, such as Polokwane Metallurgical Complex, Ferro Globe Silicon Smelters, FBT Logistics, South African Breweries (SAB) Polokwane, Engen petroleum depots, Oil Separation Waste Services and Polokwane Coca-Cola Beverages South Africa. Throughout the map area large scale farming occurs, many of these are legal water users or in the process to apply.

During the period or at the renewal date of the water user license, DWS can request monitoring data from license holders. As licensing is compulsory, holders should familiarize themselves with the license requirements as the license can be cancelled. Regular or continuous measurements of groundwater level fluctuations together with accurate abstraction and rainfall measurements all displayed on one graph, is a sure way of keeping one's finger on an aquifer's pulse. 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 accurate measurements of groundwater levels, abstraction, and rainfall are essential in the accurate assessment of recharge and storage of an aquifer 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 to detect any deterioration in the water quality in advance. The frequency of sampling for chemical analysis depends on the water usage (human, agricultural, industrial) and vulnerability of the aquifer to pollution or other influences but should be analysed at least once or twice a year for macro, tracer, and microbiological constituents. Further information on this can be obtained from Resource Quality Services (formerly the Institute for Water Quality Studies).

In the license application no distinction is made between surface water or groundwater use as it is all part of the hydrological cycle. From a hydrogeological point of view the conjunctive use of groundwater and surface water is recommended. During summertime when evaporation is at its highest resulting in high losses,

surface water should be utilized extensively with groundwater only supplementing any shortages. During wintertime groundwater should be utilized extensively which could be recharged again during summertime. Evaporation losses should be at their lowest during wintertime. Surface water could thus only supplement shortages during this period.

For water level monitoring, observation boreholes are developed, especially where large well fields are established. A thorough knowledge of the geology of the terrain and an understanding of the anticipated groundwater flow, are requirements for the correct positioning of observation boreholes. The Department of Water and Sanitation manage 212 monitoring boreholes in the map area of which 68 are active and equipped with electronic data loggers, (Figure 138 and Table 83). The data is available on request from the Department's National Groundwater Archive (NGA) in Pretoria.

#### **9.4.1 Groundwater contamination and pollution**

Groundwater contamination is defined as the introduction of any substance into groundwater by the action of man, while pollution is 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 be expected to be used.
- b) Harmful or potentially harmful:
  - To the welfare, health or safety of human beings,
  - To any aquatic or non-aquatic organisms,
  - To the resource quality, or to property,

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

Pollution is one of the greatest threats to groundwater resources. Like surface water, groundwater is highly vulnerable to contamination, and rehabilitating an aquifer once polluted is difficult and costly.

The Environmental Act follows the "polluter pays" principle, holding companies responsible for rehabilitation costs. Managers of companies that degrade the environment can be held accountable even after many years.

#### **Pollution mitigation models classify pollution sources based on geometry:**

Point sources include waste disposal sites, underground storage tanks, commercial petrochemical sites, large storage sites for fertilizers, oils and chemical products, septic tanks, and sewage works. These require careful site selection, continuous monitoring, and expert reporting to protect aquifers. Their establishment and closure of many of the larger point sources are strictly regulated by the Government through the relevant Departments such as, the Department of Water and Sanitation (DWS), The Department of Forestry, Fisheries and the Environment (DFFE) and Department of Mineral resources and Energy (DMRE). The larger point sources that may lead to pollution are mostly confined but not restricted to the major urban centres such as Polokwane, Mokopane, and Louis Trichardt. In recent years commercial points for petroleum products increased within the map area and can even be found in the medium to larger sized rural villages. In rural areas, a common groundwater pollution issue is high nitrate concentrations, often linked to pit latrines and cattle kraals. High nitrate occurrences are mapped and displayed in Figure 8 (page 80).

#### **9.4.2 Groundwater utilization**

Factors such as topography, geohydrological setting (underlying geology, soil, and groundwater occurrences), and the availability of water resources (both surface and groundwater) are key influences on farming in the map area, see also section 4.1 for more information regarding water sources used for the various regional water schemes.

The south-western section of the map sheet is underlain by the Waterberg Supergroup, consisting of sedimentary rocks intruded by diabase sills and dykes. This area falls within the Waterberg Ecoregion, where economic activities are primarily limited to provincial and private game reserves, associated tourism, game farming, livestock farming, and some irrigation in the lower-lying areas.

The Limpopo Plain Ecoregion, which covers a large portion of the centre and north-western part of the map sheet, supports large-scale irrigation along the Lephhalala River, as well as scattered irrigation areas near Tolwe, Tom Burke, Marnitz, and Baltimore. The primary farming activities include provincial and private game reserves associated with tourism, and livestock farming. Rural villages are concentrated in the western section of the Ecoregion and in the centre section that is north of Mokopane. Most villages rely on groundwater, except for those along the Mogalakwena and Lephhalala Rivers, which use a combination of surface and groundwater sources.

Mining in the area is limited to platinum mines underlain by rocks of the Rustenburg Layered Suite and dimension stone quarries underlain by Nebo Granite. Water supply to these mines comes from a combination of groundwater sources, water from mining operations, storm water collection, recycled water, bulk water from Lepelle Northern Water, and treated sewage water pumped from Polokwane.

In the north-eastern part of the map sheet, the Limpopo Plain Ecoregion is underlain by Goudplaats and Hout River Gneiss. This area is extensively covered by large-scale irrigation, particularly along the Hout and Sand Rivers. Water for irrigation is primarily sourced from groundwater, while releases of treated sewage water enhance the flow in the Sand River and contribute to groundwater recharge near the river. However, at times, the treated water exceeds maximum water quality limits, negatively impacting farming.

The discharge of treated wastewater into the Sand River by the Polokwane Municipality is from the Polokwane and Seshego wastewater treatment works (WWTWs). Available volumes from the Polokwane municipal treatment plant are that it discharges approximately 13.78 million cubic meters per annum (13.78Mm<sup>3</sup>/annum), which is utilized by mines north of Mokopane and also contributes to the Sand River's flow. However, concerns have been raised about the quality of this treated effluent. Studies have indicated that the Sand River receives sewage effluent from the Polokwane and Seshego treatment works, with elevated levels of nitrogen, phosphorus, and coliform counts exceeding stipulated standards. Additionally, reports suggest that the treatment plants may be malfunctioning, leading to the release of insufficiently treated wastewater, which negatively impacts downstream users, including farmers.

Regarding the specific volumes of treated water released into the Sand River by the Polokwane Municipality, while the overall discharge is documented, detailed daily or monthly release volumes are not readily available in the provided sources.

The eastern and south-eastern sections of the map sheet fall within the North Eastern Highlands and Eastern Bankenveld Ecoregions. Due to its mountainous topography, the area is primarily used for nature reserves and farming, including forestry and crops such as blueberries and avocados. Some villages are located at the foot of the mountains. Water resources in the area include boreholes, springs, and surface water. Villages on the western side, particularly in the Mankweng area, receive part of their water supply from the Ebenezer and Molepo Dams.

A section of the map falls within the Northern Plateau Ecoregion, where the major urban and commercial centres are Polokwane and Louis Trichardt.

Polokwane and the surrounding rural villages receive water from boreholes and surface water sources, including the Olifants-Sand Water Transfer Scheme and the Dap Naude, Hout River, Seshego, Mashashane, and Ebenezer Dams. Louis Trichardt relies on boreholes and surface water from the Albasini Dam, with a planned future supply from the Nandoni Dam.

Large-scale irrigation takes place outside rural village areas, particularly near the Hout and Sand Rivers and their tributaries.

Table 86: Localities where large-scale groundwater abstraction (>400 000 M<sup>3</sup>/a) are taking place.

LOCALITY/AREA	APPROXIMATE ABSTRACTION (10 <sup>6</sup> m <sup>3</sup> /a)	APPROXIMATE ABSTRACTION (10 <sup>6</sup> m <sup>3</sup> /a)
Louise Trichardt	1.5 million m <sup>3</sup> /a	1-1.8 million m <sup>3</sup> /a
Polokwane Town	5-7 million m <sup>3</sup> /a	
Dendron Irrigation area		15-20 million m <sup>3</sup> /a
Vivo Irrigation area		1-3 million m <sup>3</sup> /a
Buysdorp Irrigation area		0,4-1 million m <sup>3</sup> /a
Hout River Irrigation area		3-5 million m <sup>3</sup> /a
Louis Trichardt Airbase	0,4-0.7 million m <sup>3</sup> /a	
Brakspruit/Kalkbank/Makgodu Irrigation areas		6-8 million m <sup>3</sup> /a
Doornbult Irrigation area		3-5 million m <sup>3</sup> /a

#### 9.4.2.1 Harvest potential

The information for the Harvest potential was obtained from the Groundwater Harvest Potential of the Republic of South Africa, A. Seymour, and P. Seward 1995. The harvest potential (safe abstraction volume) is the maximum amount of groundwater that can be abstracted per square kilometer per annum in South Africa without depleting the aquifers, (DWS groundwater dictionary). The Harvest Potential method was developed to provide a first estimate of the national sustainable groundwater resource. It considers recharge, storage, and time periods between recharge events.

For the largest sections of the map, the harvest potential is between 5 000 and 15 000m<sup>3</sup>/km<sup>2</sup>/annum. Within the Polokwane map sheet, 4 harvest potential zones are depicted, (Figure 140). Using the values and the aerial extent of each zone the harvest potential for the Polokwane map sheet was calculated. The safe abstraction is 115.390 million cubic meters per annum (Mm<sup>3</sup>/annum) that represents the low volume to 291.670Mm<sup>3</sup>/annum that represents the high volume. The average is 203.530Mm<sup>3</sup>/annum.

Table 87: Harvest potential within the Polokwane map sheet.

Zone m <sup>3</sup> /km <sup>2</sup> /annum	Zone Areal extent km <sup>2</sup>	Minimum safe abstraction m <sup>3</sup>	Maximum safe abstraction m <sup>3</sup>	Minimum safe abstraction Mm <sup>3</sup>	Maximum safe abstraction Mm <sup>3</sup>
2000-5000	2319	4683000	11595000	4.640	11.600
5000-10000	8211	41955000	82110000	41.000	82.110
10000-15000	10436	52180000	156540000	52.180	156.540
15000-25000	1657	16570000	41425000	16.570	414.430
<b>Totals</b>	<b>22623</b>	<b>115388000</b>	<b>291670000</b>	<b>115.390</b>	<b>291.670</b>
			<b>Average:</b>	<b>203.530</b>	

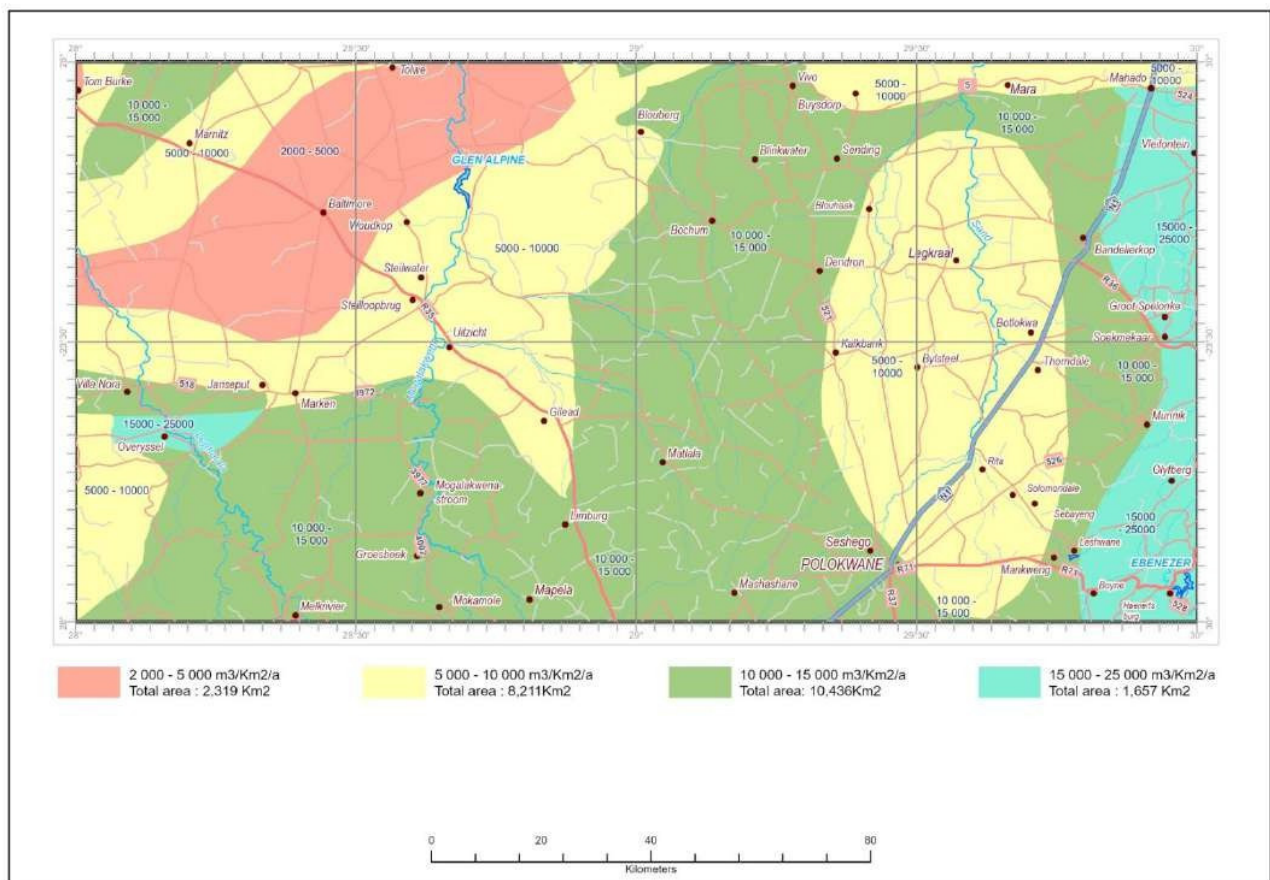


Figure 140: Harvest potential showing values in  $m^3/km^2/annum$  (A. Seymour and P. Seward, 1995)

The total safe abstraction arrived at using the Harvest potential amounts to 261.225 million cubic meters of water annually. This is a considerable amount of water if one considers that the total area covered by the Polokwane map, is approximately 22 623  $km^2$ .

## 9.5 Future groundwater and associated projects

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. As many of the aquifers in South Africa are past the development phase, management and intervention measures will start to dominate the groundwater industry. To be able to maintain water supply to the relevant sectors in South Africa, the country should invest in groundwater management and protection. Management is considered a strong groundwater database, monitoring of rainfall and water levels, updating of recharge estimates, research into mitigation actions such as artificial recharge, legal enforcements to protect aquifers from over exploitation and most importantly prevention of the pollution of water resources. The private sector is already willingly or legally bound to contribute to management by submitting data to DWS such as quarterly monitoring data.

The following possible subjects are suggested:

### Monitoring Sites: Upgrades and Maintenance

- Investigate the current network of monitoring sites, including water level and meteorological stations.
- Upgrade and maintain sites where necessary to ensure accurate and continuous data collection.

- Assess the possible effects of environmental changes and large-scale abstraction on natural conditions and implement a monitoring framework.
- Recognize that long-term data collection is critical for scientifically measuring and quantifying the impacts of climate change.

### **Sanitation Audit and Improvements**

- Conduct an audit of sanitation practices, identifying areas where improvements are required. On municipal level the IDP documents do address some of these. The methodology needs to be uniformly applied between the different spheres of Government to address sanitation. The framework of the Catchment Managing Agencies (CMAs) includes sustainability. As such, recommendations on mitigation measures should form part of management of the catchments with the Local or District Municipality or the implementing agent.
- Regular audits and investigations into the effectiveness of large sewage plants need to be done by DWS and/or CMA officials. The recommendations should be enforced on the relevant authorities to prevent pollution.
- Address high nitrate levels and bacteriological pollution, which are known to occur in rural communities. The slogan prevention is more effective than rehabilitation that need to be applied.
- Investigate and mitigate sources of *e-coli* contamination, which have been detected in some groundwater sources. The bacteria were even detected in the water from groundwater resources where the water strike depth were deemed too deep (>30m) to be affected by bacterial pollution.

### **Groundwater Recharge and Artificial Recharge**

- Investigate the feasibility of artificial recharge interventions in areas experiencing high abstraction rates.
- Assess the recharge potential in these areas; assess the potential increase in recharge by considering hydrogeological conditions and water availability.

### **Data Management and National Groundwater Archive (NGA)**

- Invest in the National Groundwater Archive (NGA) to improve data accessibility and integrity.
- Ensure extensive use of the e-WULAAS system to maintain an up-to-date database.
- Incorporate all legally required groundwater data submissions into the NGA.
- Ensure that Hydrocensus data obtained through the WULA process include accurate geographic coordinates.
- Before capturing data, verify existing records to prevent duplication.
- If new sources are identified, ensure the inclusion of borehole logs, pump test results, and chemical analysis certificates in the documentation.
- Require geohydrological reports from consultants working for government or semi-government entities to be submitted to the Department of Water and Sanitation (DWS).
- Link municipal water source asset registers to the groundwater database for better resource management.

### **Water Use License Applications (WULA) and Compliance Monitoring**

- Ensure that WULA approvals include conditions for quarterly water level measurements and chemical analysis where required.
- Incorporate this data into the NGA to support long-term monitoring efforts.
- Align measurement dates within specific timeframes to facilitate regional water level trend analysis.

## Capacity-building and awareness

- Develop capacity-building programs for local authorities and stakeholders on groundwater monitoring and data management.
- Enhance public awareness and community participation in groundwater protection initiatives.
- Establish partnerships with research institutions to improve methodologies for groundwater assessment and recharge strategies.

## 10. REFERENCES

The Department of Water and Sanitation maintains a library with digital reports. The reports cited in this document can be obtained from the DWS website; some of the direct links are included. If not, the following link can be used with further search functions on the web site.

(<https://www.dws.gov.za/ghreport/Default.aspx>).

- AFRI GS 95 (PTY) LTD, (2023). A Geohydrological Report for Goudmyn Farming Primary Cooperative. DWS e-WULAAS, Ref: 5682681052017388156. DWS Consultant's Report: 2.2(5613). [https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205613\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205613)%20)
- AFRI GS 95 (PTY) LTD., (2023). A Geohydrological Report for Goudmyn Farming Primary Cooperative. DWS e-WULAAS, Ref: 5281679148802499152. DWS Consultant's Report: 2.2(5594). [https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205594\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205594)%20)
- Aganang Local Municipality., (2016-2017). Integrated Development plan, 2016-2017. <http://www.aganang.gov.za/docs/plans/Final%20IDP%202016-2017.pdf>
- Blouberg Local Municipality., (2023-2024). Integrated Development Plan, 2023-2024. <https://www.blouberg.gov.za/sstaff/pages/sites/blouberg/documents/idp/BLOUBERG%20LOCAL%20%20FINAL%20%20IDP%2023.24.pdf>.
- Bredenkamp, D.B., Janse van Rensburg, H., Botha, L.J, (1993). Estimation of the groundwater potential of the Dorpsriver aquifer by means of different methods and compilation of a dynamical model of the aquifer system. DWS Report No: GH3793, Directorate: Geohydrology, Department of Water Affairs and Forestry. [https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20\(INFLECTIONAL,%20Gh3793\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20(INFLECTIONAL,%20Gh3793))
- Crosby R., Pretorius S.J., Vivier J.J.P., (2000). Geohydrological Investigation to determine the groundwater potential of the Rooisloot Aquifer Potgietersrus. GC/9/00/09/04.
- Crosby, R., (2020). Groundwater Resource Development and Water Use Authorisation: Lapalala Nature Reserve Wilderness School. AGES Report Number: 2020/04/01/GHYD, DWS e-WULAAS, Ref: 5019726713633525186. DWS Consultant's Report: 2.2(5622). [https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205622\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205622)%20)
- Dabishi, R., (2021). Groundwater testing source, Molemole West Potato Belt Project , Nkukeng Farm. DWS e-WULAAS, Ref: 5611485227166839937. DWS Consultant's Report: 2.2(5610). [https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205610\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205610)%20)

- De Villiers, S.B., (1967). Fonteine in die Dolomiet-gebied ten ooste van Chuniespoort. DWS Report No: GH2849, Directorate: Geohydrology, Department of Water Affairs and Forestry.  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20\(INFLECTIONAL,%20gh2849\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20(INFLECTIONAL,%20gh2849))
- Diges Group, (Pty) Ltd., (2019). Siting, Drilling, Testing and Equipping of a Borehole at Ebenezer Plant. Contract Number RFQ 01/16/17. Report No.: G170011, Version: 001, DWS e-WULAAS, Ref: 4897478338075012522. DWS Consultant's Report: 2.2(5579).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205579\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205579)%20)
- Diges Group, (Pty) Ltd., (2023). Geohydrological investigation for a water use license Application. Ref No.: 2023-Ga-Hlahla #001. DWS e-WULAAS, Ref: 5392488683519629949. DWS Consultant's Report: 2.2(5599).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205599\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205599)%20)
- Ditoto, N., (2023). NGK Geological Services. Geohydrological Investigations Involving Pump Testing of an Existing Borehole at Castle Bricks within the Polokwane Local Municipality, Capricorn District Municipality in Limpopo Province. Report No. 018/NGK\_GEO\_2023. DWS e-WULAAS, Ref: 4829869412481129319. DWS Consultant's Report: 2.2(5574).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205574\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205574)%20)
- Dziembowski, Z.M., Mew, A.C.W., (1973). Grondwatervoorraad op Altona 696LR, Potgietersrus Distrik. DWS Report No: GH1818, Directorate: Geohydrology, Department of Water Affairs and Forestry.  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20\(INFLECTIONAL,%20gh1818\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20(INFLECTIONAL,%20gh1818))
- Dziembowski, Z.M., (1976). Aanvulling van grondwaterreservoir op Altona 696LR, Distrik Potgietersrus, deur Matlalarivier tydens vloed. DWS Report No: GH2898, Directorate: Geohydrology, Department of Water Affairs and Forestry.  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20\(INFLECTIONAL,%20gh2898\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20(INFLECTIONAL,%20gh2898))
- Fayazi, M., and Potgieter, G., (1993). Groundwater development potential of the Wolkberg area as a possible source of water supply for Pietersburg and environs. DWS Report No: GH3816, Directorate: Geohydrology, Department of Water and Affairs and Forestry.  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20\(INFLECTIONAL,%20gh3816\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20(INFLECTIONAL,%20gh3816))
- Greater Letaba Local Municipality., (2023-2026). Reviewed Integrated Development plan, 2023-2026.  
<https://www.greaterletaba.gov.za/sstaff/pages/sites/letaba/documents/idp/GREATER%20LETABA%20MUNICIPALITY%20FINAL%20IDP%20replace.pdf>
- Golder Associates Africa (Pty) Ltd., (2012). Platreef Project: Hydrogeological Baseline of Turfspruit 241KR, Macalacaskop 243KR and Rietfontein 2KS, Report No 11616141-11095-6, dated August 2012.
- Golder Associates Africa (Pty) Ltd., (2013). Integrated Water and Waste Management Plan for Platreef Bulk Sample Shaft in support of an Integrated Water Use Licence Application Volume 2. Report Number: 12614052/12456/2. DWS e-WULAAS, Ref: 27.2.2.A661.1.1 Sub-File Vol 2. DWS Consultant's Report: 2.2(5634).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205634\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205634)%20)

- Golder Associates Africa (Pty) Ltd., (2014). Integrated Water and Waste Management Plan for Platreef Main Mine in support of an Integrated Water Use License Application Volume 1. Report Number: 12614052/12707/3. DWS e-WULAAS, Ref: 27.2.2.A661.1.1 Sub-File Vol 1. DWS Consultant's Report: 2.2(5635).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205635\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205635)%20)
- Golder Associates Africa (Pty) Ltd, (2021). Geohydrology Report for the Platreef Mine new Phase Development project. Report Reference No: 20394027-347249-6. DWS e-WULAAS, Ref: 5087960971084340137. DWS Consultant's Report: 2.2(5588).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205588\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205588)%20)
- Grobler, D.F., Brits, J.A.N., Maier, W.D., Crossingham, A., (2018). Litho- and chemostratigraphy of the Flatreef PGE deposit, northern Bushveld Complex. Received: 26 May 2017 /Accepted: 12 March 2018 /Published online: 2 May 2018. Mineralium Deposita (2019) 54:3-28. <https://doi.org/10.1007/s00126-018-0800-x>.
- Haupt, C.J., (2022). WSM Leshika Consulting (Pty) Ltd. Hydrogeological Evaluation for Delfarm on Prt 9, 10 and 12, portions of portion 7 of the farm Duvenageskraal 689 LS, Polokwane, Polokwane Local Municipality, Limpopo. WSM Leshika Project Number: WH22022, DWS e-WULAAS, Ref: 5285480145798535593. DWS Consultant's Report: 2.2(5595).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205595\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205595)%20)
- Huisamen; A., Naidoo, V., (2014). Geo Pollution Technologies – Gauteng (Pty) Ltd. Geohydrological Report for the Proposed Pan Palladium mining and Smelting Project, on the Farms Kransplaats 442LR, Onenwerth 421LR and La Pucella 693LR, Limpopo. GPT Reference: PanPa-13-556. Draft. DWS e-WULAAS, Ref: 4895088367049664107. DWS Consultant's Report: 2.2(5578).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205578\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205578)%20)
- Johnson, M.R., Anhaeusser, C.R. Thomas, R.J., (2006). The Geology of South Africa. Geological Society of South Africa, Council of Geoscience.
- Klemd, R., Beinlich, A., Kern, M., Junge, M., Martin, L., Regelous, M., & Schouwstra, R., (2020). Magmatic PGE Sulphide Mineralization in Clinopyroxenite from the Platreef, Bushveld Complex, South Africa. Minerals, 10(6), 570. <https://doi.org/10.3390/min10060570>.
- Kruidenier, J.H.B., (2019). HK Geohydrological Services Pty Ltd. Geohydrological Assessment Study for the CSP Site, a Decommissioned Food Processing Plant in Mokopane, Limpopo Province. Report No: G2019/036. DWS e-WULAAS, Ref: 5403102935336874547. DWS Consultant's Report: 2.2(5620).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205620\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205620)%20)
- Kruidenier, J.H.B., (2021). HK Geohydrological Services Pty Ltd. Geohydrological Study for Portion 20, Farm Doornplaats 26, Limpopo Province. Report No: G2019/123. DWS e-WULAAS, Ref: 5224975825932808596. DWS Consultant's Report: 2.2(5523)  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205523\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205523)%20)

- Koekemoer, S.J., (2016). WSM Leshika Consulting (Pty) Ltd. Hydrogeological Evaluation, Tom Burke Filling Station and Truck Stop, Tom Burke, Lephalale Local Municipality, Limpopo Province. Project Number: WH16081. DWS e-WULAAS, Ref: 5614028290053559914. DWS Consultant's Report: 2.2(5505).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205505\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205505)%20)
- Koekemoer, S.J., (2017). WSM Leshika Consulting (Pty) Ltd. Report on a Hydrogeological evaluation for the Total Ayoba 1 Stop Filling station, Erf 64 Elti Villas, Louis Trichardt, Makhado Local Municipality, Limpopo Province. WSM Leshika Project Number: WH17011, Version V1.0. DWS e-WULAAS, Ref: 5225097139142703786. DWS Consultant's Report: 2.2(5591).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205591\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205591)%20)
- Kok, T.S., (1977). Geohidrologie van Naboomspruit omgewing. DWS Report No. GH2930, Directorate: Geohydrology, Department of Water Affairs and Forestry.  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20\(INFLECTIONAL,%20gh2930\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20(INFLECTIONAL,%20gh2930))
- Lyness, L.S., (1980). Groundwater supply potential of selected areas near Potgietersrus. Report No. GH3130, Directorate: Geohydrology, Department of Water and Sanitation and Forestry.  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20\(INFLECTIONAL,%20gh3130\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20(INFLECTIONAL,%20gh3130))
- Magwaza, B., (2022). Tricon Agric Services Pty Ltd. Geohydrological Assessment in Support of a Water Use License Application for Portion 1 of the Farm Madrid 38 LR. DWS e-WULAAS, Ref: 5022763759845264288. DWS Consultant's Report: 2.2(5584).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205584\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205584)%20)
- Mahlangu, S., (2019). SRK Consulting. Sasko Mokopane Hydrogeological Assessment for Groundwater Abstraction e-WULA Report. SRK Project Number 554394. DWS e-WULAAS, Ref: 5379374392578697595. DWS Consultant's Report: 2.2(5598).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205598\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205598)%20)
- Makhado Local Municipality., (2024-2025). Integrated Development Plan 2024-2025.  
<https://www.makhado.gov.za/>
- Makgoka, C., (2020). Colbe Projects Consulting (CPC). Geohydrological Investigation Report for the Abstraction of Groundwater for the Irrigation Phenomena of Macadamia Trees, Louis Trichardt on the farm Rondebosch 287 LS under Makhado Local Municipality of Vhembe District, Limpopo Province. DWS e-WULAAS, Ref: 5029757724198331942. DWS Consultant's Report: 2.2(5585).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205585\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205585)%20)
- Maroge, J., (2020). Geohydrological Report for Portion of the Remainder of Portion 36 of the Farm Rooipoort No 46 KS in Mokopane. DWS e-WULAAS, Ref: 5041920862914010359. DWS Consultant's Report: 2.2(5586).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205586\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205586)%20)

- Masvopo T.H., (2018). Hydrogeological Investigations: Borehole Drilling and Pump Testing at Mosengoana Trading Enterprise. DWS e-WULAAS, Ref: 4875466931611526575. DWS Consultant's Report: 2.2(5577).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205577\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205577)%20)
- Mdumela D.M., (2023). Mphe Meetsi Geohydrological Services. Final Hydrogeological Evaluation for Groundwater Supplies Conducted for Ga-Mathapo Village, Limpopo Province, Capricorn District Municipality, Polokwane Local Municipality, Version 1. DWS e-WULAAS Ref: 5680671361515851404. DWS Consultant's Report: 2.2(5612).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205612\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205612)%20)
- Mogalakwena Local Municipality., (2024-2025). Integrated Development Plan, 2024-2025.  
[https://www.mogalakwena.gov.za/mogalakwena-admin/pages/sites/mogalakwena/documents/idp/2024\\_2025\\_final\\_idp\\_review.pdf](https://www.mogalakwena.gov.za/mogalakwena-admin/pages/sites/mogalakwena/documents/idp/2024_2025_final_idp_review.pdf)
- Molemole Local Municipality., (2024-2025). Integrated Development Plan, 2024-2025.  
[https://www.molemole.gov.za/docs/idp/Final%202024\\_25%20Molemole%20IDP\(1\)\(2\).pdf](https://www.molemole.gov.za/docs/idp/Final%202024_25%20Molemole%20IDP(1)(2).pdf).
- Moswathupa, H., Mahlangu, S., Mahomed, I., (2020). SRK Consulting. CCBSA Polokwane Groundwater Resource Assessment Report. SRK Project Number 526934. DWS e-WULAAS, Ref: 5552194011270638495. DWS Consultant's Report: 2.2(5604).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205604\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205604)%20)
- Moswathupa, H., Mahlangu, S., Mahomed, I., (2020). SRK Consulting. CCBSA Polokwane Groundwater Resource Assessment. SRK Project and Report Number 526934. DWS e-WULAAS, Ref: 4705324506545932348. DWS Consultant's Report: 2.2(5571).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205571\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205571)%20)
- Mouton, P., Haupth, C.J., (2011). WSM Leshika Consulting (Pty) Ltd. Report on the Development of Groundwater Resources for the Functional Area. Water Master Plan. Mogalakwena Municipal Area, WSM Leshika Technical Report: WM 11026.
- Mouton, P., Haupth, C.J., Sonnekus, C.J., (2015). Report on the Development of Groundwater Resources Under MWIG Funding for the Area North of the Functional Area. Water Master Plan. Mogalakwena Municipal Area, Limpopo Province. WSM Leshika and VSA Rebotile Metsi. Report Reference: WT15110/WM15082.
- Mouton, P., Haupth, C.J., Sonnekus, C.J., (2017). Report on the Development of Groundwater Resources in the Mogalakwena Municipal Area, Limpopo Province. Groundwater Masterplan: Volume 5. WSIG 2016, Report Number: WM16098.
- Mouton, A., (2020). Tricon Agric Services (Pty) Ltd. Didapath (Pty) Ltd. Geohydrological Report in Support of a Water Use License Application for the Farm Klein Collie 123 Portion 3. DWS e-WULAAS, Ref: 4999406565093666221. DWS Consultant's Report: 2.2(5582).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205582\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205582)%20)

- Mouton, A., (2020). Tricon Agric Services (Pty) Ltd. NU Aston Boerderye (PTY) LTD, Geohydrological Report in Support of a Water Use License Application for the Farm Nuwe Ashton 388 Portion 0. DWS e-WULAAS, Ref: 5455304149971555856. DWS Consultant's Report: 2.2(5601).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205601\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205601)%20)
- Mouton, A., (2021). Tricon Agric Services (Pty) Ltd. Geohydrological Report in support of a Water Use License Application for the Farms Kareebosch 618 Portions 3 and 25LS and Palmietfontein 620 Portion RE/2 LS. DWS e-WULAAS, Ref: 5562435117810858416. DWS Consultant's Report: 2.2(5572).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205572\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205572)%20)
- Mouton, A., (2021). Tricon Agric Services (Pty) Ltd. Geohydrological Report in Support of a Water Use License Application for the Farm Richmond 118 Portion RE LQ. DWS e-WULAAS Ref: 5352438577997828623. DWS Consultant's Report: 2.2(5527).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205527\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205527)%20)
- Mouton, A., (2021). Tricon Agric Services (Pty) Ltd. Denkra Pty Ltd, Geohydrological Report in Support of a Water Use License Application for the Farm Sydney 98 Portion 12 LR. DWS e-WULAAS, Ref: 5071201906517059475. DWS Consultant's Report: 2.2(5587).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205587\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205587)%20)
- MTK3 Trading and Projects., (2018). Pump Testing Report for Urban Africa Youth Project. DWS e-WULAAS, Ref: 5527886286768930540. DWS Consultant's Report: 2.2(5701).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205701\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205701)%20)
- Nebaimoro, N.E., (2020). Danet Trading CC. Hydrogeological Report in Support of Integrated Water Use License Application for Nkgapu Resources and Exploration (Pty) Ltd. DWS e-WULAAS, Ref: 4860721691452376401. DWS Consultant's Report: 2.2(5576).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205576\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205576)%20)
- NGK Geological Services (Pty) Ltd, (2024). Geohydrological Investigation Report Involving Pumping Test of Two Existing Boreholes at Brakspruit Farm within Makhado Local Municipality, Vhembe District Municipality in Limpopo Province. Report No. 010/NGK\_GEO\_2024. DWS e-WULAAS Ref: 5306653513713703256. DWS Consultant's Report: 2.2(5596).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205596\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205596)%20)
- Orpen, W.R.G., (1981). Groundwater resources in the vicinity of Potgietersrus and recommendations on the possible augmentation of the Potgietersrus municipal water supply from these sources. Report No. GH3191, Directorate: Geohydrology, Department of Water Affairs and Forestry.  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20\(INFLECTIONAL,%20Gh3191\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20(INFLECTIONAL,%20Gh3191))
- Orpen, W.R.G., (1984). Re-evaluation of the groundwater potential of the Dorps River catchment, Potgietersrus. Report No. GH3331, Directorate; Geohydrology, Department of Water Affairs and Forestry.  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20\(INFLECTIONAL,%20Gh3331\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20(INFLECTIONAL,%20Gh3331))

- Orpen W.R.G., Fayazi M., (1985). Installation and devaluation of water boreholes in the Roosloot Delta Area for the provision of a water supply for the Black township of Mahwelereng North-West of Potgietersrus. Report No. GH3366.  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20\(INFLECTIONAL,%20gh3366\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20(INFLECTIONAL,%20gh3366))
- Polokwane Local Municipality., (2024-2025). Integrated Development Plan, IDP 2024-2025.  
<https://www.polokwane.gov.za/>
- Prinsloo, M., (2021). Future Flow Groundwater and Project Management CC. Akanani PGM Mine. Groundwater Assessment. Report Reference Number ADE.21.026. Final. DWS e-WULAAS, Ref: 4639266220132692262. DWS Consultant's Report: 2.2(5624).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205624\)%20\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205624)%20))
- Rech, W.D., (1970). Groundwater survey along the Palala, Mogol, Matlabas and Crocodile Rivers. DWS Report No: GH1530.  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20\(INFLECTIONAL,%20gh1530\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20(INFLECTIONAL,%20gh1530))
- Reign Multy Projects (Pty) Ltd., (2021). Test Pumping & Utilization Recommendations Report for Dihlaping Aquaculture Project. DWS e-WULAAS, Ref: 4979175222114573742. DWS Consultant's Report: 2.2(5581).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205581\)%20\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205581)%20))
- Snygans, D., (2020). Aquanzi Geoconsultants CC. Groundwater Abstraction from Boreholes on the Remaining Extent of Portion 5 of the farm Haakdoornboom 223 and Portion 1 of the farm Tweeloopfontein 224 (Consolidated Farm). Report No: AQ2020/03/00. DWS e-WULAAS, Ref: 5649949197737762542. DWS Consultant's Report: 2.2(5526).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205526\)%20\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205526)%20))
- Snygans, D., (2021). Aquanzi Geoconsultants CC. Baseline Geohydrological Assessment Report in support of a Water Use License Application for Freshmark Polokwane. Report No: 2007/231058/23. DWS e-WULAAS Ref: 5593429153966334836. DWS Consultant's Report: 2.2(5609).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205609\)%20\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205609)%20))
- SRK Consulting (South Africa) (Pty) Ltd, (2019). Coca Cola Beverages South Africa (CCBSA) Polokwane Depot, Groundwater Quality Report. Draft. DWS e-WULAAS Ref: 5732420193117193645. DWS Consultant's Report: 2.2(5617).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205617\)%20\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205617)%20))
- Taylor, C.J., (1981). Geohydrology of the upper Magalakwena valley north-west of Potgietersrus, Transvaal. DWS Report No. GH3174, Directorate: Geohydrology, Department of Water Affairs and Forestry.  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20\(INFLECTIONAL,%20gh3174\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20(INFLECTIONAL,%20gh3174))

- Troskie, K., 2023. Geostratum Water Management Consultants (Pty) Ltd. Seritarita Secondary School Relocation Project, Hydrogeological Investigation. Report No. KT05\_23. DWS e-WULAAS, Ref: 4735996489719842979. DWS Consultant's Report: 2.2(5623).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205623\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205623)%20)
- Tshingwala, V., (2018). Baseline Geohydrological Study for Monomatoto Investments (PTY). LTD: DWS e-WULAAS, Ref: 5447003977778886283. DWS Consultant's Report: 2.2(5600).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205600\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205600)%20)
- Tshivhase, P., (2023). Anelle Drilling Solutions. Geohydrological Report, Pumping Test, Water Quality Test & Recommendations for Mogwadi Bulk Ground Water Supply Scheme. Report No. G180024. DWS e-WULAAS, Ref: 5734870699732228825. DWS Consultant's Report: 2.2(5618).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205618\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205618)%20)
- Tzaneen Local Municipality., (2024-2025). Integrated Development Plan, IDP 2024-2025.  
<https://www.greatertzaneen.gov.za/documents/idp/FINAL%202024.2025%20IDP%20ADOPTED%20BY%20COUNCIL%2016MAY2024.pdf>
- Van Der Merwe, A., (2010). Maleka Environmental Consulting CC. George Valley Crocodile Farm. Portion 373 & Portion 374 (A Portion of Portion 367) of the Farm Pusela 555 LT Limpopo, General Authorisation. Report Number: Crocodile Farm/MEC/0410/22eg. DWS e-WULAAS, Ref: 27.2.2.B381.5.7 Sub-File Vol 1 & 2. DWS Consultant's Report: 2.2(5638).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205638\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205638)%20)
- Van der Walt, A.P., (2019). Technical Report - Geohydrological Investigation and Groundwater Pollution Risk Assessment, Macbeef Holdings and Abattoir, Polokwane, Limpopo, AGES Report No: 2019/06/11/GENV. DWS e-WULAAS, Ref: 5487546716743790951. DWS Consultant's Report: 2.2(5602).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205602\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205602)%20)
- Vegter, J.R., Dziembowski, Z.M., (1973). Grondwater geberg in die Mafiese waterdraer van die Bosveldstollingskompleks distrik Potgietersrus. DWS Report No. GH1861, Directorate: Geohydrology, Department of Water Affairs and Forestry.  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20\(INFLECTIONAL,%20gh1861\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20(INFLECTIONAL,%20gh1861))
- Venter, B.L., (1973). Grondwater studie van die Sisteem Waterberg in die Vaalwater - Visgatgebied. Report No. GH2917, Directorate: Geohydrology, Department of Water Affairs and Forestry.  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20\(INFLECTIONAL,%20gh2917\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20(INFLECTIONAL,%20gh2917))
- Woithe, S., Weidemann, R.V., (2019). VSA Leboa Consulting. Hydrogeological Data Report, Groundwater Investigation Portion 47 of the farm Kareebosch 618. Report/VSALEB/PR19/107. DWS e-WULAAS Ref: 5209612835131990232. DWS Consultant's Report: 2.2(5590).  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=\(%20FORMSOF%20\(INFLECTIONAL,%202.2\)%20%20AND%20%20FORMSOF%20\(INFLECTIONAL,%205590\)%20](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=(%20FORMSOF%20(INFLECTIONAL,%202.2)%20%20AND%20%20FORMSOF%20(INFLECTIONAL,%205590)%20)

## ADDITIONAL REPORTS COVERING ASPECTS WITHIN THE MAP AREA

- Brandl, G., (1986). The geology of the Pietersburg area, Geological map series 1:250 000, Council of Geoscience, South Africa, Single map sheet and Explanation, 2328 (Pietersburg).
- Brandl, G., (1993). The geology of the Ellisras area, Geological map series 1:250 000, Council of Geoscience, South Africa, Single map sheet and Explanation, 2326 (Ellisras).
- Bond, G.W., (1947). 'n Geochemiese opname van die grondwatervoorade van die Unie van Suid-Afrika. Geological Survey Memoir No.41.
- CSS, (1991). Central Statistical Service, Population census, 1991. Summarised results after adjustment for undercount. CSS Report No. 03=01-01 (1991).
- Department of Water Affairs and Forestry, (1994). Department of Water and Sanitation, Republic of South Africa Magisterial Districts and Provinces, 1994. Unpublished map.
- Department of Water Affairs and Forestry, Department of Health, Water Research Commission, (1996). South African Water Quality Guidelines (Second edition). Volume 1: Quality of Domestic Waste Supplies, Volume 1, Assessment Guide.
- Department of Water Affairs and Forestry, (1996). South African Water Quality Guidelines (Second edition). Volume 5: Agricultural Use: Livestock Watering.
- Department of Water Affairs and Forestry, (1996). South African Water Quality Guidelines (Second edition). Volume 4: Agricultural Use: Irrigation.
- Department of Water Affairs and Forestry, (2005). Department of Water and Sanitation, Groundwater Resource Assessment II. (GRA II). Report 3aE constitutes the final report of Project 3a. <https://www.dws.gov.za/Groundwater/GRAll.aspx>
- Department of Water Affairs and Forestry, (2006). Report to Accompany Water Use Application in terms of the National Water Act, 1998(Act 36 of 1998).
- Department of Water Affairs and Forestry, (2007). External Guideline: Generic Water Use Authorisation Application Process.
- Department of Water Affairs and Forestry, (2008). Department of Water and Sanitation, Guide to the National Water Act.
- Department of Water and Sanitation (DWS), (2012). Aquifer Classification Map of South Africa. <https://www.dws.gov.za/Groundwater/documents/Aquifer%20Classification.pdf>
- Department of Water and Sanitation (DWS), (2013). Aquifer Vulnerability Map of South Africa. [https://www.dws.gov.za/Groundwater/documents/Aquifer%20Vulnerability\\_1.pdf](https://www.dws.gov.za/Groundwater/documents/Aquifer%20Vulnerability_1.pdf)
- Department of Water & Sanitation (DWS), (2013). Groundwater Resource Directed Measures (GRDM) Software v 2.3.0.0.
- Dennis, I., Witthusser, K., Vivier, K., Dennis, R. and Mavurayi, A., (2012). Groundwater Resource Directed Measures: 2011 Edition. WRC Report No. K8/891.
- Durov, S. A. (1948). Classification of natural waters and graphical representation of their composition. Dokl. Akad. Nauk. USSR. 59(1): 87-90.

- Du Toit, A.L., (1939). The geology of South Africa. 2nd edition, Oliver and Boyd, Edinburgh and London.
- Du Toit., W.H., & Sonnekus., C.J., (2014). An explanation of the 1:500 000 general hydrogeological map Polokwane 2326. DWS Report No. GH4170, Department of Water Affairs. [https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20\(INFLECTIONAL,%20gh4170\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20(INFLECTIONAL,%20gh4170))
- Enslin, J.F., (1970). Die grondwaterpotensiaal van Suid-Afrika. Waterjaar 1970. Gepubliseer deur konvensie: Water vir die toekoms.
- Ginsburg, A.E., JG Crafford, J.G., Harris K.R., (2010). Framework and Manual for the evaluation of aquatic ecosystems services for the Resource Directed Measures. WRC Report No. TT 462/10.
- HRU, (1981). Hydrogeological Research Unit. Surface Water Resources of South Africa. Volume 1, Drainage regions A and B. The Limpopo Olifants. Report No 9/81.
- Johnson, J.H., (1975). Hydrochemistry in groundwater exploration. Groundwater Symposium, Bulawayo, 1975.
- Johnson, M.R., Anhaeusser, C.R., Thomas, R.J., (2006). The Geology of South Africa. Geological Society of South Africa, Council of Geoscience.
- Kent, L.E., (1949). The thermal waters of the Union of South Africa and South West Africa: Trans. geol. Soc. S. Afr., 51.
- Kent, L.E., (1968). The thermal waters of the Republic of South Africa: 23 rd. Int. geol. Congress, 19.
- Kruger, G.P., (1983). Soil and Irrigation Research Institute, Department of Agriculture, Pretoria. Terrain Morphological Map of Southern Africa. Published Map.
- Kurlov, M.G., (1928). Classification of mineral waters of Siberia, Tomsk, USSR.
- Langguth, H. R., (1966). Groundwater verhaltnisse in Bereiech Des Velberter. Sattles. Der Minister Fur Eraehrung, Land Wirtsch Forste (pp. 127). Duesseldorf: NRW.
- Lin, L., Lin, H., Xu, Y., Ntuli, T., Mahlangu, F., (2015). Impact of Fault Structures on the Occurrence of Groundwater in Fractured Rock Aquifers. WRC Report No 2053/1/14. ISBN 978-1-4312-0641-4.
- Lloyd, J. A., and Heathcote, J.A., (1985). Natural inorganic hydrochemistry in relation to groundwater: An introduction. Oxford Uni. Press, New York p: 296.
- North West University, (2020). Geo-Statistical Analysis and Sub-Delineation of all Vegter Regions. WRC Report No. 2745/1/19. ISBN 978-0-6392-0098-9.
- Orpen, W.R.G., (1994). A recommended map legend and mapping methodology for the compilation of regional hydrogeological maps of the Republic of South Africa at a scale of 1: 500 000. Unpublished Report. Directorate: Geohydrology, Department of Water Affairs and Forestry. Consultation provided by WSM.
- Parsons, R. and Conrad, J., (1998). Explanatory notes of the aquifer classification map of South Africa. Water Research Commission: Department of Water Affairs and Forestry. WRC Report No. KV 116/98. ISBN 1 8845 4568.

- Parsons, P., Wentzel, J., (2006). Groundwater Resource Directed Measures-GRDM Manual. Water Research Commission with support from FET Water. WRC Project K5/1427.
  - Parsons, R. and Wentzel, J., (2007). Groundwater Resource Directed Measures Manual. Department of Water Affairs and Forestry, Pretoria, 109pp.
  - Piper, A. M., (1944). A graphic procedure in the geochemical interpretation of water analyses. American Geophysical Union Transactions, 25, 914-928.
  - Ravikumar, P., Somashekar, R.K., and Prakash, K.L., (2015). A comparative study on usage of Durov and Piper diagrams to interpret hydrochemical processes in groundwater from SRLIS river basin, Karnataka, India. Department of Environmental Sciences, Bangalore University, Bangalore – 560056.
  - Schylze, B.R., (1984). Climate of South Africa. Part 8, General Survey. Weather Bureau, Department of Transport. WB 28, Pretoria, Fifth edition 1984.
  - Seward, P., Baron, J., and Seymour, A., (1998). The Groundwater Harvest Potential Map of the Republic of South Africa (1996). Report No. GH3917, Directorate Geohydrology, Department of Water Affairs and Forestry.  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20\(INFLECTIONAL,%20gh3917\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20(INFLECTIONAL,%20gh3917))
  - Seward, P., Baron, J., (2001). An Investigation into the Groundwater Use in South Africa. DWS Technical Report GH3960. Department of Water Affairs and Forestry Pretoria.  
[https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20\(INFLECTIONAL,%20gh3960\)](https://www.dws.gov.za/ghreport/Home/Result.aspx?Search=%20FORMSOF%20(INFLECTIONAL,%20gh3960)).
  - Simonic, M., (1995). National groundwater quality assessment. Report in preparation.
- 
- South African Committee for Stratigraphy (SACS), (1980). Stratigraphy of South Africa, part 1. In: Kent, L.E. (ed.) Lithostratigraphy of the Republic of South Africa, South West Africa/Namibia and the Republics of Bophuthatswana, Transkei and Venda. Handbook Geol. Surv. S. Afr. 8.
  - South African National Standard. SANS 10299 1-9:2003. Development, maintenance and management of groundwater resources.
  - South African National Standard. SANS 241:2015. Drinking water Part 1: Microbiological, physical, aesthetic and chemical determinants.
  - UNESCO, (1983). International Association of Hydrogeologist (IAH) International Association of Hydrogeological Sciences (IAHS) United Nations Education, Scientific and Cultural Organization (UNESCO). International Legend for Hydrogeological Maps, Revised version, 1983.
  - Van Wyk, E., (2002). Sustainable Development of Groundwater Resources. Draft report. Project IAEA: RAF/8/029, Department of Water Affairs and Forestry, Pretoria.
  - Vegter, J.R., (1995). Groundwater Resources of South Africa: An Explanation of a Set of National Groundwater Maps. Water Research Commission, Pretoria: Report No. TT 74/95: A1-B33.
  - Vegter, J.R., (2003). Hydrogeology of region 3, Limpopo Granulite-Gneis Belt. WRC Report No. TT 136/00. ISBN No 1 86845 644 7. ISBN Set No 1 86845 645 5.
  - Vegter, J.R., (2003). Hydrogeology of region 7, Polokwane / Pietersburg Plateau. WRC Report No. TT 209/03. ISBN No. 1-77005-027-2. ISBN Set No. 1-86845-645-5 TT209-03.

- Walraven, F. (1986). The geology of the Nylstroom area. Geological map series 1:250 000, Council of Geoscience, South Africa, Single map sheet and Explanation, Map sheet 2428 (Nylstroom).
- Water Research Commission, (2012). Report by Dennis, I., Witthüser, K., Vivier, K., Dennis, R., Mavuray, A., Groundwater Resource Directed Measures. WRC Report No TT 506/12.
- Witthuser, K., Cobbing, J., Titus., R., (2009). Review of GRA1, GRA2 and international assessment methodologies. Project Name: National Groundwater Strategy. DWA Contract Number WP 9390. DWA Report Number P RSA 000/00/11609/6.
- Witthüser, K.T., Holland, M., Rossouw, T.G., Rambau, E., Bumby, A.J., Petzer, K.J., Dennis, I., Beekman, H., van Rooy, J.L., Dippenaar, M., and de Wit, M., (2011). Hydrogeology of Basement Aquifers in the Limpopo Province TT1693. WRC Report No. 1693/1/10. ISBN 978-1-4312-0082-5.
- Xu, Y., Colvin, C., Van Tonder, G.J., Hughes, S., Le Maitre, D., Zang, J., Mafanya, T. and Braune, E. (2003). Towards the resource direct measures: Groundwater component (Version 1.1). Final report prepared for Water Research Commission on Projects. K5/1090, 1091 and 1092, WRC Report No. 1090-2/1/03, May 2003.
- Zaporozec, A., (1972). Graphical interpretation of water quality data. Ground Water Journal, Vol 10, No 2.

---oo0oo---