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MAIN REPORT: VOLUME I

Groundwater Assessment and Development for the Vaal Gamagara Pipeline Scheme - SD1 Area

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REPORT



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Executive Summary

Introduction

Sedibeng Water and the Department of Water Affairs have initiated studies to assess the feasibility to augment and/or upgrade the Vaal Gamagara Water Supply (VGWS) scheme to meet increased water demands in the Northern Cape Province.

The Reconciliation Strategy and Water Master Plan study for Sedibeng Water's Vaal Gamagara Water Supply Scheme highlighted the potential for available groundwater resources in the general area served or proposed to be served by the pipeline to augment the bulk water supply. Areas were identified as possessing enhanced groundwater development potential, these areas were designated Source Development Areas (SD's).

Sedibeng water appointed Worley Parsons and Golder Associates to assess whether there are sufficient and sustainable groundwater resources to augment the existing VGG bulk water scheme. Based on the resource potential of resource groupings and shortfalls in the VGWS scheme four large scale groundwater source development target areas were identified (SD1 to SD4).

This report documents the exploitability and sustainable potential of SD1 (Phase 1) and consist out of:

- Main Report - Volume I;
- Appendix Report - Volume II; and
- Landowners Borehole Information - Volume III.

Background

The Vaal Gamagara Water Supply Scheme (VGWS) was completed in the late sixties with the purpose to supply Vaal River water to the arid areas of the Gamagara valley near Postmasburg and north thereof. This was done to enable large scale diamond mining at Lime Acres and the mining of iron ore and manganese at Beeshoek, Sishen, Mamatwan, Hotazel and Blackrock. Several local authorities receive water from the scheme of which the towns of Delporthshoop, Postmasburg, Kathu and Hotazel are the largest.

Later the addition of the Kalahari East Board, a bulk consumer of the VGWS scheme, brought about further changes in water demand. The Kalahari East scheme was completed in 1992 to supply domestic and stock water to an area of approximately 1 412 000 ha that includes more than 250 farms.

The VGWS scheme consists of a purification works that can purify 13.27 million m³/a water, pumps, 11 reservoirs and 370 km of pipes that delivers water to users. The pipeline has the capacity to convey and import approximately 15 million m³/a into the D41J and D41K catchments. The 13.27 million m³/a water is augmented by dewatering activities of the Kolomela, Beeshoek and Sishen mines to ensure safe mining conditions.

The need for a feasibility study of the VGWS scheme arose from the increase in water demand experienced by Sedibeng Water because of new water applications and extension of existing water allocations. The current scheme is operating at capacity and is not able to supply the future water demand due to increased mining activities. Secondary to the expected increased water demand are water supply interruptions that are amplified due to the aging infrastructure.

The major driving force of the increased water demand is the iron ore and manganese mining operations. These mines of the Northern Cape produce 84% of South Africa's iron ore and 92% of the world's high-grade manganese deposits are in the Kalahari basin. Diamond and lime operations also contribute to the water demand but to a lesser degree.



The feasibility study was completed in August 2011 and recommends the upgrade of the total VGWS scheme to supply the water demand of users for the planning horizon to 2030. The study indicated the current water demand of 13.7 million m³/a, is to increase to approximately 40 million m³/a by the year 2030. It is projected that the mining sector will be the largest consumer; consuming approximately 63.5% of the water, whereas the local authorities and other water users will utilise 14.7% and 21.8% respectively by 2030.

Households in the area supplied by the VGWS scheme are anticipated to increase from 18 332 in 2010 to 31 367 in 2030 (71% increase) with a projected increase in population from 77 316 to 129 196 over the same period.

For planning purposes a 20 year design horizon (2010 to 2030) was used. The results of the hydraulic analyses indicated that the existing infrastructure has insufficient capacity to accommodate the anticipated 2030 demand. A condition assessment of the existing pipelines also confirmed the need for refurbishment.

It was assumed that the ultimate scheme must be capable of providing the total demand from the Vaal River source. The addition of groundwater or mine dewatering sources would therefore only provide relief in terms of operational supply and water price.

Based on a cost and engineering economic point of view the feasibility study recommended Option 1- Replace the existing scheme with a single pipeline with sufficient capacity to supply the anticipated 2030 demand.

An Option 4 is being investigated concerning the identification of the four groundwater source development target areas to augment the water from the Vaal River. This option will be concluded as the groundwater data becomes available and may be the recommended option.

Objectives

The main objective of the groundwater study was to assess the exploitation potential of the identified source development area 1 (SD1) and establish the sustainable yield that can augment the Vaal Gamagara Pipeline scheme.

Description of Study Area

SD1 investigation area falls under the jurisdiction of Kgatelopele Local Municipality (LM), of the Siyanda District and is located in the North Cape Province. The study area is located approximately 145km north-west of Kimberley and 80km south of Kuruman.

The recorded MAP varies from 346mm (Danielskuil) to 448mm (Wonderwerk) and rainfall occurs predominantly in the summer months as isolated thunderstorms.

The surface bedrock geology of SD 1 consists mainly out of dolomite of the Ghaap Plateau formation in the Campbell Group and Banded Ironstone Formation (BIF) of the Asbestos Hills Subgroup in the Griqualand Group. The bedrock geology are partially concealed in some areas by semi consolidated Kalahari sediments and quaternary cover.

Groundwater resources occur throughout the study area. The major aquifers identified comprise of:

- Kalahari Sediments - intergranular unconfined aquifer system - Sandstone, Gravel & Calcrete, with low permeability retards and restrict water movement and acts as storage unit;
- Banded Ironstone Formation (BIF) - weathered and fractured semi confined aquifer system; and
- Dolomite karst aquifers - unconfined to confined aquifer system, compartmentalised by dolerite dykes.

Hydrogeological Investigations

The hydrogeological investigations undertaken include the following:

- Detailed desktop study including collation and updating of existing groundwater information;



- Land Owner Engagement process;
- Hydrocensus – identify 266 existing boreholes and verification of existing groundwater use and selective sampling of 76 boreholes to characterized water quality of exiting groundwater users;
- High resolution airborne geophysical surveys, which included magnetic and Time Domain Electromagnetic (TDEM) surveys. The surveys allowed for detailed mapping of geological structures with magnetic contrast and high resolution mapping of resistivity changes in underlying geology/aquifers with accurate mapping from very near surface to depths of 200 to 250 metres;
- Detailed remote sensing and assessment of airborne geophysical data to identify areas of potentially enhanced groundwater occurrence;
- Ground geophysical surveys: Extended gravity surveys were conducted to optimize selection of drilling targets in the dolomite and banded ironstone formations(BIF);
- Test pumping of 32 existing boreholes consisting of Step Draw-down Tests (SDT) and 1 to 24 hour Constant Discharge Test (CDT);
- Drilling of 53 exploration/test boreholes using air percussion drilling method according to DWA minimum standards and requirements;
- Groundwater sampling of 43 newly drilled exploration boreholes to confirm potable groundwater quality;
- Aquifer test pumping of 38 exploration boreholes:
 - Short term test (SDT and 24 hour CDT) to assess borehole yield capacity and aquifer sustainability; and
 - Long term test of 72hours to confirm aquifer sustainability and obtain aquifer hydraulic parameters for modelling.
- Numerical 3D modelling, to simulate the aquifers of the SD1 modelling area and predict long term sustainability of groundwater supply and test feasibility of implementing abstraction in SD1;
- Confirm management recommendations for production holes designed to ensure long term sustainability, taking the buffer effect of the aquifer into account;
- Compile investigation report.

Groundwater Resources Assessment

Groundwater use

The existing groundwater users are divided into three main water user category's namely mining sector, municipality and private use.

The estimate existing groundwater abstraction rates for SD1 modelling area is summarised in the table below.

Groundwater use	Borehole number	Abstraction Rate M ³ /Month	Abstraction Rate M ³ /Year
Mining sector	SD1-GAA261; SD1-GAA262	39 615	475 376
Municipality	SD1-GAA237; SD1-GAA239	96 163	1 153 958
Private	SD1-GAA numbers (including fountains) and WARMS registered use	215 687	2 588 246
Total Use		351 465	4 217 581



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Groundwater Levels and Flow Direction

The regional groundwater flow direction for the SD1 study area is towards the west. Groundwater piezometric contours mimic the surface topography, and regional the groundwater flow is from higher lying ground toward lower lying valleys, where groundwater accumulates in the alluvial deposits and contributes to baseflow.

Groundwater Quality

The baseline water quality of SD1 exploration boreholes is based on macro chemistry analysed for the sampled boreholes. The concentrations are compared to the SANS 241:2011 water quality standard and the baseline quality are represented by the Median of the concentrations. The baseline water quality of the new exploration boreholes are summarised in the table below.

Item	Physical Parameters			Macro Determinants (Major Ions)								Minor Determinant		
	pH	EC mS/m	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO4 mg/l	NO3 mg/l	MALK Mg/l	F mg/l	Fe mg/l	Mn mg/l
No. of Records	43	43	43	43	43	43	43	43	43	43	43	43	43	43
10 % Percentile	7.25	26.72	174.40	35.00	12.06	5.34	1.72	8.31	11.20	0.30	143.60	0.10	0.05	0.05
Median Baseline water Quality	7.54	67.1	420	86.3	33.8	11.7	2.49	29.3	28.2	3.325	292	0.1	0.05	0.05
Average	7.52	61.42	410.93	78.87	33.18	17.20	3.45	39.99	34.12	3.48	273.05	0.13	0.08	0.08
90% Percentile	7.72	87.70	588.40	98.72	50.56	35.84	5.96	80.86	66.94	5.99	377.20	0.16	0.05	0.15
Max. Allowable Limit (SANS 241:2011)	<5 >9	<170	<1200	<300	<100	<200	<100	<300	<500	<11	-	<1.5	<0.3	<0.5

The background groundwater type for SD1 study area are calcium magnesium bicarbonate type of water (Ca, Mg)(HCO₃)₂, representing unpolluted groundwater.

Aquifer Recharge

Five recharge zones were delineated for the SD1 modelling area (based on the chloride mass balance (CMB) method to estimate the mean annual recharge and using an exponential rainfall/recharge relationship to determine the median annual recharge for different rainfall stations) as listed in table below.

Recharge Zone	Representative Cl (mg/l)	% Recharge	Area km ²	Mean (mm/a)	Median (mm/a)	Mean (million m ³ /a)	Median (million m ³ /a)	Quaternary Catchment Area	GMU Number
1	6.2	9.1	453	35	23.8	15.9	10.8	C92A	C92A-01
									C92A-01A
2	8.5	7.0	12	25	17	0.3	0.2	C92A	C92A-07
3	15	4.0	192	15	10.2	2.9	2.0	C92A	C92A-02
									C92A-05
4	28	2.1	56	8	5.4	0.4	0.3	C92A	C92A-03
									C92A-06
5	38	1.6	1113	5	3.4	5.6	3.8	C92A C92C	C92A-03
									C92A-04
									C92A-06



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									C92A-07
									C92C-02
									C92C-03
									C92C-04
Total			1826	-	-	25.0	17.0	-	11

Groundwater Reserve

Africa Geo-Environmental Services (AGES) conducted an intermediate groundwater reserve study in 2008 for the Lower Vaal Water Management Area (WMA). The intermediate groundwater reserve determination was done using a Groundwater Yield Model for the Reserve (GYMR). Results are summarised in the table below and indicate a groundwater balance of 12.67 million m³/a available for use in the C92A quaternary catchment.

Scenarios	Surface Area (km ²)	Total Inflow (million m ³ /a)	Total Outflow before losses (sinks) (million m ³ /a)	Total abstraction (WARMS) + calculated (million m ³ /a)	Evapotranspiration flow loss along streams (million m ³ /a)	Net Base Flow (million m ³ /a)	Net Base Flow EWR (million m ³ /a)	Usable GW Component from base flow (million m ³ /a)	GRDM status Category
GYMR Present Day	3913	27.50	-3.19	-0.63	-6.21	-18.10	-5.43	12.67	B

Groundwater Modelling

A numerical groundwater flow model was constructed for SD1 investigation area by Delta H to access the potential impact of the proposed well fields on the regional groundwater flow, aquifer recharge and discharge and to delineate aquifer protection zones.

The conceptual hydrogeological model developed by Golder Associates was converted into a 3D numerical model with 4 element layers, with discrete consideration of hydraulic conductivity zones and geological units in the SD1 well field area. The model was satisfactorily calibrated in steady-state and transient state and derived aquifer parameter compare well with data from hydraulic aquifer tests and literature values. Spatially and temporally variable groundwater recharge rates assigned to the model use an exponential rainfall-recharge relationship and reproduce the observed water level fluctuations within reasonable accuracy for the transient calibration period (1986 to 2012).

The calibrated model was subsequently used to simulate the impacts of the proposed SD1 well fields on the groundwater environment. The historical rainfall period from 1996 to 2012 was extrapolated forward for the simulation period from 2013 to 2030 (17 years, 205 time steps). For comparison purposes, three scenarios, an upper limit scenario (1) an optimised scenario (2a) and more likely implementation scenario (2b), which includes two periods of additional abstraction capacity were assessed against a base case or no-go scenario (0) of no abstractions.

The predictive simulation model of the recommended scenario 2B, with a maximum abstraction rate of 6.6 million m³/a (from 15 long term and 7 short term SD1 production boreholes) reveals a wide-ranging cone of depression (considering a 2m cut-off value) due to the distribution of the well fields. Simulated drawdowns for the production boreholes range 4 to 7m for the SD1 well field region.

Any volume of groundwater extracted by pumping in the SD1 production boreholes will be compensated by a reduction in outflow (along the south eastern- and south western outflow boundary) and a reduced volume of groundwater baseflow (towards drainages and springs). Over the long-term a new equilibrium will be reached and in order to maintain this equilibrium, groundwater abstractions must be balanced by increased



recharge (increase in the amount of water entering the system) or reduced discharge (reducing the amount of water leaving the system) (Seward et al., 2006). However, some of the water that is pumped comes from a change in amount of water stored in the subsurface (especially in the drier periods where the abstraction is greater than the difference between the inflow and residual outflow, then an additional yield (change in S) is required to maintain the abstraction). During significant recharge events, changes in outflows and contribution to baseflow continue to occur until the water that was removed from storage is replenished.

Due to the intrinsic heterogeneity of the dolomitic groundwater system the potential impact of the groundwater abstractions on other groundwater users may not be equally distributed (spatially) around the proposed abstraction areas. Further, some surface drainages and pans may be perched on a low-permeability substrate (i.e. the calcrete layer), and may not be in hydraulic continuity with the aquifer beneath and therefore not impacted by a drawdown of the water table.

At this stage, seasonal monitoring data for the transient model calibration are only available for the catchment area upstream of the SD1 well field (mainly Danielskuil area). As a result, the confidence in the model calibration and subsequent predictions is regarded as moderate. Once monitoring data over a full hydrological year become available for the SD1 well fields area, the model should be re-calibrated and predictions updated.

The model predictions should therefore be verified once the well field becomes operational and groundwater monitoring data of the subsequent water table drawdown become available. Predicted drawdown figures for later years can significantly be improved by observation data from the earlier years and subsequent updates of the groundwater model.

Conclusions

Based on the desktop studies, field investigations and resource assessment activities undertaken during this project, the following conclusions are made for the SD1 area:

- The Vaal Gamagara Water Supply study area (SD1) is underlain by Kalahari sediments, dolomite and Banded Iron Formation (BIF) aquifers of which the latter two are compartmentalized by intrusive low permeable dolerite dyke structures;
- Thirty two high yielding boreholes were drilled with a combined air-lift yield of 871 l/s. Exploration drilling in SD1 area was completed on 18 August 2013;
- Borehole test pumping in the SD1 area was completed by 10 September 2013, with twenty seven higher yielding exploration boreholes subjected to 24 or 48 or 72 hour CDT's. The combined pumping yield of these tests was 510 l/s;
- The following aquifer systems were confirmed in the SD1 study area:
 - Intergranular Kalahari Sediments, unconfined aquifer system;
 - Banded Ironstone Formation (BIF) - weathered and fractured semi confined aquifer system; and
 - Dolomite karst aquifers – semi confined to confined aquifer system, compartmentalised by dolerite dykes.
- The aquifer testing results and continuous water level monitoring data confirmed that the upper Kalahari sediments (mainly shallow/perched calcrete aquifer) is not hydraulically linked with the deeper bedrock aquifer zones;
- Major karstification zones in the dolomite are the main aquifer system in the SD1 area, with borehole blow yields up to 60 l/s;
- Water level depths of the exploration boreholes range from 2m to 67m with an average of 14m;



- Borehole management recommendations for the identified well fields, scenario B (22 boreholes) amounts to a combined (long and short term) peak abstraction rate of **6,643,584m³/a**. The sustainable long term abstraction rate is **5,329,584m³/a** and the short term / peak supply for four months per annum from 7 boreholes is **1,314,000m³/a**.
- The recommended abstraction rate for the additional developed Danielskuil Municipality supply boreholes amounts to 236,520m³/a;
- A 3D numerical groundwater flow model was conducted to predict the impact of the proposed SD1 well field on the regional groundwater flow, aquifer recharge and discharge. The predictive simulation for scenario B (22 boreholes) with a combined peak abstraction of 6,643,584m³/a reveals a shallow extended cone of depression, with a 2 to 6m water level drawdown within the regional aquifer;
- The individual borehole pumping rates for scenario 2B (22 production boreholes), were optimised through three groundwater model simulations (scenario 1, 2A and 2B) to limit water level drawdowns on the regional dolomite aquifer to within 4 to 6m, to limit the risk of sinkhole occurrences. Simulated dynamic water level drawdowns for the production boreholes range from 4.4 (SD1-25, dolomite) to 13.5m (SD1-42, BIF) with an average drawdown of 7m;
- The conceptual assumption is made that dolerite dykes are partially permeable for +/- 4m below SWL, allowing groundwater interflow between compartments. Below 4m the dolerite dykes are impermeable and acts as groundwater flow barriers responsible for compartmentalization in the formations;
- Any volume of groundwater extracted by pumping in the SD1 production boreholes will be compensated by a reduction in outflow (along the south eastern and western outflow boundary) and a reduced volume of baseflow (towards drainages and springs). Over the long-term a new equilibrium will be reached and in order to maintain this equilibrium, groundwater abstractions must be balanced by increased recharge (increase in the amount of water entering the system) or reduced discharge (reducing the amount of water leaving the system);
- Lime Acres form part of the base case scenario with no impact on the groundwater regime; and
- An intermediate groundwater reserve study was completed in 2008 for the Lower Vaal Water Management Area (WMA). Using the GYMR (Present day scenario for 2008) as a representative value for total inflow (recharge) and net base flow, there is a groundwater balance of 12.67 million m³/a available for use in the C92A quaternary catchment. Updating the existing water use for 2013 to 4.21 million m³/a, the groundwater balance available for use by the SD1 well field is 8.45 million m³/a.

Recommendations

Based on the above discussions and conclusions the following is recommended:

- A WULA to implement the 22 production boreholes (scenario B) to abstract **5 329 584m³/a** on a sustainable basis over the long term and **1 314 000m³/a** four months per year (**6 643 584m³/a** combined peak supply) to augment water supply to the VGWS;
- The recommended well field abstractions for SD1 are summarised in table below:

Well Field	Number of BH's	Yield l/s	Long Term m ³ /m	Long Term m ³ /a	Short Term m ³ /m	Short Term m ³ /a	Long + Short Term m ³ /a
WF1	5	75	118 260	1 419 120	41 610	499 320	1 918 440
WF2	10	128	216 372	2 596 464	48 180	578 160	3 174 624
WF3	4	45	87 600	1 051 200	10 950	131 400	1 182 600



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Well Field	Number of BH's	Yield l/s	Long Term m ³ /m	Long Term m ³ /a	Short Term m ³ /m	Short Term m ³ /a	Long + Short Term m ³ /a
WF4	3	14	21 900	262 800	8 760	105 120	367 920
Total	-	262	444 132	5 329 584	109 500	1 314 000	6 643 584
Danielskuil	3	15	19 710	236 520			

- All 22 well field boreholes must be protected by a 30 m fenced area and equipped with real time water level monitoring facility as well as water sampling facility at the borehole;
- During installation of reticulation network backfilling of all excavations must be compacted to accepted geotechnical standards to avoid creating drains collecting water and generating preferential groundwater flow paths along new manmade constructions increasing the risk for sinkhole development;
- Critical water levels as indicated in the borehole management recommendations in Appendix A, must not be exceeded. Once these levels are reached daily abstraction rates must be reduced;
- No household, agricultural or animal activities must be allowed within 150 m radius of all production boreholes;
- The aquifer protection zone 3 (for ten year period) must be implemented, within which no new developments or activities may be allowed that may contaminate the aquifer;
- The performance of the well field must be evaluated once a year by updating the numerical model;
- The presented model must be used as a tool for identifying a sound management protocol of the aquifer. Recommendations given are:
 - The model must be utilized to develop optimal operational and management rules for the well field, considering their impact on the regional water balance and water levels;
 - The model must be re-calibrated once a full hydrological year of monitoring data for the SD1 well field becomes available;
 - Annual review of the model predictions and model update if required;
 - With minimal further customization, the model can be expanded to a mass transport model to simulate water quality impacts across the entire model domain.
- Proposed groundwater monitoring programme for SD1 area must comprise of:
 - Quarterly water level monitoring of all accessible exploration boreholes for period of up to three years;
 - Continuous water level monitoring at present installed electronic data loggers for period of up to three years;
 - Site-specific groundwater and rainfall monitoring data are vital for a reliable transient calibration of the model and to understand and simulate aquifer responses to abstraction and recharge at higher confidence. Two real-time rainfall monitoring stations must be installed (one each in well field area 1 and 3).
 - The designated monitoring boreholes, must be equipped for real time water level monitoring, to minimize private land access;



- During well field implementation the proposed production boreholes must be equipped with real time water level loggers;
- Monthly abstraction from each borehole must also be monitored;
- After well field implementation, quarterly sampling of well field boreholes and analysis of samples for macro chemical elements as well as bacteriological analysis;
- All water level, abstraction and water quality monitoring data must be incorporated into DWA's resource monitoring program;
- Real time water level monitoring data must also be linked to the Tshiping Water User Association's database to be accessible to all groundwater users and interested parties;
- Regional water level monitoring by DWA needs to be implemented in the modelling area and downstream below the modelling outflow boundary; and
- As part of the DWA regional water level monitoring, a monitoring borehole must be implemented in the south of the modelling area near Papkuil.



ACRONYMS AND ABBREVIATIONS

ACRONYM	EXPLANATION
CDT	Constant Discharge Test
SDT	Step Discharge Test
pH	Hydrogen Potential
CMB	Chloride Mass Balance Method
EC	Electrical Conductivity
K	Hydraulic Conductivity
MAP	Mean Annual Precipitation
S	Storativity
GU	Groundwater Unit
GMU	Groundwater Management Unit
GMA	Groundwater Management Area
MAP	Mean Annual Perception
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
NWRS	National Water Resource Strategy
T	Transmissivity
BIF	Banded Iron Stone Formation
WRC	Water Research Commission
SANS	South African National Standard
RE	Recharge Estimates
PI	Pump Inlet
DD	Draw Down



UNITS OF MEASUREMENT

UNIT OF MEASUREMENT	EXPLANATION
a	Annum
cm	Centimetre
d	Day
L	Litre
m	Metre
mg	Milligram
mm	Millimetre
m/d	Metre per day
m ³ /d	Cubic metre per day
m ³ /a	Cubic metre per annum
m ³	Cubic metre
mamsl	metres above mean sea level
mbgl	metres below ground level
mbcl	metres below casing level
mS/m	milliSiemens per Metre
mgal	milligal



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APPENDICES

APPENDIX A

Well Field Management Recommendations

APPENDIX B

Long-Term Water Level Drawdown Simulations for Production and Monitoring Boreholes

APPENDIX C

Long-Term Water Level Drawdown Simulations for Existing Boreholes

APPENDIX D

Document Limitations



1.0 INTRODUCTION

Sedibeng Water and the Department of Water Affairs have initiated studies to assess the feasibility to augment and/or upgrade the Vaal Gamagara Water Supply (VGWS) scheme to meet increased water demands in the Northern Cape Province.

The Reconciliation Strategy and Water Master Plan study for Sedibeng Water's Vaal Gamagara Water Supply Scheme highlighted the potential for available groundwater resources in the general area served or proposed to be served by the pipeline to augment the bulk water supply. Several areas were identified as possessing enhanced groundwater development potential, these areas were designated Source Development Areas (SD's).

Sedibeng water appointed Worley Parsons and Golder Associates to assess whether there are sufficient and sustainable groundwater resources to augment the existing VGG bulk water scheme.

Based on the resource potential of resource groupings and shortfalls in the VGG pipeline scheme, four large scale groundwater source development areas (Figure 1) were identified:

- SD1 – Danielskuil;
- SD2 – Postmasburg;
- SD3 – Kathu; and
- SD4 – Tsineng.

The VGG pipeline route and groundwater source assessment modelling areas are indicated on (Figure 1).

The feasibility study entails two phases:

- Phase I – Exploration and Assessment Phase, during which the groundwater resources in the study area are quantified and the feasibility of using the available resources for water supply is determined; and
- Phase II – Development of the available groundwater resources.

This study was conducted in line with the National Water Resource Strategy (NWRS) of the Department of Water Affairs (DWA) which was developed to ensure that national water resources are protected, used, developed, conserved, managed and controlled in a sufficient and sustainable manner towards achieving South Africa's development and socio-economic priorities in an equitable manner in the next five to 10 years.

This report documents the exploitability and sustainable potential of SD1 (Phase 1) and consist out of:

- Main Report - Volume I;
- Appendices Report - Volume II; and
- Landowners Borehole Information - Volume III.

1.1 Background to the Project

The Vaal Gamagara Water Supply Scheme (VGWS) was completed in the late sixties with the purpose to supply Vaal River water to the arid areas of the Gamagara valley near Postmasburg and north thereof. This was done to enable large scale diamond mining at Lime Acres and the mining of iron ore and manganese at Beeshoek, Sishen, Mamatwan, Hotazel and Blackrock. Several local authorities receive water from the scheme of which the towns of Delporthshoop, Postmasburg, Kathu and Hotazel are the largest.

Later the addition of the Kalahari East Board, a bulk consumer of the VGWS scheme, brought about further changes in water demand. The Kalahari East scheme was completed in 1992 to supply domestic and stock water to an area of approximately 1 412 000 ha that includes more than 250 farms.

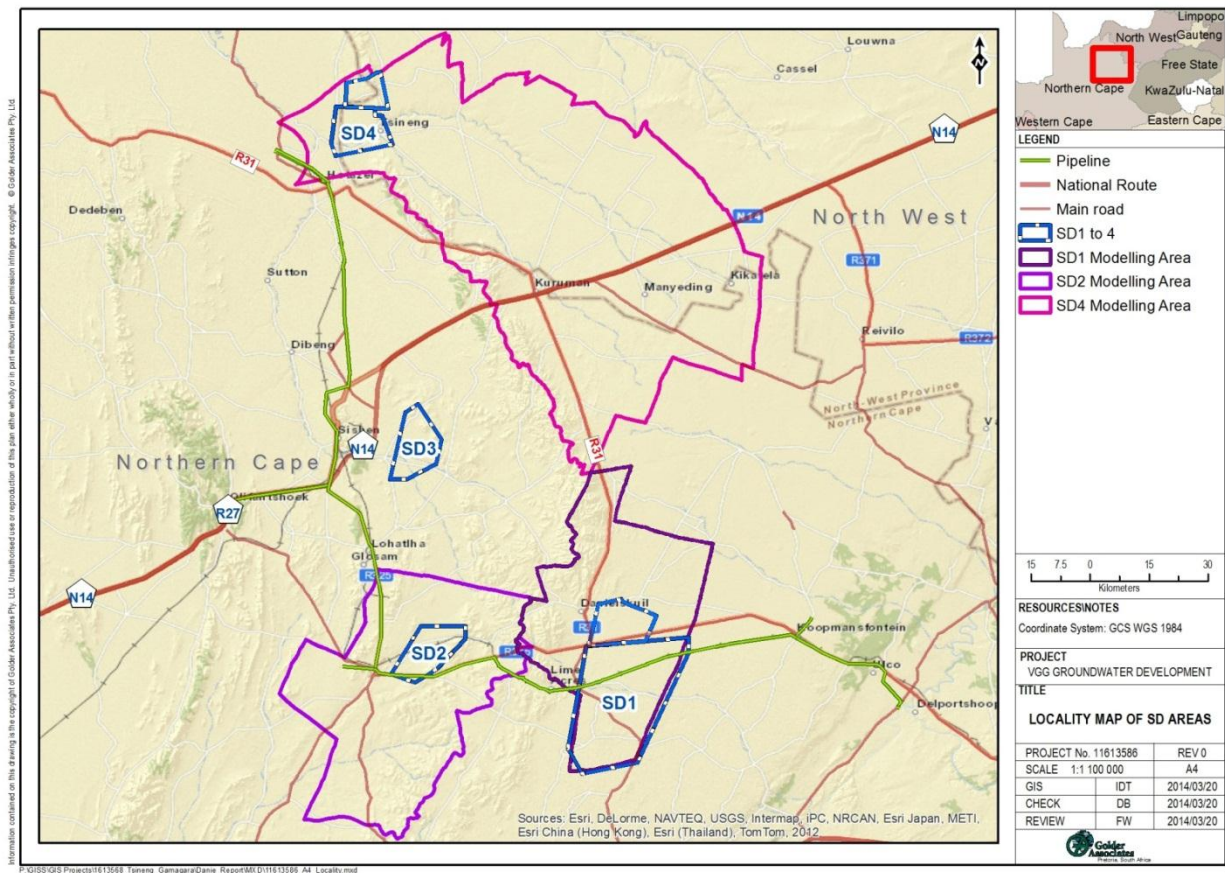


Figure 1: Locality Map of SD Areas

The VGWS scheme consists of a purification works that can purify 13.27 million m³/a water, pumps, 11 reservoirs and 370 km of pipes that delivers water to users. The pipeline has the capacity to convey and import approximately 15 million m³/a into the D41J and D41K catchments. The 13.27 million m³/a water is augmented by dewatering activities of the Kolomela, Beeshoek and Sishen mines to ensure safe mining conditions.

The need for a feasibility study of the VGWS scheme arose from the increase in water demand experienced by Sedibeng Water because of new water applications and extension of existing water allocations. The current scheme is operating at capacity and is not able to supply the future water demand due to increased mining activities. Secondary to the expected increased water demand are water supply interruptions that are amplified due to the aging infrastructure. The infrastructure, being more than 44 years old, is nearing its useful life.

The major driving force of the increased water demand is the iron ore and manganese mining operations. These mines of the Northern Cape produce 84% of South Africa's iron ore and 92% of the world's high-grade manganese deposits are in the Kalahari basin. Diamond and lime operations also contribute to the water demand but to a lesser degree.

The feasibility study was completed in August 2011 and recommends the upgrade of the total VGWS scheme to supply the water demand of users for the planning horizon to 2030. The study indicated the current water demand of 13.7 million m³/a is to increase to approximately 40 million m³/a by the year 2030. It is projected that the mining sector will be the largest consumer; consuming approximately 63.5% of the water, whereas the local authorities and other water users will utilise 14.7% and 21.8% respectively by 2030.



Households in the area supplied by the VGWS scheme are anticipated to increase from 18 332 in 2010 to 31 367 in 2030 (71% increase) with a projected increase in population from 77 316 to 129 196 over the same period.

For planning purposes a 20 year design horizon (2010 to 2030) was used. The results of the hydraulic analyses indicated that the existing infrastructure has insufficient capacity to accommodate the anticipated 2030 demand. A condition assessment of the existing pipelines also confirmed the need for refurbishment.

It was assumed that the ultimate scheme must be capable of providing the total demand from the Vaal River source. The addition of groundwater or mine dewatering sources would therefore only provide relief in terms of operational supply and water price.

Planning was performed for three options:

- Option 1: Replace the existing scheme with a single pipeline with sufficient capacity to supply the anticipated 2030 demand.
- Option 2: Add capacity to the existing scheme to supply the anticipated 2030 demand by an additional pipeline.
- Option 3: Replace the existing scheme with a double pipeline with sufficient capacity to supply the anticipated 2030 demand.

For all three options the basis was that pumping occurs from the Water Treatment Works (WTW) near Delportshoop to Clifton and that the rest of the scheme is supplied from there under gravity with no booster pumps. It was also assumed that over the pumped sector the scheme would operate at the same pressures as the existing scheme.

All the strategic and technical alternatives studied were compared mainly on economic grounds which results in the lowest present value of capital works, operations and maintenance. A costing and engineering economic analysis was conducted by means of a Unit Reference Value (URV) for each technical alternative.

From the calculations it was evident that Option 1 has the lowest URV and thus from an engineering economic point of view, Option 1 - Replace the existing scheme with a single pipeline with sufficient capacity to supply the anticipated 2030 demand, is the recommended way forward.

An Option 4 is being investigated concerning the identification of four groundwater source development target areas (Figure 1) to augment the water from the Vaal River. This option will be concluded as the groundwater data becomes available and will probably be the recommended option.

2.0 OBJECTIVES AND SCOPE OF WORK

The main objective of the groundwater feasibility study was to:

- Determine whether there is sufficient and sustainable groundwater resources to augment the existing VGG bulk water scheme and if confirmed develop the groundwater resources;
- Collect information of existing groundwater use; and
- Assess the exploitable potential of the identified source development areas.

The following scope of work was followed in order to meet the project objectives:

- Detailed desktop study, including collation and updating of existing groundwater information;
- Stake Holder Engagement process;
- Hydrocensus – identify existing boreholes and verification of existing groundwater use and selective sampling to characterized water quality of existing groundwater users;



- Specialised airborne geophysical surveys, which entailed high resolution airborne magnetic and Time Domain Electromagnetic (TEM) surveys. The survey allowed for detailed mapping of geological structures with magnetic contrast and high resolution mapping of resistivity changes in underlying geology/aquifers with accurate mapping from very near surface to depths of 200 to 250 metres;
- Detailed remote sensing and assessment of airborne geophysical data to identify areas of potentially enhanced groundwater occurrence;
- Ground geophysical survey – Detailed gravity survey was conducted to optimize drilling targets in the dolomite and banded ironstone formations(BIF);
- Test pumping of existing boreholes consisting of Step Draw-down Tests (SDT) and 1 to 24 hour Constant Discharge Test (CDT);
- Drilling of exploration boreholes using air percussion drilling method according to, but not limited to DWA minimum standards and requirements;
- Groundwater sampling on newly drilled exploration boreholes to confirm potable groundwater quality;
- Borehole and aquifer test pumping, under controlled supervision:
 - Short term test (SDT and 24 hour CDT) to assess borehole yield capacity and aquifer sustainability; and
 - Long term test of 72hours to confirm aquifer sustainability and obtain aquifer hydraulic parameters for modelling.
- Numerical 3D modelling, to simulate the aquifers of the SD1 catchment area and predict long term sustainability of groundwater supply and test feasibility of implementing development in SD1;
- Confirm management recommendations for production holes designed to ensure long term sustainability, taking the aquifer buffer effect into account; and
- Compile investigation report.

3.0 DESCRIPTION OF STUDY AREA

3.1 Location

SD1 investigation area falls under the jurisdiction of Kgatelopele Local Municipality (LM), of the Siyanda District Municipality and is located in the Northern Cape Province. The study area is located approximately 145km north-west of Kimberley and 80km south of Kuruman.

The SD1 initial investigation area was extended north towards Danielskuil as indicated on Figure 2, in order to obtain more hydrogeological background information and maximize the exploitable potential of the major karstification zone.

SD1 groundwater modelling area includes portions of the C92A, C92C, C92B and C33C quaternary catchment areas with the size of the modelling area (Figure 2) at 1826km².



VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I

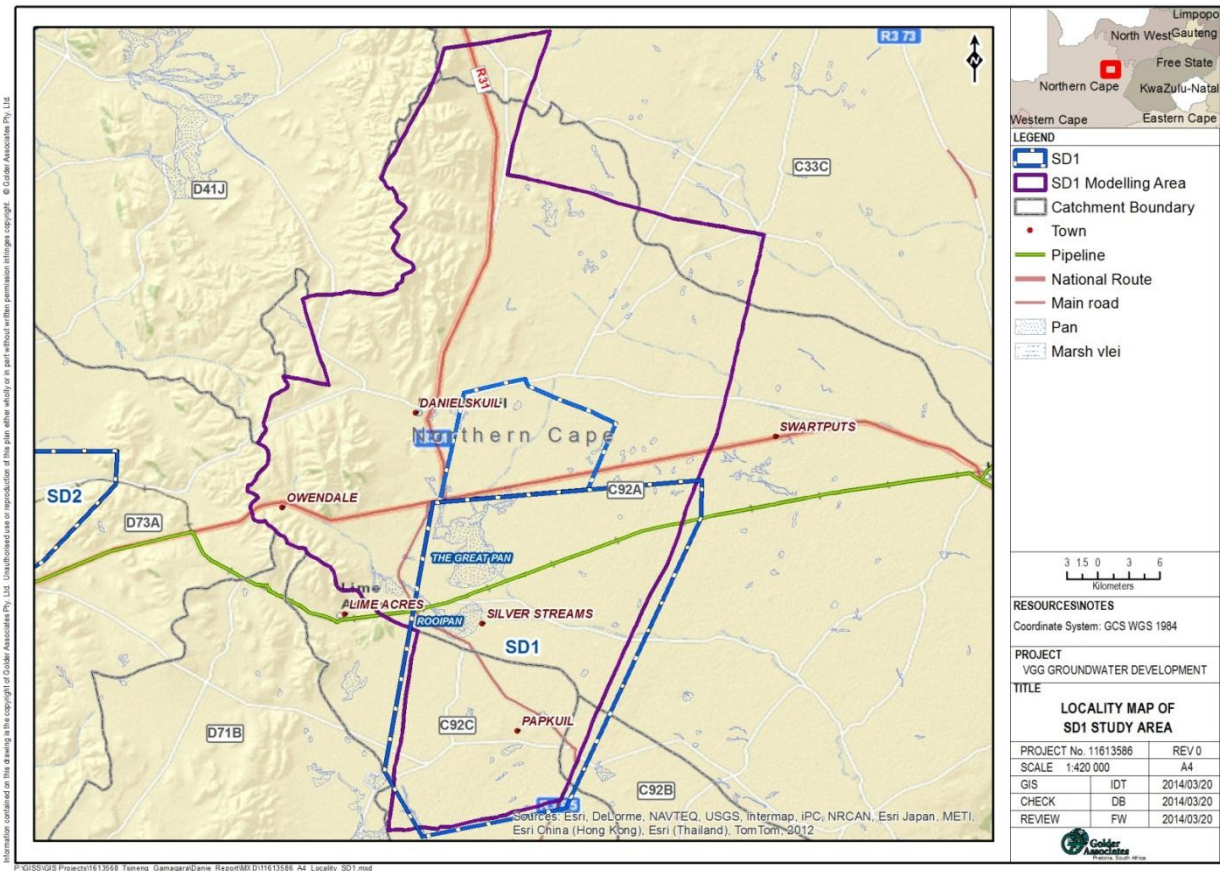


Figure 2: Locality Map of SD1 Study Area

3.2 Topography

The SD1 investigation area is bounded to the west by a broken mountain ridge, namely the Asbes Mountains. This mountain range forms the eastern margin of a regional north-south irregular highland, which resulted from positive erosion of resistant siliceous rock formations and regional tectonic events. Elevations range from 1750mamsl at the highlands to 1430mamsl at the south-east of the investigation area. The irregularities on the escarpment are caused mostly by extensive mechanical erosion of various geological structures, running from the Asbes Mountains towards the Ghaap Plateau (Van Wyk, 1986).

The topography gradually declines towards the east through a definite but irregular escarpment. Three prominent depressions/pans namely the Danielskuil, Great and Rooipan are situated at the foot of the escarpment. These depressions are in the order of 5 to 10m lower than the surrounding area. Towards the east of the escarpment lies the featureless Ghaap Plateau, a virtually flat area at an elevation of approximately 1500 mamsl. Small and localised hills mostly related to lateral differences in lithology appear sporadically on the plateau (Van Wyk, 1986).

The Plateau gradually declines northwards to 1400 mamsl to reach the Kuruman River. From the Kuruman River the topographic gradient decreases to reach the Molopo River at 900 mamsl. The Ghaap Plateau is characterised by a flat plain. In its natural state the area is relatively featureless with calcrete ridges that form over dykes. The ridges vary in height from less than one metre to several metres, depending on the width and extent of dolerite dyke intrusions (Van Wyk, 1986).



3.3 Surface Drainage

The main surface drainage arteries from the plateau are the Vaal River in the south-east. Surface runoff from the escarpment towards the plateau is mainly restricted to a system of linear depressions resulting from leaching process of the carbonate rocks (Van Wyk, 1986).

There are no major drainage systems from the local pans (Danielskuil, Great and Rooipan) towards the Vaal River. It is likely that these pans form a series of interior drainage basins which overflow occasionally during extremely high rainfall seasons, like during 1974 to 1976 period.

The major surface runoff is diverted by the drainage basins and eroded geological structures along the piedmont, to a subsurface system. This explanation is in line with the fact that Danielskuil was flooded in 1974 by groundwater and not surface water (Van Wyk, 1986).

No perennial rivers exist and run-off accumulation in surface depressions can persist for several weeks until water has evaporated or infiltrated into the ground. The Steenbokrivier and Kleinrietrivier represent non perennial surface drainage towards the east.

3.4 Vegetation

The Ghaap Plateau vegetation belongs mainly to the Vryburg Shrub Bushveld, a subdivision of the Khalahari Thornveld (Acocks 1975). This veld type occurs on rocky soil and hard rock formation and shows minor variations from north to south (Van Wyk, 1986).

The Vryburg Shrub Bushveld is again sub divided into four types of which the Tarchonanthus Veld of the Ghaap Plateau is found in the study area. Mostly this veld type is fairly dense Bushveld compose of shrubs and scattered small trees. In the presence of topsoil the area is covered with grass.

In the southern part of the study area, covered with surface limestone trees of the species, *Olea Africana* ("Olienhoutboom") (Figure 3), *Boscia Albitrunca* and *Acaia Karoo* is well presented in the study area.



Figure 3: *Olea Africana* - "Olienhoutboom"

A large *Olea Africana* ("Olienhoutboom") forest is found on the farms Rooipan 507 and Carter Block 485. These trees have an average height of 18m, with a shallow root system (Figure 4). It is a hardened tree type,



which needs little water and adjusts well in dry areas. These trees are roots are well above the water table and their influence on the groundwater level can therefore be neglected (Van Wyk, 1986).

Towards Danielskuil the surface limestone cover and some of the larger trees disappear. This area is mainly covered with ordinary savannah type grassland, with *Themada Triandra* and *Cymbopogon Plurinodis* types dominate.

The most common shrubs found on the escarpment are the *Acaia Mellifera* subspecies *Detinens* and the *Rhus Ciliata*. These species however result from over grazing and is subsequent an invasion of the Karoo vegetation (Van Wyk, 1986).



Figure 4: *Olea Africana* – “Olienhoutboom” – Shallow Root System

3.5 Climate and Rainfall

The SD1 study area lies in a semi – arid area. The climate of SD1 is typical continental with large seasonal and diurnal variations in temperature. The mean maximum temperature range between 24° C and 37° C, with the mean minimum temperature range varies between -4° C and 11° C. Maximum temperatures are experienced in January and minimum temperatures usually occur in July (Van Wyk, 1986).

The climate of the subcontinent is controlled by a low pressure system, during the hot summer months, allowing moist air to flow from the Indian Ocean toward the interior land. In the Northern Cape the movement of air masses is characterised by a fairly dry north to north-easterly wind with a low precipitation rate.

The low temperatures result in a high pressure system to develop over the Northern Cape region during the winter. In the SD1 area this airflow is represented by a north to north-easterly wind (Van Wyk, 1986).

The area is semi-arid with the annual evaporation nearly five times the annual precipitation. The Average evaporation range between 2000 and 2100mm per year. Prevailing wind directions is north-west to west during the dry and dusty July to October period (Van Wyk, 1986).

The SD1 study area lies in a summer rainfall region, with an irregular rainfall pattern and occurs mostly in the form of thunderstorms during January, February and March when moist tropical air from the north reach the area due to frontal systems.



The annual precipitation is erratic with wet and dry cycles evident. An extreme wet cycle that peaked 1974 to 1976 (3 years) was followed by a dry cycle from 1978 to 1987 (9 years). This was followed by a wet cycle 1988 to 1991 (4 years) with an extreme dry year in 1992 with a dry period lasting till 1998 (6 years). From 1999 to 2002 (3 years) above average precipitation prevailed. From 2002 below average precipitation indicate a dry cycle.

The average rainfall for the SD1 area is portrayed by rainfall stations Danielskuil and Wonderwerk. The average monthly rainfall for Danielskuil rainfall station for the period 1952 to 2012 is indicated in Figure 5, with the MAP for the period as 346mm. The average monthly rainfall for Wonderwerk rainfall station for the period 1951 to 2012 is indicated in Figure 6. The MAP for the Wonderwerk rainfall station for the period is 448mm.

The amount of annual rainfall and rainfall intensity (monthly rainfall) are the major driving forces of groundwater recharge, and both stations are used in estimating groundwater recharge..

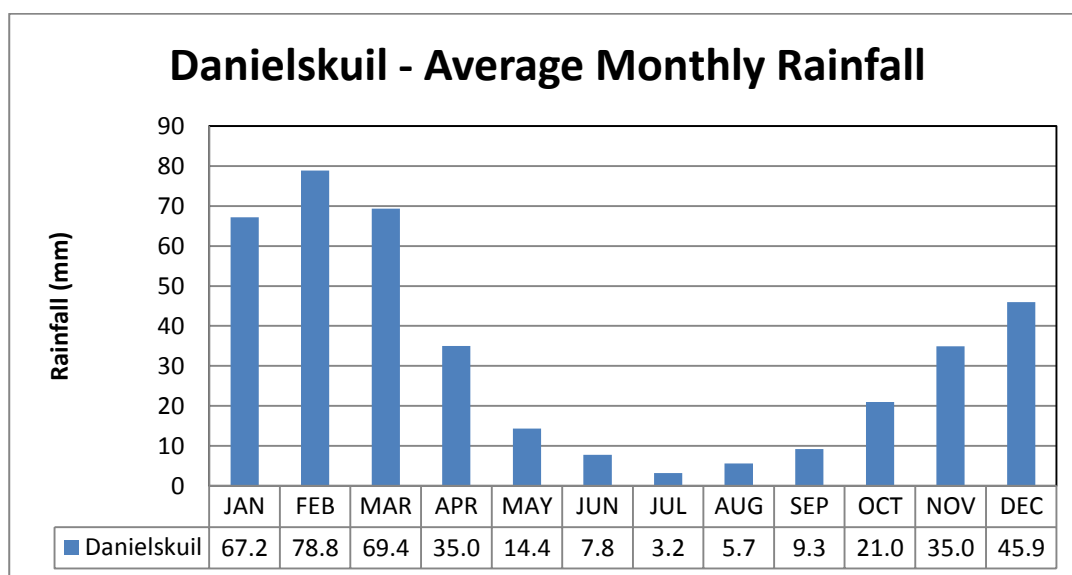


Figure 5: Danielskuil Average Monthly Rainfall

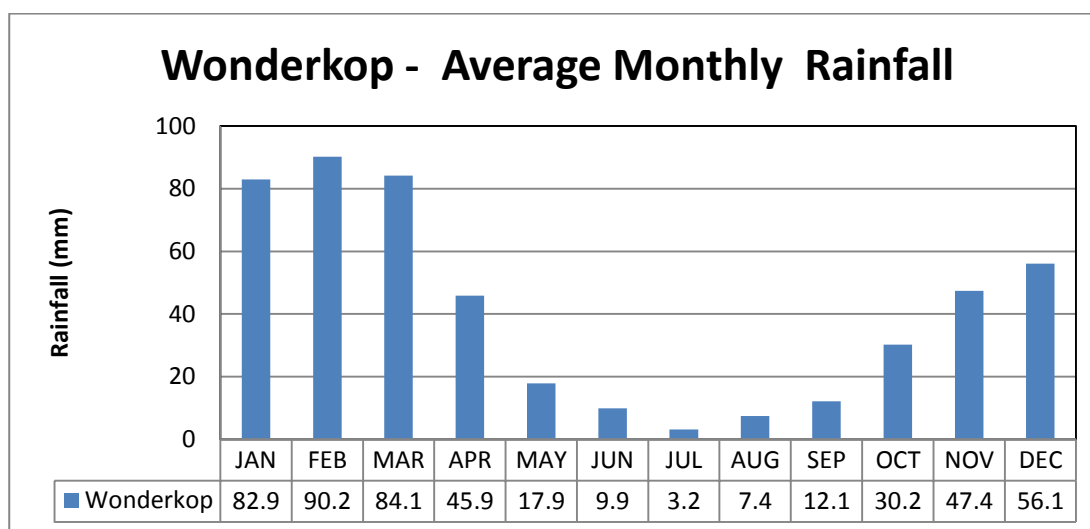


Figure 6: Wonderwerk Average Monthly Rainfall



3.6 Local Geology

SD1 fall onto the Council of Geoscience 1:250 000, (2822 Map Reference) Postmasburg geology map and is shown in Figure 7. The surface bedrock geology of SD 1 consists mainly out of dolomite of the Ghaap Plateau formation in the Campbell Group and Banded Ironstone Formation (BIF) of the Asbestos Hills Subgroup in the Griqualand Group.

In general the stratigraphy on the Postmasburg map consists of porphyritic granite which is the oldest rock unit and geological basement in this region but is not outcropping on Figure 7.

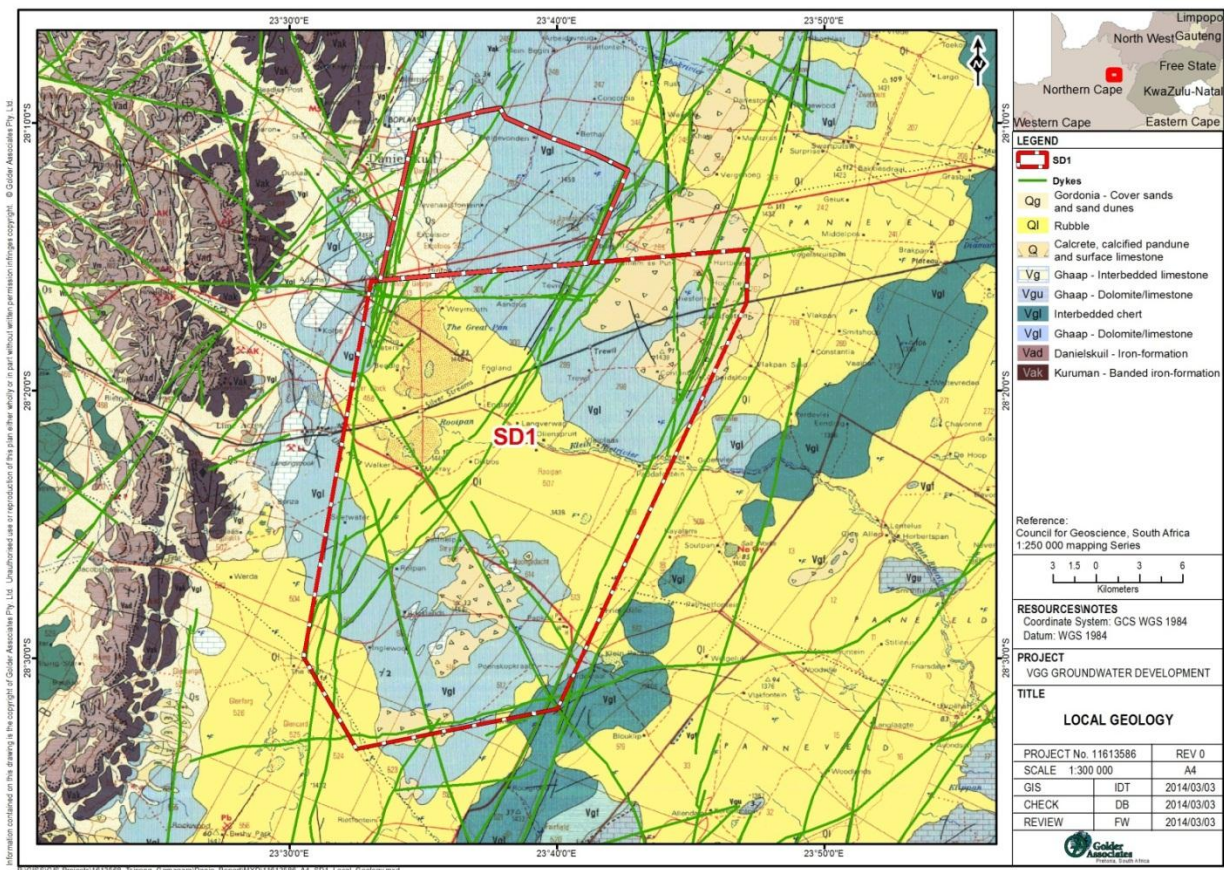


Figure 7: Local Geology

The Ventersdorp Supergroup overlies the basement granite and is unconformably overlain by the Vryburg and Schmidtsdrift Formation's which form the lowest unit of the Campbell Rand Subgroup (Stettler 2013).

The Campbell Rand Subgroup manifests itself in the Maremane Dome or anticline and consists of alternating layers of oolitic and stromatolitic dolomite with thin interbedded layers of shale and quartzite. The oolites are largely chertified. The shale becomes more prominent higher up in the succession with the result that the middle member consists mainly of ferruginous shale with siltstone and interbedded thin dolomite. The upper layer consists mainly of calcitic dolomite with few stromatolites and thin interbedded shale and siltstone (Stettler 2013).

The Koegas and Asbestos hills Subgroups lie conformably on the Campbell Rand Subgroup. The subgroups contain the Kuruman and Danielskuil marker formations which are also magnetic markers. The uppermost chert grades into banded iron stone of the Kuruman Formation which varies in thickness from 180 to 240m. It consists of a succession of thin alternating layers of light coloured chert and jasper and dark-coloured ferruginous jaspilite. The jaspilite contains mainly magnetite, haematite and limonite. The rock also contains several crocidolite-bearing zones. The "blinkklip breccia", a basal layer of banded iron stone, lies on the



Campbell Rand Formation in the Maremane Anticline. The Danielskuil Formation has an undulating structure and consists of brown jaspilite with thin magnetite layers and lenticular breccias and chert nodules. The overlying jaspilite attains a thickness of 150m and several marker layers (Stettler 2013).

Kalahari and Quaternary Deposits

The bedrock geology in the study area is partially concealed by semi consolidated sediments of the Kalahari group and Quaternary deposits. The Kalahari formation consists primarily of calcrete, gravel and clay beds.

Limestone or calcrete varies in thickness from a few millimetre to several metres covers most of the south eastern part of the study area. Relatively thick deposits of calcrete occur as capping's of the dolerite rocks and normally causes a higher relief due to the expansion mechanism present in the calcification process. These ridges of calcrete are easily distinguishable on satellite imagery and in the field.

Various deposits of ferricrete are noticeable adjacent to the escarpment, especially in places where the natural water level seems to be shallower, and consists mainly of ferruginised and silicified ironstone rubble.

Localized layers of unsorted dolomitic residuals are found in situ in the vicinity of surface streamlets and vertical drainage. These deposits are controlled by development of depressions through carbonate solution and reach thicknesses of up to 40m. The residues consist of small irregular chert and carbonate particles within a matrix of finer fragments of the same composition and medium to fine grained clayey sand. As the host rock contains some insoluble manganese minerals, subsurface deposits of manganese clay or wad are common in vertical sections (Van Wyk, 1986).

Intrusive Structures

Intrusive dolerite dykes are a common feature in the study area but seldom outcrops. Dolerite dykes are usually observed as major linear structures and intersect the geological formations perpendicular. These dykes are subjective to both positive and negative weathering, depending on the specific hydrological environment.

Chemical weathering is responsible for the deposition of secondary calcite on top of the dykes, with the intensive materializing of clayey decomposed dolerite at depth. These dykes naturally appear as ridges with depressions formed by the solution of the country rocks within the contact zone alongside the dykes. Most of the surface water drainage channels are restricted to these features.

These dolerite dykes (mainly magnetic with some low to non-magnetic) generally intruded fault zones, are mostly impervious and compartmentalize the dolomite aquifer.

3.7 Hydrogeology

3.7.1 Aquifer Types and Groundwater Occurrence

Groundwater resources occur throughout the study area. The major aquifers identified in the different geological formations comprise of:

- Kalahari Sediments - intergranular unconfined aquifer system - Sandstone, Gravel & Calcrete, with low permeability retards and restrict water movement and acts as storage unit;
- Banded Ironstone Formation (BIF) - weathered and fractured semi confined aquifer system; and
- Dolomite karst aquifers - unconfined to semi confined aquifer system, compartmentalised by dolerite dykes.

The intergranular aquifers are presented by the upper (Eden Formation) as well as basal sand and gravel beds (Wessel Formation) of the Kalahari sediments. These aquifers are characterised by borehole yields generally less than 2 l/s, but with the ability to store large volumes of water. They are separated by the red clays of the Budin Formation acting as a confining layer. The basal sand and gravel formation and underlying bedrock can be regarded as one aquifer. In the absence of red clays the upper sand and gravel aquifer of



the Eden Formation are in hydraulic conductivity with the bedrock aquifers. Wiegman (2006) prepared a preliminary delineation of the extent of saturated Kalahari sediments.

The BIF and karst aquifers associated with the Ghaap Plateau dolomite formations are quite productive and support borehole yield in excess of 40 l/s, in use at Kuruman, Sishen, Kathu, and Beeshoek. Delineation of dykes that may compartmentalize dolomite aquifers is critical to ensure sustainable use and reliable quantification of resource potential. Increased borehole yields, BIF and karst dolomite aquifers are often associated with contact ones of dykes and fault zones.

Groundwater sources are utilized and accessed through the use of boreholes, springs and dewatering of mine workings. Mining and agriculture are the main economic activities of the area and groundwater users.

At Idwala lime mine, groundwater abstraction in the process of de-watering the mine is also used for water supply and process water, although it is recognised as being controlled mining of groundwater.

Danielskuil municipality depend on the use of groundwater from boreholes for domestic use.

4.0 HYDROGEOLOGICAL INVESTIGATIONS

The hydrogeological investigation consists out of:

- Desk study and information review;
- Hydrocensus of the investigation area;
- Groundwater sampling of existing boreholes to obtain representative groundwater quality of exiting groundwater users;
- Test pumping of existing boreholes;
- Geophysical surveys; and
- Exploration drilling and yield assessments.

4.1 Desk Study and Information Review

A desk study and information review was conducted prior to field investigations. The following information was reviewed during desk study:

- 1:250 000 geological map series;
- 1:8 500 000 Groundwater Harvest Potential map of RSA (DWAF 1995);
- 1:2 500 000 Groundwater Resources map of RSA –Sheet 1 (WRC.DWAF 1995);
- 1:4 000 000 Groundwater Resources map of RSA – Sheet 2 (WRC.DWAF 1995);
- 1: 500 000 Hydrogeological Map Series of RSA (1996);
- Existing borehole information were obtained from the following database:
 - Department of Water Affairs (DWAF) National Groundwater Database (NGDB). The NGDB is a National groundwater database initiated and driven by DWAF. Groundwater information is captured from numerous government and private projects. This borehole information is available through data request to DWAF and some of the borehole information is online obtainable;
 - Borehole information from Golder's database namely Aquabase; and
 - Monitoring data from the DWAF Kimberley office.



- Previous hydrogeological reports consisting out of resource assessment, development, and monitoring studies from DWAF and hydrogeological consulting firms; and
- Reconciliation strategy for Sedibeng Water's Vaal Gamagara pipeline scheme and Water Master Plan compiled by Golder Associates Africa in 2010.

4.2 Remote Sensing

An extensive GIS mapping exercise was conducted, using Spot and Google satellite imagery to map linear structures (dykes, faults or lineaments). These linear structures mostly represent intrusive dykes, which are generally near vertical (85 to 90 degrees) and have strike lengths in excess of 100 km. The general strike directions are WSW – ENE, SSW – NNE, and ESE – WNW.

4.3 Land Owner Engagement

The Department of Water Affairs and Sedibeng Water requested Golder to early commence with stakeholder communication during the assessment phase of the project through pro-active and transparent land owner engagement, rather than *ad-hoc* and reactionary engagement, or relying only on the regulatory public consultation that is being triggered by the environmental authorisation processes.

The Communication and Stakeholder Engagement Strategy involved:

- Confirmation of land ownership in the SD1 area. This was done by means of title deeds searches, verification and confirmation of details of landowners, surface rights permit holders and lawful occupiers of land through a process of networking and referral (e.g., liaising with the local agricultural union's chairperson). In addition, Golder determined whether there was any land claims in any of the demarcated project areas;
- Identification of the relevant authorities with jurisdiction in the proposed demarcated project areas;
- Created community and landowner awareness as follows:
 - Compilation and distribution of a background information letter accompanied by a full-colour map of the proposed project area and comment sheet to the relevant authorities (national, regional and local) and directly affected landowners within the SD1 – 4 areas.
- Golder convened small focus group meetings, as follows:
 - District Municipalities with jurisdiction in the proposed demarcated project areas (SD1 – 4);
 - Local Municipalities with jurisdiction in the proposed demarcated project areas (SD 1 – 4);
 - Agricultural Union;
 - Water bodies (e.g., water board, CMA/WUA, if applicable);
 - Relevant provincial government department(s); and
 - Relevant national government department(s).
- Golder convened group consultations with directly affected landowners/lawful occupiers of land for SD1.

4.4 Hydrocensus

An extensive hydrocensus was conducted within the investigation area during 2012. The hydrocensus also included groundwater users with high abstraction rates, namely Danielskuil Municipality boreholes and Idwala Lime mine production boreholes.

During the hydrocensus, 266 boreholes and fountains were surveyed in SD1 area with the co-operation of the land owners. The hydrocensus survey could not be conducted on some private land areas due to



farmers not allowing access. To maintain good relationships with landowners access was not enforced as alternative exploration options were available.

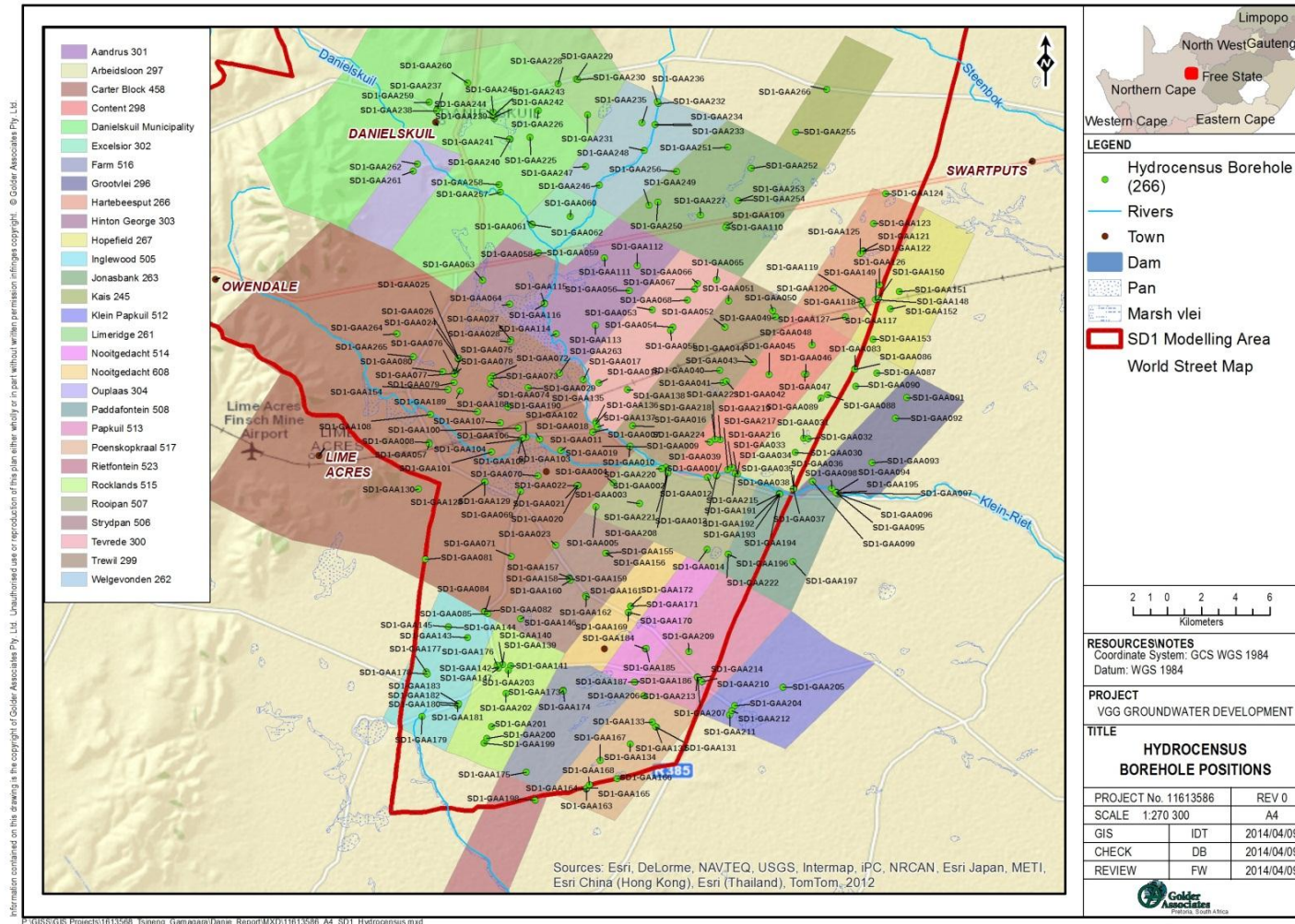
The hydrocensus borehole information is summarised in Table 1 and borehole position are indicated on Figure 8.

The objective of the hydrocensus was to:

- Determine the status of existing boreholes;
- Borehole use and equipment;
- Estimated Yield determination;
- Land owners;
- Record GPS coordinates of boreholes;
- Measure static water levels;
- Collect representative groundwater samples to determine baseline groundwater quality;
- Collect water samples at fountains; and
- Measure field parameters (pH, EC) of samples.



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4.4.1 Discussion

From the borehole information obtained during the hydrocensus the recorded borehole depths of the existing boreholes vary between 4.2m and 130m with an average depth of 38.8m.

From the 266 boreholes listed in Table 1 168 water levels were measured. The groundwater levels of SD1 range between 0.45m (SD1-GAA098) and 43.9m (SD1-GAA260) with an average water level of 8.2mbgl (metre below ground level).

The reported borehole discharge rates for the investigation area range between 0.02l/s (SD1-GAA072) to 28l/s (SD1-GAA077) with an average discharge rate of 3.3l/s.

Field parameters including pH and EC were measured in the field during sampling and are listed in Table 1. The field measurements were compared to the Department of Water Affairs and Forestry (DWAF), 1998 Class 1 guideline for drinking water and the SANS 241:2011 maximum allowable standard as reference. The maximum allowable limit for Electrical Conductivity (EC) Class 1(life time use) is 150mg/l and the pH range is 5 to 10. Those values exceeding the DWAF 1998 Class 1 drinking water limit are highlighted in red.

From the field measurements the following observations have been made:

- The pH value range between 4.82 (SD1-GAA224) and 9.3 (SD1-GAA265) with an average value of 7.23 (alkaline). Except for SD1-GAA244, these pH values are within the accepted quality range of 5 to 10 and is typical of the host formations (dolomite, BIF and calcrete) of the investigation area; and
- The EC values range between 27.0 (SD1-260) and 488mS/m (SD1-GAA189) with an average of 115.7mS/m. Most of the samples are below the DWAF 1998 Class 1 drinking water limit, whereas boreholes with elevated EC concentration are may have a geological origin due to increased dissolved concentrations of calcium and magnesium from the formations.

A total of 76 water samples were collected at existing boreholes during the hydrocensus to determine the baseline water quality of the existing groundwater users. The samples were sampled as per Golder standards and were submitted to UIS Analytical Services in Centurion for analysis.

The reported groundwater use as listed in Table 1 for the existing boreholes are mainly for domestic use purpose (DA) and stock watering (AS) except for Idwala mine (boreholes SD1-GAA261 and SD1-GAA262) where water is used for mining purposes (process water).



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Table 1: Summarised Hydrocensus Borehole Information

Borehole Number	Farm Name	Owner	Latitude	Longitude	Reported Borehole Depth (m)	Discharge Rate (l/s)	Reported Yield (l/s)	Measured WL (mbgl)	Measured EC (mS/m)	Measured pH	Equipment	Use	Date Surveyed
SD1-GAA001	ROOIPAN PTN. OLIENSPRUIT	KOKKIE YORK	-28.3687	23.65721	50.39	6.03	-	-	79	6.74	S	AS	20120203
SD1-GAA002	ROOIPAN PTN. OLIENSPRUIT	KOKKIE YORK	-28.3687	23.65719	52.48	4.33	-	-	-	-	W	DA	20120203
SD1-GAA003	ROOIPAN PTN. OLIENSPRUIT	KOKKIE YORK	-28.3875	23.64321	43.13	0.52	-	-	54	7.5	W	AS	20120203
SD1-GAA004	ROOIPAN PTN. OLIENSPRUIT	KOKKIE YORK	-28.3767	23.62931	16.24	0.53	-	-	-	-	N	-	20120203
SD1-GAA005	ROOIPAN PTN. OLIENSPRUIT	KOKKIE YORK	-28.3894	23.62023	38.31	3.03	-	-	-	-	N	DA	20120203
SD1-GAA006	ROOIPAN PTN. OLIENSPRUIT	KOKKIE YORK	-23.3893	28.62065	45	-	-	8.89	-	-	N	-	20120203
SD1-GAA007	CARTERBLOCK PTN. DIKBOS	KOKKIE YORK	-28.35	23.61845	-	-	-	9.44	-	-	N	-	20120203
SD1-GAA008	CARTER BLOCK PTN. PAPKUIL	KOKKIE YORK	-28.3555	23.53243	130	-	-	-	78	7.93	N	-	20120203
SD1-GAA009	LANGVERWAGHT	G.P. DU PLESSIS	-28.3577	23.63797	-	-	-	5.22	112	6.57	W	AS	20120203
SD1-GAA010	LANGVERWAGHT	G.P. DU PLESSIS	-28.3576	23.63796	-	-	-	4.99	-	-	M	-	20120203
SD1-GAA011	LANGVERWAGHT	G.P. DU PLESSIS	-28.3574	23.63833	-	-	-	4.54	-	-	N	-	20120203
SD1-GAA012	ROOIPAN PTN. WITPUT	G.P. DU PLESSIS	-28.3737	23.67906	-	-	-	2.2	87	6.32	W	AS	20120203
SD1-GAA013	ROOIPAN PTN. WITPUT	G.P. DU PLESSIS	-28.3731	23.68378	-	-	-	-	-	-	W	-	20120203
SD1-GAA014	ROOIPAN PTN. WITPUT	G.P. DU PLESSIS	-28.4118	23.67877	-	-	-	-	162	6.2	W	AS	20120203
SD1-GAA015	ENGLAND	I.H. VERMEULEN	-28.3242	23.62187	31.6	0.55	-	-	75	6.58	W	DA	20120203
SD1-GAA016	ENGELAND	I.H. VERMEULEN	-28.30435	23.65370	-	-	-	-	111	6.4	W	AS	20120206
SD1-GAA017	CARTER BLOCK PTN. DIKBOS	KOKKIE YORK	-28.3223	23.61353	23	0.55	-	-	140	6.14	W	AS	20120206
SD1-GAA018	CARTER BLOCK PTN. DIKBOS	KOKKIE YORK	-28.3538	23.59059	30.1	0.51	-	10.21	-	-	W	AS	20120206
SD1-GAA019	CARTER BLOCK PTN. DIKBOS	KOKKIE YORK	-28.3596	23.60183	29	0.51	-	-	-	-	W	AS	20120206
SD1-GAA020	CARTER BLOCK PTN. DIKBOS	KOKKIE YORK	-28.3779	23.61085	37.33	1.23	-	-	-	-	W	-	20120206
SD1-GAA021	CARTER BLOCK PTN. DIKBOS	KOKKIE YORK	-28.3784	23.61022	25.82	1.25	-	-	110	5.85	S	AS	20120206
SD1-GAA022	CARTER BLOCK PTN. DIKBOS	KOKKIE YORK	-28.3782	23.61039	-	-	-	12.07	-	-	W	AS	20120206
SD1-GAA023	CARTER BLOCK PTN. DIKBOS	KOKKIE YORK	-28.4095	23.59912	37.48	0.54	-	-	93	5.87	W	AS	20120206
SD1-GAA024	CARTER BLOCK PTN. LAUGHING WATERS	STEFAANS PRENS	-28.3115	23.5477	-	-	-	-	-	-	N	-	20120206
SD1-GAA025	CARTER BLOCK PTN. LAUGHING WATERS	STEFAANS PRENS	-28.3112	23.54797	25	-	-	16.19	91	7.03	W	DA	20120206
SD1-GAA026	CARTER BLOCK PTN. LAUGHING WATERS	STEFAANS PRENS	-28.311	23.5479	36.35	1	-	16.05	-	-	N	-	20120206
SD1-GAA027	CARTER BOX PTN. LAUGHING WATERS	STEFAANS PRENS	-28.3013	23.57529	75.2	6.21	-	-	-	-	M	DA	20120206
SD1-GAA028	CARTER BLOCK PTN. LAUGHING WATERS	STEFAANS PRENS	-28.3024	23.57499	-	3.2	-	-	69	6.61	W	AS	20040921
SD1-GAA029	CARTER BLOCK PTN. LAUGHING WATERS	STEFAANS PRENS	-28.3267	23.5845	-	-	-	2.4	75	7.21	N	-	20120206
SD1-GAA030	SEEKOEIVLEI	ADELE RENIER	-28.3607	23.72521	-	-	-	-	-	-	W	-	20120206
SD1-GAA031	SEEKOEIVLEI	ADELE RENIER	-28.3534	23.72964	-	-	-	5.32	103	7.26	W	-	20120206
SD1-GAA032	SEEKOEIVLEI	ADELE RENIER	-28.3535	23.73209	-	-	-	2.0	96	7.35	N	-	20120206
SD1-GAA033	SEEKOEIVLEI	ADELE RENIER	-28.3719	23.69451	-	-	-	-	-	-	W	-	20120206
SD1-GAA034	SEEKOEIVLEI	ADELE RENIER	-28.3721	23.6949	33	1.3	-	-	84	7.41	W	AS	20120206



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Borehole Number	Farm Name	Owner	Latitude	Longitude	Reported Borehole Depth (m)	Discharge Rate (l/s)	Reported Yield (l/s)	Measured WL (mbgl)	Measured EC (mS/m)	Measured pH	Equipment	Use	Date Surveyed
SD1-GAA035	SEEKOEIVLEI	ADELE RENIER	-28.3798	23.72443	9.83	6.05	-	-	-	-	W	DA	20120206
SD1-GAA036	SEEKOEIVLEI	ADELE RENIER	-28.3799	23.72452	-	-	-	1.64	-	-	W	DA	20120206
SD1-GAA037	SEEKOEIVLEI	ADELE RENIER	-28.38	23.72436	-	-	-	-	-	-	W	DA	20120206
SD1-GAA038	SEEKOEIVLEI	ADELE RENIER	-28.38	23.72434	-	-	-	2.27	83	7.2	S	DA	20120206
SD1-GAA039	ROOIPAN PTN. WITPUT	G.P. DU PLESSIS	-28.3729	23.68365	-	-	-	-	-	-	N	-	20120206
SD1-GAA040	TREWILL	ARRIE FOURIE	-28.3174	23.68554	-	-	-	5.21	-	-	W	AS	20120206
SD1-GAA041	TREWILL	ARRIE FOURIE	-28.3239	23.68731	-	-	-	6	-	-	W	AS	20120206
SD1-GAA042	TREWILL	ARRIE FOURIE	-28.3231	23.68888	-	-	-	-	-	-	W	-	20120206
SD1-GAA043	TREWILL	ARRIE FOURIE	-28.3133	23.70315	-	-	-	2.76	-	-	W	-	20120206
SD1-GAA044	TREWILL	ARRIE FOURIE	-28.3133	23.70326	-	-	-	2.84	-	-	W	AS	20120206
SD1-GAA045	CONTENT	ARRIE FOURIE	-28.3196	23.71148	-	-	-	2.45	89	7.43	W	-	20120206
SD1-GAA046	CONTENT	ARRIE FOURIE	-28.3194	23.73094	-	3.79	-	-	91	6.95	W	AS	20040921
SD1-GAA047	CONTENT	ARRIE FOURIE	-28.3193	23.73007	-	-	-	-	169	8.52	N	AS	20120206
SD1-GAA048	CONTENT	ARRIE FOURIE	-28.304	23.73417	-	-	-	-	137	6.98	W	AS	20120207
SD1-GAA049	TREWILL	ARRIE FOURIE	-28.2894	23.71482	-	-	-	3.27	-	-	M	AS	20120207
SD1-GAA050	TREWILL	ARRIE FOURIE	-28.2861	23.71331	-	-	-	8.81	-	-	W	AS	20120207
SD1-GAA051	TREWILL	ARRIE FOURIE	-28.2809	23.6902	-	-	-	2.29	113	7.27	W	AS	20120207
SD1-GAA052	TREWILL	ARRIE FOURIE	-28.2947	23.68815	-	-	-	3.69	-	-	W	AS	20120207
SD1-GAA053	NIE TE VER	ARRIE FOURIE	-28.2857	23.65	-	-	-	-	-	-	W	AS	20120207
SD1-GAA054	NIE TE VER	ARRIE FOURIE	-28.2947	23.66068	100	8.89	-	-	-	-	M	DA	20120207
SD1-GAA055	NIE TE VER	ARRIE FOURIE	-28.2966	23.65955	-	-	-	-	91	7.59	W	DA	20120207
SD1-GAA056	AANDRUS	DAAN VAN DEVENTER	-28.2754	23.63783	-	-	-	-	100	7.12	W	AS	20120207
SD1-GAA057	CARTER BLOCK	KOKKIE YORK	-28.3562	23.53227	85	-	-	-	134	7.41	S	-	20120207
SD1-GAA058	HINTON GEORGE	LENNOX CLOETE	-28.2556	23.58974	-	-	-	15.76	-	-	W	AS	20120207
SD1-GAA059	HINTON GEORGE	LENNOX CLOETE	-28.2556	23.58979	-	-	-	15.84	-	-	W	-	20120207
SD1-GAA060	EXCELSIOR	LENNOX CLOETE	-28.2365	23.60668	-	-	-	-	-	-	W	AS	20120207
SD1-GAA061	EXCELSIOR	LENNOX CLOETE	-28.2403	23.58656	-	-	-	-	79	6.79	W	DA	20120207
SD1-GAA062	EXCELSIOR	LENNOX CLOETE	-28.2406	23.58659	-	-	-	12.66	-	-	W	-	20120207
SD1-GAA063	HINTON GEORGE	LENNOX CLOETE	-28.2701	23.56058	-	-	-	21.73	123	7.08	W	AS	20120207
SD1-GAA064	HINTON GEORGE	LENNOX CLOETE	-28.2826	23.57483	-	-	-	7.53	84	7.17	W	AS	20120207
SD1-GAA065	TEVREDE	COBUS VAN NIEKERK	-28.2699	23.68386	-	-	-	-	-	-	W	AS	20120207
SD1-GAA066	TEVREDE	COBUS VAN NIEKERK	-28.2718	23.67379	-	-	-	4.41	187	7.86	W	DA	20120207
SD1-GAA067	TEVREDE	COBUS VAN NIEKERK	-28.2747	23.67204	-	-	-	-	232	6.69	W	AS	20120207
SD1-GAA068	TEVREDE	COBUS VAN NIEKERK	-28.2803	23.66856	-	-	-	4.92	114	7.12	W	-	20120207
SD1-GAA069	CARTER BLOCK PTN. MURRAY	MARIKA DE JAGER	-28.3811	23.58045	-	-	-	-	230	6.4	S	DA	20120207



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Borehole Number	Farm Name	Owner	Latitude	Longitude	Reported Borehole Depth (m)	Discharge Rate (l/s)	Reported Yield (l/s)	Measured WL (mbgl)	Measured EC (mS/m)	Measured pH	Equipment	Use	Date Surveyed
SD1-GAA070	CARTER BLOCK PTN. MURRAY	MR A DE JAGER	-28.3731	23.58975	30	0.444	-	-	91	7.33	W	AS	20120207
SD1-GAA071	CARTER BLOCK PTN. MURRAY	MR A DE JAGER	-28.4155	23.57559	30	0.444	-	-	75	7.03	W	AS	20120207
SD1-GAA072	CARTER BLOCK PTN. BEADLE	HENNIE VAN ZYL	-28.3205	23.56594	50	0.02	-	6.53	102	7.17	N		20120207
SD1-GAA073	CARTER BLOCK PTN. BEADLE	HENNIE VAN ZYL	-28.3216	23.56481	50	0.05	3.6	-	137	7.0	S		20120207
SD1-GAA074	CARTER BLOCK PTN. BEADLE	HENNIE VAN ZYL	-28.3247	23.56469	50	-	0.1	-	111	7.2	N		20120207
SD1-GAA075	CARTER BLOCK PTN. BEADLE	HENNIE VAN ZYL	-28.318	23.54644	46	2.8	16.7	-	74	7.36	N		20120207
SD1-GAA076	CARTER BLOCK PTN. BEADLE	HENNIE VAN ZYL	-28.3186	23.54597	24.34	9.05	-	-	51	7.27	N		20120207
SD1-GAA077	CARTER BLOCK PTN. BEADLE	HENNIE VAN ZYL	-28.3189	23.54586	23	28	27.8	-	73	7.1	S	DA	20120207
SD1-GAA078	CARTER BLOCK PTN. BEADLE	HENNIE VAN ZYL	-28.3194	23.54573	46	8.3	27.8	-	69	7.74	M	DA	20120207
SD1-GAA079	CARTER BLOCK PTN. BEADLE	HENNIE VAN ZYL	-28.3238	23.54548	38	22	5.6	-	73	7.37	M	AI	20120207
SD1-GAA080	CARTER BLOCK PTN. BEADLE	HENNIE VAN ZYL	-28.3182	23.53948	50	8.3	5.6	-	72	7.11	S	DA	20120207
SD1-GAA081	CARTER BLOCK PTN. ROLPAN	HANNES MEYER	-28.4171	23.53039	-	-	-	-	93	6.89	W	AS	20120208
SD1-GAA082	CARTER BLOCK PTN. ROLPAN	HANNES MEYER	-28.4445	23.56155	-	-	-	-	114	7.03	W	AS	20120208
SD1-GAA083	ARBEIDSLOON	KEITH WILLIAMS	-28.3168	23.75672	30	-	-	4.48	144	7.28	W	AS	20120208
SD1-GAA084	CARTER BLOCK PTN. ROLPAN	HANNES MEYER	-28.4447	23.56174	-	-	-	6.55	-	-	W	AS	20120208
SD1-GAA085	CARTER BLOCK PTN. ROLPAN	HANNES MEYER	-28.4455	23.56315	-	-	-	9.93	107	7.16	S	DA	20120208
SD1-GAA086	ARBEIDSLOON	KEITH WILLIAMS	-28.3169	23.75673	5	-	-	4.12	-	-	W		20120208
SD1-GAA087	ARBEIDSLOON	KEITH WILLIAMS	-28.3189	23.76824	18	-	-	3.69	131	7.24	W	AS	20120208
SD1-GAA088	ARBEIDSLOON	KEITH WILLIAMS	-28.3304	23.74239	30	-	-	-	107	6.91	W	AS	20120208
SD1-GAA089	ARBEIDSLOON	KEITH WILLIAMS	-28.332	23.73883	-	-	-	3.36	-	-	N		20120208
SD1-GAA090	ARBEIDSLOON	KEITH WILLIAMS	-28.3259	23.75706	18	-	-	-	154	7.23	W	DA	20120208
SD1-GAA091	GROOTVLEI	PIET AUSTIN	-28.3318	23.78396	30.15	0.52	-	-	169	7.02	W	AS	20120208
SD1-GAA092	GROOTVLEI	PIET AUSTIN	-28.3427	23.77807	14.2	0.71	-	3.37	115	7.2	W	AS	20120208
SD1-GAA093	GROOTVLEI	PIET AUSTIN	-28.3661	23.7657	17.12	8.01	-	-	91	7.12	W	AS	20120208
SD1-GAA094	GROOTVLEI	PIET AUSTIN	-28.3815	23.74695	-	-	-	-	-	-	W	DA	20120208
SD1-GAA095	GROOTVLEI	PIET AUSTIN	-28.3821	23.74723	-	-	-	1.48	-	-	N		20120208
SD1-GAA096	GROOTVLEI	PIET AUSTIN	-28.3826	23.74786	28.04	1.8	-	-	-	-	W	DA	20120208
SD1-GAA097	GROOTVLEI FOUNTAIN SMALL	PIET AUSTIN	-28.382	23.74756	-	-	-	-	78	8.17	N		20120208
SD1-GAA098	GROOTVLEI FOUNTAIN LARGE	PIET AUSTIN	-28.3798	23.74455	-	-	-	0.45	88	7.87	W	AS	20120208
SD1-GAA099	GROOTVLEI	PIET AUSTIN	-28.3761	23.73451	35.6	0.45	-	4.51	192	7.67	W	DA	20120208
SD1-GAA100	CARTER BLOCK PTN. SILVER STREAMS	JOHAN FAIHST	-28.3478	23.57931	40	-	-	-	-	-	W		20120208
SD1-GAA101	CARTER BLOCK PTN. SILVER STREAMS	JOHAN FAIHST	-28.3605	23.56518	23.65	0.5	-	-	-	-	W		20120208
SD1-GAA102	CARTER BLOCK PTN. SILVER STREAMS	JOHAN FAIHST	-28.3527	23.5834	40	-	-	-	-	-	W		20120208
SD1-GAA103	CARTER BLOCK PTN. SILVER STREAMS	JOHAN FAIHST	-28.3537	23.581	-	0.117	-	-	101	7.23	W	DA	20120208
SD1-GAA104	CARTER BLOCK PTN. SILVER STREAMS	JOHAN FAIHST	-28.3537	23.58082	-	-	-	-	113	6.96	N		20120208



VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I

Borehole Number	Farm Name	Owner	Latitude	Longitude	Reported Borehole Depth (m)	Discharge Rate (l/s)	Reported Yield (l/s)	Measured WL (mbgl)	Measured EC (mS/m)	Measured pH	Equipment	Use	Date Surveyed
SD1-GAA105	CARTER BLOCK PTN. SILVER STREAMS	JOHAN FAIHST	-28.3537	23.58079	56.04	1.41	-	-	146	6.8	S	AS	20120208
SD1-GAA106	CARTER BLOCK PTN. SILVER STREAMS	JOHAN FAIHST	-28.3529	23.58158	35	0.33	-	-	102	7.53	S	AD	20120208
SD1-GAA107	CARTER BLOCK PTN. OUTPOST	JOHAN FAIHST	-28.3451	23.56997	30.2	0.53	-	-	175	7.44	S	DA	20120208
SD1-GAA108	CARTER BLOCK PTN. SILVER STREAMS	JOHAN FAIHST	-28.3407	23.5332	39	2.83	-	-	96	7.12	S	AS	20120208
SD1-GAA109	JONAS BANK	SAKKIE VAN NIEKERK	-28.2411	23.68916	-	-	-	3.62	124	7.3	W	DA	20050801
SD1-GAA110	JONAS BANK	SAKKIE VAN NIEKERK	-28.2421	23.68865	-	-	-	4.1	122	7.13	S	DA	20050801
SD1-GAA111	AANDRUS	DAAN VAN DEVENTER	-28.2581	23.62467	-	-	-	-	90	7.16	W	AS	20120208
SD1-GAA112	AANDRUS	DAAN VAN DEVENTER	-28.2625	23.64191	-	-	-	-	104	7.07	W	AS	20120208
SD1-GAA113	WEYMOUTH	DAAN VAN DEVENTER	-28.2937	23.62004	-	-	-	-	83	6.87	W	AS	20120208
SD1-GAA114	WEYMOUTH	DAAN VAN DEVENTER	-28.2982	23.59917	-	-	-	12.46	84	6.99	W	AS	20120208
SD1-GAA115	WEYMOUTH	DAAN VAN DEVENTER	-28.2822	23.59318	-	-	-	-	-	-	W	AS	20120208
SD1-GAA116	WEYMOUTH	DAAN VAN DEVENTER	-28.2824	23.59311	17	-	-	11.66	84	7.05	N		20120208
SD1-GAA117	HARTEBEESPUT	JOHAN VISSER	-28.283	23.76047	17.6	-	-	2.54	137	-	W	AS	20040921
SD1-GAA118	HARTEBEESPUT	JOHAN VISSER	-28.2809	23.76026	-	-	-	-	89	-	W	DA	20040921
SD1-GAA119	HARTEBEESPUT	JOHAN VISSER	-28.2806	23.76014	-	1.5	-	3.3	89	7.17	S	DA	20120208
SD1-GAA120	HARTEBEESPUIT	JOHAN VISSER	-28.2742	23.74522	-	-	-	11.7	189	-	W	AS	20040921
SD1-GAA121	HARTEBEESPUT	JOHAN VISSER	-28.2545	23.76097	-	-	-	4.8	-	-	W	AS	20040921
SD1-GAA122	HARTEBEESPUT	JOHAN VISSER	-28.2546	23.76092	-	-	-	2.97	-	-	S	DA	20120208
SD1-GAA123	HARTEBEESPUT	JOHAN VISSER	-28.2403	23.76648	-	-	-	11.7	147	7.02	W	AS	20120208
SD1-GAA124	HARTEBEESPUT	JOHAN VISSER	-28.2243	23.77303	-	-	-	6.61	115	6.24	W	AS	20120208
SD1-GAA125	HARTEBEESPUT	JOHAN VISSER	-28.256	23.75955	-	-	-	-	-	-	W		20120208
SD1-GAA126	HARTEBEESPUT	JOHAN VISSER	-28.2726	23.76978	-	-	-	-	151	7.03	W	AS	20120209
SD1-GAA127	HARTEBEESPUT	JOHAN VISSER	-28.2893	23.7517	-	-	-	-	-	-	W	AS	20040921
SD1-GAA128	CARTER BLOCK PTN. WALKER	JOHAN VISSER	-28.3762	23.56141	41.45	-	-	-	92	6.99	W	AS	20040921
SD1-GAA129	CARTER BLOCK PTN. WALKER	JOHAN VISSER	-28.3762	23.56164	-	-	-	-	95	7.14	W		20120209
SD1-GAA130	CARTER BLOCK PTN. WALKER	JOHAN VISSER	-28.3798	23.5266	24	-	-	19.05	103	6.99	W		20120209
SD1-GAA131	POENSKOPKRAAL	JOHAN DU PLESSIS	-28.5054	23.65206	-	-	-	5.04	202	7.0	S	DA	20120209
SD1-GAA132	POENSKOPKRAAL	JOHAN DU PLESSIS	-28.5052	23.65158	-	-	-	-	-	-	W	DA	20120209
SD1-GAA133	POENSKOPKRAAL	JOHAN DU PLESSIS	-28.5026	23.64985	-	-	-	-	111	6.99	W	AS	20120209
SD1-GAA134	POENSKOPKRAAL	JOHAN DU PLESSIS	-28.5144	23.63826	-	-	-	5.46	166	6.93	W	AS	20120209
SD1-GAA135	ENGELAND	THEUNS VERMEULEN	-28.3443	23.62028	30	-	-	-	-	-	W	DA	20120209
SD1-GAA136	ENGELAND	THEUNS VERMEULEN	-28.3454	23.62038	25	-	-	-	-	-	W	AS	20120209
SD1-GAA137	ENGELAND	THEUNS VERMEULEN	-28.3473	23.62114	30.78	-	-	-	-	-	M	AS	20120209
SD1-GAA138	ENGELAND	THEUNS VERMEULEN	-28.3275	23.63677	40	-	1.0	-	-	-	W	AS	20120209
SD1-GAA139	ROCKLANDS	THINUS VAN DER SPUY	-28.4725	23.57099	27	2	-	9.3	-	-	W	DA	20040921



VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I

Borehole Number	Farm Name	Owner	Latitude	Longitude	Reported Borehole Depth (m)	Discharge Rate (l/s)	Reported Yield (l/s)	Measured WL (mbgl)	Measured EC (mS/m)	Measured pH	Equipment	Use	Date Surveyed
SD1-GAA140	ROCKLANDS	THINUS VAN DER SPUY	-28.4725	23.57102	-	-	-	-	91	7.27	W	DA	20120213
SD1-GAA141	ROCKLANDS	THINUS VAN DER SPUY	-28.4731	23.57524	-	-	-	-	84	7.35	W	AS	20040921
SD1-GAA142	ROCKLANDS	THINUS VAN DER SPUY	-28.4736	23.56889	-	-	-	-	-	-	W	AS	20040921
SD1-GAA143	INGLEWOOD PTN. ROCKLANDS	THINUS VAN DER SPUY	-28.4583	23.55253	55	0.3	-	-	81	8.31	W	AS	20040921
SD1-GAA144	INGLEWOOD	THINUS VAN DER SPUY	-28.4526	23.54254	-	-	-	18.44	106	6.85	W	AS	20120213
SD1-GAA145	INGLEWOOD PTN. ROCKLANDS	THINUS VAN DER SPUY	-28.4526	23.54246	-	-	-	18.44	-	-	W	AS	20120213
SD1-GAA146	STRYDPAN	THINUS VAN DER SPUY	-28.4483	23.58052	-	-	-	-	86	7.46	W	AS	20120213
SD1-GAA147	ROCKLANDS	THINUS VAN DER SPUY	-28.4743	23.56881	-	-	-	8.66	-	-	S	DA	20120213
SD1-GAA148	ARRIESFONTEIN	GERRIE CLOETE	-28.2802	23.76801	40	-	-	3.42	89	7.23	S	DA	20120213
SD1-GAA149	ARRIESFONTEIN	GERRIE CLOETE	-28.2801	23.76747	9.14	-	-	3.74	-	-	W	DA	20120214
SD1-GAA150	ARRIESFONTEIN FOUNTAIN	GERRIE CLOETE	-28.2796	23.76896	-	-	-	0.1	103	8.03	N	AS	20120214
SD1-GAA151	ARRIESFONTEIN	GERRIE CLOETE	-28.276	23.7802	-	-	-	-	113	7.2	W	AS	20120214
SD1-GAA152	ARRIESFONTEIN	GERRIE CLOETE	-28.285	23.77538	-	-	-	2.31	76	7.4	N		20120214
SD1-GAA153	ARRIESFONTEIN	GERRIE CLOETE	-28.3012	23.76636	-	-	-	30.5	94	7.15	W	AS	20120214
SD1-GAA154	CARTER BLOCK PTN. ELIM	DRIES SCHEEPERS	-28.3276	23.5423	40	-	6.7	-	73	7.43	S	DA	20120405
SD1-GAA155	STRYDPAN PTN. SELFHELP	THINUS VAN DER SPUY	-28.4139	23.62567	-	-	-	-	74	7.18	W	AS	20120214
SD1-GAA156	STRYDPAN PTN. SELFHELP	THINUS VAN DER SPUY	-28.4138	23.62559	-	-	-	-	-	-	W	AS	20120214
SD1-GAA157	STRYDPAN PTN. SELFHELP	THINUS VAN DER SPUY	-28.4265	23.60632	-	0.83	-	5.12	253	7.44	S	DA	20120214
SD1-GAA158	STRYDPAN PTN. SELFHELP	THINUS VAN DER SPUY	-28.4271	23.60638	-	-	-	4.81	-	-	N		20120214
SD1-GAA159	STRYDPAN PTN. SELFHELP	THINUS VAN DER SPUY	-28.4273	23.60636	-	-	-	-	183	7	W	AS	20120214
SD1-GAA160	STRYDPAN PTN. SELFHELP	THINUS VAN DER SPUY	-28.4281	23.60682	-	-	-	-	158	7.15	W	AS	20120214
SD1-GAA161	STRYDPAN PTN. SELFHELP	THINUS VAN DER SPUY	-28.436	23.61479	-	-	-	-	-	-	W	AS	20120214
SD1-GAA162	STRYDPAN PTN. SELFHELP	THINUS VAN DER SPUY	-28.4366	23.61514	-	-	-	-	87	7.54	W	AS	20120214
SD1-GAA163	HUISTENBOSCH	JACQUES JACOBS	-28.5381	23.61518	-	-	-	5.03	173	7.0	N		20120214
SD1-GAA164	HUISTENBOSCH	JACQUES JOCAOBS	-28.5377	23.61544	-	-	-	-	-	-	W	AS	20120214
SD1-GAA165	HUISTENBOSCH	JACQUES JACOBS	-28.5375	23.61546	-	-	-	4.77	-	-	S	DA	20120214
SD1-GAA166	HUISTENBOSCH	JACQUES JACOBS	-28.5326	23.63141	-	-	-	4.74	121	7.94	W	AS	20120214
SD1-GAA167	HUISTENBOSCH	JACQUES JACOBS	-28.523	23.62258	-	-	-	-	165	7.08	W	AS	20120214
SD1-GAA168	HUISTENBOSCH	JACQUES JACOBS	-28.5358	23.61678	-	-	-	-	-	-	W		20120214
SD1-GAA169	NOOITGEDACHT	THINUS VAN DER SPUY	-28.4451	23.63744	-	-	-	-	113	7.2	W	AS	20120214
SD1-GAA170	NOOITGEDACHT	THINUS VAN DER SPUY	-28.445	23.63725	-	-	-	4.0	-	-	N		20120214
SD1-GAA171	NOOITGEDACHT	THINUS VAN DER SPUY	-28.4416	23.63848	-	-	-	-	-	-	W		20120214
SD1-GAA172	NOOITGEDACHT	THUNIS VAN DER SPUY	-28.4416	23.63868	-	-	-	4.26	87	7.2	N		20120214
SD1-GAA173	SWARTDAM	THUNIS VAN DER SPUY	-28.4858	23.60299	-	-	-	10.89	116	7.02	W	AS	20120214
SD1-GAA174	SWARTDAM	THUNIS VAN DER SPUY	-28.4864	23.60309	-	-	-	-	108	6.93	W	AS	20120214



VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I

Borehole Number	Farm Name	Owner	Latitude	Longitude	Reported Borehole Depth (m)	Discharge Rate (l/s)	Reported Yield (l/s)	Measured WL (mbgl)	Measured EC (mS/m)	Measured pH	Equipment	Use	Date Surveyed
SD1-GAA175	SWARTDAM	THUNIS VAN DER SPUY	-28.529	23.58341	-	-	-	-	88	7.4	W	AS	20120216
SD1-GAA176	ROCKLANDS	THINUS VAN DER SPUY	-28.4727	23.56829	-	-	-	9.61	130	7.06	N		20120216
SD1-GAA177	INGLEWOOD	HANNES CORNELISSEN	-28.4763	23.5309	30	-	-	17.1	96	7.12	W	AS	20120216
SD1-GAA178	INGLEWOOD	HANNES CORNELISSEN	-28.4775	23.53133	-	-	-	17.13	-	-	N		20120216
SD1-GAA179	INGLEWOOD	HANNES CORNELISSEN	-28.4997	23.52854	-	-	-	20.18	74	7.4	W	AS	20120216
SD1-GAA180	INGLEWOOD	HANNES CORNELISSEN	-28.494	23.54731	40	-	-	-	160	6.94	W	AS	20120216
SD1-GAA181	INGLEWOOD	HANNES CORNELISSEN	-28.494	23.54744	40	-	-	-	147	6.93	W	AS	20120216
SD1-GAA182	INGLEWOOD	HANNES CORNELISSEN	-28.4931	23.54769	40	-	-	10.94	93	7.1	N		20120216
SD1-GAA183	INGLEWOOD	HANNES CORNELISSEN	-28.4929	23.54795	-	-	-	11.87	106	7.3	W	DA	20120216
SD1-GAA184	NOOITGEDAGHT	GERT FABER	-28.4642	23.64622	21	-	-	-	83	7.44	W	AS	20040921
SD1-GAA185	NOOITGEDAGHT	GERT FABER	-28.4638	23.64679	42	1	-	9.1	158	7.1	Q	DA	20040921
SD1-GAA186	NOOITGEDAGHT	GERT FABER	-28.4816	23.64072	14	-	-	2.57	-	-	Q	AS	20040921
SD1-GAA187	NOOITGEDAGHT	GERT FABER	-28.4818	23.64053	-	-	-	5.32	-	-	W	AS	20040921
SD1-GAA188	CARTER BLOCK PTN. ELIM	DRIES SCHEEPERS	-28.3284	23.54857	40	-	-	21.9	-	-	W		20120405
SD1-GAA189	CARTER BLOCK PTN. BEADLE	DRIES SCHEEPERS	-28.3392	23.55776	30	-	0.4	-	488	7.43	W	AS	20120410
SD1-GAA190	CARTER BLOCK PTN. ELIM	DRIES SCHEEPERS	-28.3367	23.57397	-	2.8	8.3	1.66	470	7.2	S	AS	20120410
SD1-GAA191	PADDAFONTEIN	CHRISTO STEENKAMP	-28.3825	23.7168	30.48	1.82	-	-	80	7.05	S	DA	20040921
SD1-GAA192	PADDAFONTEIN	CHRISTO STEENKAMP	-28.3826	23.71689	-	-	-	2.01	-	-	N		20120410
SD1-GAA193	PADDAFONTEIN	CHRISTO STEENKAMP	-28.3827	23.71704	-	-	-	2.41	-	-	W	AS	20120410
SD1-GAA194	PADDAFONTEIN	CHRISTO STEENKAMP	-28.3828	23.71713	-	-	-	-	-	-	W	DA	20120410
SD1-GAA195	PADDAFONTEIN	CHRISTO STEENKAMP	-28.382	23.74681	-	-	-	-	-	-	W	AS	20120410
SD1-GAA196	PADDAFONTEIN	CHRISTO STEENKAMP	-28.4142	23.68984	78.6	2.02	-	-	119	6.61	S	AS	20120410
SD1-GAA197	PADDAFONTEIN	CHRISTO STEENKAMP	-28.4183	23.7241	47.18	1.23	-	-	83	6.7	S	AS	20120410
SD1-GAA198	FARM 523	LUCAS BURGER	-28.544	23.58809	-	-	-	7.0	132	7.17	W	AS	20040921
SD1-GAA199	FARM 515	LUCAS BURGER	-28.5137	23.56132	73	0.11	-	17.85	-	-	S	AS	20120410
SD1-GAA200	FARM 515	LUCAS BURGER	-28.5114	23.56269	73	0.11	-	21.9	112	7.52	S	AS	20120410
SD1-GAA201	FARM 515	LUCAS BURGER	-28.5052	23.56528	-	-	-	28.3	-	-	S	AS	20120410
SD1-GAA202	FARM 515	LUCAS BURGER	-28.4876	23.57287	61	0.25	-	17.8	-	-	W	AS	20040921
SD1-GAA203	FARM 515	LUCAS BURGER	-28.4754	23.57414	-	-	-	-	105	7.17	W	AS	20040921
SD1-GAA204	KLEIN PAPKUIL	J GERS	-28.494	23.69337	-	-	-	7.59	102	6.78	W	AS	20040921
SD1-GAA205	KLEIN PAPKUIL	J GERS	-28.4844	23.71893	-	-	-	7.7	-	-	W	AS	20040921
SD1-GAA206	POENSKOPKRAAL-TBC	J GERS	-28.489	23.64554	-	-	-	-	106	6.8	W	AS	20040921
SD1-GAA207	PAPKUIL	J GERS	-28.4795	23.67383	-	-	-	0.56			W	DA	20040921
SD1-GAA208	ROOIPAN PTN. OLIENSPRUIT	KOKKIE YORK	-28.3717	23.65812	-	-	-	5.87	163	8.14	N		20121022
SD1-GAA209	PAPKUIL	J GERS	-28.4657	23.66907	14.7	-	-	3.8	92	7.41	W	AS	20040921



VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I

Borehole Number	Farm Name	Owner	Latitude	Longitude	Reported Borehole Depth (m)	Discharge Rate (l/s)	Reported Yield (l/s)	Measured WL (mbgl)	Measured EC (mS/m)	Measured pH	Equipment	Use	Date Surveyed
SD1-GAA210	PAPKUIL	J GERS	-28.4814	23.67608	-	-	-	-	-	-	W	AS	20040921
SD1-GAA211	KLEIN PAPKUIL	J GERS	-28.4991	23.69065	-	-	-	-	88	7.25	S	DA	20040921
SD1-GAA212	KLEIN PAPKUIL	J GERS	-28.4968	23.69196	-	-	-	5.74	90	7.4	W	DA	20040921
SD1-GAA213	PAPKUIL	VAUGHN MARAIS	-28.4789	23.67368	15.24	-	-	1.62	-	-	W		20040921
SD1-GAA214	PAPKUIL	VAUGHN MARAIS	-28.4793	23.674	-	0.83	-	0.56	75	7.6	N		20040921
SD1-GAA215	VLEIPLAAS	BOTHA MARKRAM	-28.3717	23.69357	48	-	-	-	-	-	W	DA	20120410
SD1-GAA216	VLEIPLAAS	BOTHA MARKRAM	-28.3685	23.69189	-	-	-	-	75	6.76	W	DA	20120410
SD1-GAA217	VLEIPLAAS	BOTHA MARKRAM	-28.3697	23.68975	-	-	-	2.84	-	-	N		20120410
SD1-GAA218	VLEIPLAAS	BOTHA MARKRAM	-28.3538	23.68306	51.18	5.03	-	-	-	-	N	DA	20120410
SD1-GAA219	VLEIPLAAS	BOTHA MARKRAM	-28.3541	23.68582	-	-	-	-	111	7.33	W	AS	20120410
SD1-GAA220	ROOIPAN PTN. OLIENSPRUIT	KOKKIE YORK	-28.3692	23.65492	52.24	0.53	-	-	-	-	W	AS	20040921
SD1-GAA221	ROOIPAN PTN. OLIENHOUT	KOKKIE YORK	-28.3716	23.65812	-	-	-	10.04	-	-	N		20121022
SD1-GAA222	PADDAFONTEIN	CHRISTO STEENKAMP	-28.4143	23.68997	-	-	-	-	-	-	W	AS	20121023
SD1-GAA223	VLEIPLAAS	BOTHA MAKRAM	-28.3538	23.68314	90.7	-	-	-	-	-	N		20121023
SD1-GAA224	VLEIPLAAS	BOTHA MAKRAM	-28.3553	23.6803	7	-	-	5.4	263	4.82	N		20121023
SD1-GAA225	DANIELSKUIL ALLOTMENT	MUNICIPALITY BH - JAN BARNARD TENANT	-28.1948	23.58557	-	-	-	14.86	192	5.85	W	DA	20121113
SD1-GAA226	DANIELSKUIL ALLOTMENT	MUNICIPALITY BH - JAN BARNARD TENANT	-28.1806	23.58988	-	-	-	-		-	W	DA	20121113
SD1-GAA227	JONASBANK	SAKKIE VAN NIEKERK	-28.2357	23.67536	11.2	-	-	3.45	203	7.37	N		20050801
SD1-GAA228	FREDERIK	THEUNS CLOETE	-28.1664	23.60016	-	-	-	-	-	-	S	DA	20121113
SD1-GAA229	FREDERIK	THEUNS CLOETE	-28.164	23.6099	-	-	-	-	-	-	S	AS	20121113
SD1-GAA230	FREDERIK	THEUNS CLOETE	-28.1642	23.61069	-	-	-	-	-	-	W	AS	20121113
SD1-GAA231	FREDERIK	THEUNS CLOETE	-28.1827	23.61573	-	-	-	-	-	-	W	AS	20121113
SD1-GAA232	WELGEVONDEN	THEUNS CLOETE	-28.1768	23.65305	-	-	-	-	73	6.86	W	AS	20121113
SD1-GAA233	WELGEVONDEN	THEUNS CLOETE	-28.1881	23.65149	-	-	-	-	-		W	AS	20121113
SD1-GAA234	WELGEVONDEN	THEUNS CLOETE	-28.188	23.6515	-	-	-	3.76	-	-	N		20121113
SD1-GAA235	WELGEVONDEN	THEUNS CLOETE	-28.1869	23.64454	-	-	-	-	-	-	W	AS	20121113
SD1-GAA236	WELGEVONDEN	THEUNS CLOETE	-28.1759	23.65259	-	-	-	2.19	-	-	N		20121113
SD1-GAA237	DANIELS ALLOTMENT PTN. DANLIME 1	MUNICIPALITY BH - RIKKIE ALVELD	-28.1797	23.5367	68	-	-	25.2	33	7.9	S		20050801
SD1-GAA238	DANIELSKUIL PTN. INVAL (BACKUP)	MUNICIPALITY BH	-28.1806	23.53622	-	-	-	-	-	-	S		20121113
SD1-GAA239	DANIELSKUIL (APIE SE GAT 4) PTN. DANLIME 2	MUNICIPALITY BH	-28.1848	23.56658	83	-	50.0	8.07	58	8.35	S	DA	20050801
SD1-GAA240	DANIELSKUIL MEENT PTN. DANLIME 4 (BACKUP)	MUNICIPALITY BH	-28.1957	23.57514	60	-	12.0	9.98	51	7.8	S	DA	20050801
SD1-GAA241	DANIELSKUIL MEENT PTN. DANLIME 3 (BACKUP)	MUNICIPALITY BH	-28.1957	23.57467	33	-	10.0	9.04	-	-	S	DA	20050801



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Borehole Number	Farm Name	Owner	Latitude	Longitude	Reported Borehole Depth (m)	Discharge Rate (l/s)	Reported Yield (l/s)	Measured WL (mbgl)	Measured EC (mS/m)	Measured pH	Equipment	Use	Date Surveyed
SD1-GAA242	DANIELSKUIL (PILOT BH)	MUNICIPALITY BH	-28.1837	23.567	-	-	-	8.87	-	-	N		20121113
SD1-GAA243	DANIELSKUIL(APIE SE GAT2)	MUNICIPALITY BH	-28.1826	23.56692	90	-	39.0	9.58	58	6.99	N		20050801
SD1-GAA244	DANIELSKUIL MEENT (APIE SE GAT)	MUNICIPALITY BH	-28.1827	23.56603	102	-	24.0	9.31	58	7.8	N	DA	20050801
SD1-GAA245	DANIELSKUIL MEENT (APIE SE GAT3)	MUNICIPALITY BH	-28.1817	23.56622	90	-	1.0	9.84	-	-	N	DA	20050801
SD1-GAA246	WELGEVONDEN	MATHUIS BEESLAAR	-28.22	23.6221	-	-	-	9.56	86	7.47	W	AS	20121113
SD1-GAA247	WELGEVODEN	MATHUIS BEESLAAR	-28.2101	23.61479	-	-	-	12.17	127	7.57	N		20121113
SD1-GAA248	WELGEVONDEN	MATHUIS BEESLAAR	-28.2016	23.64582	-	-	-	-	88	7.91	W	AS	20121113
SD1-GAA249	JONASBANK	MATHUIS BEESLAAR	-28.2306	23.64811	4.2	-	-	4.2	105	7.59	W	AS	20050801
SD1-GAA250	JONASBANK	MATHUIS BEESLAAR	-28.2288	23.65292	4.6	-	-	2.85	-	-	N		20050801
SD1-GAA251	JONASBANK	MATHUIS BEESLAAR	-28.1999	23.68968	5.3	-	-	5.3	122	9.07	W	AS	20050801
SD1-GAA252	JONASBANK	MATHUIS BEESLAAR	-28.2109	23.70194	-	-	-	-	121	8.82	W	AS	20050801
SD1-GAA253	JONASBANK	MATHUIS BEESLAAR	-28.2281	23.69509	6.9	-	-	5.1	157	8.97	W	AS	20050801
SD1-GAA254	JONASBANK	MATHUIS BEESLAAR	-28.2281	23.69501	6.4	-	-	5.1	-	-	N	-	20050801
SD1-GAA255	KAIS	ALLIE SYLLIMAN	-28.1919	23.72548	19.8	-	-	5.7	157	8.52	W	AS	20050801
SD1-GAA256	JONASBANK	MATHUIS BEESLAAR	-28.2127	23.66276	6	-	-	6	100	8.35	W	AS	20050801
SD1-GAA257	OUPLAAS	DANIELSKUIL MUNICIPALITY	-28.2236	23.56998	14.44	-	-	6.93	-	-	N	-	20050801
SD1-GAA258	DANIELSKUIL	DANIELSKUIL MUNICIPALITY	-28.2195	23.56912	-	-	-	-	-	-	W	DA	20130311
SD1-GAA259	DANIELSKUIL ALLOTMENT	DANIELSKUIL MUNICIPALITY	-28.1762	23.53238	70.6	1.8	-	12.6	-	-	N	DA	20050801
SD1-GAA260	DANIELSKUIL OOG	DANIELSKUIL MUNICIPALITY	-28.1659	23.55263	-	-	-	43.87	27	6.87	N	-	20050606
SD1-GAA261	OUPLAAS - MAIN WATER HOLE	ELRINA - IDWALA MINE	-28.2125	23.52394	-	-	-	12.045	-	-	S	DA	20130311
SD1-GAA262	OUPLAAS - MAIN WATER HOLE	IDWALA MINE	-28.2089	23.52606	36	-	-	10.94	-	-	S	DA	20050801
SD1-GAA263	CARTER BLOCK	KOKKIE YORK	-28.319	23.60093	54.8	20.55	-	-	-	-	N	-	20130604
SD1-GAA264	CARTER BLOCK PTN. KOLBE	PPC/BOTHA MARKRAM	-28.2982	23.51539	-	-	-	7.34	73	9.3	W	AS	20140204
SD1-GAA265	CARTER BLOCK PTN. KOLBE	PPC/BOTHA MARKRAM	-28.3104	23.52384	-	-	-	-	79	6.74	W	AS	20140204
SD1-GAA266	KAIS FOUNTAIN	ALLIE SYLLIMAN	-28.169440	23.741680	-	0.5	0.5	-	-	-	W	DA	20140220
Min					4.2	0.02	0.1	0.45	27.0	4.8			
Max					130.0	28.0	50.0	43.9	488.0	9.3			
Average					38.7	3.3	14.0	8.2	115.7	7.2			
SANS 241:2011 Max Allowable Limit									<170	5 - 9.7			
DWAF 1998 Class I Drinking Water Limit									70-150	5-10			



4.5 Geophysical Survey

The geophysical survey at SD1 comprises of:

- A high resolution airborne magnetic survey (at 50m flight line spacing) was flown to allow detail mapping of magnetic properties and identification of intrusive dykes of the main exploration target area. The airborne magnetic survey included detail digital elevation data along flight lines;
- The magnetic survey identified a paleo-channel and it was decided to investigate this feature with a SkyTEM (TDEM) survey of selected flight lines to obtain resistivity data from 2 to over 250 m deep;
- Extended ground gravity surveys conducted at 50 and 100m station intervals along access routes and over selected geological targets as identified via the air borne geophysical survey.

The position of survey flight lines for the extensive magnetic survey at SD1 is indicated on Figure 9.

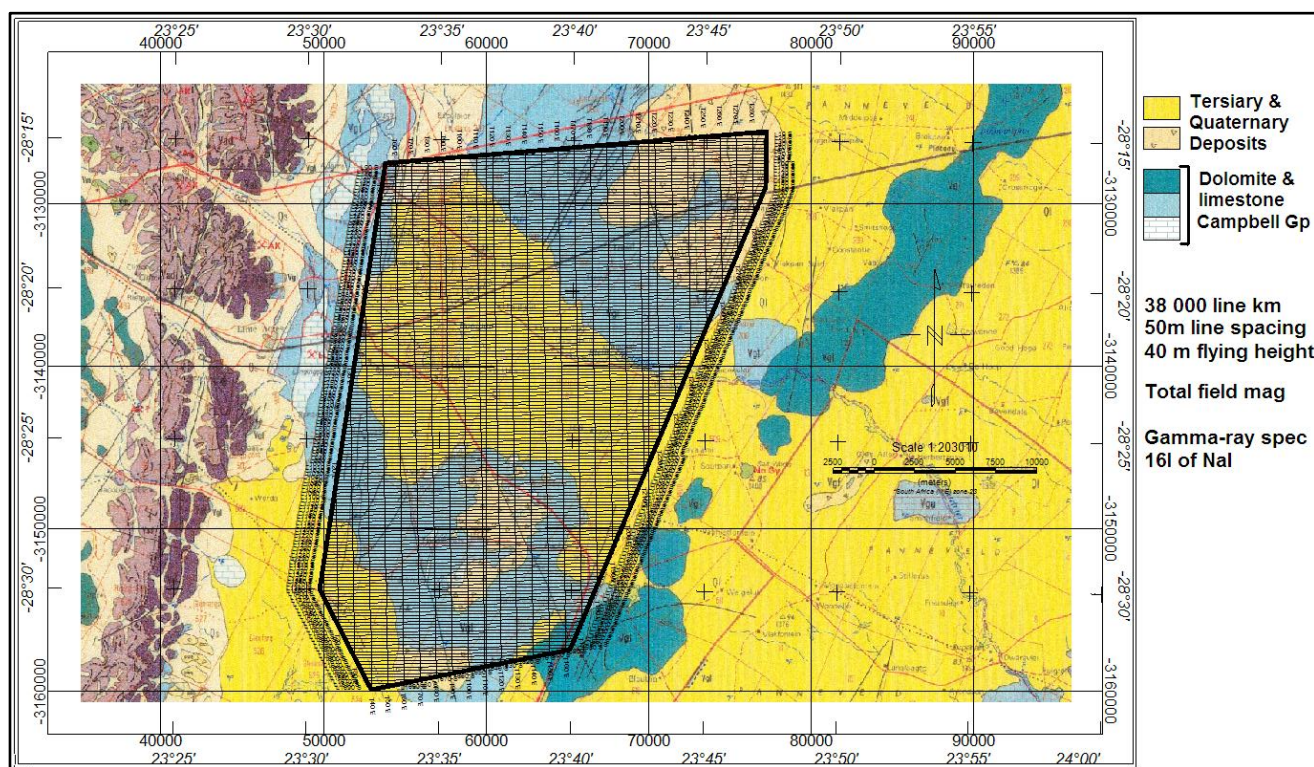


Figure 9: SD1 Airborne Survey Flight Lines

The gravity survey was conducted by EEGS of Centurion within the confines of the SD1 (Figure 10) in order to optimize the selection of drilling targets primary in the leached karst formation.



Figure 10: Gravity Survey - SD1 Area

4.5.1 Digital Elevation Data

The topography was determined from subtracting the Laser height (altimeter) from the on board GPS elevation, is shown in Figure 11 .

The elevations over the Campbell Rand Subgroup dolomite are fairly flat and of interest is the drainage pattern. There are 2 pans in the north western part of the map and the more northern one is fed from a stream entering on the northern apex of the pan and water drains again from the southeastern corner. This stream is augmented by a tributary further east and that tributary can only be a natural spring located at approximately X=66000, Y=-3138000.

The second more southern pan is fed from a stream entering it from the NW and this stream drains the iron rich Kuruman and Danielskuil Formations to the west. This second pan has no visible exit on the topography map but water probably leaves it via underground passages in the dolomite. The magnetic map will display the presence of a paleo-river run extending from this pan to the southeast and probably that is the most likely route of excess water leaving the pan (Stettler 2013).

The very narrow linear structures seen in the data are due to fences and farm boundaries and the overall wooly texture of the elevation map is due to the extensive brush being present. Smaller round depressions in the map most probably stem from a period of ancient subsidence in the dolomite and a good example is at X=67000 Y=-3145000. From a groundwater location prospective both the natural spring and the possible subsidence features would be good points to keep in mind and to build on with further evidence.

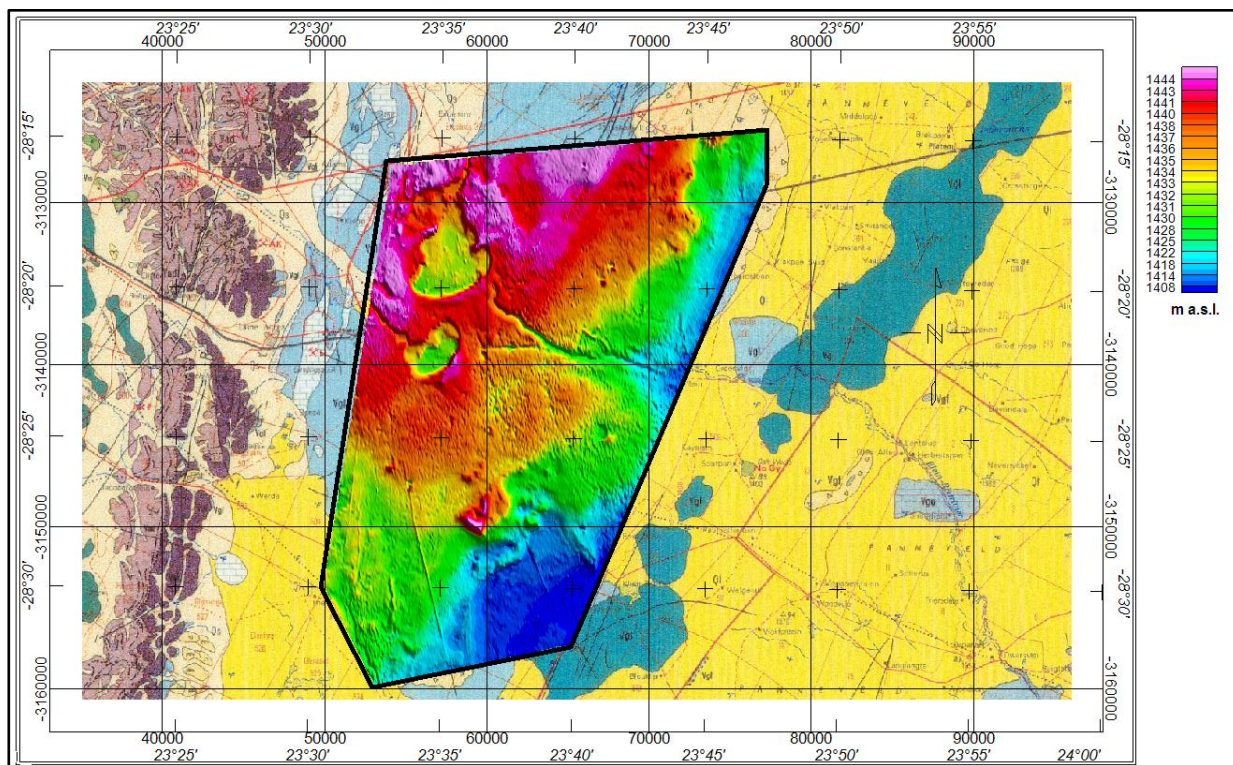


Figure 11: SD1 Digital Elevation Model

4.5.2 Aeromagnetic Data

The total magnetic field for SD1 is shown in Figure 12 as an artificially sun shaded color image and the warm colors indicate the magnetic highs. Increases in the magnetic field strength or 'magnetic highs' are portrayed as ridges or hills colored in a (warm), reddish hue and decreases in the field strength appear as valleys or troughs and are colored in a (cold) bluish hue.

When reading a color magnetic map the following has to be taken into consideration. Since magnetic geological bodies are considered as 'bar magnets' they have two poles, a north and south seeking pole. In the southern magnetic hemisphere the magnetic high is equated with the north seeking pole and the magnetic low (valley) with the south seeking pole. The poles are respectively at maximum field strength over the northern perimeter and minimum field strength over the southern perimeter of a magnetic body, and will have a more subdued high on its western edge and a magnetic low over the eastern perimeter indicating the extreme boundaries of a magnetic body. The body is therefore situated between the north and south seeking poles and not solely under the magnetic high as many non-geophysicists believe.

The difficulty lies in determining which poles belong to which body and is referred to as the high-low pair of a body. In the southern magnetic hemisphere, for purely induced magnetism the larger part of the causative magnetic body occurs under the magnetic high (hues of orange to red to mauve). However if remanent or 'fossil' magnetism is present in a geological body the high-low patterns can change and can make it awkward to determine the dip of a body if the magnetic inclination and declination of the remanent magnetism is not known. These can only be determined with confidence in a palaeomagnetic laboratory on physical oriented rock samples taken from the suspected remanent magnetic body.

Spectacular and most obvious is the broad broken-up pattern of magnetic highs (purple-red) and that start in the NW and WNW corner of the map, meet in the center of the map on a slightly curved NNE striking lineament (magnetic dyke) and then continuing to the ESE where it is slightly displaced by a NNE trending dyke before continuing to the ESE. This feature is due to a paleo-river filled with remnants of Kuruman and Danielskuil magnetic rock material.



A number of dykes occur and are defined by their magnetic anomaly highs. A sill is also visible in the SW corner of the map where it is connected to a dyke and forms a slightly oblate pattern connected to the dyke (Stettler 2013).

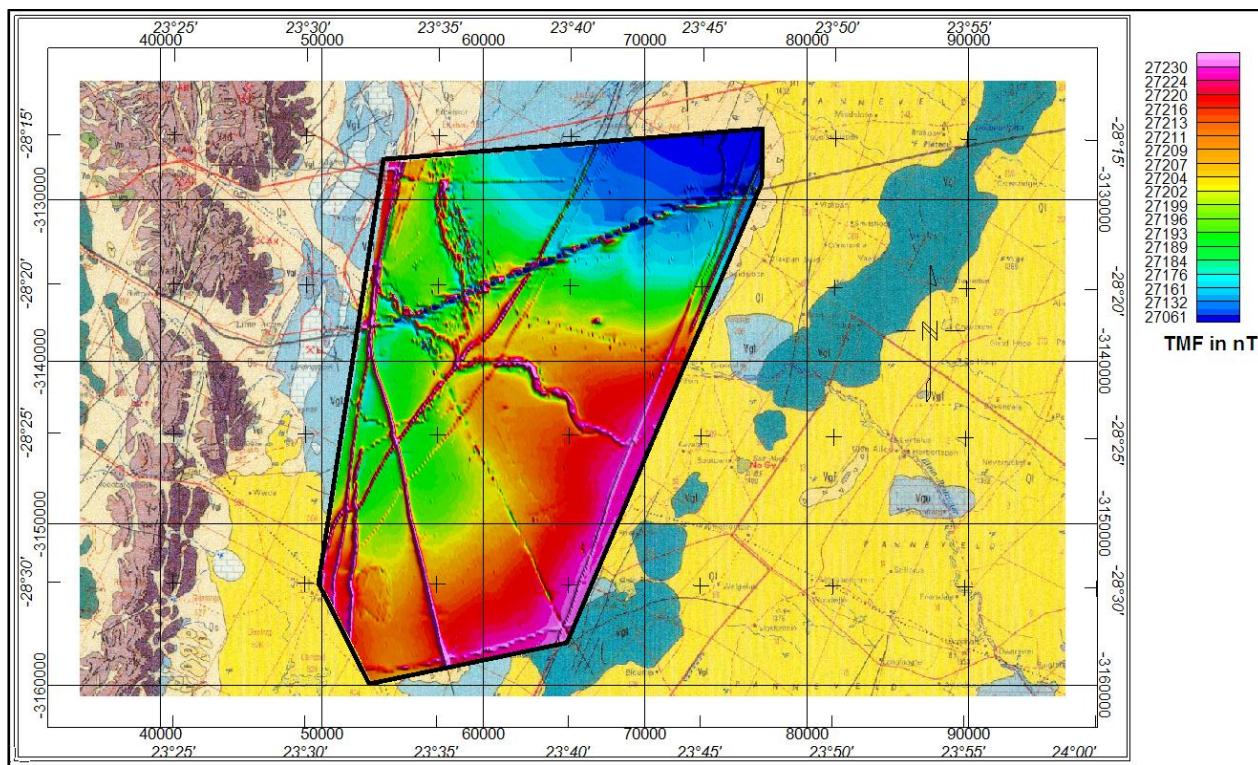


Figure 12: SD1 Total Magnetic Field

To highlight all possible features and lineaments a ternary color image is produced by using the Cyan, Magenta, Yellow (CMY) color scheme to combine the Analytical Signal, the $\partial M/\partial h$ derivative and the tilt-angle in one diagram as shown in Figure 13. The magnetic bodies occur under the green-black colored hues except if they exhibit strong remanent magnetism when they are marked by the strong blue hues. The ternary image shows the disturbed linear pattern caused by the Sishen Saldanah railway line and the broader green mottled pattern coinciding with the two pans filled and indicating them to be filled with alluvial magnetic sediments from the Kuruman and Danielskuil magnetic rocks. The many dykes with mostly NNE strike are also visible and a third drainage pattern flowing into the more southern pan can also be seen.



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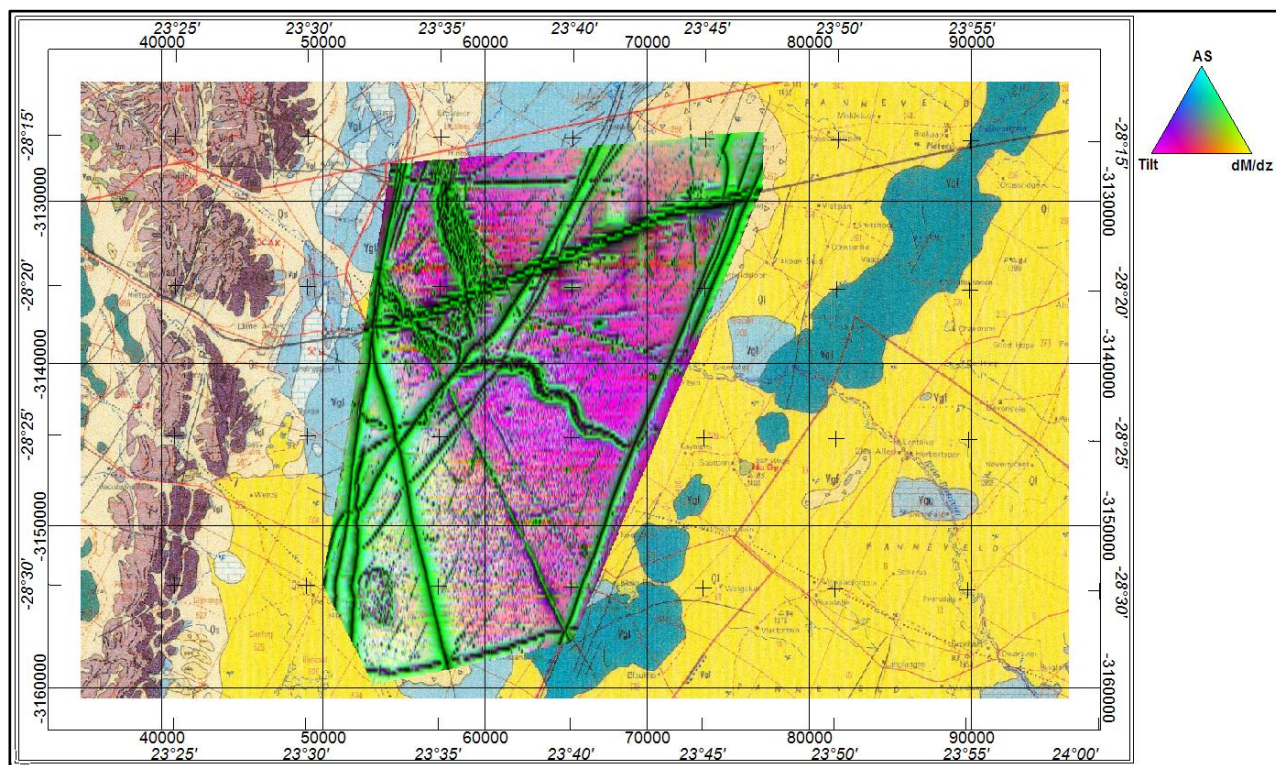


Figure 13: Ternary Plot of the Magnetic Data combining the Analytical Signal, $\partial M/\partial h$ and the Magnetic Tilt Angle

Figure 14 gives a qualitative interpretation of the data, indicating fences, railway line, paleo-drainage channel, several dykes and one sill.

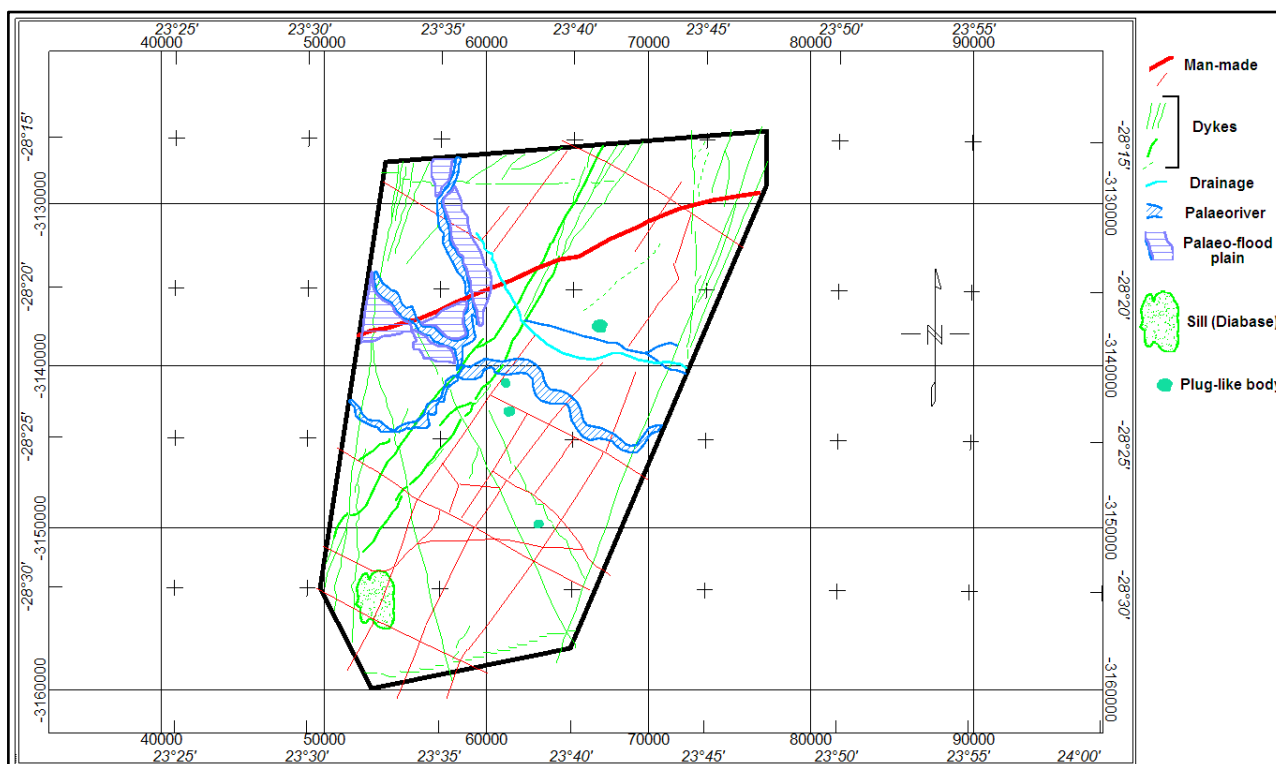


Figure 14: A Qualitative Interpretation of the Magnetic Data Set



4.5.3 Airborne Time Domain Electromagnetic Data

The transmitter coil has a high and low moment and data were provided for both moments as just the signal strength measured in the receiver coil or converted into an apparent resistivity as a function of time channels which were converted into an approximate depth below surface.

The survey area flown with the SkyTEM system is shown in Figure 15 and lines were flown both N-S and E-W with a line spacing of 300m in the central part of SD1 to sample all possible directions. A few additional lines at 1km line spacing were also flown to provide a wider coverage.

Numerous plots can be generated to show how the electrical resistivity changes as a function of depth and position. The Time Domain Electromagnetic (TDEM) result thus gives us a good indication of the internal make-up of the paleo-river sediments and the depth extent.

For example the resistivity distribution near surface between 10 and 15 m below surface, the paleo-river does not show up clearly and this is probably due to the highly calcretized river sediments present near surface. In contrast Figure 15 clearly shows the paleo-river at a depth between 50 and 50m indicating permeable material whereas at the depth interval of 98 to 110 m the paleo-river disappeared. The TDEM results thus gives us a good indication of the internal make-up of the paleo-river sediments and the depth extent shows the paleo-river clearly at a depth between 50 and 50m indicating permeable material

Most dykes are slight conductors at surface but all turn into electrical resistors at depth and are not clearly seen. Other conductors apart from the paleo-rivers, are present and are probably due to graphitic/carbonaceous films in the dolomite (Stettler 2013).

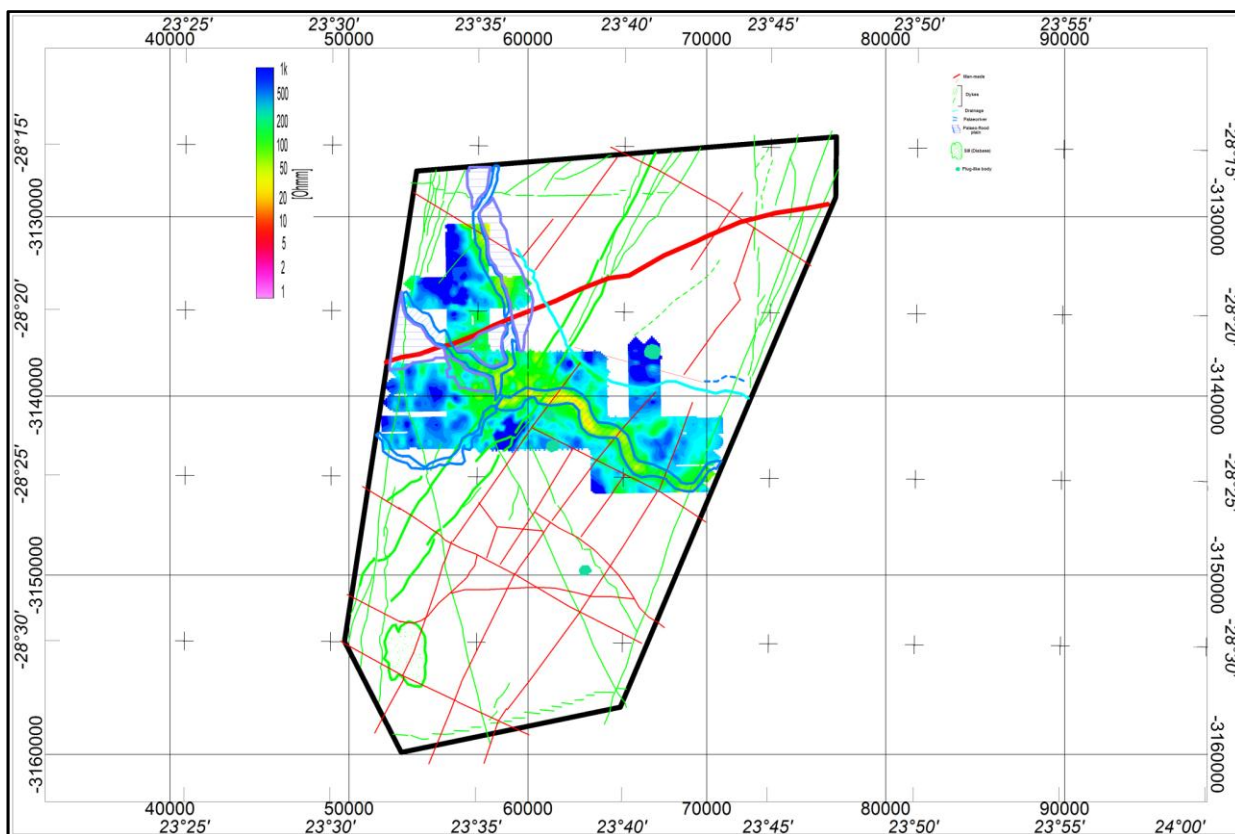


Figure 15: Resistivity Distribution at a Depth interval between 50 and 60m Below Surface



4.5.4 Ground Geophysics - Gravity Survey

The objective of the gravity survey was to investigate karstification in the:

- Subsurface dolomitic aquifer; and
- Define leached areas along dolerite dyke contact zones.

The gravity method measure the gravitational field of the earth at different location over an area of interest, to associate variations in the gravitational field with differences in the distribution of densities of the formation. Such density variations in dolomite terrain are produced by varying thicknesses of unconsolidated deposits over bedrock, and solution cavities in bedrock. The method is effectively applied for locating zones of karstification and infilling by residual debris in dolomite strata.

The survey was conducted along easily accessible fences, tracks and roads as indicated by the fine dotted lines in Figure 16. Figure 16 also depicts the relative Bouguer anomaly map, which indicates a gravity low in the south and a high in the north. This could indicate that the underlying Campbell Rand dolomite thins considerably going from north to south. Shown in Figure 17 are the regional gravity values along the gravity traverses and the residual field which was obtained by subtracting the upward continued (by 500m) relative Bouguer map from the relative Bouguer map.

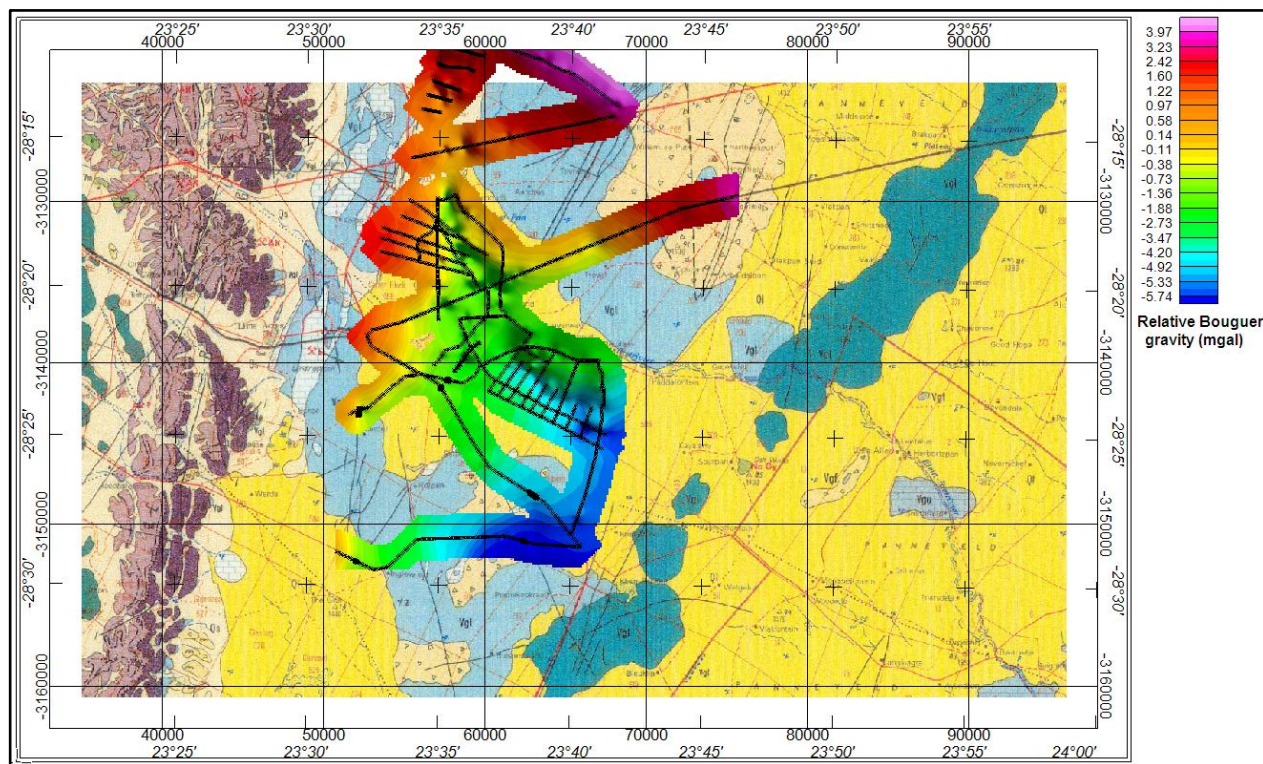


Figure 16: Relative Bouguer Anomaly Map

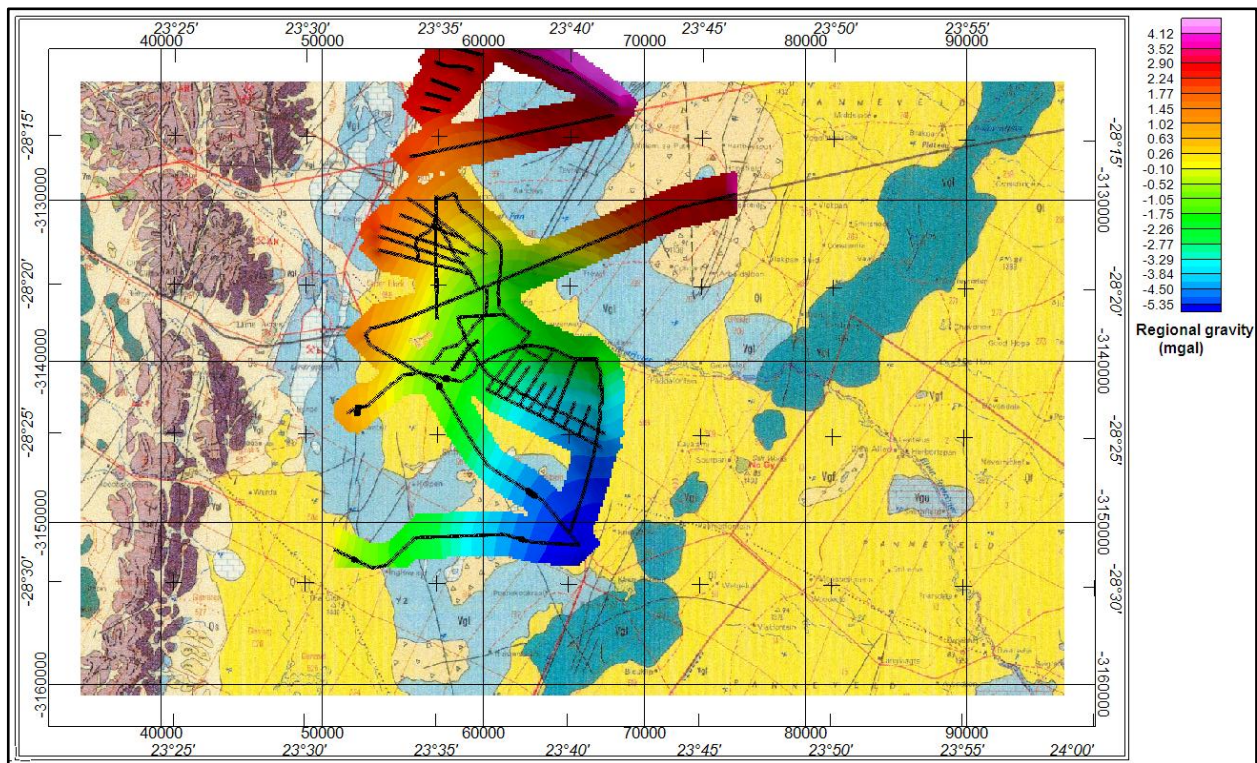


Figure 17: Regional Gravity Map

The residual gravity map is shown in Figure 18 and shows some deep gravity lows, indicating most likely leached out water-filled cavernous zones in the dolomite. The magnetic dykes and lineaments do not correlate clearly with any of the residual gravity anomalies but the residual gravity lows correlate very well with the paleo-river courses.

The advantage of the gravity data is that it indicates possible leached, permeable water-bearing zones and the central gravity lows (blue color) represent fill-in of an old karst area in the dolomite which were exploited by the paleo-rivers. The other deep gravity lows are also to be considered as indicating target areas and are those in the eastern and southern corners of the gravity coverage for SD1. The present day drainage from the northern pan to the eastern boundary of the SD1 survey area follows the gravity low structure (Stettler 2013).

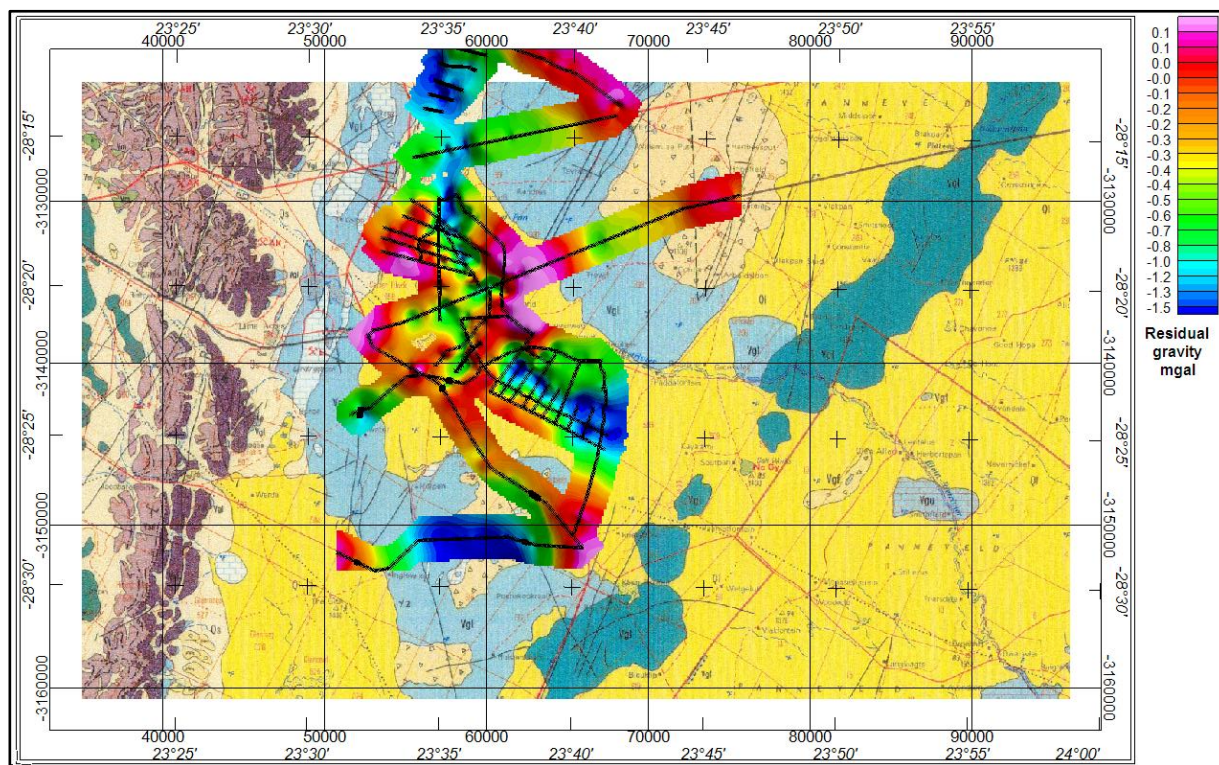


Figure 18: Residual Gravity Map

4.5.5 Geophysical Survey Conclusions

From the collection of three geophysical data sets used namely airborne magnetics and time domain electromagnetic (TDEM) a better understanding of the geology in SD1 was obtained.

The magnetic data indicated that the iron stones of the Danielskuil and Kuruman Formations overlie the dolomite of the Campbell Rand Group and the contact between them is slightly further west, but the drainage shows that the magnetic material from the former form today the paleo-river sediments of today. The magnetic lineaments can be subdivided into 2 groups, NNE-SSW striking ones and NW-SE striking lineaments amongst the dolomites.

The paleo-river sediments are conductive from about 50m downwards to ~100m and this depth extend is also expected to have the best porosity. Above 50m the river sediments are expected to be severely calcretized. The paleo-rivers are also considered the best target for groundwater extraction.

The resistivity data from the TDEM could be used to generate a 3D model showing the structural complexity of the geological units, just based on the resistivity measurements.

The water quality in the paleo-river system is expected to be good.

All three techniques augmented each other and the understanding of the subsurface geology would not have been possible if not all these techniques would have been applied. The TDEM results gave a good indication of the internal make-up of the paleo-river sediments and the depth extent. The gravity results indicate the dolomitic material surrounding the paleo-runs to be decomposed and have an additional storage capacity and the magnetic data set outlined the many dykes and the extend of the magnetic material in the palaeo-runs and pans filled with magnetic sediments (Stettler 2013).



4.5.6 Exploration Drill Sites

The exploration drill sites were selected mainly on the residual gravity data presented on linear graphs. These linear graphs are presented in the appendix volume II of this report. The linear graphs permit an evaluation of residual gravity (mgal) plotted against the terrain elevation. The residual gravity values were also used to delineate the major and minor karstification zones in the SD1 study area.

One drill site was selected hydrogeological (SD1-25) and was a re-drill of a reported high yielding municipality borehole OP058. The geophysical selected drill sites which were drilled are shown in Table 4 as Traverse No/Station No.

The positions of gravity survey traverses with final residual gravity values are indicated on Figure 19.

Examples of linear gravity graphs indicating drill sites, exploration borehole and blow yield are listed as Figure 20 to Figure 24 with the remaining of the graphs listed in the appendices volume II of the report.



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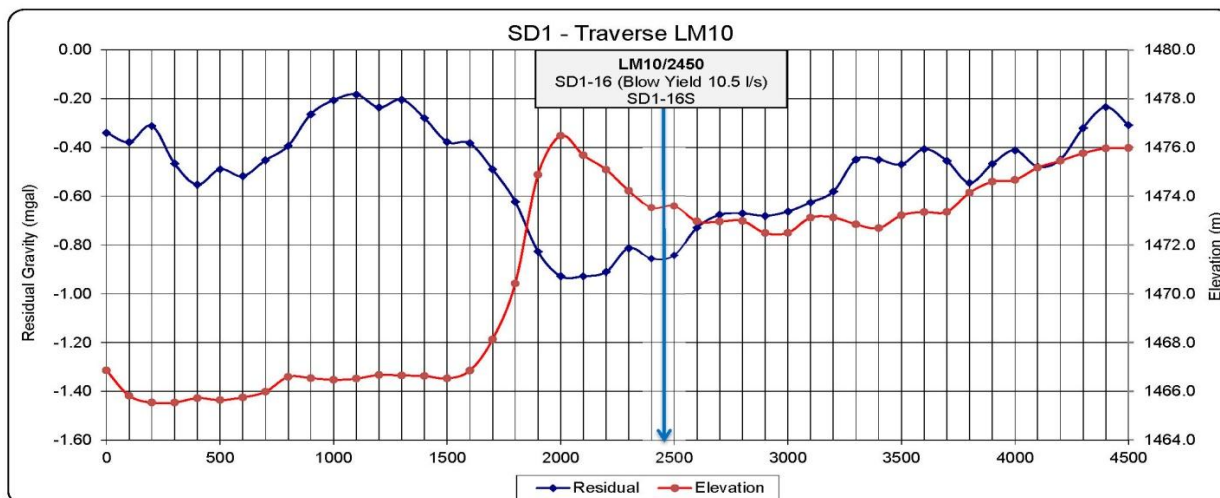


Figure 20: Drill Site LM10/2450 – Borehole SD1-16

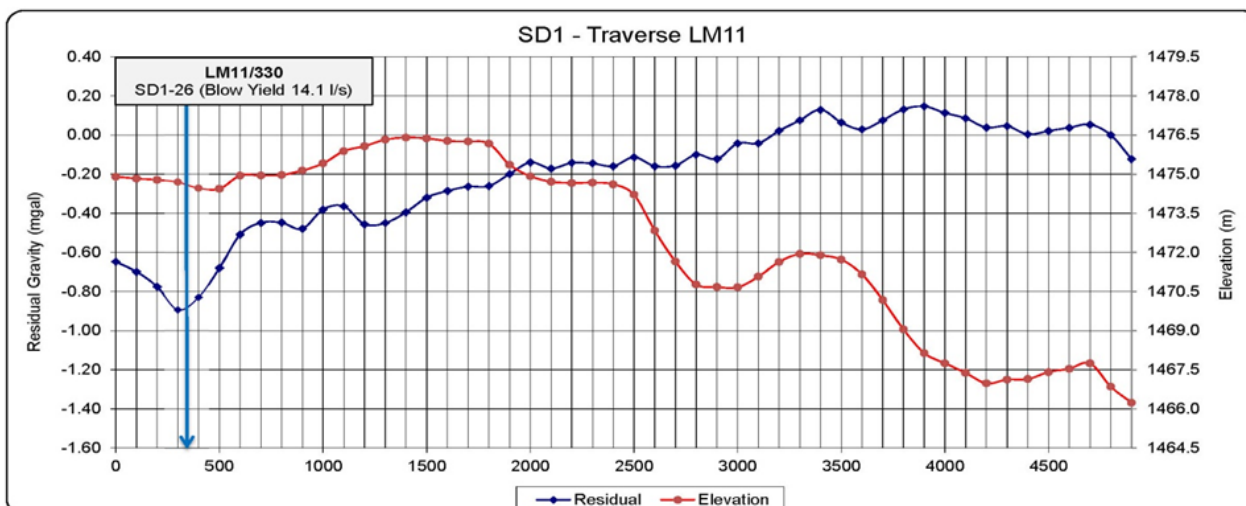


Figure 21: Drill Site LM11/330 – Borehole SD1-26

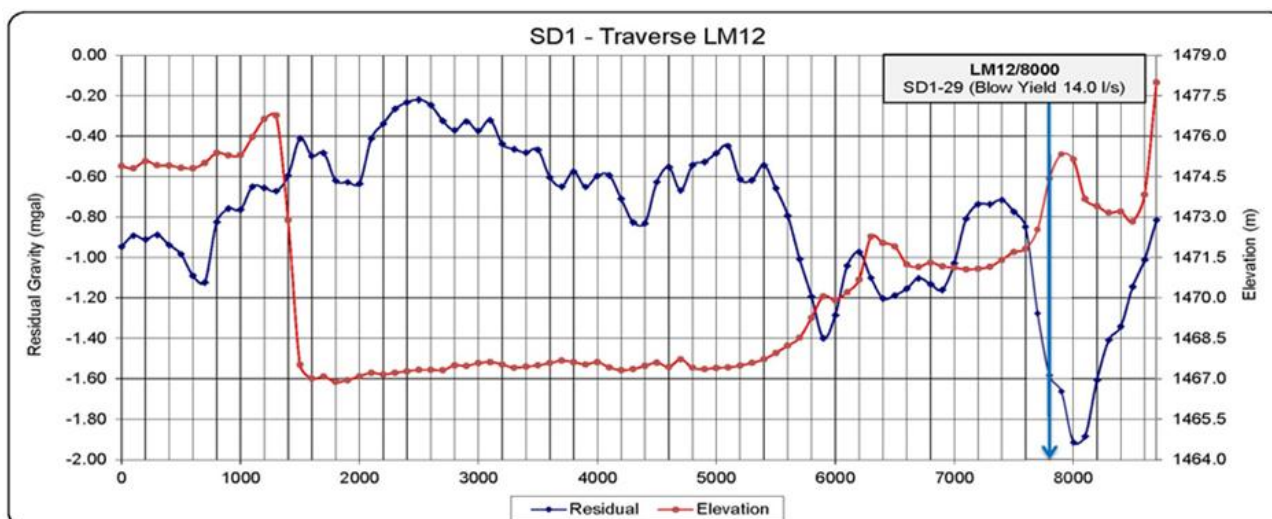


Figure 22: Drill Site LM12/8000 – Borehole SD1-29



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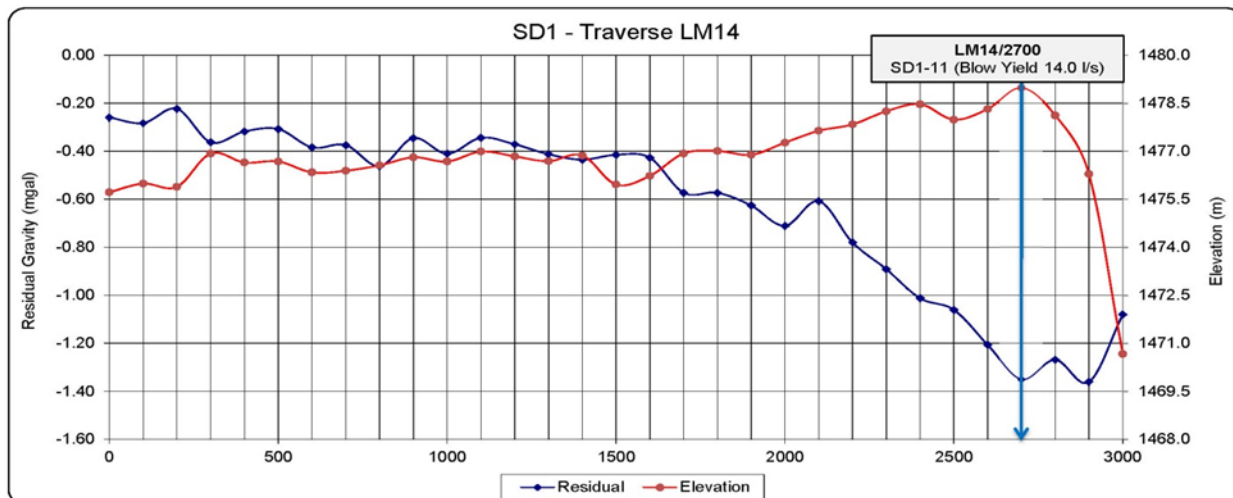


Figure 23: Drill Site LM14/2700 – Borehole SD1-11

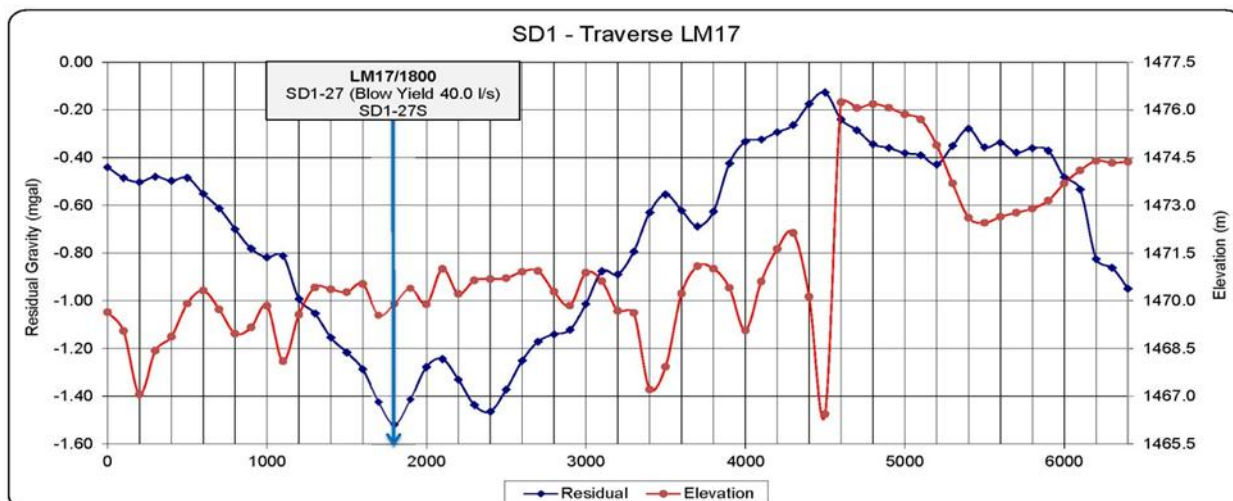


Figure 24: Drill Site LM17/1800 – Borehole SD1-27

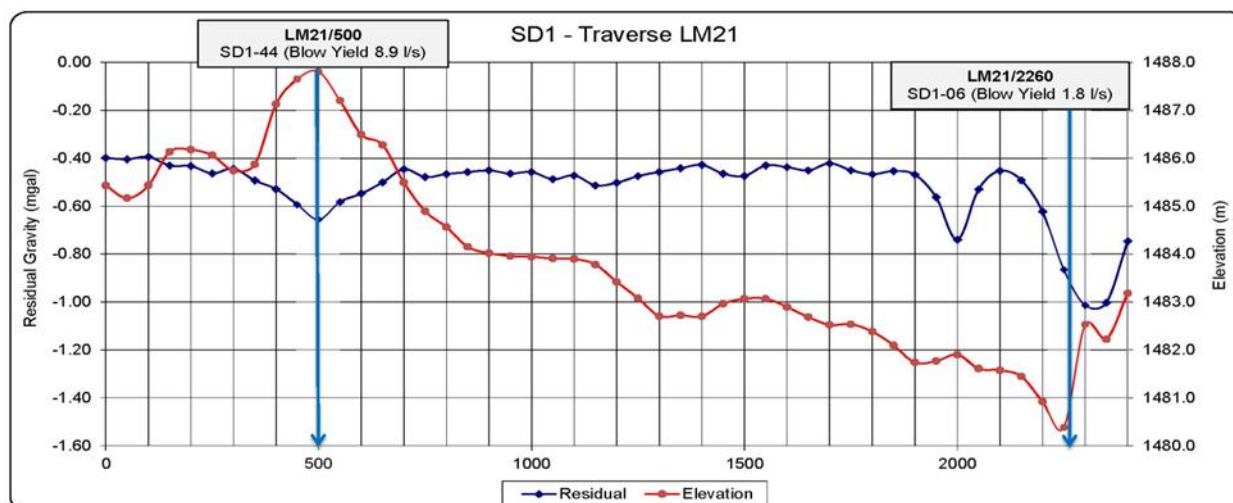


Figure 25: Drill Site LM21/2260 – Borehole SD1-44; Drill Site LM21/2260 – Borehole SD1-06



4.6 Exploration Drilling

The exploration drilling programme started on 25 February 2013 and was completed 18 August 2013 with a total of 53 exploration boreholes installed as indicated on Figure 27. The drilling programme was conducted by Environmental Drilling & Remediation Services (EDRS).

The objective of the exploration drilling was to quantify the sustainable groundwater of the source development area and to determine the feasibility of the source to contribute to the VGG pipeline.

Borehole drilling sites was selected to investigate geological structure and lithology, determine aquifer characteristics, measurement of groundwater levels to determine groundwater flow directions, and to establish potential production and monitoring boreholes.

The boreholes were drilled according to a sustainable yield approach, where boreholes were drilled over the entire major karstification zone of SD1 to minimize draw down of the water level. The exploration borehole drilling depths were controlled by geology, water strike depths and yields. Exploration boreholes with sufficient yields were utilized as possible production ($>10\text{l/s}$) boreholes (Figure 26). This approach is contradictory to a mining approach of de- watering were deep ($>100\text{m}$) production boreholes are concentrated in an area in order to lower/dewater the water table.



Figure 26: Drilling of SD1-08 - BY 38.9l/s

Three monitoring borehole (SD1-17M, SD1-32M, and SD1-40M) were drilled within 20 to 40m distance from high yielding boreholes. The purposes of these monitoring boreholes apart from monitoring facilities are to determine hydraulic parameters of the formation during long term test pumping. These monitoring boreholes were marked using the after-fix "M" after the borehole number (SD1-17M).



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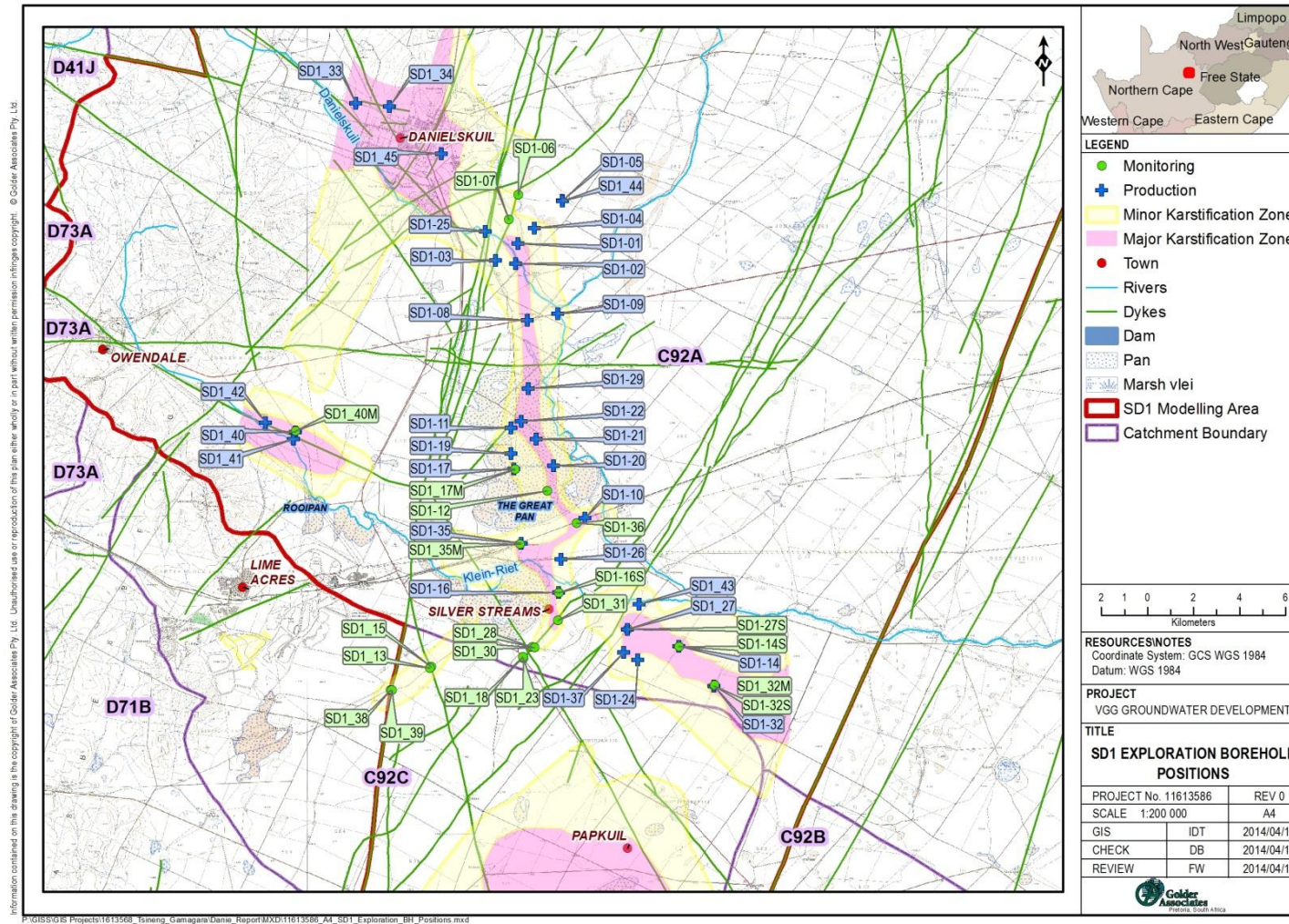


Figure 27: SD1 Exploration Borehole Positions



Four shallow boreholes (SD1-14S, SD1-16S, SD1-27S and SD1-32S) to investigate hydrogeological conditions of the upper Kalahari Aquifer (calcrete) were drilled next to exploration boreholes (Figure 28). The depths of the shallow monitoring boreholes were drilled to below the water level but restricted to the thickness of the calcrete layer (Figure 29). These shallow boreholes were marked using the after-fix "S" after the borehole number (SD1-14S).



Figure 28: SD1-14 and SD1-14S



Figure 29: SD1-16S Calcrete Zone - Samples

The drilling approach entails specialized drilling (large diameter percussion) and construction of monitor/production boreholes in areas underlain by dolomite, banded iron formation and Kalahari sediments.

The new exploration boreholes were drilled by air percussion drilling rigs (Figure 30), using the telescoping drilling approach. The drilling diameters started at 381mm diameter as a maximum and reducing to 305, 254, 203 and 165mm as minimum pending on the geology and water strikes intersected.



The exploration boreholes were cased with steel 4mm thickness steel casings. High yielding boreholes were developed as potential production boreholes en low yielding boreholes were constructed to serve as potential monitoring boreholes.



Figure 30: Drilling SD1 -27

Gravel packs were installed in the annulus between the sides of the borehole and the casing of the borehole to stabilise the geological formation and allow groundwater inflow into the borehole. Bentonite seals of 3m to 5m were installed above the gravel pack at surface. The borehole head works (Figure 31) at surface consists out of a cement collar block, maker pole and the casing was closed with a steel cap which can be opened with a 14 mm Alan key.



Figure 31: SD1-16 Completed Headwork's

Drill cuttings were sampled at 1m intervals (Figure 32) and were used to compile geological borehole logs as listed appendices volume II of the report.



Figure 32: SD1-03 Borehole Drill Samples/Cuttings

Three exploration boreholes (SD1-33 SD1-34 and SD1-45) were allocated to Danielskuil municipality to help fulfil their future municipality water demand. SD1-45 (Figure 33) was drilled to the east of Danielskuil close to Tlhakalatlou settlement.



Figure 33: Drilling of SD1-45 Danielskuil Municipality Supply Borehole

4.6.1 Drilling Results

The drilling results are summarised in Table 4 with details of water strike depths, strike yields and main geology intersected. Detailed borehole construction and geological logs for all boreholes are presented in the appendices volume II of this report.



A total of 53 exploration boreholes were drilled, from which 32 boreholes were constructed as potential production status and 21 as monitoring status.

The drilling results for SD1 are summarised as follows:

- The drilling depth range between 16m shallow calcrete boreholes and 137m (SD1-34) with an average depth of 63.3m;
- Groundwater strikes intersected range between 6m and 110m with an average strike depth of 46m;
- The final blow yield range between 0.2l/s and 62l/s (SD1-25) with an average blow yield of 18.6l/s; and
- The recorded water level range between 2.04m (SD1-21) and 66.8m (SD1-38) with the average water level as 14.04mbgl.

The final blow yield (%) of the exploration boreholes are indicated in Figure 34 and summarised as follows:

- Seepage intersected – 6 exploration boreholes – 11%;
- Yields <10l/s - 13 exploration boreholes – 24%;
- Yields 10l/s to 20 l/s - 22 exploration boreholes – 42%; and
- Yields >20l/s – 12 exploration boreholes –23%.

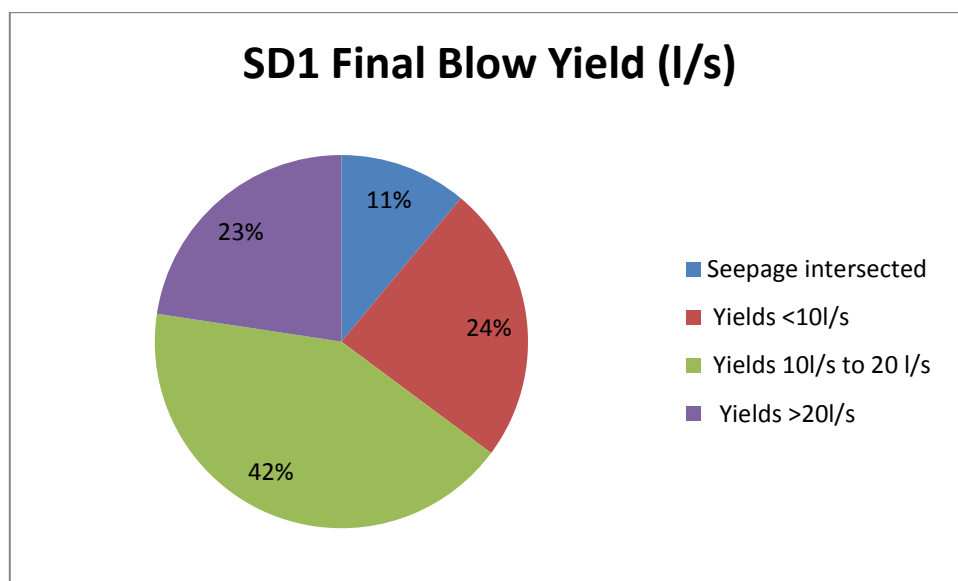


Figure 34: SD1 Final Blow Yield (l/s)

A comparison between drilling depths and yields of existing and new exploration boreholes are listed in Table 2. The comparison shows that the average borehole depth of the existing boreholes are relatively shallow and is mostly confined to the Kalahari sediments in some areas.



Table 2: SD1 Comparison of Existing and Exploration Borehole

Average	Existing Boreholes	New Exploration Boreholes
Drilling Depth (m)	38.7	63.3
Yield (l/s)	3.3	18.6
Water Strike Depth (m)	-	45.9

4.6.2 Land Owners Included by SD1 Drilling Programme

The Landowners included by the drilling programme in SD1 area, on whose farms exploration drilling was conducted are summarised in Table 3 and indicated on Figure 35.

Table 3: Land Owners Included by Drilling Programme in SD1

Land Owner	Farm Name	Number BH	Production Status	Monitoring Status
Danielskuil Municipality	Danielskuil Supply BH's	3	3	0
Danielskuil Municipality	Danielskuil Allotment	9	7	2
PPC	Carter Block 458 Ptn. Kolbe	4	3	1
Kokkie York	Rooipan 507 Ptn. Olienspruit	9	5	4
Kokkie York/Killian	Carter Block 458 Ptn. Dikbos	6	4	2
Lena Kok/Community	Carter Block 458	8	6	2
Daan Van Deventer	Farm 301	1	0	1
Lennox Cloete	Excelsior 302	1	1	0
	Hinton George 303	1	1	0
	Carter Block 458	2	1	1
Wynand De Jager	Carter Block 458	7	0	7
Hannes Meyer	Carter Block 458	2	0	2
Total		53	31	22



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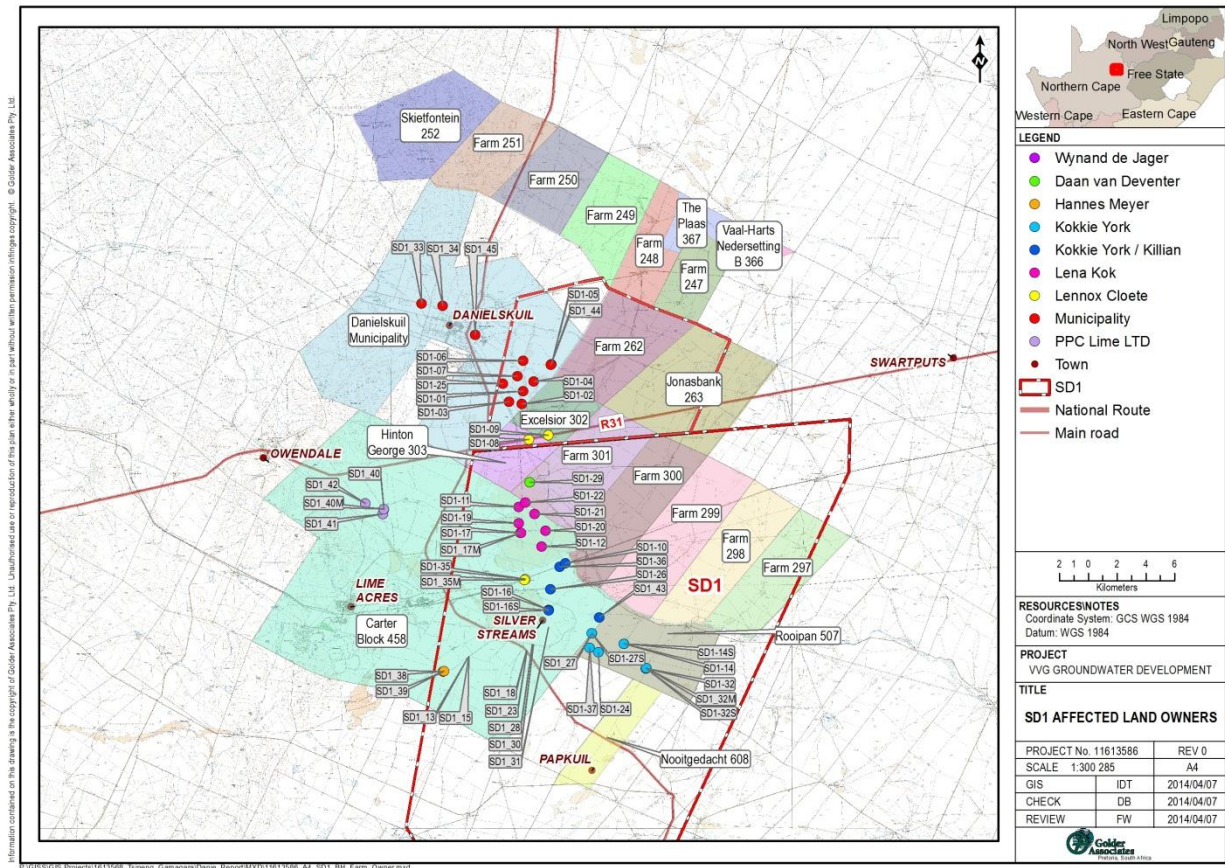


Figure 35: SD1 Land Owners Included by Exploration Drilling Programme

4.6.3 Survey of Exploration Boreholes

Exploration boreholes, fountains and some existing boreholes with known water levels, altitudes and coordinates were surveyed during 2013 by Hart Mart 3 using a differential GPS system. The differential GPS system ties in to the national trig beacons network.

The borehole coordinates and altitudes were measured to an accuracy of approximately 20mm. These accurate borehole altitudes are important for compiling detailed groundwater piezometric contour maps, to determine groundwater flow directions and delineation of different compartments in dolomitic aquifers.

4.6.4 Kalahari Sediment Delineation

The boreholes logs of the exploration boreholes were used to delineate and contour the thickness of the Kalahari sediments (calcrete and clay) as indicated on Figure 36. These sediments thickness range up to 60m below surface, have a low permeability, retards and restrict groundwater movement and acts as storage unit. These delineated Kalahari sediment thicknesses correlate closely with the residual gravity values outlining areas of low formation density.



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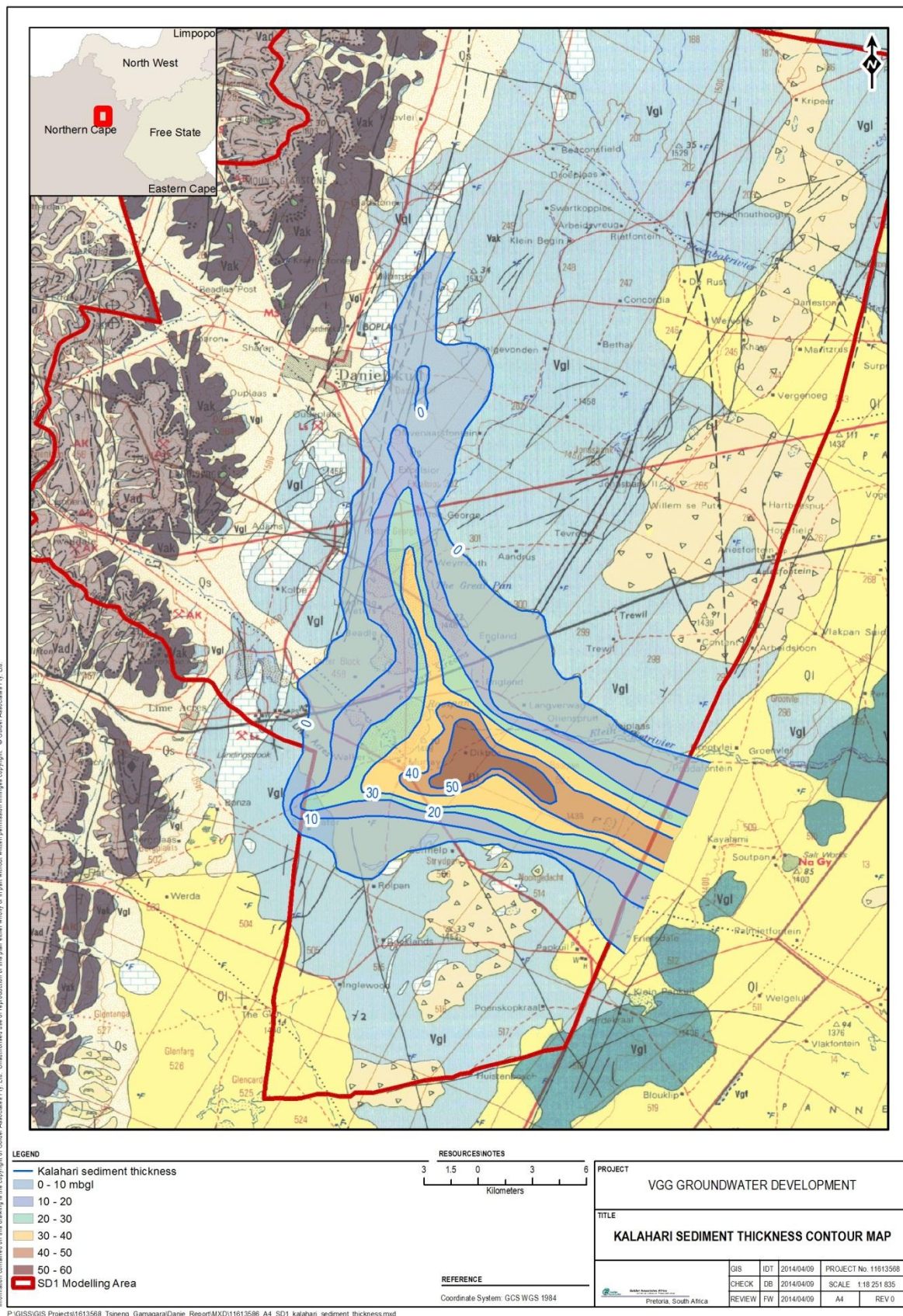


Figure 36: Kalahari Sediment Thickness



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Table 4: Summarised Drilling Results

Borehole Number	Farm Name	Land Owner	Latitude	Longitude	Altitude (mamsl)	Traverse No/Station No	Drilling Depth (m)	Casing Depth (m)	Final Diam. (mm)	Water Strike (m)	Water strike (l/s)	Final Blow yield (l/s)	Measured WL (mbgl)	Measured WL (mamsl)	Aquifer Type Geological Formation	Date Completed	BH Status
SD1-01	DANIELSKUIL	Danielskuil Municipality	-28.22787	23.58190	1447.07	LM23/775	82	58	165	27;44;52-58	8,0; 2; 17	12.50	10.62	1436.45	Fractured Dolomite at contact with dolerite	07/03/2013	Production
SD1-02	DANIELSKUIL	Danielskuil Municipality	-28.23577	23.58102	1445.68	LM24/170	30	30	165	18;28	0.2; >10	20.00	9.89	1435.79	Fractured Dolomitic-limestone	07/03/2013	Production
SD1-03	DANIELSKUIL	Danielskuil Municipality	-28.23446	23.57317	1448.1	LM24/950	80	80	203	18,70	7.6,1	12.00	12.03	1436.07	Fractured Dolomitic-limestone	21/02/2013	Production
SD1-04	DANIELSKUIL	Danielskuil Municipality	-28.22185	23.58840	1448.99	LM22/700	61	42	203	19	18.0	18.00	11.58	1437.41	Fractured Dolomitic-limestone	18/03/2013	Production
SD1-05	DANIELSKUIL	Danielskuil Municipality	-28.21119	23.59939	1457.23	LM21/500	40	31	165	20-27	2.0	20.00	17.25	1439.98	Fractured Dolomitic-limestone	25/03/2013	Production
SD1-06	DANIELSKUIL	Danielskuil Municipality	-28.20901	23.58192	1449.8	LM21/2260	70	25	203	22	1.8	1.8	11.70	1438.10	Fractured Dolomitic-limestone	23/03/2013	Monitoring
SD1-07	DANIELSKUIL	Danielskuil Municipality	-28.21856	23.57834	1450.11	LM22/1750	50	24	165	Seepage(30-36)	Seepage	0.1	12.98	1437.13	Fractured Dolomitic-limestone	22/03/2013	Monitoring
SD1-08	HINTON GEORGE	Lennox Cloete	-28.25789	23.58555	1449.15	L17/2100	40	36	254	22;27-31	8;30	38.90	13.68	1435.47	Fractured Dolomitic-limestone	25/04/2013	Production
SD1-09	CARTER BLOCK	Lennox Cloete	-28.25527	23.59748	1444.01	L17/3300	40	36	203	10-19;32-36	25;13	38.00	6.84	1435.48	Fractured Dolomitic-limestone	16/04/2013	Production
SD1-10	CARTER BLOCK	Kokkie York/Killian	-28.33522	23.60812	1444.5	LM15/5100	28	28	254	22;25-28	0.1;20	20.00	11.92	1432.09	Fractured BIF	29/05/2013	Production
SD1-11	CARTER BLOCK	Lena Kok	-28.29988	23.57918	1435.9	LM14/2700	70	61	165	43;67-70	3.8;10.2	14.00	13.44	1432.93	Fractured Dolomitic-limestone	07/04/2013	Production
SD1-12	CARTER BLOCK	Lena Kok	-28.32459	23.59331	1442.51	LM13/4900	112	36	254	19	4.0	5.9	3.27	1432.63	Fractured Dolomitic-limestone	29/04/2013	Monitoring
SD1-13	ROOIPAN	Wynand De Jager	-28.39381	23.54737	1437.63	LM2/2500	60	60	165	49	4.4	5.00	18.31	1424.20	Fractured Dolomitic-limestone	04/07/2013	Monitoring
SD1-14	ROOIPAN	Kokkie York	-28.38532	23.64480	1437.54	LM9/1900	67	67	254	56	14.0	14.00	13.11	1424.52	Fractured BIF	26/05/2013	Production
SD1-14S	CARTER BLOCK	Kokkie York	-28.38538	23.64476	1443.08	LM9/1900	18	18	165	Seepage	Seepage	Seepage	12.64	1424.90	Calcrete	23/05/2013	Monitoring
SD1-15	LIME ACRES	Wynand De Jager	-28.39334	23.54794	1441.14	LM2/2600	64	64	165	36	1.6	1.60	18.74	1424.34	Calrete dolerite contact	22/06/2013	Monitoring
SD1-16	LIME ACRES	Kokkie York/Killian	-28.36428	23.59780	1441.14	LM10/2450	69	59	165	23;40;53-55	0.1;2;10	10.50	9.61	1431.53	BIF/ Fractured Dolomitic-limestone	24/05/2013	Production
SD1-16S	CARTER BLOCK	Kokkie York/Killian	-28.36441	23.59788	1435.15	LM10/2450	16	16	165	Seepage	Seepage	Seepage	9.67	1431.47	Calcrete	24/05/2013	Monitoring
SD1-17	CARTER BLOCK	Lena Kok	-28.31607	23.58026	1436.9	T1/3600	58	53	203	40;52	10;>20	50.00	2.29	1432.86	Fractured Dolomitic-limestone	25/04/2013	Production
SD1-17M	CARTER BLOCK	Lena Kok	-28.31614	23.58062	1443.18	T1/3640	24	24	165	17;21	6.6;5	10.00	2.32	1432.83	Fractured Dolomitic-limestone	18/08/2013	Monitoring
SD1-18	CARTER BLOCK	Lena Kok	-28.38957	23.58370	1443.18	TB4/0	72	72	165	29;50	0.1;0.1	0.20	16.22	1426.96	Fractured Dolomitic-limestone	19/06/2013	Monitoring
SD1-19	CARTER BLOCK	Lena Kok	-28.31002	23.57928	1434.82	T2/3300	40	34	203	13-31	>20	20.00	2.4	1432.42	Fractured Dolomitic-limestone	15/04/2013	Production
SD1-20	CARTER BLOCK	Lena Kok	-28.31478	23.59588	1435	T2/5050	48	48	203	6;19;32;44-47	0.1;2;2;>20	33.00	2.2	1432.80	Fractured BIF and Dolomitic-limestone	01/05/2013	Production
SD1-21	CARTER BLOCK	Lena Kok	-28.30433	23.58906	1434.86	T3/3200	103	90	165	21;73;101-103	2;5.2;25.8	33.00	2.04	1432.82	Fractured BIF and Dolomitic-limestone	12/04/2013	Production
SD1-22	CARTER BLOCK	Lena Kok	-28.29738	23.58331	1435.87	T4/2400	49	49	203	19;38;46	3;7;10	20.00	2.93	1432.94	Fractured BIF and Dolomitic-limestone	26/04/2013	Production
SD1-23	CARTER BLOCK	Lena Kok	-28.39005	23.58404	1442.91	TB4/60	76	76	165	Seepage	Seepage	Seepage	18.07	1424.84	Calcrete/ Fractured BIF - Dolomitic-limestone	17/06/2013	Monitoring
SD1-24	ROOIPAN	Kokkie York	-28.39055	23.62879	1437.27	LM5/5620	68	68	203	67	>25	34.00	12.7	1424.57	Calcrete/ Fractured Dolomitic-limestone	02/06/2013	Production
SD1-25	DANIELSKUIL	Danielskuil Municipality	-28.22309	23.56914	1446.64	Redrill/OP058	51	52	203	49	>50	62.00	7.02	1439.62	Fractured Dolomitic-limestone	29/04/2013	Production
SD1-26	LIME ACRES	Kokkie York/Killian	-28.35129	23.59879	1441.82	LM11/330	69	61	203	38-39;56-58;66-69	1;3;8	14.10	10.41	1431.41	Calcrete/ Fractured BIF - Dolomitic-limestone	28/05/2013	Production
SD1-27	CARTER BLOCK	Kokkie York	-28.37868	23.62470	1437.42	LM17/1800	104	104	203	85;101	11;>25	40.00	12.93	1424.49	Calcrete/ Fractured Dolomitic-limestone	15/06/2013	Production
SD1-27S	ROOIPAN	Kokkie York	-28.37873	23.62472	1437.38	LM17/1800	18	18	165	Seepage	Seepage	Seepage	12.08	1425.30	Calcrete	02/05/2013	Monitoring
SD1-28	CARTER BLOCK	Wynand De Jager	-28.38563	23.58745	1444.43	TG3/30	64	56	165	34;52	0.2;2.0	2.00	14.15	1430.28	Calcrete/ Fractured Dolomite at dolerite contact	15/06/2013	Monitoring
SD1-29	FARM 301	Daan van Deventer	-28.28456	23.58589	1442.75	LM12/8000	68	68	165	16;63-68	4;>10	14.00	9.61	1433.14	Fractured BIF and Dolomitic-limestone	05/04/2013	Production
SD1-30	CARTER BLOCK	Wynand De Jager	-28.38575	23.58834	1444.45	TG3/120	71	71	165	40	0.8	0.80	17.42	1427.03	Calcrete/ Fractured Dolomitic-limestone	14/06/2013	Monitoring
SD1-31	CARTER BLOCK	Wynand De Jager	-28.37524	23.59744	1444.41	TL4/150	120	72	203	23	0.1	0.83	13.06	1431.35	Calcrete/ Fractured Dolomitic-limestone	21/06/2013	Monitoring



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Borehole Number	Farm Name	Land Owner	Latitude	Longitude	Altitude (mamsl)	Traverse No/Station No	Drilling Depth (m)	Casing Depth (m)	Final Diam. (mm)	Water Strike (m)	Water strike (l/s)	Final Blow yield (l/s)	Measured WL (mbgl)	Measured WL (mamsl)	Aquifer Type Geological Formation	Date Completed	BH Status
SD1-32	ROOIPAN	Kokkie York	-28.40082	23.65853	1436.43	LM8/1000	73	73	203	71-73	>25	36.00	12.65	1423.78	Calcrete/ Fractured Dolomitic-limestone	31/05/2013	Production
SD1-32S	ROOIPAN	Kokkie York	-28.40079	23.65846	1435.9	LM8/1000	16	16	165	Seepage	Seepage	Seepage	14.12	1422.47	Calcrete	27/05/2013	Monitoring
SD1-32M	ROOIPAN	Kokkie York	-28.40039	23.65872	1436.59	LM8/1040	72	72	165	16-17;70-71	0.1;10	10.00	12.19	1423.71	Calcrete/ Fractured Dolomitic-limestone	25/07/2013	Monitoring
SD1-33	DANIELSKUIL	Danielskuil Municipality	-28.17310	23.51860	1494.17	D1/2530	74	74	203	33;73-78	0.2;>10	18.00	26.12	1468.05	Fractured BIF and Dolomitic-limestone	08/07/2013	Production
SD1-34	DANIELSKUIL	Danielskuil Municipality	-28.17447	23.53161	1493.4	D2/2850	137	137	203	60;97	6;2	17.00	25.59	1467.81	Fractured BIF and Dolomitic-limestone	23/06/2013	Production
SD1-35	CARTER BLOCK	Lennox Cloete	-28.34501	23.58328	1442.33	LM4/5000	28	28	254	16;22;26	0.2;2;>20	34.00	9.58	1432.75	Calcrete/ Fractured Dolomitic-limestone	01/05/2013	Production
SD1-35M	CARTER BLOCK	Lennox Cloete	-28.34544	23.58276	1442.16	LM4/4960	30	30	165	27	>20	10.00	9.68	1432.48	Calcrete/ Fractured Dolomitic-limestone	29/07/2013	Monitoring
SD1-36	LIME ACRES	Kokkie York/Killian	-28.33717	23.60471	1443.95	LM4/7350	88	36	254	28	2.0	2.00	11.92	1432.03	Calcrete/ Fractured Dolomitic-limestone	25/05/2013	Monitoring
SD1-37	ROOIPAN	Kokkie York	-28.38772	23.62333	1436.74	LM5/5000	81	81	203	81	20.0	20.00	12.27	1424.47	Calcrete/ Fractured Dolomitic-limestone	02/06/2013	Production
SD1-38	CARTER BLOCK	Hannes Meyer	-28.40251	23.53199	1443.05	TC08/60	70	70	165	Seepage	Seepage	Seepage	66.82	1376.23	Calcrete at contact at dolerite	05/07/2013	Monitoring
SD1-39	CARTER BLOCK	Hannes Meyer	-28.40240	23.53262	1442.98	TC08/120	72	72	165	41	1	1.00	20.77	1422.21	Fractured Dolomitic-limestone	06/07/2013	Monitoring
SD1-40	CARTER BLOCK	PPC	-28.30157	23.49494	1468.72	D9/1850	97	93	165	52;60-61	2;4	10.00	30.24	1438.48	Fractured BIF	15/07/2013	Production
SD1-40M	CARTER BLOCK	PPC	-28.30125	23.49500	1467.00	D9/1810	100	64	165	51;61	0.4;0.4	0.90	30.05	1438.67	Fractured BIF	04/08/2013	Monitoring
SD1-41	CARTER BLOCK	PPC	-28.30427	23.49428	1467.44	D9/1550	97	91	203	73-91	12	16.00	43.43	1423.46	Fractured BIF and Dolomitic-limestone	15/07/2013	Production
SD1-42	CARTER BLOCK	PPC	-28.29786	23.48335	1477.226	D8/2050	112	110	165	70-71;107-110	2;10	10.00	53.46	1423.77	Fractured BIF and Dolomitic-limestone	11/08/2013	Production
SD1-43	CARTER BLOCK	Kokkie York/Killian	-28.36883	23.62928	1437.83	LM2/11900	64	64	203	23;60	0.2;22	23.00	14.81	1423.02	Calcrete/ Fractured Dolomitic-limestone	15/06/2013	Production
SD1-44	DANIELSKUIL	Danielskuil Municipality	-28.21134	23.59929	1457.283	LM21/500	34	29	203	24-29	>10	8.90	17.83	1439.45	Fractured Dolomitic-limestone	27/07/2013	Production
SD1-45	DANIELSKUIL	Danielskuil Municipality	-28.19284	23.55202	1453.9	LM23/775	44	44	203	25;35;38-42	2.5;20;20	41.00	12.82	1434.25	Fractured Dolomitic-limestone	03/07/2013	Production
Min						-	16	16	-	6	0.1	0.2	2.04	1376.23	-	-	32 Production
Max						-	137	137	-	110	50	62	66.8	1468.05	-	-	21 Monitoring
Average						-	63.3	56.1	-	45.9	8.9	18.6	14.04	1431.19	-	-	53 Total



4.7 Aquifer Testing

Aquifer testing was performed on 32 existing boreholes (Figure 38) and 38 newly drilled exploration boreholes (Figure 39). The testing programme in SD1 area was completed 10 September 2013.

The aquifer testing programme was conducted by AB Pumps testing contractor using a positive displacement pump (Figure 37) under the supervision of a Golder's hydrogeologist. The objective of the aquifer testing at SD1 was to:

- To gain an understanding of the distribution of groundwater in the study area;
- To determine aquifer parameters;
- To define the distribution of aquifers;
- To determine sustainable borehole yields;
- To help in construction of conceptual model; and
- To be used as inputs into the numerical flow and transport model.



Figure 37: Aquifer Testing SD1-27

The aquifer testing programme consists out of a step drawdown/discharge test (SDT) followed by a constant discharge test (CDT), and a water level recovery test. Each SDT comprised three to four 60-minute steps at increasing pumping rates. The aim of the SDT is to assess the performance of the borehole under different pumping yields and determine the pumping rate for the CDT.

The CDT is conducted to determine the hydraulic parameters of the aquifer and identify possible aquifer boundaries. The CDT at the exploration boreholes were conducted for periods of between 24 and 72 hours, after which the water level recovery was measured. The CDT pumping rates were set at yields determined from the SDT to be sustainable for the planned duration of the test.

Pumping rates varied from 0.1 l/s to 30.0 l/s (Figure 40). Water-level recovery measurements were taken for the same period as pumping during the SDT and CDT or to 100% recovery of the original water level. The recovery of the boreholes provides an independent measure of the Transmissivity of the aquifer.

Water levels were monitored in adjacent boreholes during the CDT to determine if there is connectivity between the boreholes.



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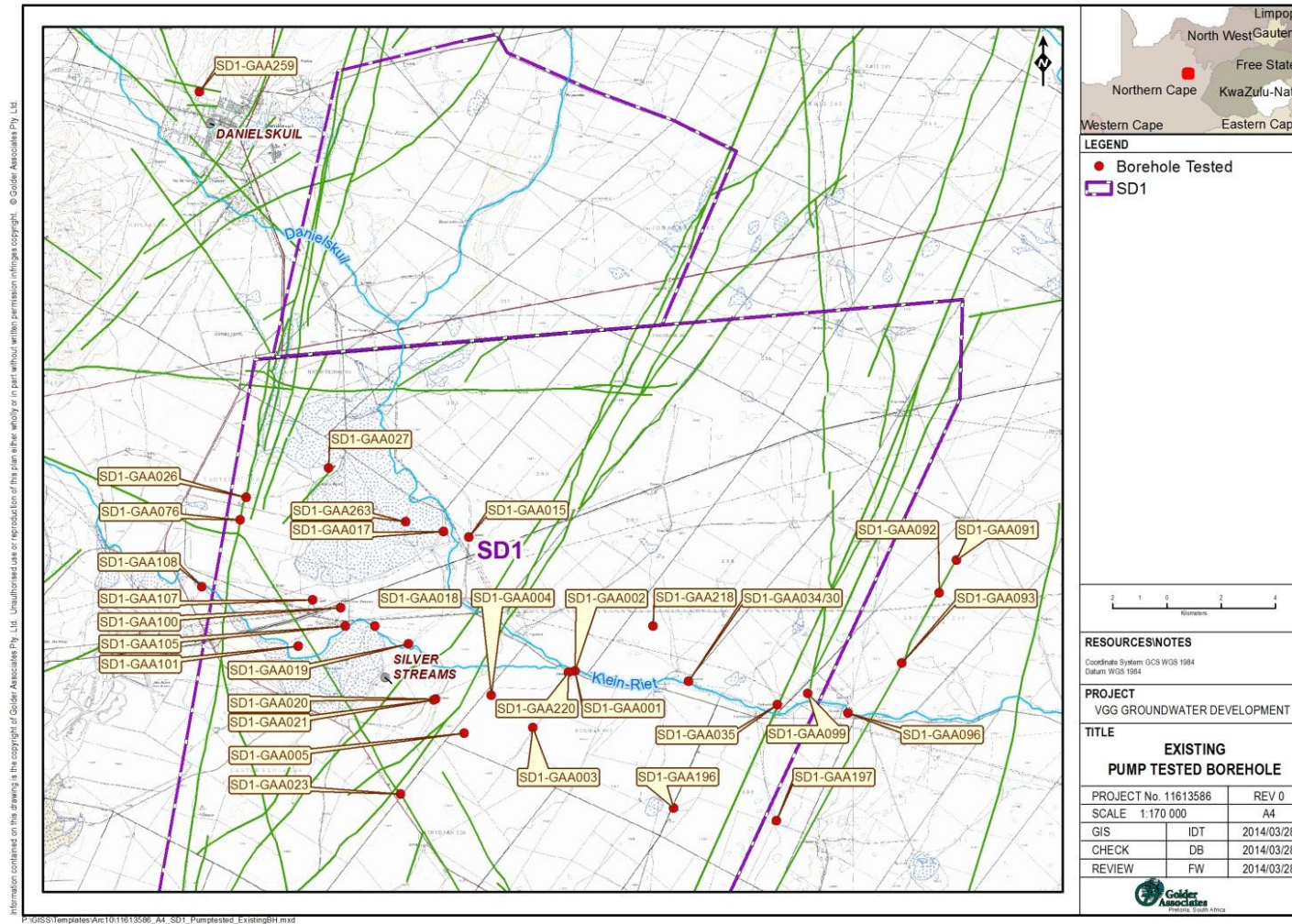


Figure 38: Position of Existing Test Pumped Boreholes



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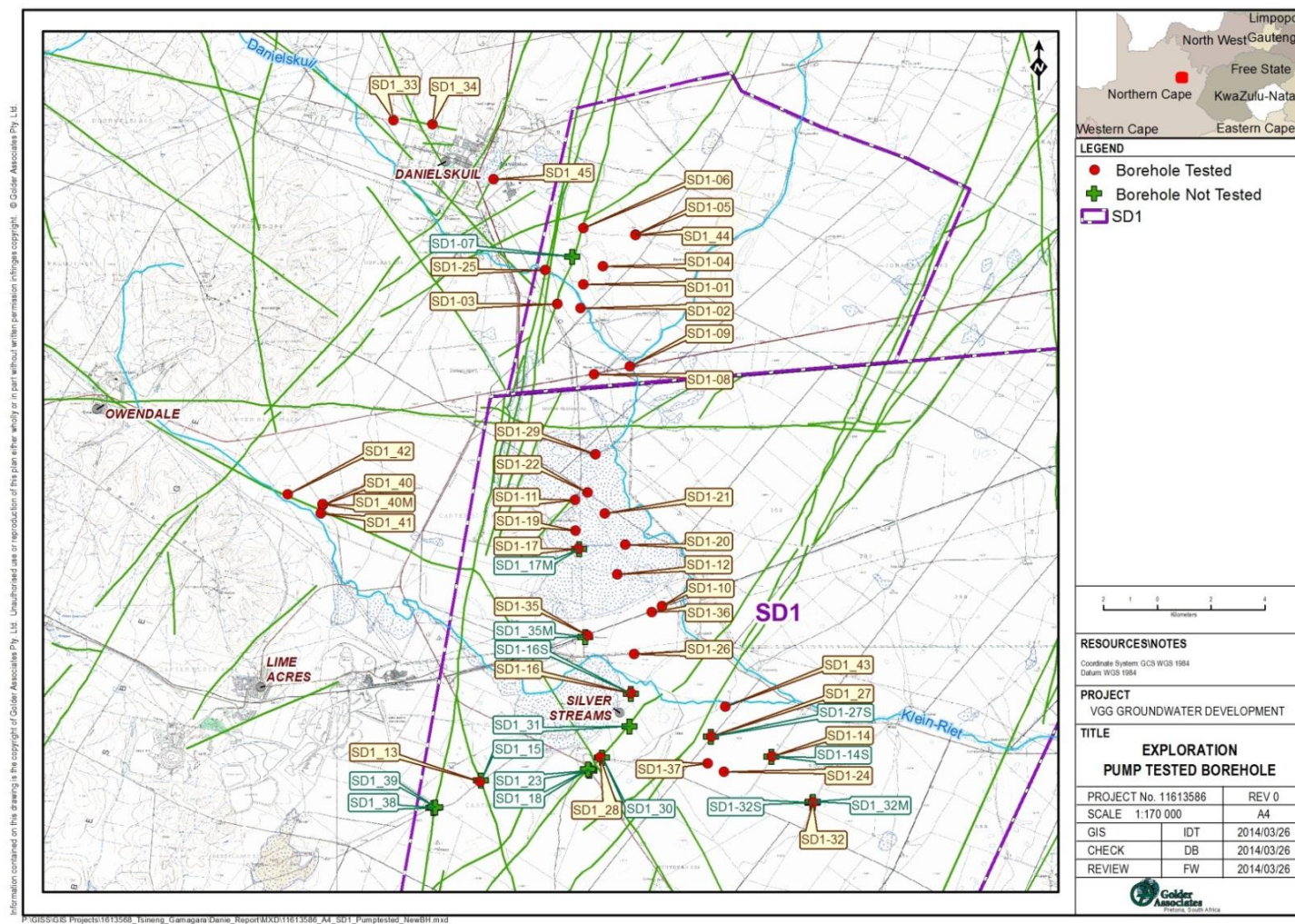


Figure 39: Position of Exploration Test Pumped Boreholes



At low yielding boreholes only a SDT was conducted. Falling head testing was conducted at the four shallow calcrete boreholes. During the SDT's if the last discharge rate reached pump inlet the yield at pump-inlet was measured.

In the case of existing boreholes with limited yield a calibration test (Cal) comprising 4 to 5, 15 minute, steps was carried out.

The number of aquifer test pumping completed for SD1 Area is summarized Table 5.

Table 5: Summarised Aquifer Tests Completed at SD1

Total BH's Tested	No. SDT Only	No. SDT and CDT	CDT Pumping Time (Hours)	CDT Yield (l/s)
Existing Boreholes				
32	15	17	1 to 24	0.53 to 9.05
New Exploration Boreholes				
38	4	34	24 to 72	2.4 to 30.2



Figure 40: Aquifer Testing of Existing Borehole SD1-GAA001

The test pumping programme of existing and exploration boreholes are summarised in Table 6. The positions of existing boreholes tested are indicated in Figure 38 and the positions the exploration boreholes tested is indicated in Figure 39.

The aquifer testing pumping graphs are listed in the appendix volume II of the report.

Test pumping yields were measured volumetrically as indicated in Figure 41.



Figure 41: Volumetric Measurement of Yield SD1-32 (30l/s)



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Table 6: SD1 Summarised Test Pumping Programme

Borehole Number	Borehole Coordinates		Borehole Information			Pump Testing Details								
	Latitude	Longitude	Completion Date	Borehole Depth (m)	Static Water level (mbgl)	Pump Installation Depth (m)	No of SDT's	PI Yield (l/s)	Final Yield of SDT	Duration of CDT (Min)	Yield of CDT (l/s)	CDT Drawdown (m)	WL Recovery (m)	WL Recovery (Min)
Existing Boreholes														
SD1-GAA001	-28.36874	23.65721	28/09/2012	50.39	10.64	48	4	Not Reached	6.98	60	6.03	6.98	0	3
SD1-GAA002	-28.36866	23.65719	01/10/2012	52.48	9.78	48	3	-	4.33	No CDT	-	0.17	0	40
SD1-GAA003	-28.38748	23.64321	02/10/2012	43.13	12.56	41.5	1	0.24	0.52	No CDT	-	-	0	50
SD1-GAA004	-28.37671	23.62931	01/10/2012	16.24	11.84	14.8	Cal Test	0.12	0.53	No CDT	-	-	0	50
SD1-GAA005	-28.38934	23.62031	30/09/2012	38.31	17.71	35.8	4	4.02	5.22	720	3.03	5.22	0	3
SD1-GAA015	-28.32417	23.62187	04/10/2012	31.6	11.7	29.5	1	0.27	0.55	No CDT	-	-	0	-
SD1-GAA017	-28.32231	23.61353	03/10/2012	23	13.71	20.5	1	0.25	0.55	No CDT	-	-	0	-
SD1-GAA018	-28.35382	23.59059	05/10/2012	30.1	7.15	29.5	1	0.42	0.51	No CDT	-	-	0	-
SD1-GAA019	-28.35966	23.60185	02/10/2012	29	14.29	26.1	3	1.38	1.5	720	0.51	16.54	2.35	3
SD1-GAA020	-28.37794	23.61085	05/10/2012	37.33	2.09	32.8	Cal Test 4	0.54	1.23	No CDT	-	-	0	-
SD1-GAA021	-28.37837	23.61022	03/10/2012	25.82	2.6	23.8	3	1.68	2	720	1.25	3.96	0.02	12
SD1-GAA023	-28.40951	23.59912	06/10/2012	37.48	2.91	32.8	2	0.63	1.05	720	0.54	8.69	0.46	12
SD1-GAA026	-28.31103	23.54790	22/10/2012	36.35	3.36	32.8	2	0.69	1	No CDT		16.75	0.1	1.33
SD1-GAA027	-28.30131	23.57529	23/10/2012	75.2	2.46	72	4	Not Reached	6.3	720	6.21	0.24	0	5
SD1-GAA034	-28.3721	23.6949	18/10/2012	33	3.3	30	4	1.73	3.03	720	1.3	5.25	0.27	12
SD1-GAA035	-28.37980	23.72443	16/10/2012	9.83	10.22	9	4	Not Reached	6.24	960	6.05	0.31	0	2
SD1-GAA076	-28.31857	23.54597	23/10/2012	24.3	7.36	23.8	3	Not Reached	10.65	720	9.05	3.11	0.09	12
SD1-GAA091	-28.33180	23.78396	15/10/2012	30.15	9.58	27	1	0.38	0.52	No CDT	-	22.61	0.2	1
SD1-GAA092	-28.34273	23.77807	13/10/2012	14.2	11.92	12	2	0.56	0.71	No CDT	-	-	-	-
SD1-GAA093	-28.36610	23.76570	13/10/2012	17.12	9.61	14.8	4	Not Reached	9.43	1440	8.01	2.59	0	4
SD1-GAA096	-28.38259	23.74786	08/10/2012	28.04	10	26.8	3	2.63	4.05	720	1.8	0.78	0	5
SD1-GAA099	-28.37610	23.73451	11/10/2012	35.6	13.55	32.1	2	0.55	1	258	0.45	27.42	0.25	5
SD1-GAA101	-28.36046	23.56518	17/10/2012	23.65	11.92	23.1	1	0.12	0.5	No CDT	-	5.34	0.08	1
SD1-GAA105	-28.35374	23.58079	18/10/2012	56.04	13.06	50.8	4	1.97	3.14	720	1.41	9.74	0.46	12



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Borehole Number	Borehole Coordinates		Borehole Information			Pump Testing Details								
	Latitude	Longitude	Completion Date	Borehole Depth (m)	Static Water level (mbgl)	Pump Installation Depth (m)	No of SDT's	PI Yield (l/s)	Final Yield of SDT	Duration of CDT (Min)	Yield of CDT (l/s)	CDT Drawdown (m)	WL Recovery (m)	WL Recovery (Min)
SD1-GAA107	-28.34507	23.56997	20/10/2012	30.2	13.06	26.1	1	0.09	0.53	No CDT	-	11.41	0	40
SD1-GAA108	-28.34071	23.53320	20/10/2012	39	13.77	36	4	3.06	5.22	720	2.83	1.24	0	3
SD1-GAA196	-28.41422	23.68984	11/10/2012	78.6	14.81	65.5	3	1.04	2.02	No CDT	-	-	-	-
SD1-GAA197	-28.41831	23.72410	09/10/2012	47.18	15.45	44.5	3	1.74	2.04	480	1.23	8.19	0.03	2
SD1-GAA218	-28.35383	23.68306	11/10/2012	51.18	25.08	48	4	3.29	6.02	240	3.29	41.87	0.68	8
SD1-GAA220	-28.36919	23.65492	07/10/2012	52.24	25.43	50.5	2	0.63	1.02	720	0.53	13.81	0.01	8
SD1-GAA259	-28.17634	23.53239	22/07/2013	70.6	13.45	64.8	2	0.80	1.8	No CDT	-	-	0	120(SDT)
SD1-GAA263	-28.31905	23.60095	28/05/2013	54	18.76	46.8	4	Not Reached	20.5	No CDT	-	-	0	20(SDT)
Exploration Boreholes														
SD1-01	-28.22785	23.58191	20/04/2013	82	19.15	70.5	4	not reached	20.2	1440	15.02	4.16	0	300
SD1-02	-28.23577	23.58101	17/04/2013	30	13.8	28.5	4	not reached	20.14	1440	15.12	3.36	0	240
SD1-03	-28.23445	23.57317	14/04/2013	82.6	34.91	70.5	4	not reached	24.01	1440	12.08	18.27	0.48	1440
SD1-04	-28.22183	23.58841	23/04/2013	61.55	44.07	28.5	4	not reached	20.09	1440	20.08	1.31	0	960
SD1-05	-28.21118	23.59941	26/04/2013	40	30.05	28.5	4	not reached	22.5	2880	20.02	0.61	0	60
SD1-06	-28.20899	23.58191	27/04/2013	70.26	29.77	58.8	3	4.90	10	No CDT	No CDT	39.8(sdt)	0(sdt)	180(sdt)
SD1-08	-28.25787	23.58558	02/05/2013	39.85	2.13	34.8	4	not reached	30.21	1440	30.08	0.71	0	10
SD1-09	-28.25526	23.59750	29/04/2013	40.3	10.64	34.8	4	not reached	30.13	1440	25.09	3.42	0	150
SD1-10	-28.33522	23.60812	14/06/2013	27	10.22	22.8	4	not reached	30.21	1440	25.08	3.24	0	150
SD1-11	-28.29988	23.57916	05/05/2013	70	9.78	58	4	not reached	20	1440	20.0	0.73	0	30
SD1-12	-28.32463	23.59330	09/05/2013	110	17.71	34.6	3	5.40	7.26	No CDT	No CDT	29.21(sdt)	0.02	180
SD1-13	-28.39381	23.54737	02/08/2013	60	13.06	58.8	4	5.00	7.1	1440	3.5	8.67	0	240
SD1-14	-28.38532	23.64478	08/06/2013	67.5	3.3	58.8	3	8.40	12.04	2880	6.13	7.17	0	360
SD1-16	-28.36429	23.59782	02/06/2013	59.4	3.36	52.8	4	not reached	20.52	2880	20.09	3.07	0	240
SD1-17	-28.31607	23.58024	09/05/2013	57.6	11.84	34.8	4	not reached	30.53	1440	30.02	0.74	0	90
SD1-17	-28.31607	23.58026	04/09/2013	57.6	9.58	34.8	No SDT	not reached	No SDT	4320	30	1.25	0	5
SD1-19	-28.31003	23.57927	06/05/2013	40.22	12.56	28.8	4	not reached	30.1	1440	25.02	0.74	0	60



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Borehole Number	Borehole Coordinates		Borehole Information			Pump Testing Details								
	Latitude	Longitude	Completion Date	Borehole Depth (m)	Static Water level (mbgl)	Pump Installation Depth (m)	No of SDT's	PI Yield (l/s)	Final Yield of SDT	Duration of CDT (Min)	Yield of CDT (l/s)	CDT Drawdown (m)	WL Recovery (m)	WL Recovery (Min)
SD1-20	-28.31477	23.59588	11/05/2013	49.4	11.7	45.8	4	not reached	30.33	1440	30.13	0.77	0	30
SD1-21	-28.30433	23.58906	13/05/2013	103	13.71	82.8	4	not reached	21.55	1440	20.11	2.7	0	150
SD1-22	-28.29763	23.58330	15/05/2013	49	7.15	46.8	4	not reached	25.12	1440	20.04	11.59	0	120
SD1-24	-28.39051	23.62882	16/06/2013	68.5	9.58	64.5	4	not reached	30.21	1440	30.1	1.16	0	180
SD1-25	-28.22307	23.56911	22/05/2013	51.5	2.09	51.5	4	not reached	30.3	2880	30.29	1.83	0	30
SD1-26	-28.35129	23.59878	05/06/2013	69	2.46	52.8	4	not reached	20.21	1440	15.06	3.79	0	210
SD1-27	-28.37868	23.62470	26/07/2013	104	13.06	82.8	4	not reached	30.1	2880	30.1	4.12	0	300
SD1-28	-28.38561	23.58744	25/06/2013	71.8	10	64.8	3	3.40	5.49	720	2.4	11.8	0	350
SD1-29	-28.28454	23.58590	19/05/2013	68.65	14.29	58.8	4	17.10	20.12	1440	10.1	21.98	0	300
SD1-32	-28.40087	23.65860	12/06/2013	73.85	7.36	70.8	4	not reached	30.1	2880	25.08	3.91	0	120
SD1-32	-28.40082	23.65853	31/07/2013	73	13.77	70.8	No SDT	not reached	No SDT	4320	30.2	5.33	0	40
SD1-33	-28.17310	23.51860	21/07/2013	78.7	13.55	64.8	4	18.20	20.1	4320	12.0	15.74	0	1080
SD1-34	-28.17447	23.53161	14/07/2013	137	11.92	76.8	4	18.20	20.1	4320	12.0	13.47	0	2160
SD1-35	-28.34501	23.58329	26/05/2013	28.7	2.6	22.5	4	not reached	30.2	2880	30.0	1.55	0	120
SD1-35	-28.34501	23.58328	03/08/2013	28.7	14.81	22.8	No SDT	not reached	No SDT	4320	30.0	2.37	0	60
SD1-36	-28.33714	23.60471	29/05/2013	70.9	2.91	34.8	3	4.60	7.64	No CDT	No CDT	22.16(sdt)	0	40(sdt)
SD1-37	-28.38772	23.62334	22/06/2013	82	11.92	70.8	4	21.75	26.19	1440	15.0	12.63	0	90
SD1-40	-28.30157	23.49494	30/08/2013	97.6	13.62	82.8	4	not reached	20	4320	10.08	14.47	0	1320
SD1-40M	-28.30125	23.49500	25/08/2013	64.44	13.45	58.8	3	2.44	3.52	No CDT	No CDT	27.30(sdt)	0	100
SD1-41	-28.30427	23.49428	24/08/2013	97	18.76	82.8	4	18.10	20	4320	12.0	14.21	0	600
SD1-42	-28.29786	23.48335	18/08/2013	112	25.43	76.8	4	14.50	16.3	2880	10.1	10.38	0	360
SD1-43	-28.36883	23.62930	24/06/2013	68	9.61	64.8	4	not reached	20.01	1440	15.0	6.27	0	1440
SD1-44	-28.21134	23.59929	09/08/2013	34.42	15.45	28.8	4	not reached	30.21	4320	30.0	1.14	0	20
SD1-45	-28.19284	23.55202	14/08/2013	44.9	25.08	40.8	4	not reached	30.03	2880	30.0	2.05	0	540



4.7.1 Falling Head Testing

Falling head testing provides a rapid means of assessing the in-situ hydraulic conductivity in dry boreholes or boreholes with insufficient water for slug testing. The test involves measuring the water-level response in a borehole to a displacement of water. The displacement was induced through the introduction of additional water to the rest water level. The rate of recession of the water level displacement provides an indication of the hydraulic conductivity of the borehole. The water level responses were measured using an electronic water level data recorder.

Four falling head test were conducted in the shallow calcrete aquifer present at surface. This low yielding aquifer zone is also the hosting formation of a large indigenous *Olea Africana* ("Olienhoutboom") forest. The impact of well field on these trees were of concern to the landowners and hence the investigation of the hydraulic parameters of the calcrete aquifer zone. The results of the falling head test are summarised in Table 7.

The results confirmed that this aquifer zone have low permeability, retards and restrict water movement and acts as storage unit.

Table 7: Calculated Conductivity (K) Values of Shallow Aquifer

Borehole No.	Latitude	Longitude	Altitude (mamsl)	Drill Depth (m)	K Conductivity(m/d)
SD1-16S	-28.36441	23.59788	1441.142	16	0.00654
SD1-27S	-28.37873	23.62472	1437.378	18	0.00151
SD1-32S	-28.40079	23.65846	1436.591	16	0.00493
SD1-14S	-28.38538	23.64476	1437.544	18	0.00101

4.7.2 Test Pumping Results

Test pumping results were interpreted by means of WHI Aquifer Test version 3 software, by Waterloo Hydrogeologic Inc. and the FC Method developed by the Institute for Groundwater Studies at Free State University, Bloemfontein.

The test pumping results interpreted from test pumping software are summarised in Table 8 and pump testing graphs are listed in the appendix volume II of this report.

Storativity (S) values calculated for existing and new exploration boreholes are summarised in Table 9. The drilling and test pumping results confirm the presence of a semi confined aquifer system in the dolomite and BIF formations, as an aquifer that is partly confined by layers of lower permeability (calcrete) material through which recharge and discharge may occur.

The aquifer testing results confirmed that the upper Kalahari sediments (mainly shallow/perched calcrete aquifer) are not hydraulically linked with the deeper bedrock aquifer zones. The calcrete layer however, acts as an unconfined aquifer system where the water table is the upper boundary and with no confining layer between the water table and the ground surface and can fluctuate up and down.



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Table 8: Calculated Transmissivity Values - SD1

Borehole Number	Borehole Depth (m)	Static Water level (mbgl)	Constant Draw Down Test			Recovery		Transmissivity (T)		Borehole Diameter (mm)	Primary aquifer/ Geology	Boreholes Status
			Duration (Min)	Yield (l/s)	Drawdown (m)			CJ Method (m²/day)	Aquifer Test (m²/day)			
						(Min)	%					
Existing Boreholes												
SD1-GAA001	50.39	5.97	1080	6.0	0.07	3	100	6529	7230	110	Dolomite	Existing
SD1-GAA005	38.31	10.90	720	3.0	14.06	3	100	22	18	165	Dolomite	Existing
SD1-GAA021	25.82	14	720	1.25	3.96	720	99	75	48	165	Dolomite	Existing
SD1-GAA035	9.83	2.51	960	6.0	0.31	120	100	245	2890	165	Dolomite	Existing
SD1-GAA076	24.34	15.46	720	9.0	4.24	720	97	1731	1560	165	Dolomite	Existing
SD1-GAA105	56.04	11	720	1.4	9.87	720	95	15	10	165	Dolomite	Existing
SD1-GAA218	51.18	6.09	480	3.3	41.91	480	98	5	8	165	Dolomite	Existing
SD1-GAA019	29	9.56	720	0.5	2.35	50	100	7	-	165	Dolomite	Existing
SD1-GAA023	37.48	11.65	720	0.5	8.86	720	95	8	-	165	Dolomite	Existing
SD1-GAA027	75.20	14.11	720	6.2	0.24	5	100	500	-	165	Dolomite	Existing
SD1-GAA030	33	2.69	720	1.3	5.38	720	95	82	-	165	Dolomite	Existing
SD1-GAA093	17.12	3.5	1440	8.0	2.59	240	100	375	-	165	Dolomite	Existing
SD1-GAA096	28.04	1.28	720	1.8	0.78	300	100	208	-	165	Dolomite	Existing
SD1-GAA099	35.60	4.51	270	0.45	27.59	300	99	0.7	-	165	Dolomite	Existing
SD1-GAA108	39	22.02	720	2.8	1.24	3	100	786	-	165	Dolomite	Existing
SD1-GAA197	47.18	16.10	480	1.2	8.23	120	100	7	-	165	Dolomite	Existing
SD1-GAA220	52.24	10.87	720	0.53	14.05	480	100	7	-	165	Dolomite	Existing
Exploration Boreholes												



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Borehole Number	Borehole Depth (m)	Static Water level (mbgl)	Constant Draw Down Test			Recovery		Transmissivity (T)		Borehole Diameter (mm)	Primary aquifer/ Geology	Boreholes Status
			Duration (Min)	Yield (l/s)	Drawdown (m)			CJ Method (m²/day)	Aquifer Test (m²/day)			
						(Min)	%					
SD1-01	82.0	11.75	1440	12.0	4.16	300	100	658	541	165	Dolomite	Production
SD1-02	30.0	10.80	1440	15.0	3.36	240	100	194	274	165	Dolomite	Production
SD1-03	82.60	13.35	1440	12.0	19.78	1440	97	85.5	-	203	Dolomite	Production
SD1-04	61.55	12.99	1440	20.0	1.31	960	100	1686	1680	203	Dolomite	Production
SD1-05	36.67	18.61	1440	20.0	0.62	60	100	10273	-	165	Dolomite	Production
SD1-08	39.85	13.76	1440	30.0	0.71	10	100	2573	-	254	Dolomite	Production
SD1-09	40.30	8.04	1440	25.0	2.11	150	100	987	-	203	Dolomite	Production
SD1-10	27.0	12.90	1440	25.0	3.24	150	100	917	-	254	BIF	Production
SD1-11	61.0	14.61	1440	20.0	0.73	30	100	3424	-	165	Dolomite	Production
SD1-13	60.0	19.0	1440	3.5	8.67	240	100	35	23.1	165	Dolomite	Monitoring
SD1-14	67.50	14.53	2880	16.0	7.17	360	100	684	317	254	Dolomite	Production
SD1-16	59.40	10.28	2880	20.0	3.07	240	100	934	624	165	Dolomite	Production
SD1-17	57.60	3.53	1440	30.0	0.74	90	100	855	1170	203	Dolomite	Production
SD1-17_2	57.60	3.34	4320	30.0	1.25	5	100	620	708	203	Dolomite	Production
SD1-19	40.22	3.24	1440	25.0	0.74	60	100	1290	-	203	Dolomite	Production
SD1-20	49.40	4.26	1440	30.0	0.77	30	100	3082	-	203	Dolomite	Production
SD1-21	103.0	3.32	1440	20.0	2.70	150	100	714	-	165	Dolomite	Production
SD1-22	49.0	4.24	1440	20.0	11.59	120	100	681	-	203	Dolomite	Production
SD1-24	68.50	14.15	1440	30.0	1.16	180	100	486	-	203	Dolomite	Production
SD1-25	51.50	8.20	2880	30.0	1.83	30	100	2533	2180	203	Dolomite	Production



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Borehole Number	Borehole Depth (m)	Static Water level (mbgl)	Constant Draw Down Test			Recovery		Transmissivity (T)		Borehole Diameter (mm)	Primary aquifer/ Geology	Boreholes Status
			Duration (Min)	Yield (l/s)	Drawdown (m)			CJ Method (m²/day)	Aquifer Test (m²/day)			
						(Min)	%					
SD1-26	69.0	10.90	1440	16.0	3.79	210	100	747	-	203	Dolomite	Production
SD1-27	104.0	13.45	2880	30.0	4.12	300	100	273	299	203	Dolomite	Production
SD1-28	66.0	15.45	1440	15.0	6.27	360	100	326	-	165	Dolomite	Production
SD1-29	68.65	11.07	2880	10.0	21.98	300	100	35	-	165	BIF	Production
SD1-32	73.0	13.92	2880	25.0	3.91	120	100	480	905	203	Dolomite	Production
SD1-32(2)	73.0	13.92	4320	30.0	5.33	40	100	1078	997	203	Dolomite	Production
SD1-35	28.70	10.82	2880	30.0	1.76	120	100	2568	3600	254	Dolomite	Production
SD1-35(2)	28.70	10.82	4320	30.0	2.37		100	3852	3600	254	Dolomite	Production
SD1-37	82.0	13.77	1440	15.0	12.63	90	100	156	-	254	Dolomite	Production
SD1-43	68.0	14.81	1440	15.0	6.27	1440	100	313	-	203	Dolomite	Production
SD1-44	34.42	19.15	4320	30.0	1.14	20	100	748	720	203	Dolomite	Production
SD1-40	97.6	29.77	4320	10.0	14.37	1320	100	79	73	165	BIF	Production
SD1-41	97.0	44.07	4320	12.0	14.21	600	100	83	83.5	203	BIF	Production
SD1-42	112.0	35.90	2880	10.0	10.38	360	100	52	143	165	BIF	Production
SD1-33	79.0	25.08	4320	12.0	15.74	1080	100	68	-	203	BIF/Chert	Production
SD1-34	137	25.43	4320	12.0	13.47	2160	100	71	-	203	Dolomite	Production
SD1-45	44.9	19.15	2880	30.0	2.05	540	100	1948	1340	203	Dolomite	Production



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Table 9: Calculated Storativity Values - SD1

Borehole Number	Borehole Depth (m)	Static Water level (mbgl)	Monitor borehole	Draw Down (m)	Storativity (S)	Storativity (S)
Existing Boreholes						
SD1-GAA001	50.39	5.97	SD1-GAA002	0.089	3.80×10^{-1}	0.380
SD1-GAA021	25.82	14.0	SD1-GAA020	0.51	2.83×10^{-5}	0.0000283
			SD1-GAA022	1.19	7.61×10^{-5}	0.0000119
SD1-GAA035	9.83	2.51	SD1-GAA036	0.06	2.39×10^{-2}	0.0239
			SD1-GAA037	0.48	4.09×10^{-2}	0.0409
			SD1-GAA038	0.43	3.14×10^{-2}	0.0314
SD1-GAA076	24.34	15.46	SD1-GAA075	0.33	1.22×10^{-3}	0.0033
			SD1-GAA077	0.69	1.06×10^{-3}	0.0069
			SD1-GAA0078	0.49	1.06×10^{-3}	0.0049
SD1-GAA105	56.04	11.0	SD1-GAA103	3.21	6.37×10^{-4}	0.000321
			SD1-GAA104	2.86	7.02×10^{-3}	0.00702
SD1-GAA218	51.18	6.09	SD1-GAA223	34.69	2.63×10^{-3}	0.00263
New Exploration Boreholes						
SD1_25	51.50	8.20	SD1_GAA257	0.07	1.97×10^{-2}	0.0197
SD1_32	73.0	12.6	SD1_32M	0.33	3.21×10^{-4}	0.000321
SD1_13	60.0	18.76	SD1_15	0.64	2.24×10^{-8}	0.0000000224
SD1_14	67.50	14.53	SD1_GAA003	0.08	6.60×10^{-4}	0.000660
SD1_35	28.70	10.62	SD1_35M	0.11	3.49×10^{-1}	34.9
SD1_40	97.6	31.0	SD1_40M	0.33	3.22×10^{-2}	0.0322
SD1_45	44.9	19.15	SD1_5	0.0	-	-
SD1_17	57.60	3.53	SD1_17M	0.0	-	-



5.0 GROUNDWATER RESOURCE ASSESSMENT

5.1 Groundwater Use

5.1.1 Existing Groundwater Users

The existing groundwater use for the SD1 area are summarised in Table 10 and were calculated from data and abstraction rates required during the hydrocensus. The existing groundwater users are divided into three main use category's namely mining sector, municipality and private use.

Private used boreholes where no yields were reported were calculated based on an average of:

- Windmill 0.3l/s for 8 hours per day; and
- Motorized pumps at 0.5l/s for 8 hours per day.

Table 10: SD1 Existing Groundwater Use - 2013

Groundwater use	Borehole number	Abstraction Rate M ³ /Month	Abstraction Rate M ³ /Year
Mining sector	SD1-GAA261; SD1-GAA262	39 615	475 376
Municipality	SD1-GAA237; SD1-GAA239	96 163	1 153 958
Private	SD1-GAA numbers (including fountains) and WARMS registered use	215 687	2 588 246
Total Use		351 465	4 217 581

10 Groundwater users located within the SD1 modelling area which is registered with the Water Authorization and Registration Management System (WARMS) are indicated on Figure 42 and summarised in Table 11.

Table 11: WARMS Registered Groundwater Users

Groundwater user Name	No. on Map	Latitude	Longitude	Licence number	Drainage Region	WARMS Mm ³ /Year
Idwala Industrial Holdings	W1	-28.185717	23.546489	25007019	C92A	380 000
Danielskuil Municipality	W2	-28.188473	23.535934	10080342/1	C92A	630 720
A.D. Scheepers	W3	-28.334688	23.561645	-	C92A	11 200
H.K. van Niekerk	W4	-28.160419	23.719550	25017730	C92A	63 000
J.G. van Heerden	W5	-28.055425	23.815110	-	C33C	58 000
Heinrich Poolman	W6	-28.034037	23.679272	25006877	C92A	32 200
Bernean Boerdery BK	W7	-28.272579	23.752884	-	C92A	97 500
M.G. Willemse	W8	-28.172507	23.507034	25040081	C92A	10 330
J.M. Bezuidenhout	W9	-28.202136	23.528064	25021306/1	C92A	51 000
J.A. & B.J. Visser	W10	-28.297328	23.752773	-	C92A	97 500
Total						1 431 450



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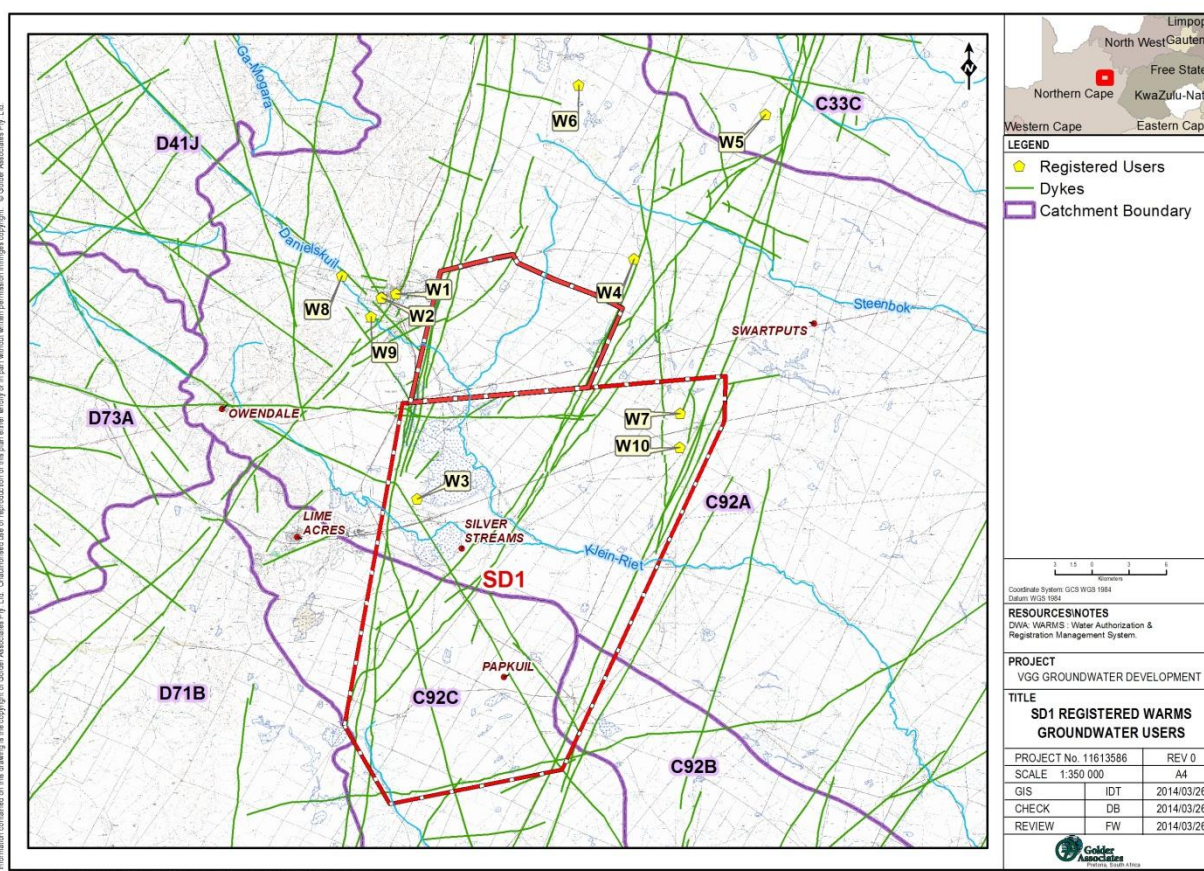


Figure 42: SD1 Registered WARMS Groundwater Users

5.1.2 Fountains

Various active fountains (springs) were located during the hydrocensus and are summarised in Table 12, and the positions are indicated on Figure 43. Some existing fountains are non-perennial in the modelling area and may start flowing during high rainfall seasons. The surveyed fountains are shown as a photo gallery in Table 13.

Table 12: SD1 Fountains

Fountain	Hydrocensus number	Latitude	Longitude	Altitude (mamsl)	Estimated/Reported Flow (l/s)	Estimated Flow M ³ /Month	Estimated Flow M ³ /Year
Danielskuil	SD1-GAA260	-28.166480	23.557010	1464.53	25.0	64800	777 600
Content	SD1-GAA047	-28.319330	23.730070	1433.79	Pool/Not Flowing	-	-
Arriesfontein	SD1-GAA150	-28.279570	23.768960	1423.16	Pool/Not Flowing	-	-
Klein Papkuil	SD1-GAA214	-28.479270	23.674000	1420.19	Pump house	432	5 184
Papkuil	SD1-GAA211	-28.499080	23.690650	1400.74	0.83	2151.4	25816.3
Grootvlei	SD1-GAA097/98	-28.379790	23.744550	1409.90	Pool/Not Flowing	-	-
Khais	SD1-GAA266	-28.16944	23.74168	1456.29	0.5	1296.0	15552.0
Total					26.33	68679.4	824 152



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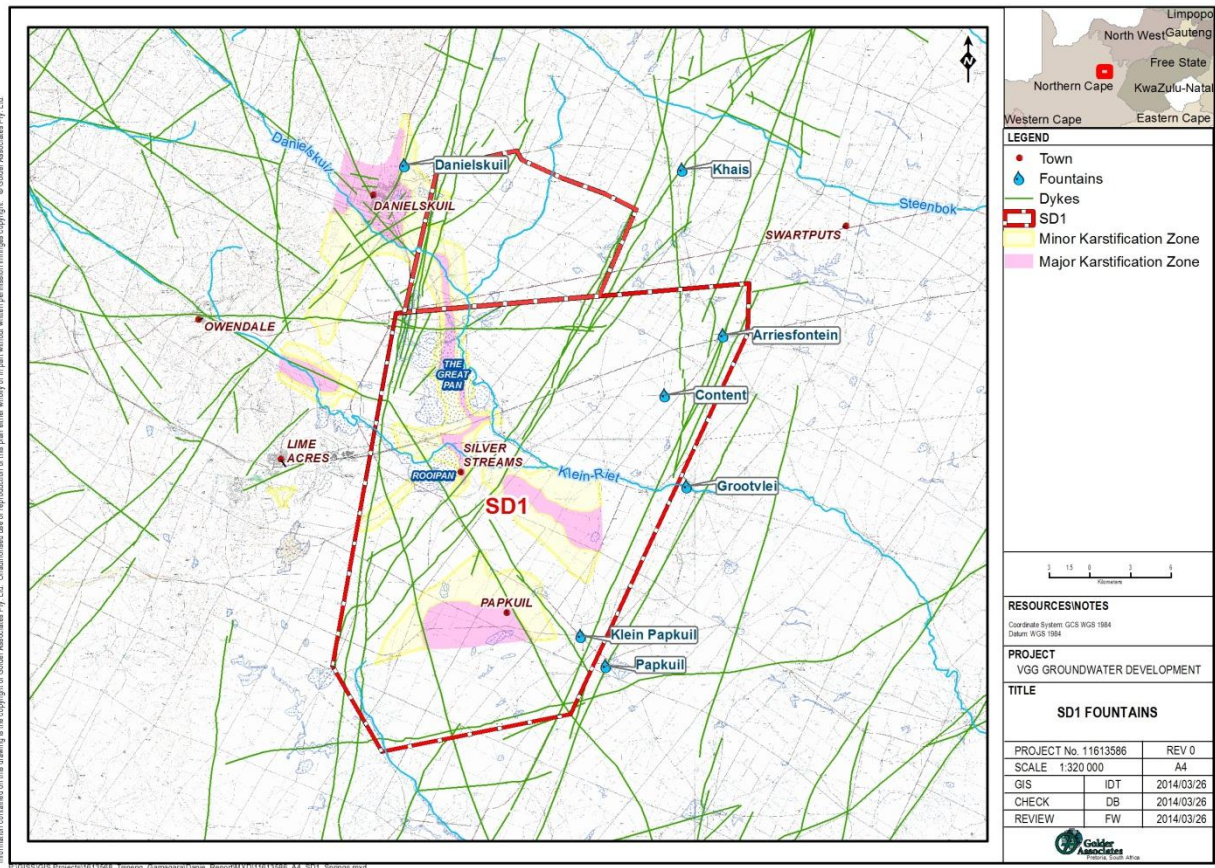


Figure 43: SD1 Fountain Positions

Table 13: SD1 Fountain Photos

Fountain	Photo
Danielskuil Located north of Danielskuil next to the tar road. Used for irrigation and stock watering on small holdings.	



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Fountain	Photo
Content Located on the farm Content as a still standing pool. Used for stock watering.	
Arriesfontein Located on the farm Arriesfontein as a still standing pool. Used for stock watering	



Fountain	Photo
Klein Papkuil Located on the farm Klein Papkuil, enclosed and being pumped with submersible pump. Used for domestic and stock watering	
Papkuil Located on the farm Papkuil, as a pool. Used for domestic and stock watering.	



Fountain	Photo
Grootvlei Located on the farm Grootvlei as a still standing pool. Used for stock watering.	
Khais Located on the farm Khais as a still standing pool. Used for domestic, stock watering and Irrigation.	

5.2 Groundwater Levels and flow directions

Manual derived groundwater piezometric contours were compiled at 10 metre intervals for the SD1 study area. The contours are based on 373 water level elevation data points, sourced from the Golder in-house database, as indicated in Figure 44.

Information taken in to account during manual contouring included:

- Surface topography contours at 10 meter intervals;
- Mapped geological formations, faults and intrusive dykes;
- Surface elevation of spring flows; and
- Surface drainage features.



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The manual compiled contours were all digitized. These digitized contours were used as input values and contoured on Surfer software, to compile the final groundwater piezometric contours, at 10 meter intervals, as depicted in Figure 44.

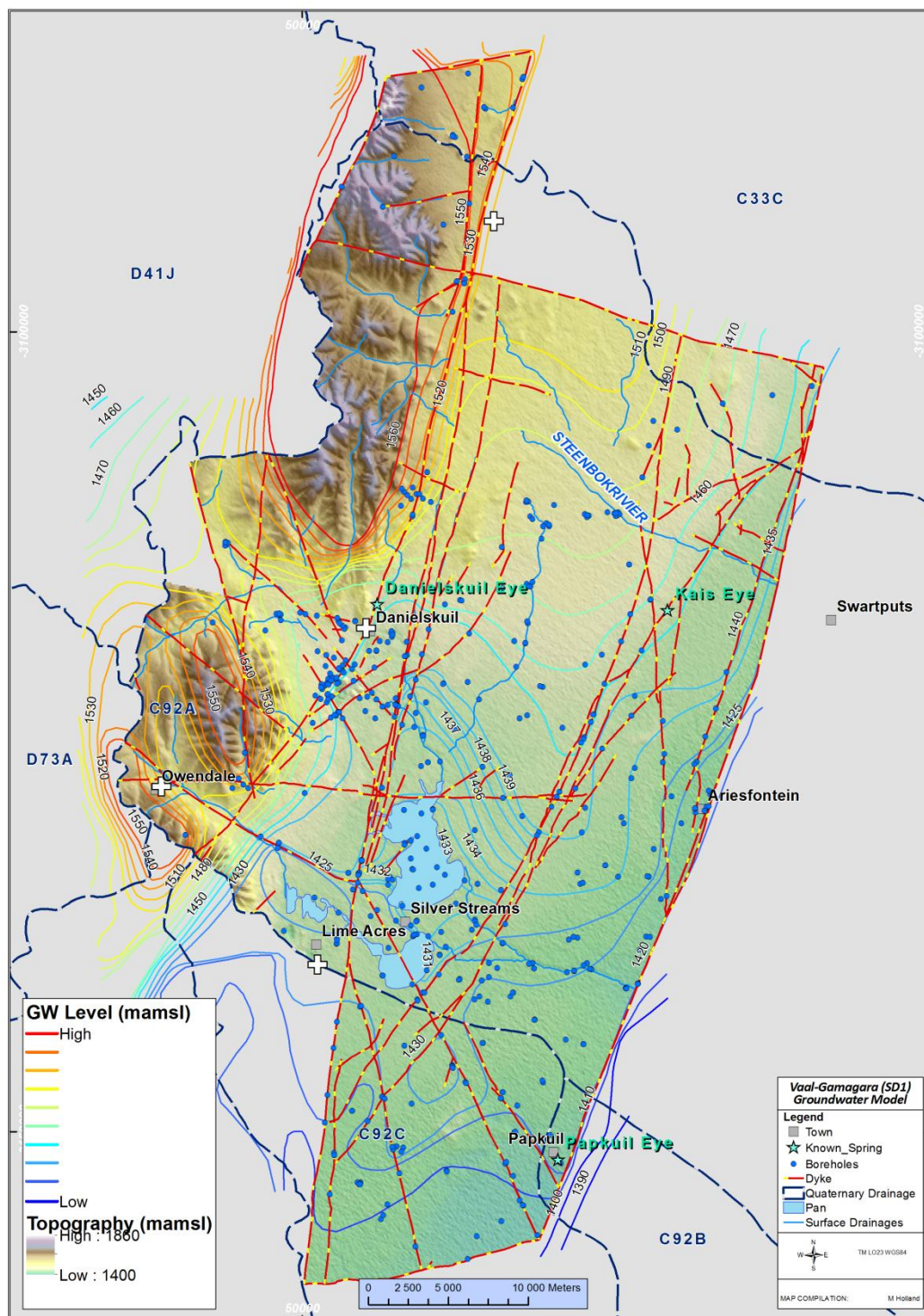


Figure 44: SD1 Groundwater Piezometric Contour Map

The regional groundwater flow direction for the SD1 study area is towards the west. Groundwater piezometric contours mimic the surface topography, and regional the groundwater flow is from higher lying ground toward lower lying valleys, where groundwater accumulates in the alluvial deposits and contributes to baseflow.



Groundwater piezometric contour levels ranges from 1390mamsl in the east to 1560mamsl in the north-west, representing a maximum head of 170 metres for the study area.

Groundwater piezometric contours within the vicinity south and west of the Danielskuil dyke have a low hydraulic gradient due to high aquifer Transmissivity within the dolomitic compartments, bounded by dolerite dykes with moderate steps (~ 5m) in the piezometric levels.

Piezometric levels north and northwest of the model domain show steeper gradients, indicating lower transmissivity in the bedrock aquifer.

5.3 Groundwater Quality

The groundwater quality of SD1 is discussed according to the following topics:

- Groundwater sampling;
- Groundwater chemical parameters analysed;
- Baseline Groundwater quality;
- Groundwater analytical results related to water quality Classes according to DWAF 1998 Drinking Water Quality Guideline; and
- Groundwater classification as Piper and Expanded Durov (EDD) quality Diagrams.

5.3.1 Groundwater Sampling

Groundwater samples were collected from 76 existing boreholes during the hydrocensus and aquifer testing programme. Groundwater samples were furthermore collected from 43 monitoring/production boreholes during the aquifer testing programme.

These samples were collected as per Golder's standard sampling procedures during CDT or with disposable bailers at low yielding boreholes. The objective of the groundwater sampling was to assess and determine a representative baseline groundwater quality of the existing groundwater users and new monitoring/production boreholes.

Duplicate groundwater samples were collected during the programme for quality assurance/quality control (QA/QC). Duplicate samples were analysed for the full set of parameters. Duplicate results are approximately similar for both analyses, indicating that analytical results are reliable.

All analytical results certificates (duplicates included) are listed in appendix Volume II of SD1 report.

5.3.2 Groundwater Chemical Parameters

The chemical parameters analysed during the water sampling are based on water quality guidelines for domestic and drinking water use. This was done in view of existing and future groundwater use in the study area.

Table 14 shows the list of main parameters analysed together with other trace metals included in the Water Quality Standards.

Table 14: Parameters Analysed

Physical Parameters	Macro determinants	Micro determinants
pH	Ammonium as NH ₄	Aluminium (Al)
Electrical Conductivity (EC)	Calcium (Ca)	Antimony (Sb)
Total Dissolved Solids (TDS)	Chloride (Cl)	Arsenic (As)
	Fluoride (F)	Cadmium (Cd)
	Magnesium (Mg)	Total Chromium as Cr
	Nitrate as N and NO ₂	Copper (Cu)
	Potassium (K)	Total Fe (Fe)



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	Sodium (Na)	Lead) (Pb)
	Sulphate (SO ₄)	Manganese (Mn)
	Zinc (Zn)	

5.3.3 Water quality Standards

The analytical results of the groundwater samples were compared to the following standards;

- Department of Water Affairs and Forestry, domestic water quality guidelines, volume 1, 1996 and Water Research Commission, water quality guidelines, 1998; and
- South African National Standards, drinking water standards, 2011 (SANS 241:2011).

The SANS 241:2011 drinking water standard is used as reference in Table 17 and Table 18, whereas the DWAF 1998 guidelines were used to classify and discuss the baseline water quality water quality classes (Table 15).

Table 15: DWAF Water Quality Classes (1998)

Water quality class	Description	Drinking health effects
Class 0	Ideal water quality	No effects, suitable for many generations.
Class 1	Good water quality	Suitable for lifetime use. Rare instances of sub-clinical effects
Class 2	Marginal water quality, water suitable for short-term use only	May be used without health effects by majority of users, but may cause effects in some sensitive groups. Some effects possible after lifetime use.
Class 3	Poor water quality	Poses a risk of chronic health effects, especially in babies, children and the elderly. May be used for short-term emergency supply with no alternative supplies available.
Class 4	Unacceptable water quality	Severe acute health effects, even with short-term use.

5.3.4 Baseline Groundwater Quality

The baseline groundwater quality of SD1 exploration boreholes is based on macro chemistry analyses of the sampled boreholes. The concentrations are compared to the SANS 241:2011 water quality standard and the baseline quality are represented by the Median of the concentrations. The baseline water quality of the new exploration boreholes are summarised in Table 16 below.

Table 16: SD1 Baseline Groundwater Quality

Item	Physical Parameters			Macro Determinants (Major Ions)								Minor Determinant		
	pH	EC mS/m	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO ₄ mg/l	NO ₃ mg/l	MALK Mg/l	F mg/l	Fe mg/l	Mn mg/l
No. of Records	43	43	43	43	43	43	43	43	43	43	43	43	43	43
10 % Percentile	7.25	26.72	174.40	35.00	12.06	5.34	1.72	8.31	11.20	0.30	143.60	0.10	0.05	0.05
Median Baseline water Quality	7.54	67.1	420	86.3	33.8	11.7	2.49	29.3	28.2	3.325	292	0.1	0.05	0.05
Average	7.52	61.42	410.93	78.87	33.18	17.20	3.45	39.99	34.12	3.48	273.05	0.13	0.08	0.08
90% Percentile	7.72	87.70	588.40	98.72	50.56	35.84	5.96	80.86	66.94	5.99	377.20	0.16	0.05	0.15
Max. Allowable Limit (SANS 241:2011)	<5 >9	<170	<1200	<300	<100	<200	<100	<300	<500	<11	-	<1.5	<0.3	<0.5



5.3.5 Groundwater Analytical Results

Mostly the water quality in the dolomite and BIF aquifers is of good quality and acceptable for human consumption for life time use.

The analytical results (major cations and anions) of existing boreholes are listed in Table 17 and the new exploration boreholes results are listed in Table 18. A highlighted value in red exceeds the SANS 241:2011 maximum allowable limit, whereas the water quality classes are classified using the DWAF (1998) drinking water quality standards.

The aquifer systems at SD1 consist out of sedimentary rocks which chemical composition contributes to the chemical character of the groundwater quality:

- Dolomite is a calcium, magnesium carbonate $\text{CaMg}(\text{CO}_3)_2$ formation and highly soluble;
- BIF is a sedimentary rock consisting out of layers of iron oxides, either magnetite (Fe_3O_4) or hematite (Fe_2O_3), alternating with bands of iron-poor shale's, and chert and is often red in color; and
- Calcrete is a hardened sedimentary rock natural of calcium carbonate binding other materials such as gravel, sand, clay, and silt.

The following determinants exceeds the DWAF (1998) Class 1 drinking water quality standard EC, TDS, Ca, K, Mg, Na, Cl, NO_3 , F, Fe and Mn and are discussed accordingly below.

5.3.5.1 Electrical Conductivity

Seven exiting boreholes Electrical Conductivity (EC) exceed the maximum allowable limit of the DWAF (1998) Class 1 drinking water standard of 150mS/m. The values exceeding the limit range from 153mS/m (SD1-GAA091) to 217mS/m (SD1-GAA069). These exceeding EC values are related to the geology of the formation contributing to higher Ca and Mg concentration in the water due to the diverse solubility of these elements.

All the new exploration boreholes EC values are below the DWAF (1998) Class 1 drinking water standard of 150mS/m.

5.3.5.2 TDS

Eight existing boreholes exceeds TDS values exceeds the maximum allowable limit of the DWAF (1998) Class 1 drinking water standard of 1000mg/l. Similar to EC these elevated values are related to higher Ca, Mg and K concentration in the water due to more solubility of these elements in the formation.

All the new exploration boreholes TDS values are below the DWAF (1998) Class 1 drinking water standard of 1000mg/l.

5.3.5.3 Calcium (Ca)

Three existing boreholes and one new exploration borehole (SD1-13; 174mg/l) calcium concentration exceeds maximum allowable limit of the DWAF (1998) Class 1 drinking water standard of 150mg/l.

These elevated calcium concentrations are related to the geology of the area.

5.3.5.4 Potassium (K)

One existing boreholes (SD1-GAA159; 87.2mg/l) potassium concentration exceeds maximum allowable limit of the DWAF (1998) Class 1 drinking water standard of 50mg/l.

This elevated potassium concentration place this borehole in Class II of the DWAF (1998) drinking water standard and are probably related point source pollution caused by animal farming and stockades.

5.3.5.5 Magnesium (Mg)

Eight existing boreholes magnesium concentration exceeds maximum allowable limit of the DWAF (1998) Class 1 drinking water standard of 100mg/l.

These elevated magnesium concentrations are related to the geology formations of the area.



All the new exploration boreholes magnesium concentrations are below the DWAF (1998) Class 1 drinking water standard of 100mg/l.

5.3.5.6 Chloride (Cl)

Six existing boreholes chloride concentration exceeds maximum allowable limit of the DWAF (1998) Class 1 drinking water standard of 200mg/l.

The chloride concentrations exceeding the limit range from 200mg/l (SD1-GAA047) to 422mg/l (SD1-GAA069) and place these boreholes in Class II of the DWAF (1998) drinking water standard. Elevated chloride values are probably related to localised impacts.

5.3.5.7 Nitrate (NO₃ as N)

Eight existing boreholes and one new exploration borehole (SD1-10;13.4mg/l) nitrate concentration exceeds maximum allowable limit of the DWAF (1998) Class 1 drinking water quality standard of 10mg/l.

The nitrate concentrations exceeding the limit range from 10.5mg/l (SD1-GAA066) to 34.4mg/l (SD1-GAA159) and place these boreholes in Class II and Class III of the DWAF (1998) drinking water standard.

These elevated nitrate concentrations are probably related point source pollution caused by animal farming and stockades.

5.3.5.8 Fluoride (F)

Two boreholes one existing boreholes (SD1-GAA259; 2.96mg/l) and one new exploration borehole (SD1-34; 1.05mg/l) fluoride concentrations exceeds maximum allowable limit of the DWAF (1998) Class 1 drinking water quality standard of 1.0mg/l.

These elevated fluoride concentrations put these two boreholes respectively in to Class II and Class III of the DWAF (1998) drinking water standard.

5.3.5.9 Iron (Fe) and Manganese (Mn)

One existing boreholes (SD1-GAA101) exceeds the maximum allowable limits of the DWAF (1998) Class 1 drinking water standard for both the iron (0.2mg/l) and manganese(0.4mg/l) concentrations, concentrations of 1.02mg/l and 1.5mg/l respectively.

One new exploration borehole SD1-32 (1.21mg/l) iron concentration exceeds the maximum allowable limit of the DWAF (1998) Class 1 standard of 0.2mg/l.

These elevated iron and manganese concentrations are probably related to the geology of the SD1 area.



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Table 17: SD1 Existing Borehole Analytical Results

Borehole No.	Date Sampled	Physical Determinants			Chemical Determinants												Water Quality Class
		pH	EC mS/m	TDS mg/l	MALK mg/l	Ca mg/l	K mg/l	Mg mg/l	Na mg/l	Cl mg/l	NO3 as N mg/l	SO4 mg/l	Si mg/l	F mg/l	Fe mg/l	Mn mg/l	
SD1-GAA001	2012/10/08	7.59	74.7	490	320	83.4	5.12	43.7	28.7	54.3	3.85	43.8	15.3	0.167	<0.05	<0.05	I
SD1-GAA002	2012/10/08	7.44	75	528	321	82	4.97	43.1	27.9	54.1	3.77	43.4	14.8	0.178	<0.05	<0.05	I
SD1-GAA003	2012/10/08	7.79	48.1	318	281	61.7	1.49	33.5	5.33	8.47	1.15	7.66	17.2	0.217	<0.05	<0.05	I
SD1-GAA004	2012/10/08	7.34	51.5	348	306	94.5	2.02	14.3	5.56	6.49	0.3	6.86	20.2	0.1	<0.05	<0.05	I
SD1-GAA005	2012/09/31	7.5	60.6	418	278	78.8	2.54	29.8	14.3	37.9	2.75	21.8	16.7	0.152	<0.05	<0.05	0
SD1-GAA008	2012/02/16	7.12	70.5	522	67.2	42.7	5.67	37.1	42.2	165	1.01	33.6	0.21	0.1	-	-	I
SD1-GAA009	2012/02/16	8.03	100	710	327	116	4.84	54.8	38.1	111	3.9	89.6	18.1	0.233	-	-	I
SD1-GAA012	2012/02/16	7.59	74.2	506	317	82.5	4.85	41	28.5	27.1	3.03	20.7	17.8	0.111	-	-	I
SD1-GAA015	2012/10/08	7.55	70.1	468	303	98.9	3.03	35.9	11.2	56.2	6.66	16.5	21.2	0.153	<0.05	<0.05	I
SD1-GAA017	2012/10/08	7.56	131	934	352	78.7	16.7	108	60.5	185	19.5	94.7	18.4	0.147	<0.05	<0.05	II
SD1-GAA018	2012/10/23	7.73	99.9	732	286	90.9	9.63	64.2	42.7	84.3	22.8	73	17	0.18	-	-	II
SD1-GAA019	2012/10/08	7.48	73.1	512	304	83.4	4.79	44.3	24.4	51.1	6.38	41.3	14.2	0.159	<0.05	<0.05	I
SD1-GAA020	2012/10/23	7.29	131	886	364	157	5.48	44.6	48.7	187	17.8	52.4	23.2	0.1	-	-	II
SD1-GAA021	2012/10/08	7.2	102	642	358	130	6.02	46	34.3	116	8.72	46.6	20.9	0.143	<0.05	<0.05	I
SD1-GAA023	2012/10/23	7.36	77.8	514	424	112	2.53	50.8	12.3	31.3	2.35	15.2	23.9	0.153	-	-	I
SD1-GAA026	2012/10/25	7.35	71.1	472	299	104	1.79	30.6	12.9	39.1	2.79	60.1	14.3	0.1	<0.05	<0.05	I
SD1-GAA027	2012/10/25	7.79	58	468	216	91.4	2.53	31.3	14.3	37.8	3.9	52	12.3	0.105	<0.05	<0.05	I
SD1-GAA028	2012/02/16	7.87	58.4	426	246	89.5	2.58	23.4	12.8	32	3.63	41.4	12.3	0.113	-	-	I
SD1-GAA030	2012/10/25	7.89	65.3	488	284	85.5	4.52	45.5	27.2	43.3	2.5	35.5	16.7	0.151	<0.05	<0.05	I
SD1-GAA034	2012/02/16	7.72	71.2	504	316	87.3	4.93	43	28.7	46.1	1.95	41.3	18.9	0.196	-	-	I
SD1-GAA035	2012/10/25	7.78	68.4	502	335	96.8	3.98	47.1	20.4	34.2	2.51	28.8	20.4	0.182	<0.05	<0.05	I
SD1-GAA038	2012/02/16	7.68	64.8	500	315	95.1	3.85	39.9	17.7	31.5	2.01	29.3	19.7	0.202	-	-	I
SD1-GAA046	2012/02/16	7.69	80.8	506	384	99.6	2.03	57.1	17.8	41	6.74	29.6	22.5	0.275	-	-	I
SD1-GAA047	2012/02/16	7.4	163	1030	609	81	37.6	148	86.2	200	0.3	83	41.6	0.194	-	-	II
SD1-GAA055	2012/02/16	7.76	66.8	498	278	86.3	1.57	51.4	14.2	44.3	4.9	37.1	18.8	0.173	-	-	I
SD1-GAA060	2012/10/08	7.84	59.8	412	287	75.1	2.85	35.4	13.2	27.3	6.33	15.3	20.9	0.135	<0.05	<0.05	0
SD1-GAA061	2012/10/08	7.62	68.6	436	324	73.8	3.11	42	25.3	28.5	1.9	22.4	16.3	0.126	<0.05	<0.05	0
SD1-GAA062	2012/10/08	7.54	59.1	318	291	62.9	2.68	37.5	21.3	30.7	2.27	19.3	14.4	0.155	<0.05	<0.05	0
SD1-GAA066	2012/02/16	8.29	169	1220	594	66.1	18.8	146	124	198	10.5	124	28.1	0.589	-	-	II
SD1-GAA069	2012/02/16	7.96	217	1600	286	119	35.3	111	211	442	5.67	239	12.7	0.133	-	-	II
SD1-GAA076	2012/10/25	7.54	67.1	462	268	103	1.82	28.6	12.4	36.4	3.5	57.6	13.3	0.111	<0.05	<0.05	I
SD1-GAA077	2012/02/16	7.56	66.4	432	271	104	2.05	25.7	13.1	37	3.66	59.3	12	0.105	-	-	I
SD1-GAA079	2012/02/16	7.54	56.5	452	207	96.8	1.91	24.3	12.1	35.9	3.96	55.1	12.7	0.1	-	-	I
SD1-GAA083	2012/02/16	7.81	132	994	458	106	3.32	97.4	54	160	9.01	68.5	22.8	0.365	-	-	I



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Borehole No.	Date Sampled	Physical Determinants			Chemical Determinants												Water Quality Class
		pH	EC mS/m	TDS mg/l	MALK mg/l	Ca mg/l	K mg/l	Mg mg/l	Na mg/l	Cl mg/l	NO3 as N mg/l	SO4 mg/l	Si mg/l	F mg/l	Fe mg/l	Mn mg/l	
SD1-GAA085	2012/02/16	7.79	95.2	656	376	104	9.2	52.5	37.2	77.7	8.88	47.8	24.6	0.379	-	-	I
SD1-GAA091	2013/05/16	7.97	153	1170	462	83.9	4.06	135	73.1	233	4.36	101	27	0.49	-	-	II
SD1-GAA092	23/10/2012	7.61	104	802	401	84.9	2.73	92.2	41.1	97.9	2.21	54.7	22.6	0.316	-	-	I
SD1-GAA093	25/10/2012	8.2	116	926	419	82.2	3.43	110	48.9	144	2.07	69.5	22.9	0.399	<0.05	<0.05	II
SD1-GAA096	23/10/2012	7.57	85.4	594	388	85.3	19	58.2	31.8	55.5	1.48	47.9	21.9	0.188	-	-	I
SD1-GAA097	2013/05/16	7.56	71.8	454	361	83.5	4.62	42.9	24.8	45.2	0.3	35.7	18.5	0.185	-	-	I
SD1-GAA099	2012/10/23	7.29	172	1360	481	117	12.4	129	109	255	1.34	152	30.7	0.219	-	-	II
SD1-GAA101	2012/10/25	6.91	154	1030	529	244	11	48.3	28.2	292	0.3	25.3	22.8	0.1	1.02	1.5	II
SD1-GAA105	2012/10/25	7.89	137	1010	335	12	8.33	76.3	54.1	187	23	101	19.6	0.132	<0.05	<0.05	III
SD1-GAA107	2012/10/25	7.64	167	1270	247	159	14.2	78.2	111	310	14.5	207	18.7	0.127	<0.05	<0.05	II
SD1-GAA108	2012/10/25	7.71	86.3	656	297	130	2.7	34.8	24.4	90.2	6	46.2	17.6	0.103	<0.05	<0.05	I
SD1-GAA110	2012/02/16	7.76	104	774	455	96.9	2.16	93	36.7	86.9	1.7	54.7	21.8	0.483	-	-	I
SD1-GAA119	2012/02/16	7.62	74.3	550	374	96	2.73	52.8	13.7	31.1	3.84	30.4	19.8	0.276	-	-	I
SD1-GAA124	2012/02/16	7.66	104	716	439	103	3.32	76	35.4	95.2	0.64	55.1	24.9	0.272	-	-	I
SD1-GAA134	2012/02/16	7.57	94	674	461	120	1.19	65.9	20.8	52.9	2.94	42.3	24.6	0.268	-	-	I
SD1-GAA141	2012/02/16	7.85	69.8	438	344	87.1	17.2	34.5	17.7	37.6	1.28	20.2	15.9	0.246	-	-	I
SD1-GAA148	2012/02/16	7.69	75.2	514	369	86.6	2.36	60.9	17.1	43.3	1.84	26.6	16.5	0.195	-	-	I
SD1-GAA150	2012/02/16	7.97	89.5	664	471	76.6	4.9	83.2	23	51	0.3	25.6	27.1	0.277	-	-	I
SD1-GAA154	2012/02/16	7.83	47.5	334	276	62.0	1.35	31.4	5.05	7.88	1.13	6.71	16.6	0.163	-	-	0
SD1-GAA159	2012/02/16	7.69	168	1280	431	138	87.2	79.7	80.7	188	34.3	114	16.1	0.161	-	-	III
SD1-GAA174	2012/02/16	7.47	85	546	420	115	1.63	67	18.6	37.3	0.3	53.8	24.5	0.351	-	-	I
SD1-GAA177	2012/02/16	7.7	86.4	562	382	114	4.88	42.8	25.6	57.1	3.74	42.2	19.5	0.174	-	-	I
SD1-GAA191	2012/03/23	7.78	67.6	508	294	84.9	4.83	38.5	25.5	45.6	1.95	36.1	18.3	0.196	-	-	I
SD1-GAA196	2012/10/23	7.61	69.7	464	420	85.2	3.39	43.2	21.6	50.1	3.25	27.7	8.7	0.204	-	-	I
SD1-GAA197	2012/10/23	7.51	75.8	528	376	118	3.35	37.6	19.7	41.6	1.23	25.8	20.3	0.136	-	-	I
SD1-GAA211	2012/03/27	7.7	76.6	552	321	97.1	4.33	42.7	26.7	61	2.08	40.7	18.9	0.196	-	-	I
SD1-GAA212	2012/03/27	7.75	75.2	562	285	96.6	10.2	43.4	28.5	66.4	3.98	43.8	19.1	0.148	-	-	I
SD1-GAA214	2012/03/28	7.63	66	466	306	80.5	9.43	35.5	21.1	43	0.85	32.5	16.2	0.152	-	-	I
SD1-GAA218	2012/10/23	7.3	81.7	620	386	96.4	2.12	57	16.9	43.7	6.73	25.1	28.3	0.164	-	-	I
SD1-GAA220	2012/10/23	7.33	79.9	576	328	98.8	4.42	45.7	30.2	62.3	3.46	35	18.4	0.115	-	-	I
SD1-GAA225	2012/11/12	7.92	74.5	554	344	118	3.78	38.7	16.9	38.6	7.09	32.5	15.4	0.1	-	-	I
SD1-GAA227	2012/11/12	8.2	125	752	461	95.3	4.22	111	61.1	125	19.3	67.6	14.2	0.302	-	-	II
SD1-GAA232	2012/11/12	8.16	60.6	430	334	78.1	1.36	50.2	8.9	21.7	2.62	14	11.9	0.1	-	-	0
SD1-GAA237	2012/11/12	7.93	19.1	114	98.2	25.6	1.65	10.5	4.74	4.16	0.47	7.81	8.33	0.11	-	-	0
SD1-GAA239	12/11/2012	7.78	51.9	408	259	85.1	2.11	21.1	10.1	16.3	1.58	27.9	9.57	<0.1	-	-	I



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Borehole No.	Date Sampled	Physical Determinants			Chemical Determinants												Water Quality Class
		pH	EC mS/m	TDS mg/l	MALK mg/l	Ca mg/l	K mg/l	Mg mg/l	Na mg/l	Cl mg/l	NO3 as N mg/l	SO4 mg/l	Si mg/l	F mg/l	Fe mg/l	Mn mg/l	
SD1-GAA246	2012/11/22	8.08	75.9	424	351	72.6	9.9	69.9	28.2	55.2	4.87	32.9	14.5	0.129	-	-	I
SD1-GAA249	2012/11/12	8.15	97.5	574	431	89.2	3.97	89.6	31.5	84.3	3.28	67.8	10.6	0.248	-	-	I
SD1-GAA253	2012/11/12	7.95	149	1090	477	103	3.43	130	72.2	202	6.68	122	26.5	0.236	-	-	II
SD1-GAA259	2013/07/22	7.53	31.6	142	152	52.7	1.99	17.5	4.87	5.22	0.3	21.6	6.24	2.96	<0.05	0.25	III
SD1-GAA260	2013/02/28	8.04	29.7	172	156	43.3	1.77	13.2	6.78	6.14	1.94	12	9.1	0.1	<0.05	<0.05	0
SD1-GAA263	2013/05/28	7.49	68.3	460	305	91.1	2.91	36.8	17.7	40.6	4.06	40	15.1	0.1	<0.05	<0.05	I
SD1-GAA266	18/02/2014	7.34	78	568	386	73.9	2.18	64.9	15.1	43.2	0.987	29	-	-	-	-	I
SANS241: 2011		5-9.7	<170	1200	-	-	-	-	200	300	11	500	-	1.5	0.3	0.5	
Class 0 Max. Allowable Limit		5-9.5	<70	<450	-	<80	<25	<70	<100	<100	<6	<200	-	<0.7	<0.01	<0.1	0
Class 1 Max. Allowable Limit		10	150	1000	-	150	50	100	200	200	10	400	-	0.7-1.0	0.01-0.2	0.1-0.4	I
Class 2 Max. Allowable Limit		10.5	370	2400	-	300	100	200	400	600	20	600	-	1.0-1.5	0.2-2.0	1-4	II
Class 3 Max. Allowable Limit		11	520	3400	-	>300	500	400	1000	1200	40	1000	-	1.5-3.5	2-10	4-10	III
Class 4 Max. Allowable Limit		>11	>520	>3400	-		>500	>400	>1000	>1200	>40	>1000	-	>3.5	>10.0	>10.0	IV
Min		6.91	19.1	114	67.2	12	1.19	10.5	4.74	4.16	0.3	6.71	0.21	0.1	0.05	0.05	
Max		8.29	217	1600	609	244	87.2	148	211	442	34.3	239	41.6	2.96	1.02	1.5	
Average		7.68	88.10	620.95	342.95	93.19	6.83	56.55	33.02	82.27	4.94	50.10	18.32	0.23	0.09	0.12	

Table 18: SD1 Exploration Borehole Analytical Results

Borehole No.	Date Sampled	Physical Determinants			Chemical Determinants												Water Quality Class
		pH	EC mS/m	TDS mg/l	MALK mg/l	Ca mg/l	K mg/l	Mg mg/l	Na mg/l	Cl mg/l	NO3 as N mg/l	SO4 mg/l	Si mg/l	F mg/l	Fe mg/l	Mn mg/l	
SD1-01	20/04/2013	7.51	68.2	418	351	91.2	2.05	43	11.2	28.6	3.16	23.9	12.8	0.1	<0.05	0.12	I
SD1-02	17/04/2013	7.39	62.4	356	299	89.8	2.32	32.5	11.7	28.8	4.16	28.2	12.5	0.1	<0.05	<0.05	I
SD1-03	14/04/2013	7.26	60.8	434	279	94.8	2.24	25.2	11.9	27	2.96	41.4	15	0.1	<0.05	<0.05	I
SD1-04	22/04/2013	7.25	69.5	370	369	90.2	1.61	48	10.7	26.2	2.75	25.7	12.8	0.1	<0.05	<0.05	I
SD1-05	26/04/2013	7.17	73.7	490	392	92.4	1.61	53.2	11.3	29.5	2.14	23.6	13.2	0.1	<0.05	<0.05	I
SD1-06	27/04/2013	7.47	76.2	420	382	101	1.89	47.7	11.8	35.5	3.02	28.8	12.9	0.1	<0.05	<0.05	I
SD1-08	02/05/2013	7.29	66.3	400	332	87	1.89	41.6	11.1	28.2	3.55	24.2	12.8	0.1	<0.05	<0.05	I
SD1-09	29/04/2013	7.32	73.1	450	370	82.3	1.8	54.5	15.7	29.5	3.91	26.9	13.9	0.1	<0.05	<0.05	I
SD1-10	14/06/2013	7.61	88.1	594	288	75.5	9.76	59.4	40	81.1	13.4	68.8	18.6	0.1	<0.05	<0.05	II
SD1-11	04/05/2013	7.6	63.7	462	302	90.5	2.33	33.7	11.7	29.3	3.93	32.3	14.8	0.137	<0.05	<0.05	I



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Borehole No.	Date Sampled	Physical Determinants			Chemical Determinants												Water Quality Class
		pH	EC mS/m	TDS mg/l	MALK mg/l	Ca mg/l	K mg/l	Mg mg/l	Na mg/l	Cl mg/l	NO3 as N mg/l	SO4 mg/l	Si mg/l	F mg/l	Fe mg/l	Mn mg/l	
SD1-12	09/05/2013	7.69	92.2	722	268	112	3.64	45.1	31.8	122	6.39	94.5	15.5	0.158	<0.05	0.11	I
SD1-13	02/08/2013	7.13	97	730	302	174	4.72	33.8	27.5	133	3.06	58.6	21.6	0.1	<0.05	<0.05	II
SD1-14	08/06/2013	7.69	44.6	312	252	67.4	1.67	27.6	5.85	8.6	0.96	7.44	18.7	0.1	<0.05	<0.05	0
SD1-14S	13/07/2013	7.76	35	208	187	27.4	3.2	32.8	7.3	14.8	0.3	14.1	1.72	0.1	<0.05	0.11	0
SD1-16	01/05/2013	7.42	73.1	504	296	94.3	4.16	37.2	23.3	51.9	5.41	45.2	-	0.1	<0.05	<0.05	I
SD1-16S	13/07/2013	7.61	25.8	156	110	28.1	3.82	13.8	7.67	15.8	0.3	16.2	0.88	0.1	<0.05	0.16	0
SD1-17	09/05/2013	7.57	67.1	462	288	91.8	2.8	32.4	16.4	41.6	3.96	41.8	14.7	0.1	<0.05	<0.05	I
SD1-19	06/05/2013	7.6	63.9	412	302	89.3	2.33	33.5	11.6	30.1	3.91	33.1	14.6	0.1	<0.05	<0.05	I
SD1-20	18/02/2014	7.39	80.8	580	316	97.7	6	47.8	34.1	68.8	1.73	57	-	0.13	<0.05	<0.05	I
SD1-21	31/05/2013	7.56	67.1	430	339	84.9	2.41	43.1	12.5	30.2	3.96	25.5	16	0.1	<0.05	<0.05	I
SD1-22	15/05/2013	7.49	59.8	376	292	86.3	2.32	31.2	11.7	27.5	3.38	26.6	14.7	0.1	<0.05	<0.05	I
SD1-24	16/06/2013	7.58	67.6	476	295	94.8	4.88	36	20	48.5	3.39	30.3	19.4	0.1	<0.05	<0.05	I
SD1-25	22/05/2013	7.47	61.1	418	238	89.8	2.9	24.2	19.6	44.8	4.2	45.3	12.4	0.1	<0.05	<0.05	I
SD1-26	05/06/2013	7.49	72.9	486	293	93.3	4.41	38.7	23.6	51.8	6.24	44.8	-	0.1	<0.05	<0.05	I
SD1-27	26/07/2013	7.58	72.8	532	289	64.5	5.39	36	28.1	56.8	3.75	44.2	16.6	0.184	<0.05	<0.05	I
SD1-27S	13/07/2013	7.7	19.4	116	149	34.1	1.85	6.13	2.68	2.88	0.3	8.05	1.54	0.1	<0.05	0.22	0
SD1-28	23/06/2013	7.48	92.8	652	241	81.9	8.12	49.9	52.3	114	3.23	67.1	12	0.1	<0.05	0.26	I
SD1-29	19/05/2013	7.5	58.7	402	282	78.9	4.97	32.6	13.3	28.8	3.61	23.2	17.8	0.129	<0.05	<0.05	0
SD1-30	11/05/2013	7.6	83	576	305	91.5	5.9	43.3	37	77	4.53	66.7	15	0.116	<0.05	<0.05	I
SD1-32	18/02/2014	7.2	55.6	402	325	97.1	1.91	20.7	4.39	9.97	0.3	3.59	-	0.1	1.21	0.14	II
SD1-32S	13/07/2013	7.77	22.5	144	182	35.3	1.88	11.9	3.77	8.11	0.3	11	0.07	0.1	<0.05	0.08	0
SD1-33	21/07/2013	7.64	22.1	136	103	34.8	2.17	11.6	6.39	7.65	1.23	11.5	8.35	0.1	<0.05	<0.05	0
SD1-34	14/07/2013	7.46	35.2	236	140	57.3	2.07	13.6	5	5.34	0.3	49.2	7.46	1.05	<0.05	0.29	II
SD1-35	26/05/2013	7.53	75	492	289	93.6	4.23	37.2	26.5	64.8	4.53	55.7	14.1	0.148	<0.05	<0.05	I
SD1-36	29/05/2013	7.62	87.1	570	290	76.9	8.25	51	46.6	80.5	13	76.7	16.2	0.1	<0.05	0.07	I
SD1-37	19/06/2013	7.49	72.6	486	292	99.4	4.5	36.9	21.6	63.1	3.83	34.5	19.9	0.1	<0.05	<0.05	I
SD1-40	30/08/2013	7.67	38.9	260	168	60.3	2.49	12.6	10	16.8	2.55	14.6	10.7	0.1	<0.05	<0.05	0
SD1-40M	25/08/2013	7.71	38.7	284	174	59.6	2.89	13.3	11.5	19.2	1.53	18.2	9.3	0.1	<0.05	<0.05	0
SD1-41	23/08/2013	7.54	35.5	224	162	55	2.4	12.3	9.33	15.6	1.66	13.2	9.67	0.123	<0.05	<0.05	0
SD1-42	18/08/2013	7.62	28.1	202	118	39.3	2.44	10.6	9.4	14.5	2.16	12.7	10.5	0.1	<0.05	0.12	0
SD1-43	22/06/2013	7.39	74.4	508	300	74.8	5.3	39.8	31.7	56.3	4.41	45.2	15.5	0.1	<0.05	<0.05	I
SD1-44	10/08/2013	7.73	73.9	500	395	65.2	1.46	49.8	10.5	28.4	1.99	23.9	14.9	0.185	<0.05	<0.05	I
SD1-45	18/01/2014	7.93	44.6	282	395	66.3	3.28	21.5	9.34	16.6	3.27	23.7	10.2	0.153	0.14	<0.05	I
SANS241: 2011	Max. Allowable Limit	5-9.7	<170	1200	-	-	-	-	200	300	11	500	-	1.5	0.3	0.5	



Borehole No.	Date Sampled	Physical Determinants			Chemical Determinants												Water Quality Class
		pH	EC mS/m	TDS mg/l	MALK mg/l	Ca mg/l	K mg/l	Mg mg/l	Na mg/l	Cl mg/l	NO3 as N mg/l	SO4 mg/l	Si mg/l	F mg/l	Fe mg/l	Mn mg/l	
Class 0 Max. Allowable Limit		5-9.5	<70	<450	-	<80	<25	<70	<100	<100	<6	<200	-	<0.7	<0.01	<0.1	0
Class 1 Max. Allowable Limit		10	150	1000	-	150	50	100	200	200	10	400	-	0.7-1.0	0.01-0.2	0.1-0.4	I
Class 2 Max. Allowable Limit		10.5	370	2400	-	300	100	200	400	600	20	600	-	1.0-1.5	0.2-2.0	1-4	II
Class 3 Max. Allowable Limit		11	520	3400	-	>300	500	400	1000	1200	40	1000	-	1.5-3.5	2-10	4-10	III
Class 4 Max. Allowable Limit		>11	>520	>3400	-		>500	>400	>1000	>1200	>40	>1000	-	>3.5	>10.0	>10.0	IV
Min		7.13	19.4	116	103	27.4	1.46	6.13	2.68	2.88	0.3	3.59	0.07	0.1	0.05	0.05	
Max		7.93	97	730	395	174	9.76	59.4	52.3	133	13.4	94.5	21.6	1.05	1.21	0.29	
Average		7.52	61.42	410.93	273.05	78.87	3.45	33.18	17.20	39.99	3.41	34.12	12.80	0.13	0.08	0.08	



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5.3.5.10 Existing Point Source Pollution

From the analytical results existing point source pollution was reported in eight of the existing boreholes and one newly drilled exploration borehole. Point source pollution is from well-defined and specific sources e.g. animal farming and stockades.

Existing boreholes impacted by source point pollution exceeding the DWAF (1998) Class 1 drinking water quality standard are listed in Table 19 and indicated on Figure 45.

Table 19: SD1 Existing Point Source Pollution

Borehole No.	Farm	Chemical Determinants Exceeding DWAF drinking Water Standard Class I	Water Quality Class
SD1-GAA017	Carter Block Ptn. Dikbos	Mg, NO3	II
SD1-GAA018	Carter Block Ptn. Dikbos	NO3	II
SD1-GAA020	Carter Block Ptn. Dikbos	Ca, NO3	II
SD1-GAA066	Tevrede	EC, TDS, Mg, NO3	II
SD1-GAA105	Carter Block Ptn. Siver Streams	NO3	III
SD1-GAA107	Carter Block Ptn. Outpost	EC, TDS, Ca, Cl, NO3	II
SD1-GAA159	Strydpan Ptn. Selfhelp	EC, TDS, K, NO3	III
SD1-GAA227	Jonasbank	Mg, NO3	II
SD1-10	Carter Block Ptn. Dikbos	NO3	II

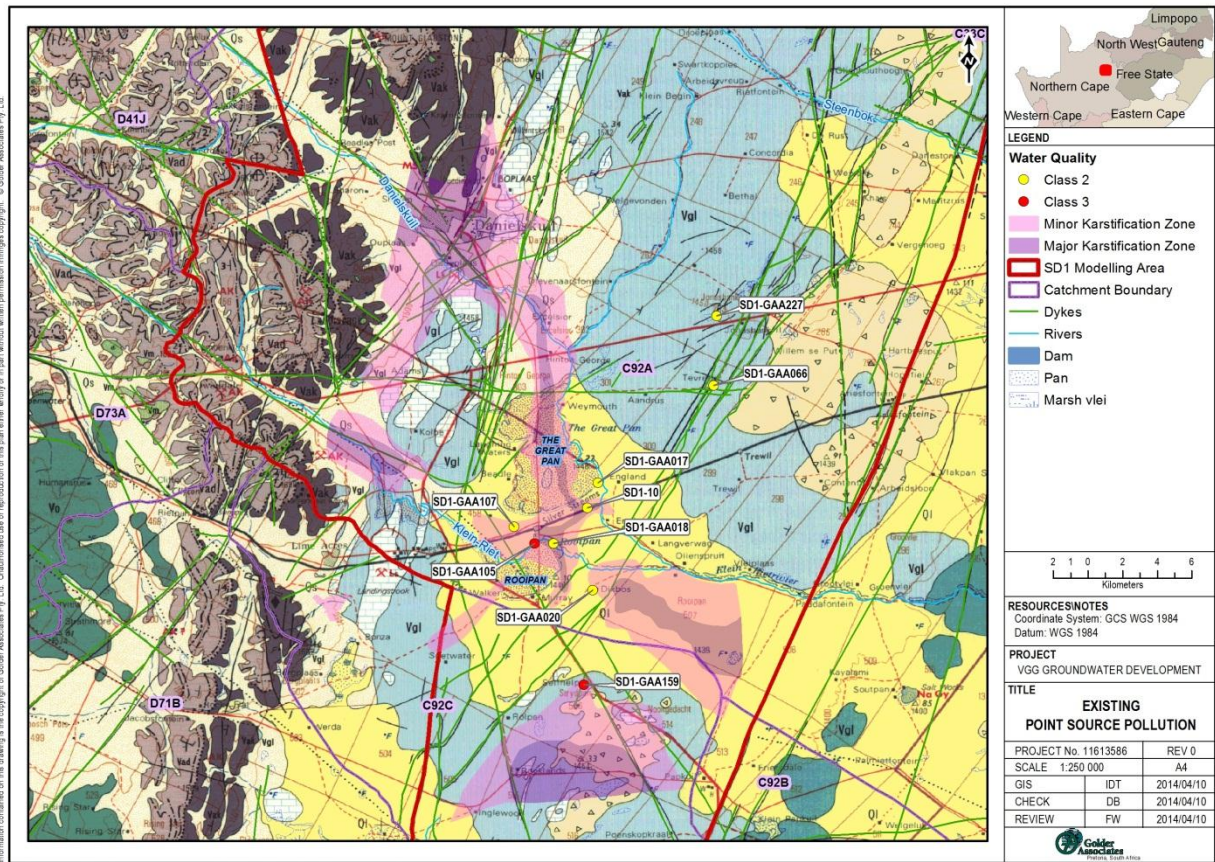


Figure 45: SD1 Existing Point Source Pollution



5.3.6 Groundwater Classification

The groundwater quality results of boreholes sampled at SD1 are visually represented on Piper and expanded Durov diagrams to distinguish between the different water quality classes/types.

Piper diagrams graphically represent the relative percentages of anions and cations in water samples. The cation percentages are plotted in the left triangle and the anion percentages in the right triangle. A projection of these cation and anion presentations onto the central diamond presents the chemical signature of the major ion composition of the water.

Expanded Durov diagrams graphically represent the relative percentages of anions and cations in water samples. The cation percentages are plotted in the top part of the diagram and the anion percentages in the left part. A projection of these cation and anion percentages onto the central area presents the chemical signature of the major ion composition of the water. The chemical signature can be related to various hydrochemical environments and conditions.

The groundwater classes/types of SD1 featuring as Piper expanded Durov diagrams are discussed as follows with unpolluted groundwater indicated in blue sectors:

- Fountains;
- Existing Boreholes;
- Exploration boreholes;
- Shallow monitoring boreholes;
- Well field boreholes; and
- Danielskuil Municipality Boreholes.

5.3.6.1 Fountains

The seven fountains located and sampled during the hydrocensus analytical results are illustrated in Figure 46 on as a Piper diagram. The plot indicates a signature of calcium magnesium bicarbonate type of water (Ca, Mg) (HCO₃)₂. This type of water is associated with recent rainfall recharge and unpolluted groundwater (blue sector).

On the Expanded Durov Diagram (EDD) Figure 47 the results plot on the first two sectors of the diagram and represent unpolluted groundwater (blue sector).

The groundwater quality of the fountains as calcium magnesium bicarbonate type of water (Ca, Mg) (HCO₃)₂ are representative of the background water quality for SD1 study area.

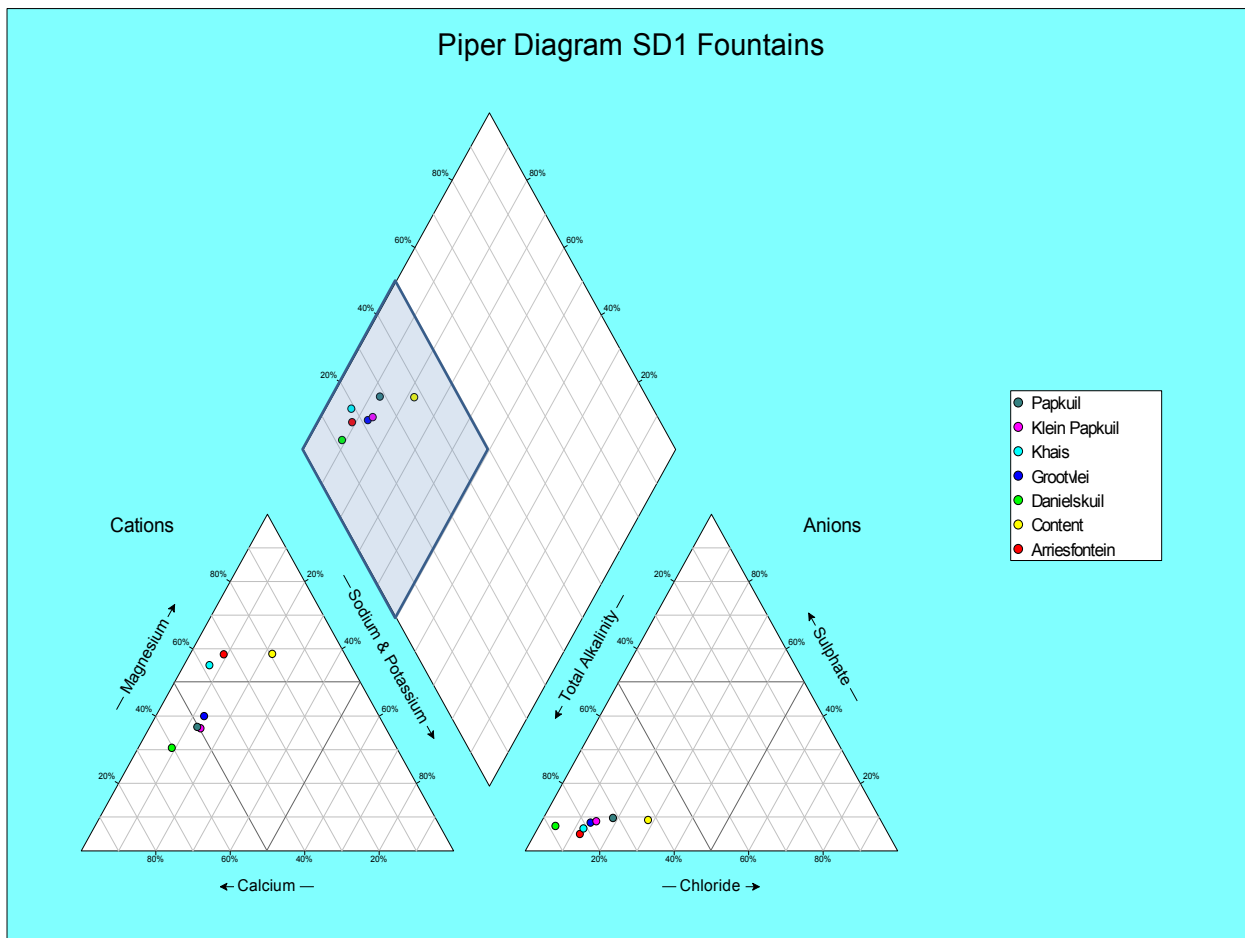


Figure 46: Piper Diagram SD1 Fountains

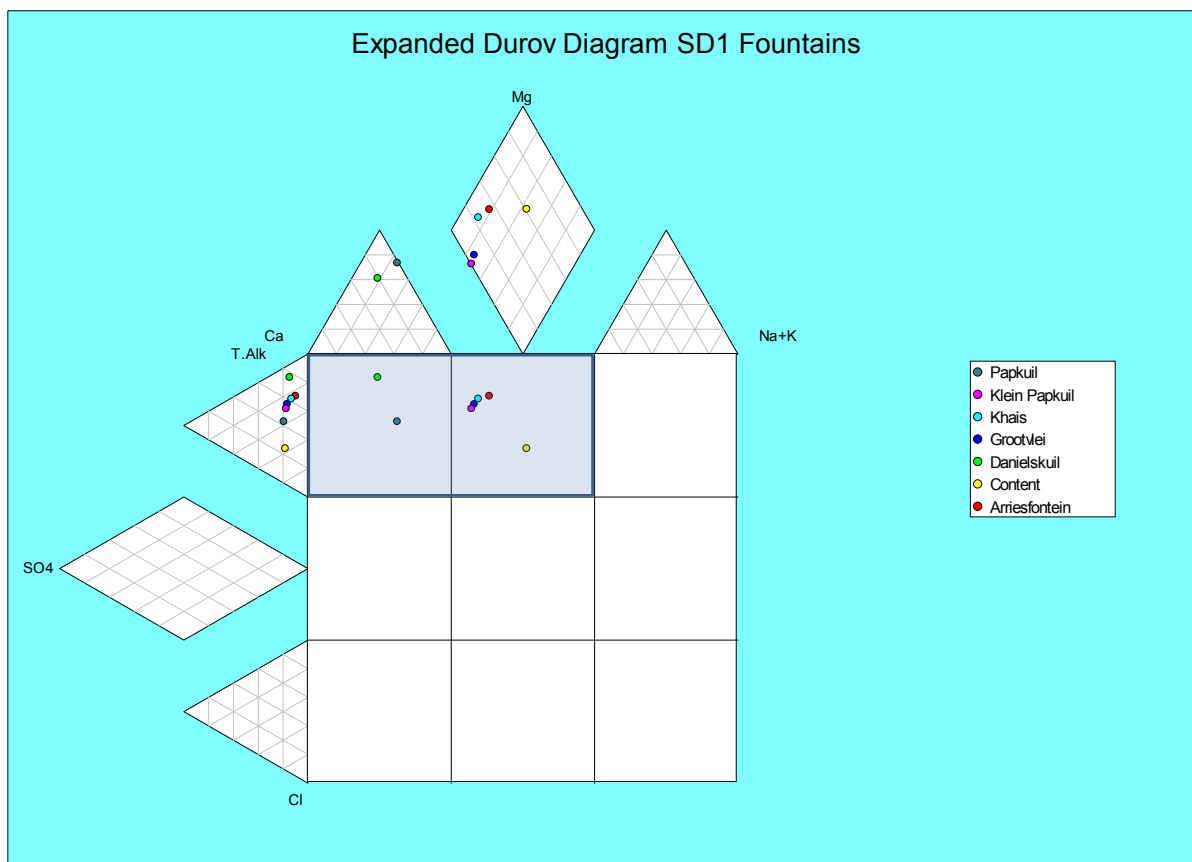


Figure 47: Expanded Durov Diagram SD1 Fountains

5.3.6.2 Existing Boreholes

The existing boreholes groundwater quality is characterized by 76 groundwater samples analysed. The results are represented as two manageable data sets.

On the two Piper diagrams (Figure 48 and Figure 49) the majority of water sample are representative of calcium magnesium bicarbonate type of water $(Ca, Mg)(HCO_3)_2$ and representative of unpolluted groundwater. Six boreholes samples plot on to the $(Ca, Mg)Cl_2/(Ca, Mg)SO_4$ type of water.

On the expanded Durov diagrams (Figure 50 and Figure 51) the majority of the results plot on the first two sectors of the diagram representing unpolluted groundwater. Three water types are distinguished on the expanded Durov diagrams specifically:

- Calcium magnesium bicarbonate type of water $(Ca, Mg)(HCO_3)_2$ – Majority of existing boreholes plot on first 2 segments of EDD, typical of unpolluted groundwater;
- Magnesium sulphate $(Mg)SO_4$ type of water (SD1-GAA105; SD1-GAA107; SD1-GAA099; SD1-GAA017); and
- Magnesium chloride $(Mg)Cl$ type of water; SD1-GAA008; SD1-GAA69.

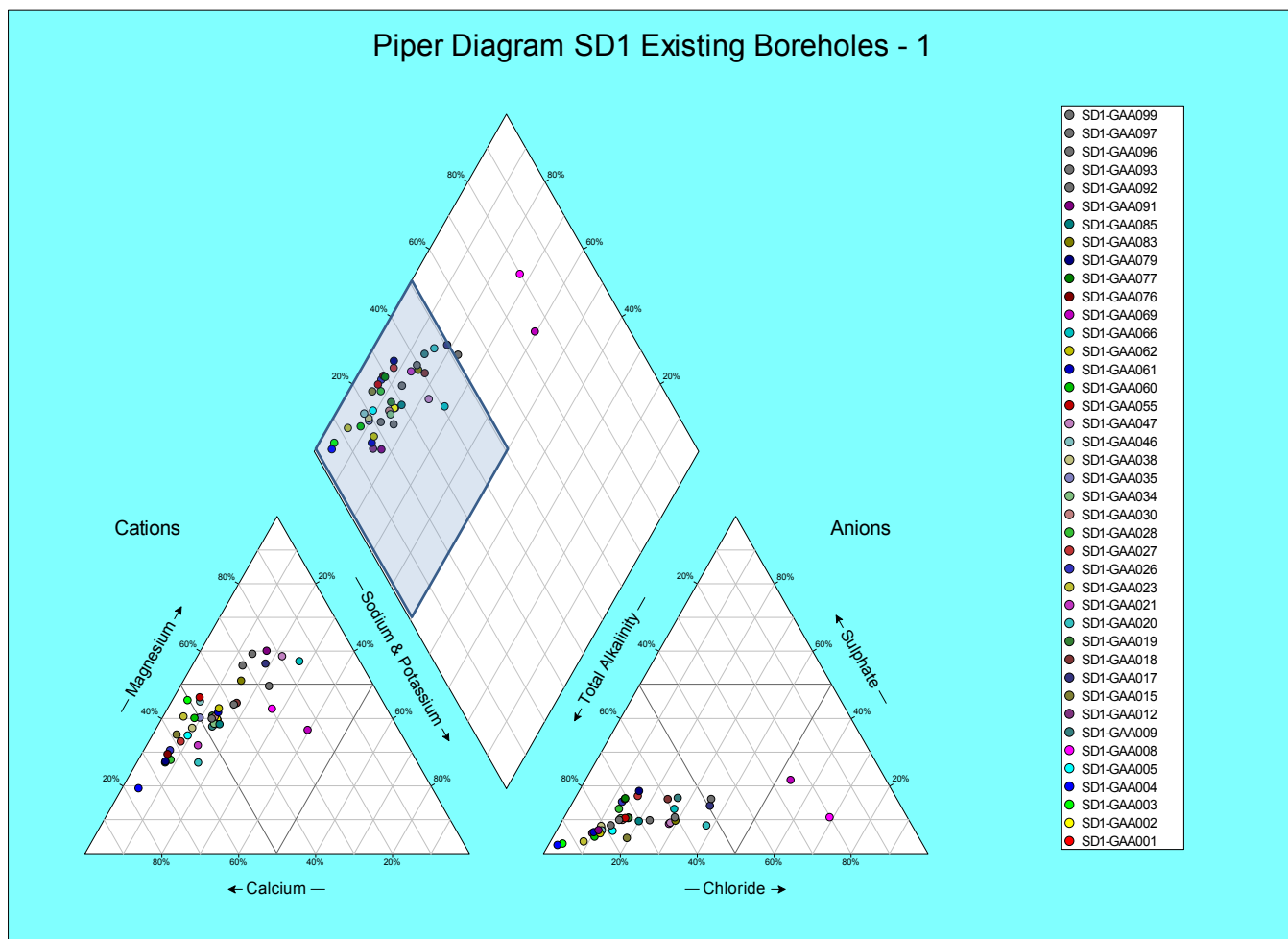


Figure 48: Piper Diagram SD1 Existing Boreholes -1

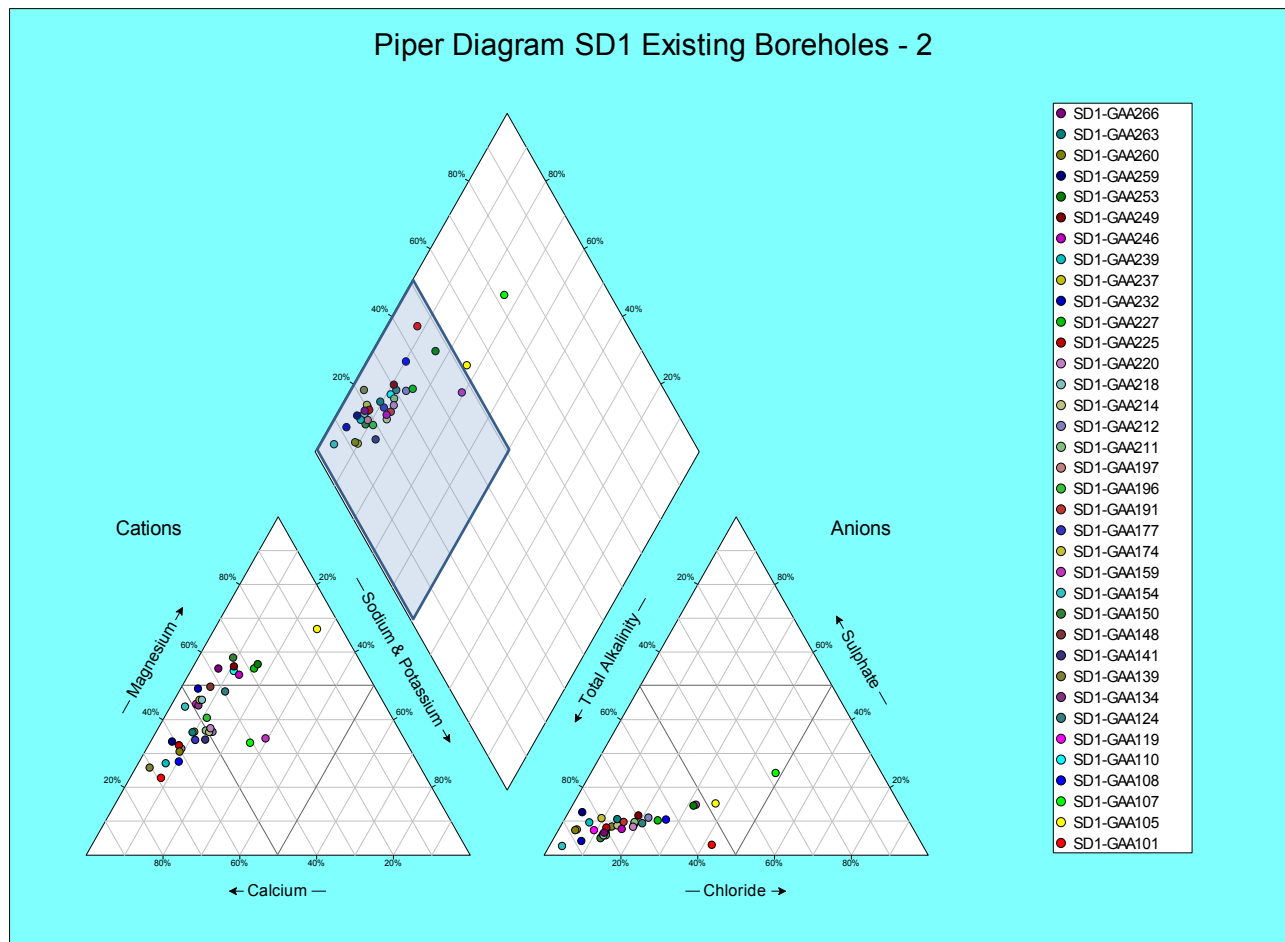


Figure 49: Piper Diagram SD1 Existing Boreholes -2

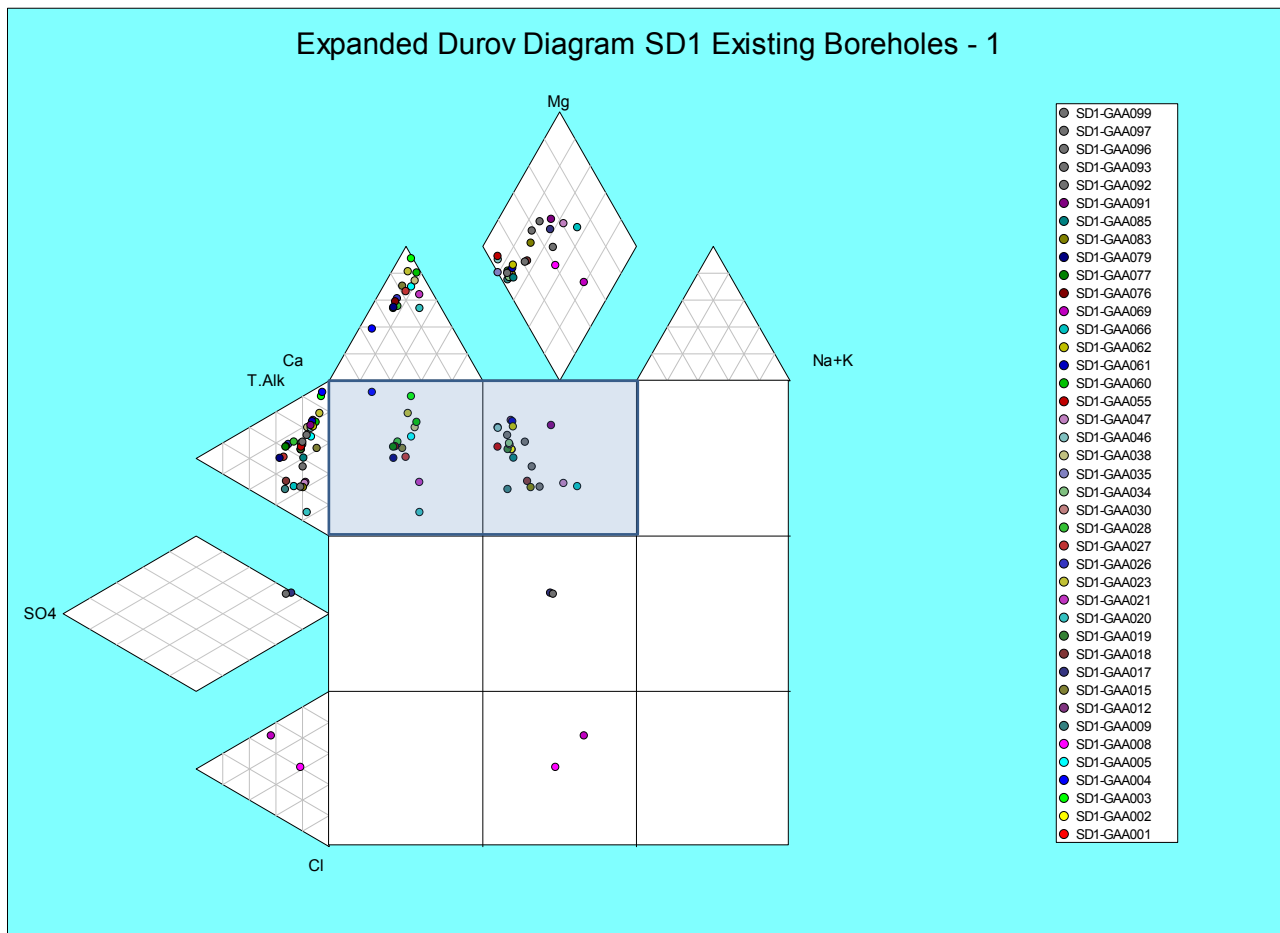


Figure 50: Expanded Durov Diagram SD1 Existing Boreholes - 1

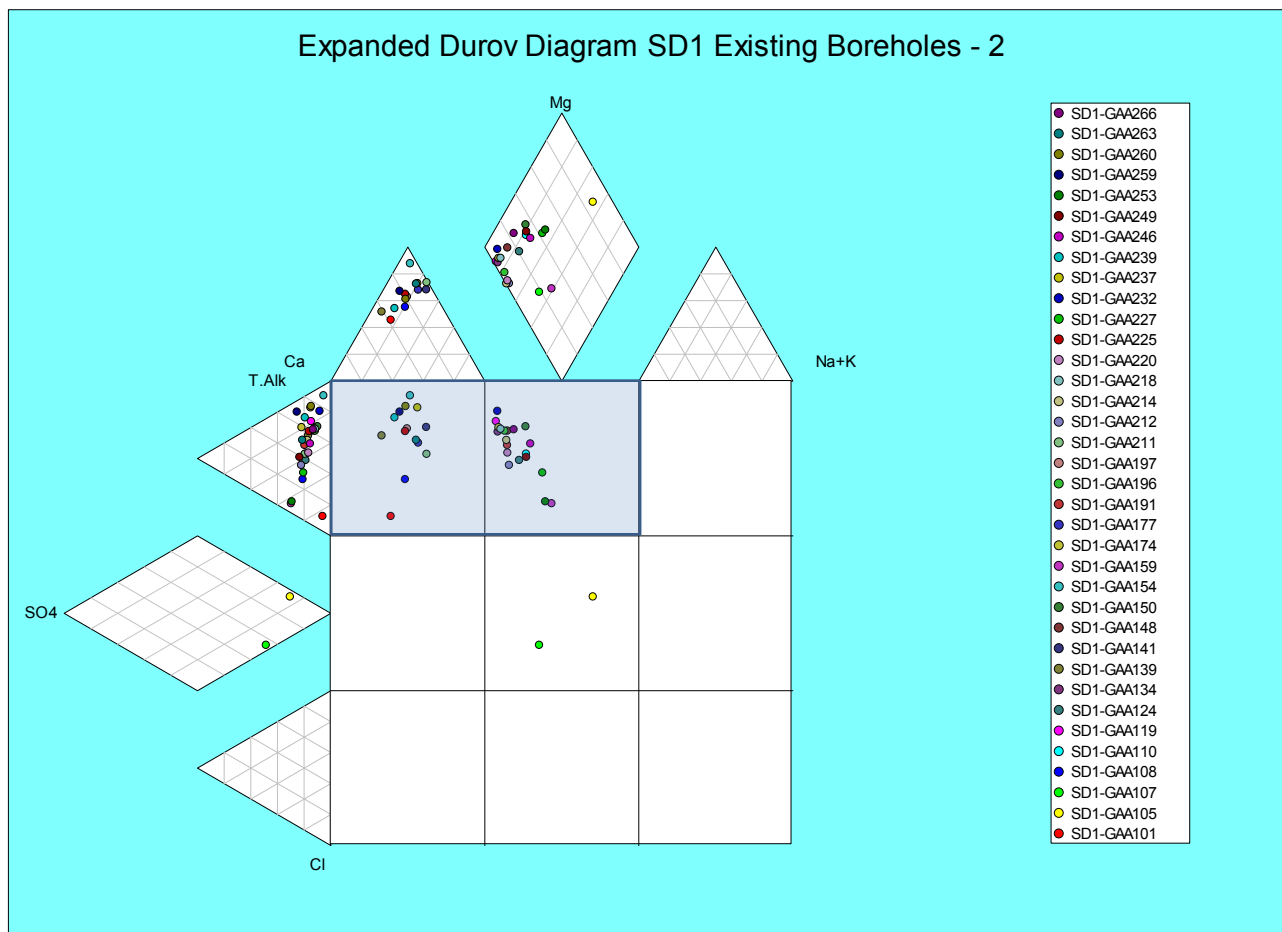


Figure 51: Expanded Durov Diagram SD1 Existing Boreholes – 2



5.3.6.3 Exploration Boreholes

The results of the exploration boreholes sampled position on the Piper diagram (Figure 52) show a signature of calcium magnesium bicarbonate type of water $(Ca, Mg)(HCO_3)_2$. This type of water is associated with recent rainfall recharge and unpolluted groundwater.

The majority of the exploration boreholes on the Expanded Durov Diagram (Figure 53) plot on the first two sectors of the diagram and represent unpolluted groundwater. These samples are representative of calcium magnesium bicarbonate type of water $(Ca, Mg)(HCO_3)_2$. These samples represent unpolluted groundwater.

SD1-12 is representative of calcium sulphate type $(Ca)SO_4$ type of water, indicating calcium enrichment. .

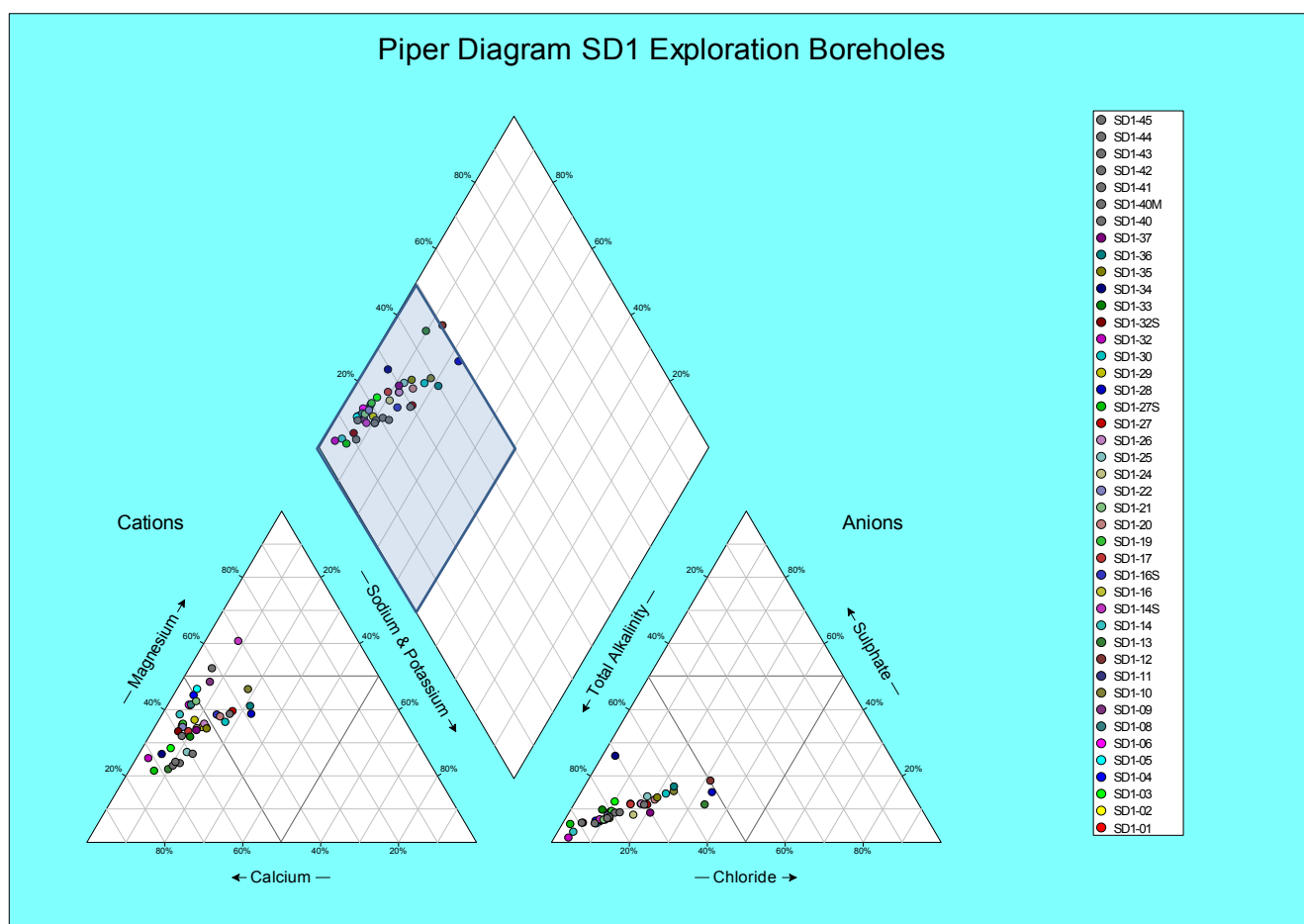


Figure 52: Piper Diagram SD1 Exploration Boreholes

5.3.6.4 Shallow Monitoring Boreholes

The plot of the shallow monitoring calcrete boreholes on the Piper Diagram (Figure 54) show a signature of calcium magnesium bicarbonate type of water $(Ca, Mg)(HCO_3)_2$. This type of water is associated with recent rainfall recharge and unpolluted groundwater. On the Expanded Durov Diagram (Figure 55) the results plot on the first two sectors of the diagram and represent unpolluted groundwater.

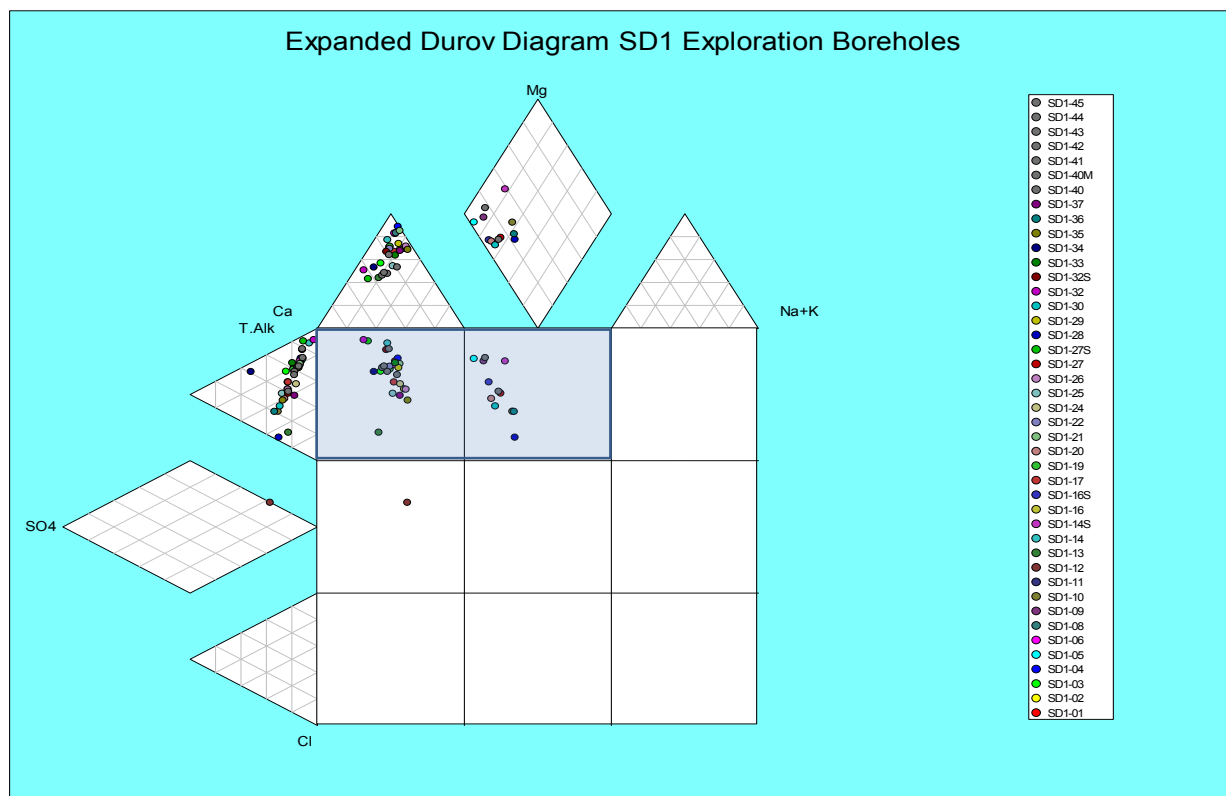


Figure 53: Expanded Durov Diagram SD1 Exploration Boreholes

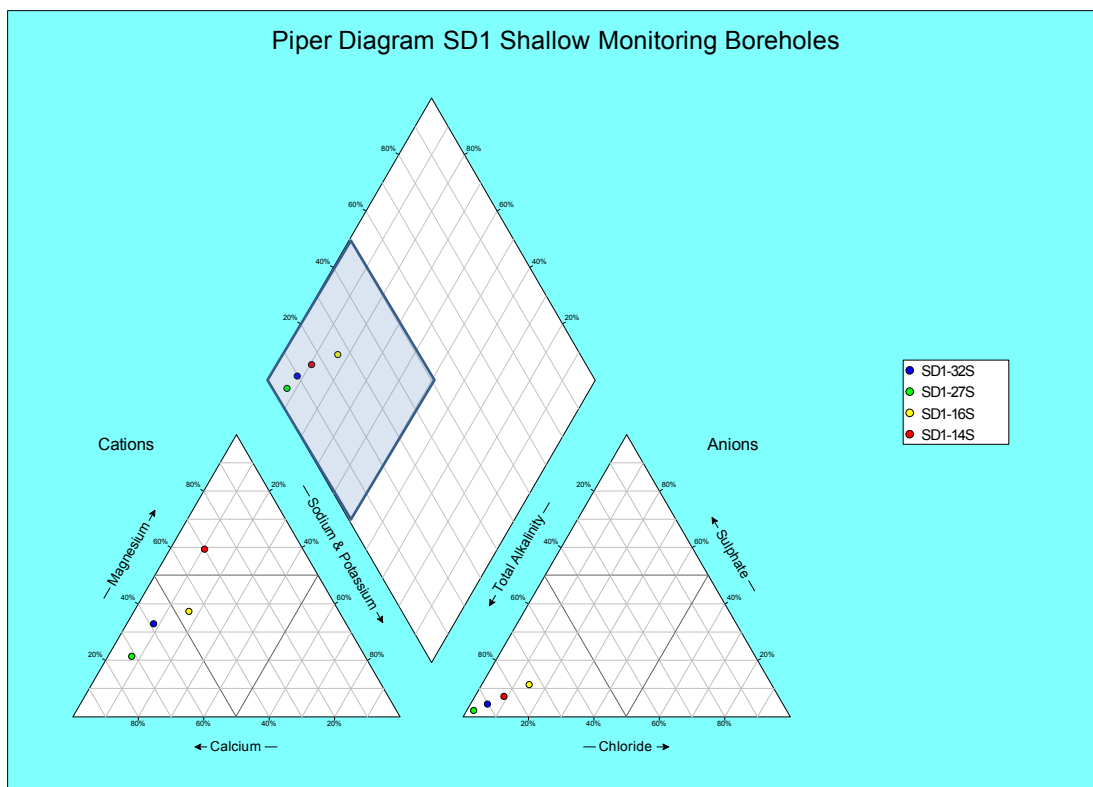


Figure 54: Piper Diagram SD1 Shallow Monitoring Boreholes

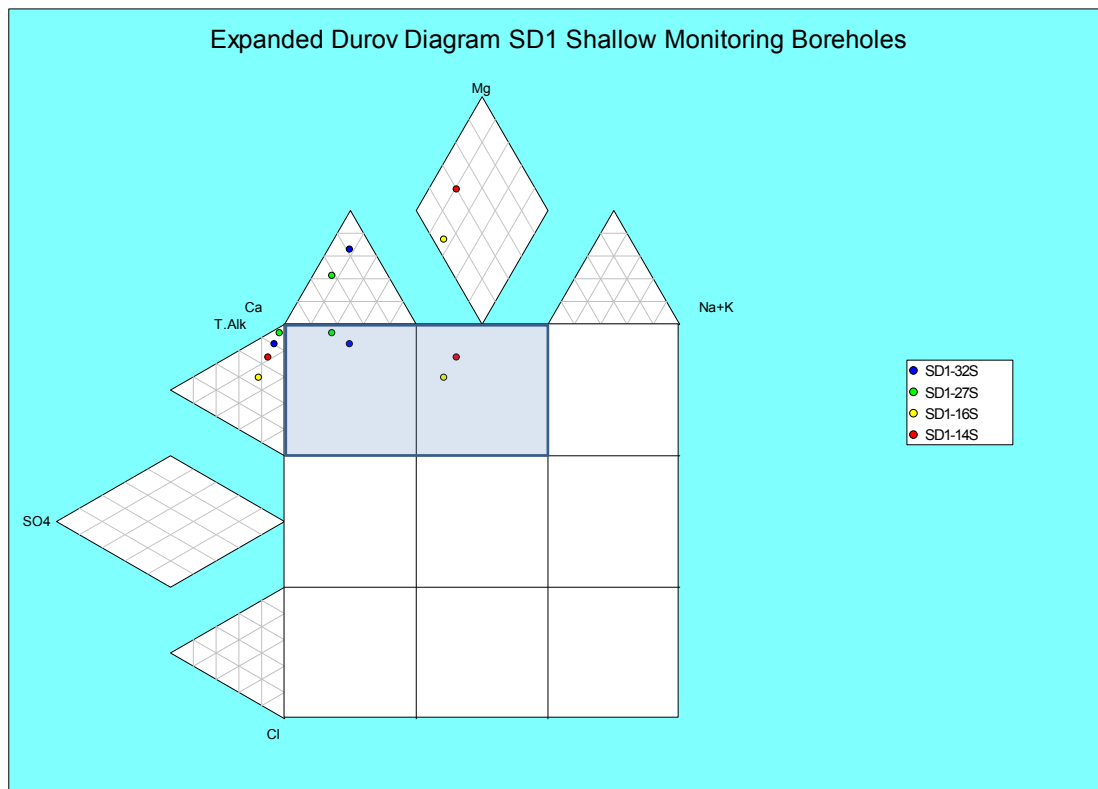


Figure 55: Expanded Durov Diagram SD1 Shallow Monitoring Boreholes

5.3.6.5 Well Field Boreholes

The proposed 22 well field boreholes groundwater quality on the Piper diagram (Figure 56) show a signature of calcium magnesium bicarbonate type of water $(Ca, Mg)(HCO_3)_2$. This type of water is associated with recent rainfall recharge and unpolluted groundwater.

On the Expanded Durov Diagram (Figure 57) the results plot on the first two sectors of the diagram and represent unpolluted groundwater.

5.3.6.6 Danielskuil Municipality Supply Boreholes

The results of the three boreholes allocated to Danielskuil municipality supply boreholes position on the Piper diagram (Figure 58) show a signature of calcium magnesium bicarbonate type of water $(Ca, Mg)(HCO_3)_2$. This type of water is associated with recent rainfall recharge and unpolluted groundwater.

On the Expanded Durov Diagram (Figure 59) the results plot on the first two sectors of the diagram and represent unpolluted groundwater, and suitable for human consumption.

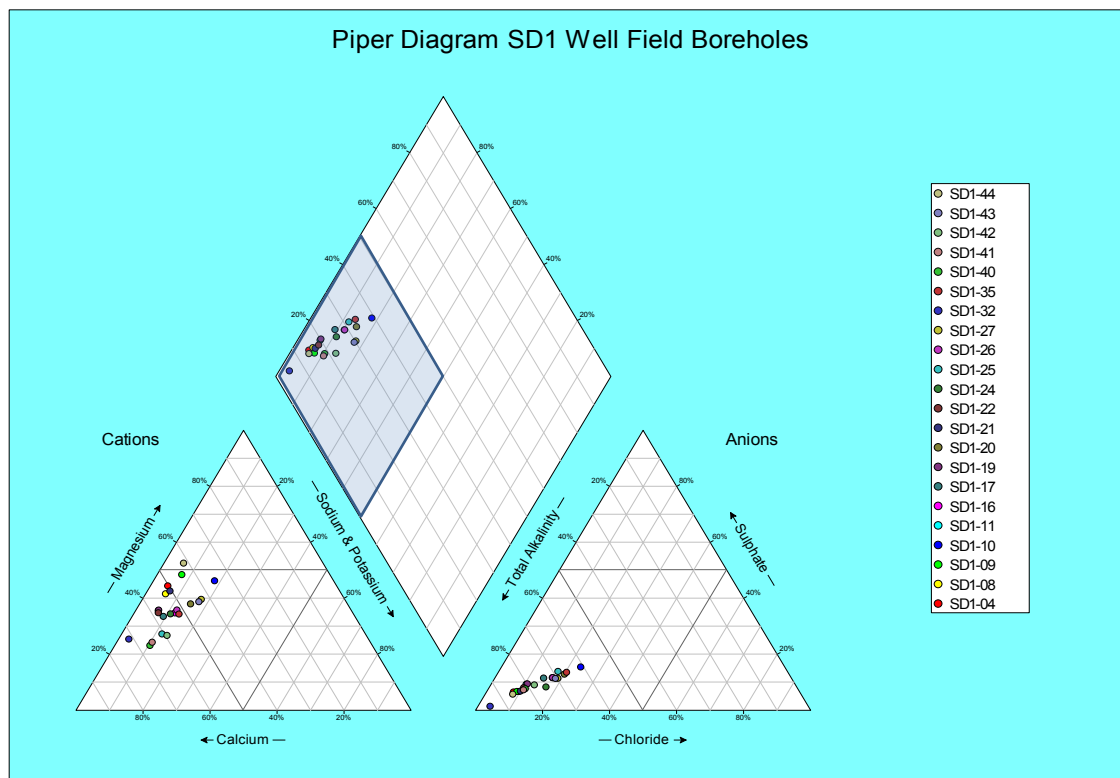


Figure 56: Piper Diagram SD1 Well Field Boreholes

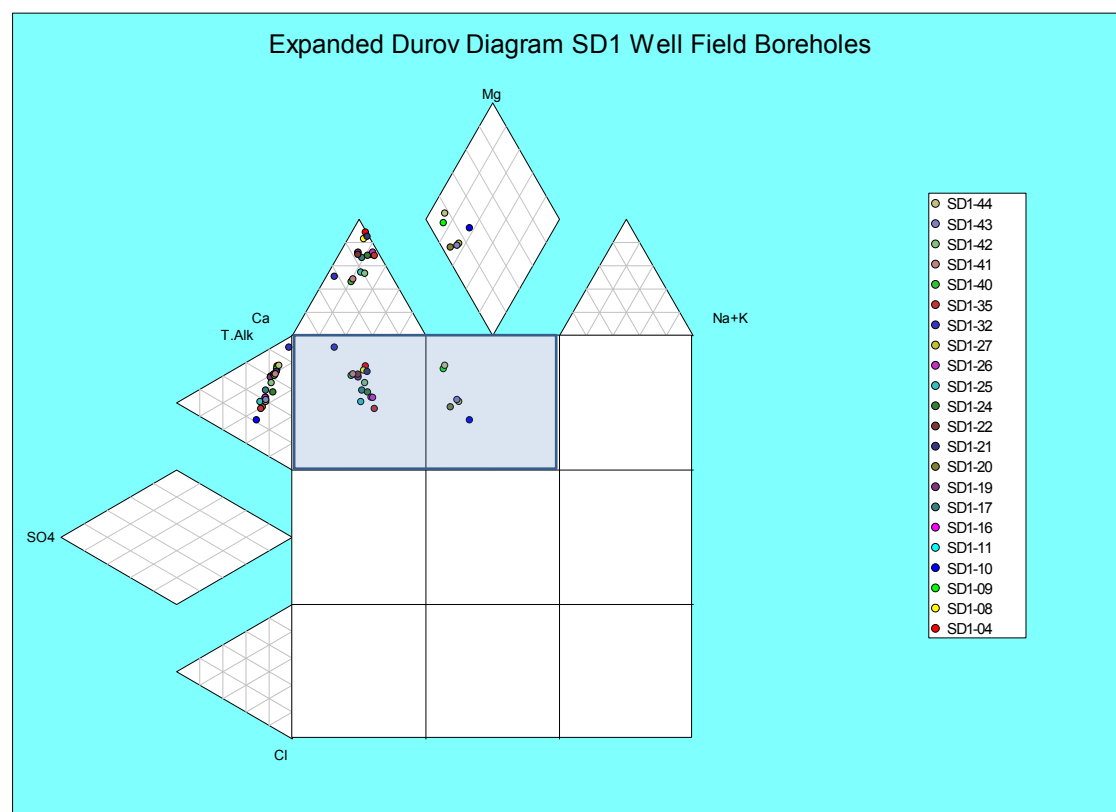


Figure 57: Expanded Durov Diagram SD1 Well Field Boreholes

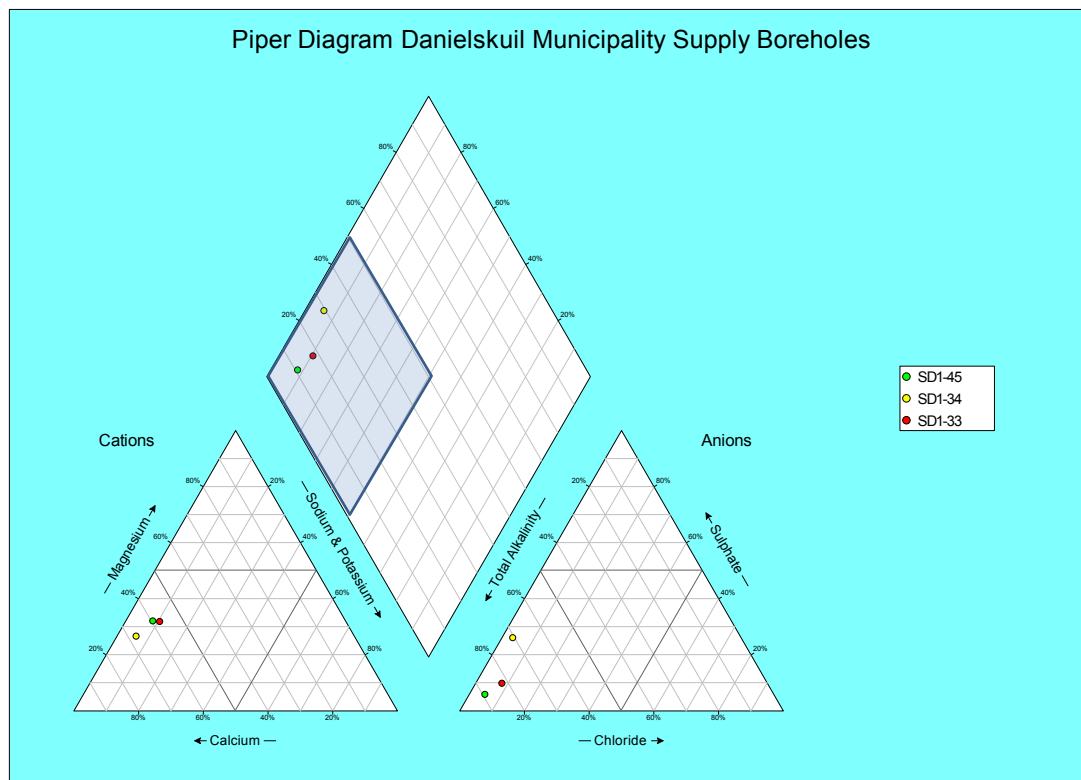


Figure 58: Piper Diagram Danielskuil Municipality Boreholes

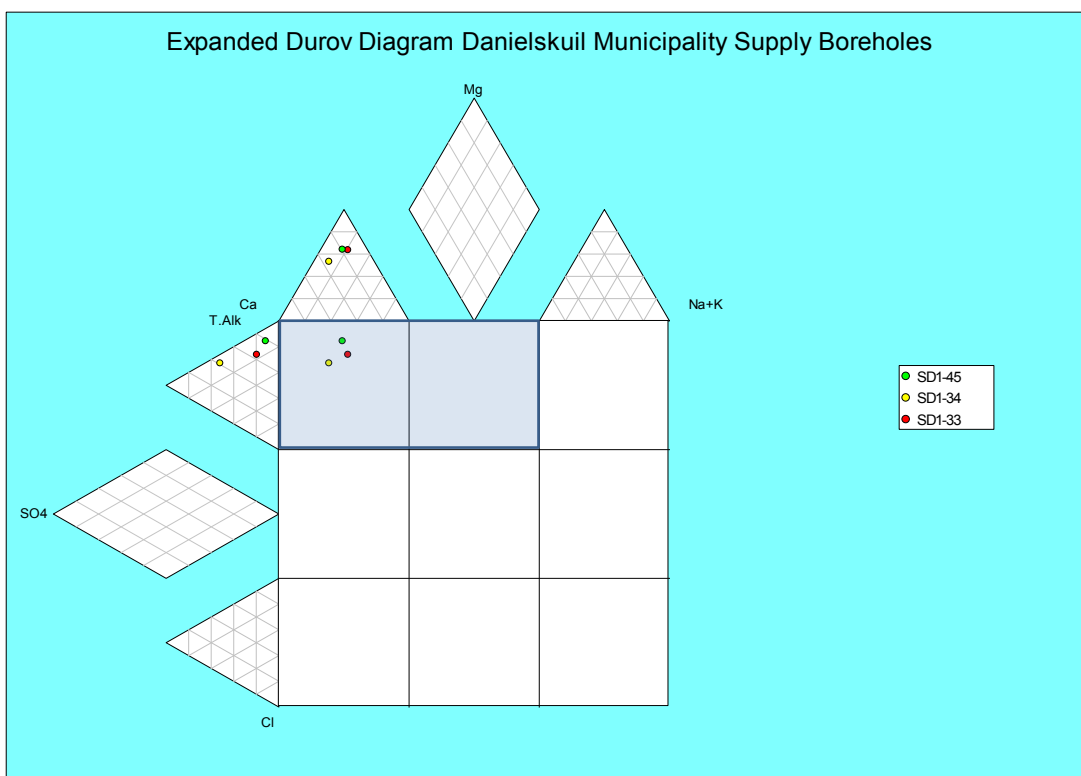


Figure 59: Expanded Durov Diagram Danielskuil Municipality Boreholes



5.4 SD1 Groundwater Monitoring

Monitoring records of groundwater quality and water levels at SD1 area are essential to establish a history of the natural status of the groundwater.

The newly drilled exploration boreholes were subsequently implemented into a quarterly monitoring programme, where water levels are monitored quarterly by hand at all the newly drilled boreholes. The hand held water level monitoring record up to date is listed in Table 20. All monitoring data are captured on Golder's groundwater data base (Aquabase) and serve as background reference against which quality and water levels can be correlated.

The monitoring data base consists of:

- Baseline water quality and water levels as determined during exploration phase;
- Quarterly (three monthly) hand measured water level records where accessible;
- Continuous water level logger data at seven selected monitoring boreholes; and
- Incorporation of DWAF historical and current monitoring data.

The proposed short term groundwater monitoring programme for SD1 area comprises of:

- Quarterly water level monitoring of all accessible exploration boreholes for a minimum period of 3 years; and
- Continuous water level monitoring (every six hours) at present installed electronic data loggers for a minimum period of 3 years.



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Table 20: SD1 Quarterly Water Level Monitoring Record

Borehole No.	Depth (m)	Final Blow Yield (l/s)	Altitude (mamsl)	Measured 2013 SWL (mbgl)	Date	Monitoring Date	Jan 2014 SWL (mbgl)	Water Level Difference +/- (m)
SD1-01	82	12.5	1444.01	10.62	07/03/2013	15/01/2014	10.88	0.26
SD1-02	30	20	1446.37	9.89	07/03/2013	15/01/2014	9.93	0.04
SD1-03	80	12	1435.90	12.03	21/02/2013	15/01/2014	12.3	0.27
SD1-04	61	18	1442.51	11.58	18/03/2013	15/01/2014	12.20	0.62
SD1-05	40	20	1437.63	17.25	25/03/2013	17/01/2014	18.36	1.11
SD1-06	70	1.8	1437.54	11.70	23/03/2013	17/01/2014	11.85	0.15
SD1-07	50	0.1	1443.08	12.98	22/03/2013	15/01/2014	13.34	0.36
SD1-08	40	38.9	1441.14	13.68	25/04/2013	17/01/2014	13.90	0.22
SD1-09	40	38	1441.14	6.84	16/04/2013	15/01/2014	7.07	0.23
SD1-10	28	20	1435.15	11.92	29/05/2013	20/01/2014	11.84	-0.08
SD1-11	70	14	1435.15	13.44	07/04/2013	15/01/2014	13.71	0.27
SD1-12	112	5.9	1443.18	3.27	29/04/2013	17/01/2014	3.31	0.04
SD1_13	60	5	1434.82	18.31	04/07/2013	20/01/2014	18.91	0.60
SD1-14	67	14	1435.00	13.11	26/05/2013	14/01/2014	14.05	0.94
SD1-14S	18	Seepage	1434.86	12.64	23/05/2013	14/01/2014	14.03	1.39
SD1_15	64	1.6	1435.87	18.74	22/06/2013	20/01/2014	19.37	0.63
SD1-16	69	10.5	1442.91	9.61	24/05/2013	14/01/2014	9.27	-0.34
SD1-16S	16	Seepage	1437.27	9.67	24/05/2013	14/01/2014	10.11	0.44
SD1-17	58	50	1446.64	2.29	25/04/2013	15/01/2014	2.55	0.26
SD1_17M	24		1441.82	2.32	18/08/2013	15/01/2014	2.46	0.14
SD1_18	72	0.2	1437.42	16.22	19/06/2013	20/01/2014	16.69	0.47



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Borehole No.	Depth (m)	Final Blow Yield (l/s)	Altitude (mamsl)	Measured 2013 SWL (mbgl)	Date	Monitoring Date	Jan 2014 SWL (mbgl)	Water Level Difference +/- (m)
SD1-19	40	20	1437.38	2.4	15/04/2013	15/01/2014	2.21	-0.19
SD1-20	48	33	1444.43	2.2	01/05/2013	15/01/2014	2.44	0.24
SD1-21	103	33	1442.75	2.04	12/04/2013	15/01/2014	2.26	0.22
SD1-22	49	20	1444.45	2.93	26/04/2013	15/01/2014	3.20	0.27
SD1_23	76	Seepage	1444.41	18.07	17/06/2013	15/01/2014	16.54	-1.53
SD1_24	68	34	1436.43	12.7	02/06/2013	14/01/2014	13.51	0.81
SD1-25	51	62	1436.59	7.02	29/04/2013	15/01/2014	7.29	0.27
SD1-26	69	14.1	1435.90	10.41	28/05/2013	14/01/2014	9.88	-0.53
SD1_27	104	40	1494.17	12.93	15/06/2013	14/01/2014	13.51	0.58
SD1-27S	18	Seepage	1493.40	12.08	02/05/2013	14/01/2014	13.44	1.36
SD1_28	64	2	1442.33	14.15	15/06/2013	20/01/2014	13.59	-0.56
SD1-29	68	14	1442.16	9.61	05/04/2013	15/01/2014	10.05	0.44
SD1_30	71	0.8	1443.95	17.42	14/06/2013	20/01/2014	18.08	0.66
SD1_31	120	0.83	1436.74	13.06	21/06/2013	20/01/2014	12.76	-0.30
SD1-32	73	36	1443.05	12.65	31/05/2013	14/01/2014	13.38	0.73
SD1-32S	16	Seepage	1442.98	14.12	27/05/2013	14/01/2014	12.43	-1.69
SD1_32M	72	10	1468.72	12.19	25/07/2013	14/01/2014	12.79	0.60
SD1_33	74	18	1468.72	26.12	08/07/2013	15/01/2014	25.18	-0.94
SD1_34	137	17	1466.89	25.59	23/06/2013	15/01/2014	25.32	-0.27
SD1-35	28	34	1477.23	9.58	01/05/2013	15/01/2014	9.74	0.16
SD1_35M	30	10	1437.83	9.68	29/07/2013	15/01/2014	9.81	0.13



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Borehole No.	Depth (m)	Final Blow Yield (l/s)	Altitude (mamsl)	Measured 2013 SWL (mbgl)	Date	Monitoring Date	Jan 2014 SWL (mbgl)	Water Level Difference +/- (m)
SD1-36	88	2	1457.28	11.92	25/05/2013	14/01/2014	11.69	-0.23
SD1-37	81	20	1444.01	12.27	02/06/2013	14/01/2014	13.08	0.81
SD1_38	70	Seepage	1446.37	66.82	05/07/2013	20/01/2014	21.97	-44.85
SD1_39	72	1	1435.90	20.77	06/07/2013	20/01/2014	21.87	1.10
SD1_40	97	10	1442.51	30.24	15/07/2013	17/01/2014	30.35	0.11
SD1_40M	100	0.9	1437.63	30.05	04/08/2013	17/01/2014	30.76	0.71
SD1_41	97	16	1437.54	43.43	15/07/2013	17/01/2014	43.71	0.28
SD1_42	112	10	1443.08	53.46	11/08/2013	17/01/2014	53.32	-0.14
SD1_43	64	23	1441.14	14.81	15/06/2013	14/01/2014	14.17	-0.64
SD1_44	34	8.9	1441.14	17.83	27/07/2013	17/01/2014	18.54	0.71
SD1_45	44	41	1435.15	12.82	03/07/2013	18/01/2014	13.01	0.19



5.4.1 Monitoring of Shallow and Deep Borehole Pairs

The groundwater levels measured in shallow and deep monitoring boreholes are listed in Table 21, and indicate that water levels of the deep (semi confined to confined aquifer) and shallow (unconfined) aquifer systems are not linked. These aquifer conditions were confirmed by aquifer testing results.

The automatic level logger data in shallow borehole SD1-32S (Figure 65) show a rising water level trend whereas all the installed level loggers in deep monitoring boreholes show a decrease in the water level.

There are marginal differences between the water level of the deep and shallow borehole pairs except at SD1-32S where perched aquifer (aquifer above regional water table) conditions are present. Continuous water level monitoring confirms perched conditions.

Monitoring borehole SD1-16S water level are not representative of the SWL as water level measurements are inaccurately because of oil spillage during drilling. The borehole was flushed and cleaned with an air percussion drilling rig on 10 March 2014.

Table 21: Shallow Water level Monitoring Data

Borehole No.	Altitude (mamsl)	Depth (m)	Final Blow Yield (l/s)	SWL Monitoring Date			Difference Between Deep and Shallow Boreholes (m)		
				2013 (mbgl)	14 Jan 2014 (mbgl)	5 March 2014 (mbgl)	2013	14 January 2014	5 March 2014
SD1-14	1435.00	67	14	13.11	14.05	13.98	0.47	0.02	0.1
SD1-14S	1434.86	18	Seepage	12.64	14.03	13.88			
SD1-16	1442.91	69	10.5	9.61	9.27	9.22	0.06	-0.84	-0.67
SD1-16S	1437.27	16	Seepage	9.67	10.11	9.89			
SD1-27	1494.17	104	40	12.93	13.51	13.82	0.85	0.07	0.26
SD1-27S	1493.40	18	Seepage	12.08	13.44	13.56			
SD1-32	1443.05	73	36	12.65	13.38	13.39	1.47	0.95	1.34
SD1-32S	1442.98	16	Seepage	14.12	12.43	12.05			

5.4.2 Monitoring of Deep Water Levels

Electronic data loggers were installed in seven monitoring boreholes representative of different dolomitic compartments and aquifer zones as listed in Table 22.

These data loggers accurately record continuous water level data at set intervals, 2 to 4 hours and are used to accurately monitor seasonal and long term water level fluctuations.

Table 22: SD1 Installed Water Level Loggers

Borehole No.	Water Level (mbgl)	Date installed	Date Downloaded	Water Level (mbgl)	Water Level Diff
SD1-02	9.66	14/07/2013	15/01/2014	9.93	-0.27
SD1-05	17.8	10/09/2013	17/01/2014	18.36	-0.56
SD1-12	3.11	14/07/2013	17/01/2014	3.31	-0.2
SD1-29	9.86	14/07/2013	15/01/2014	10.05	-0.19



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Borehole No.	Water Level (mbgl)	Date installed	Date Downloaded	Water Level (mbgl)	Water Level Diff
SD1-32M	12.35	10/09/2013	14/01/2014	12.79	-0.44
SD1-32S	12.59	10/09/2013	14/01/2014	12.43	0.16
SD1-42	53.03	11/09/2013	17/01/2014	53.32	-0.29

The positions of the water level data loggers are indicated on Figure 60 and water level monitoring graphs of for each monitoring borehole are listed in Figure 61 to Figure 67 .

All the boreholes monitored show a seasonal decrease (0.19 to 0.56m) of water levels except for SD1-32S who showed an increase of 0.16m in the shallow calcrete aquifer zone. This is due to the unconfined aquifer conditions and perched conditions of the calcrete zone.

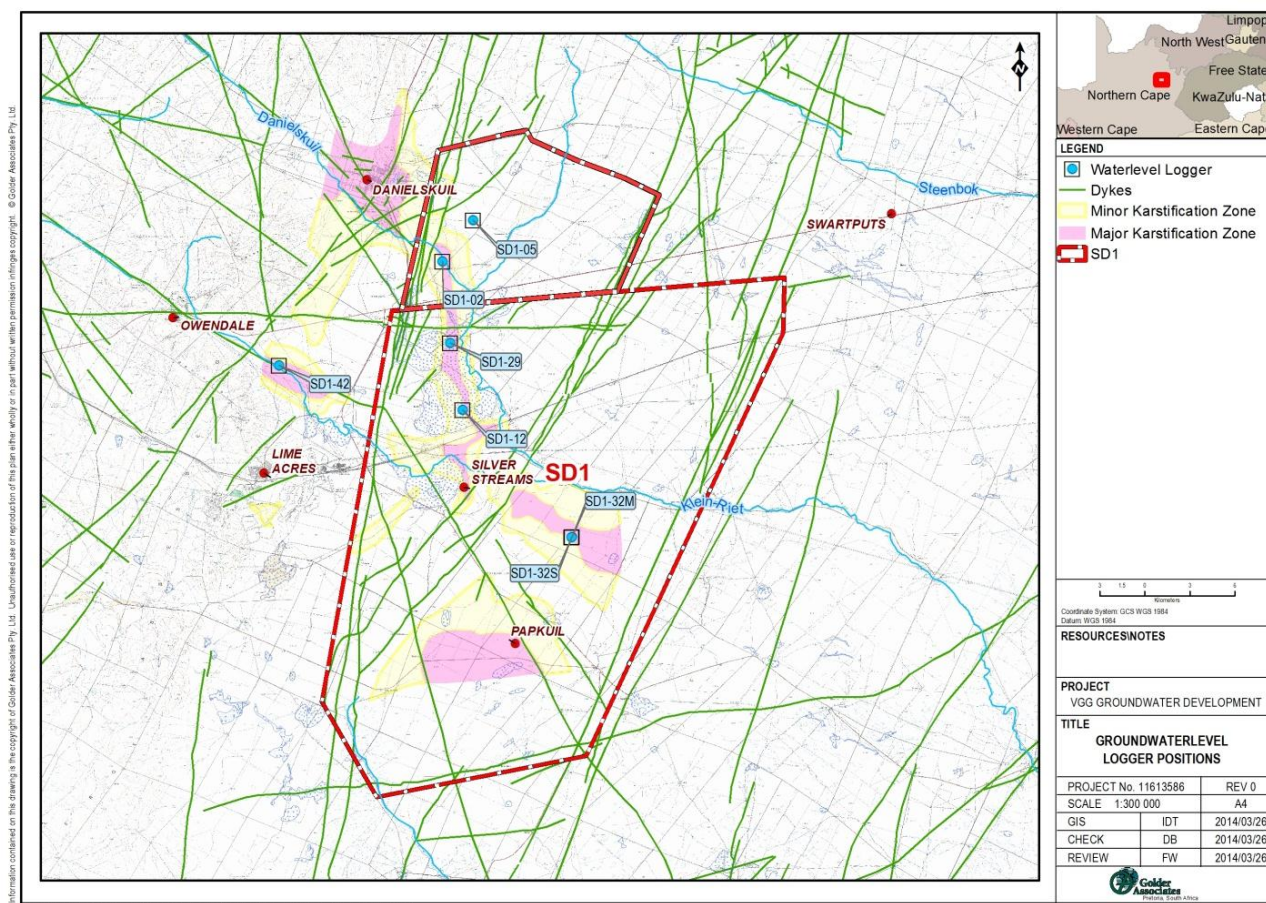


Figure 60: Positions of Installed Groundwater WL Loggers



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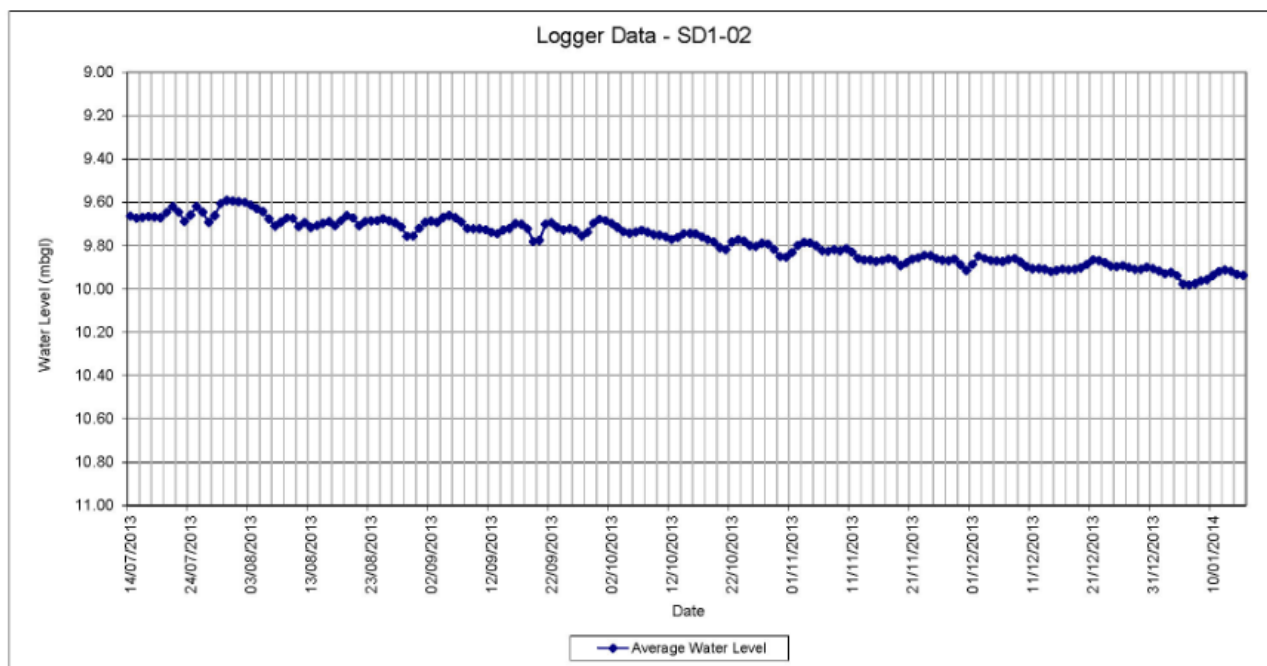


Figure 61: SD1-02 Water Level Logger Data

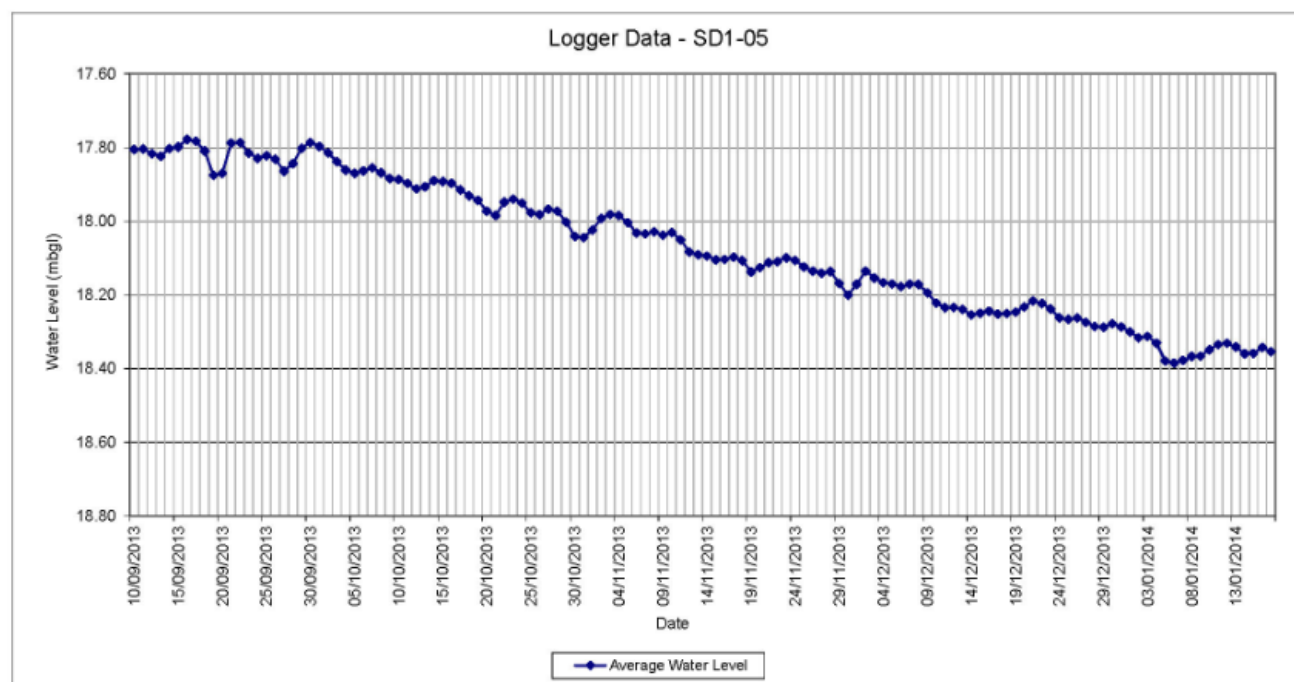


Figure 62: SD1-05 Water Level Logger Data



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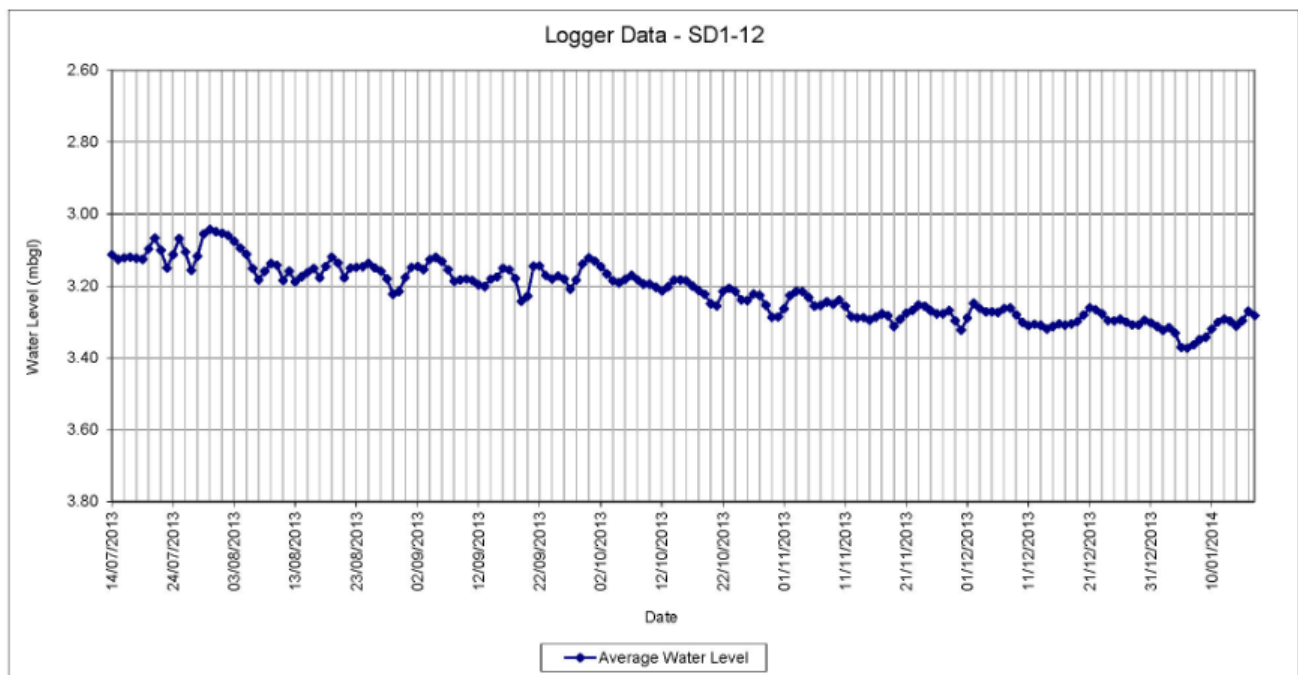


Figure 63: SD1-12 Water Level Logger Data

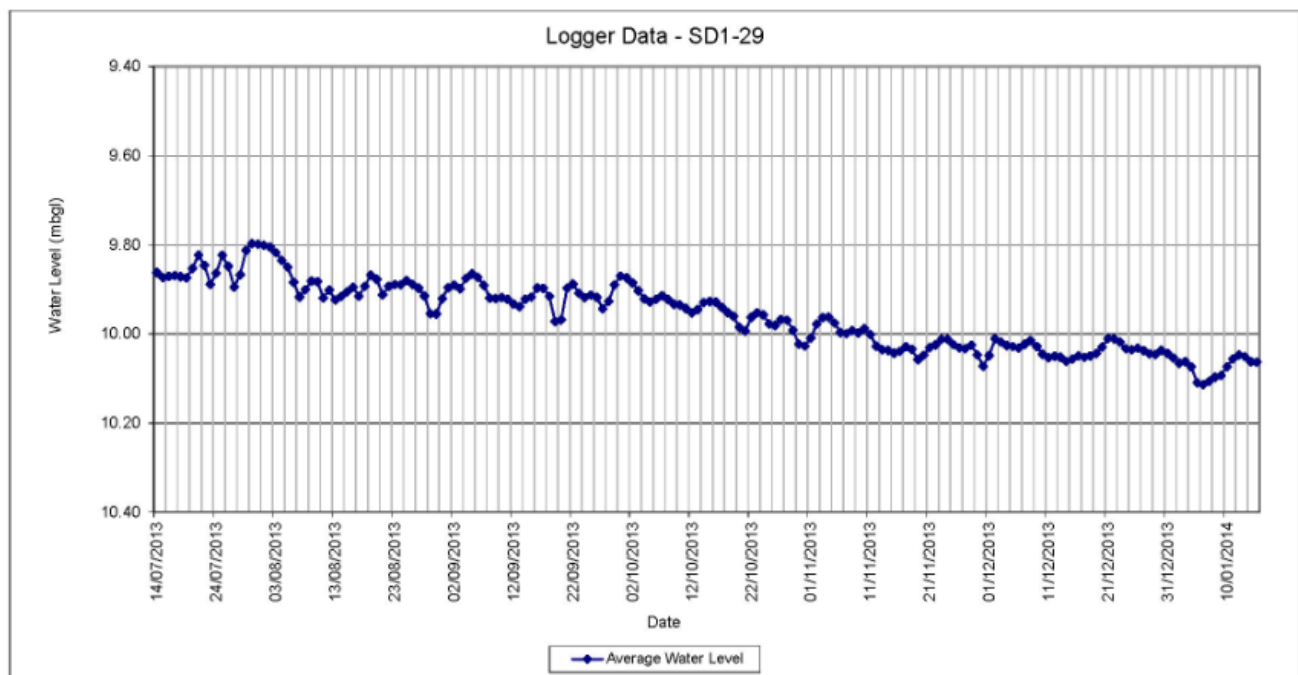


Figure 64: SD1-29 Water Level Logger Data



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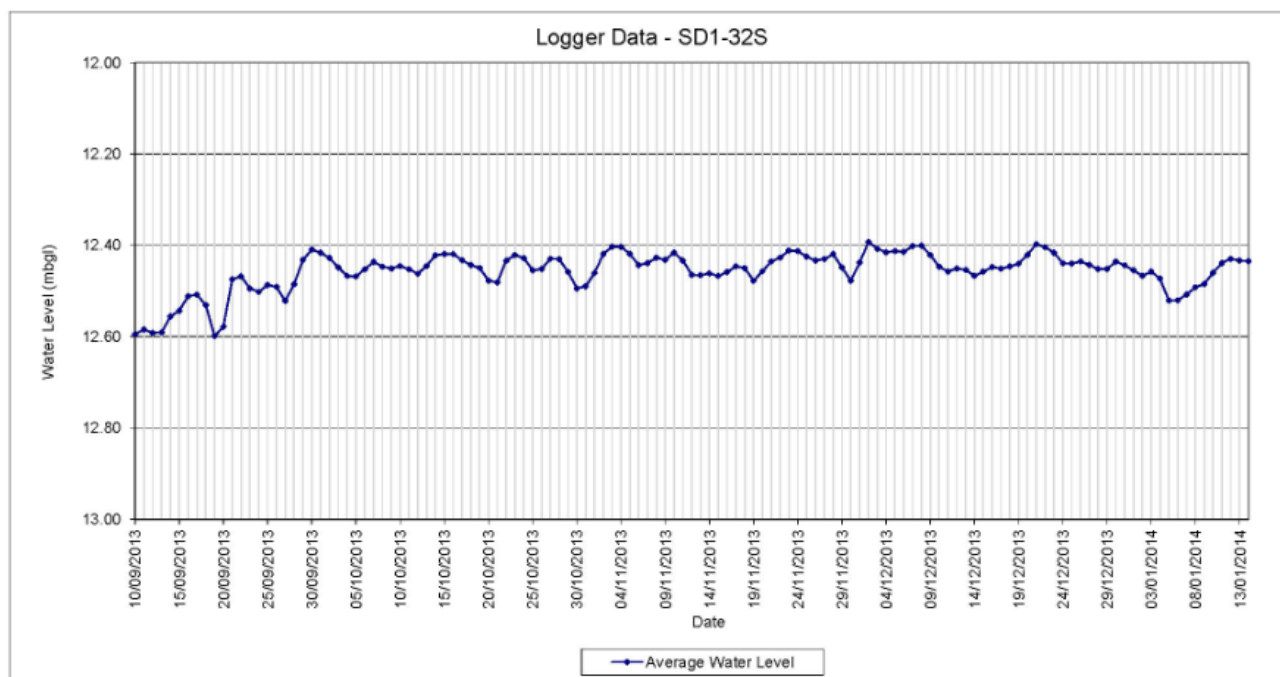


Figure 65: SD1-32S Water Level Logger Data

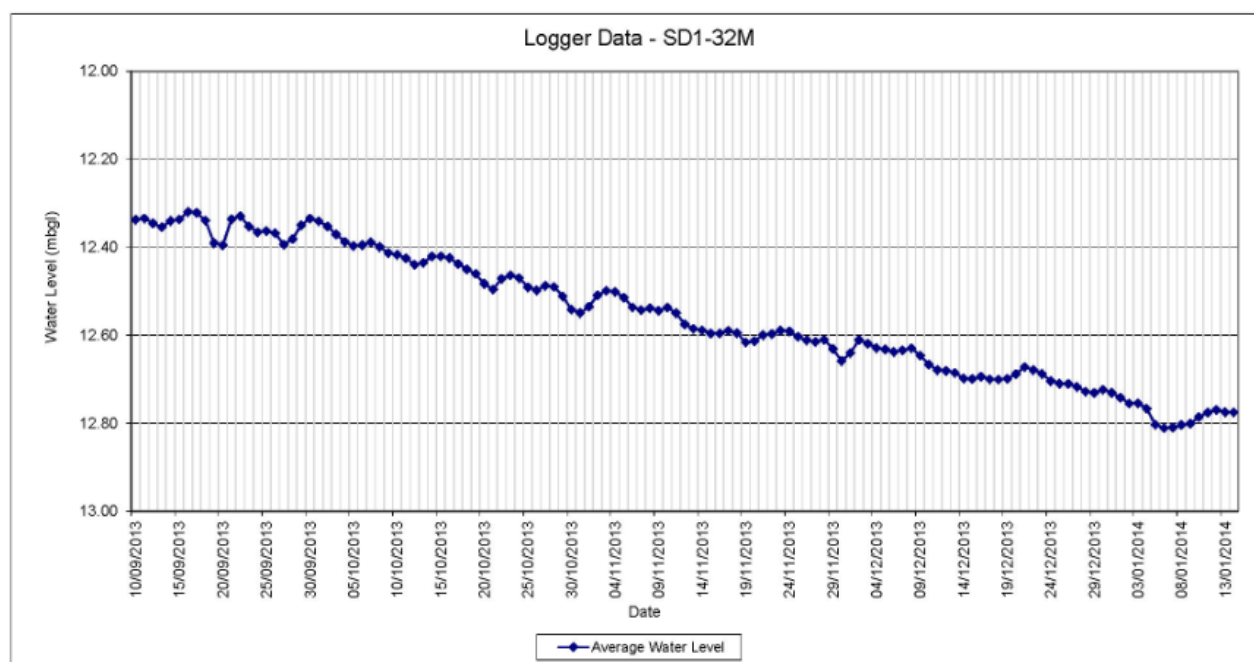


Figure 66: SD1-32M Water Level Logger Data



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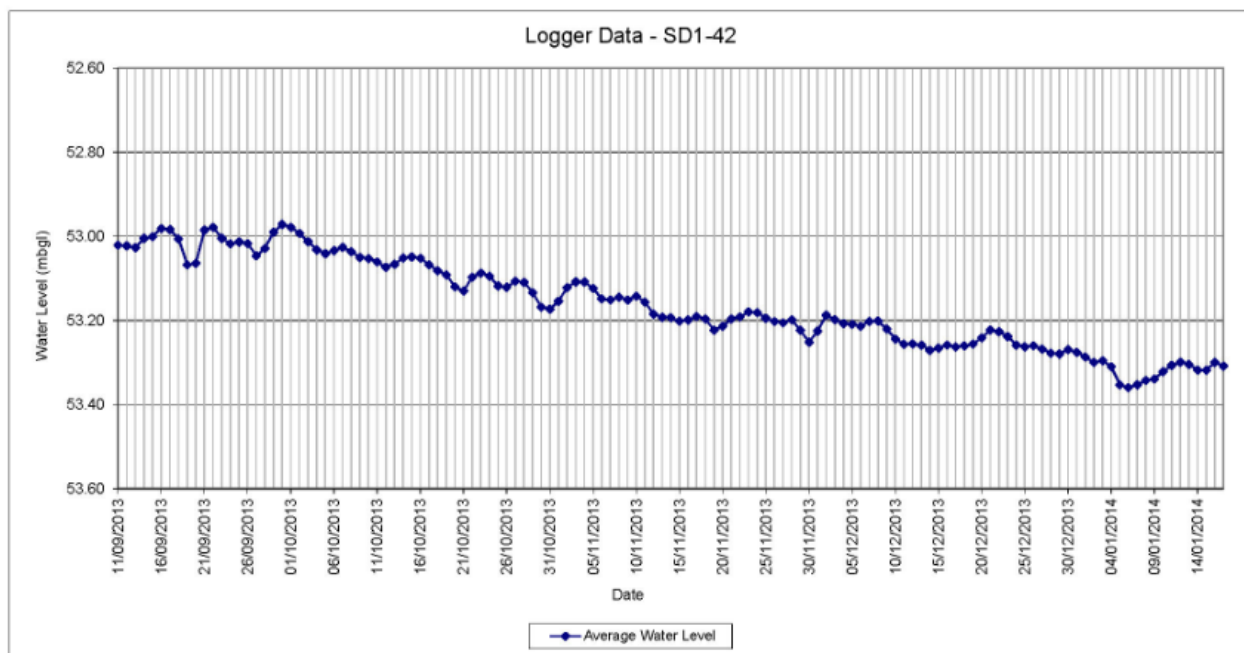


Figure 67: SD1-42 Water Level Logger Data

5.4.3 DWA Historical and Current Groundwater Monitoring

The positions of boreholes monitored by DWA historically and current are listed in Table 23 and are indicated on Figure 68.

Table 23: Historical and Current Groundwater Monitoring

GMU	BH Number	Starting WL (mbgl)	Last WL date	WL (mbgl)	Min	Max	Mean	WL Difference	Comment
C92A-05	C9N0526	9.9	05/01/1998	16.6	9.9	16.6	13.3	-6.7	Historical
C92A-05	C9N0527	8.7	25/07/1998	19.3	8.7	19.3	14.0	-10.6	Historical
C92A-05	C9N0517	16.2	06/01/1993	9.7	9.7	16.2	13.0	6.5	Historical
C92A-02	C9N0533	4.5	25/07/1998	11.8	4.5	11.8	8.1	-7.4	Historical
C92A-01	C9N0530	23.7	25/07/1998	28.0	23.7	28.0	25.8	-4.3	Historical
C92A-02	C9N0514	18.7	04/01/1993	14.0	14.0	18.7	16.3	4.6	Historical
C92A-02	C9N0513	27.8	20/06/1992	26.6	26.6	27.8	27.2	1.2	Historical
C92A-02	C9N0520	13.8	17/02/1988	16.4	13.8	16.4	15.1	-2.7	Historical
C92A-01	C9N0512	16.2	26/07/1998	17.2	16.2	17.2	16.7	-1.0	Historical
C92A-01	C9N0515	5.6	25/07/1998	7.2	5.6	7.2	6.4	-1.6	Historical
C92A-02	C9N0536	7.7	20/04/1996	12.3	7.7	12.3	10.0	-4.6	Historical
C92A-01	C9N0510	5.2	21/01/1999	7.4	5.2	7.4	6.3	-2.2	Historical
C92A-01	C9N0015	4.5	26/07/1998	8.9	4.5	8.9	6.7	-4.4	Historical
C92A-01	C9N0534	0.3	25/07/1998	7.3	0.3	7.3	3.8	-7.1	Historical
C92A-01	C9N0525	7.0	25/07/1998	20.3	7.0	20.3	13.7	-13.3	Historical



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GMU	BH Number	Starting WL (mbgl)	Last WL date	WL (mbgl)	Min	Max	Mean	WL Difference	Comment
C92A-02	C9N0524	1.8	25/07/1998	14.7	1.8	14.7	8.3	-12.9	Historical
C92A-02	C9N0548	12.1	26/11/2012	10.0	10.0	12.1	11.0	2.1	Current
C92A-02	C9N0550	8.0	26/11/2012	9.6	8.0	9.6	8.8	-1.6	Current
C92A-02	C9N0588	8.3	01/02/2007	12.0	8.3	12.0	10.1	-3.7	Current
C92A-02	C9N0549	8.3	26/11/2012	9.8	8.3	9.8	9.0	-1.6	Current
C92A-01	C9N0535	3.1	25/07/1998	10.0	3.1	10.0	6.6	-6.9	Current
C92A-01	C9N0551	22.8	05/04/2011	9.4	9.4	22.8	16.1	13.3	Current
C92A-02	OPL072	0.0	26/05/2013	0.0	0.0	0.0	0.0	-6.7	Current
C92A-01	OPL070	0.0	28/04/2013	0.0	0.0	0.0	0.0	-10.6	Current
C92A-02	OPL069	0.0	15/07/1999	0.0	0.0	0.0	0.0	6.5	Current
C92A-02	OPL068	0.0	15/10/2001	0.0	0.0	0.0	0.0	-7.4	Current
C92A-01	OPL046	0.0	26/06/1986	0.0	0.0	0.0	0.0	0.0	Current

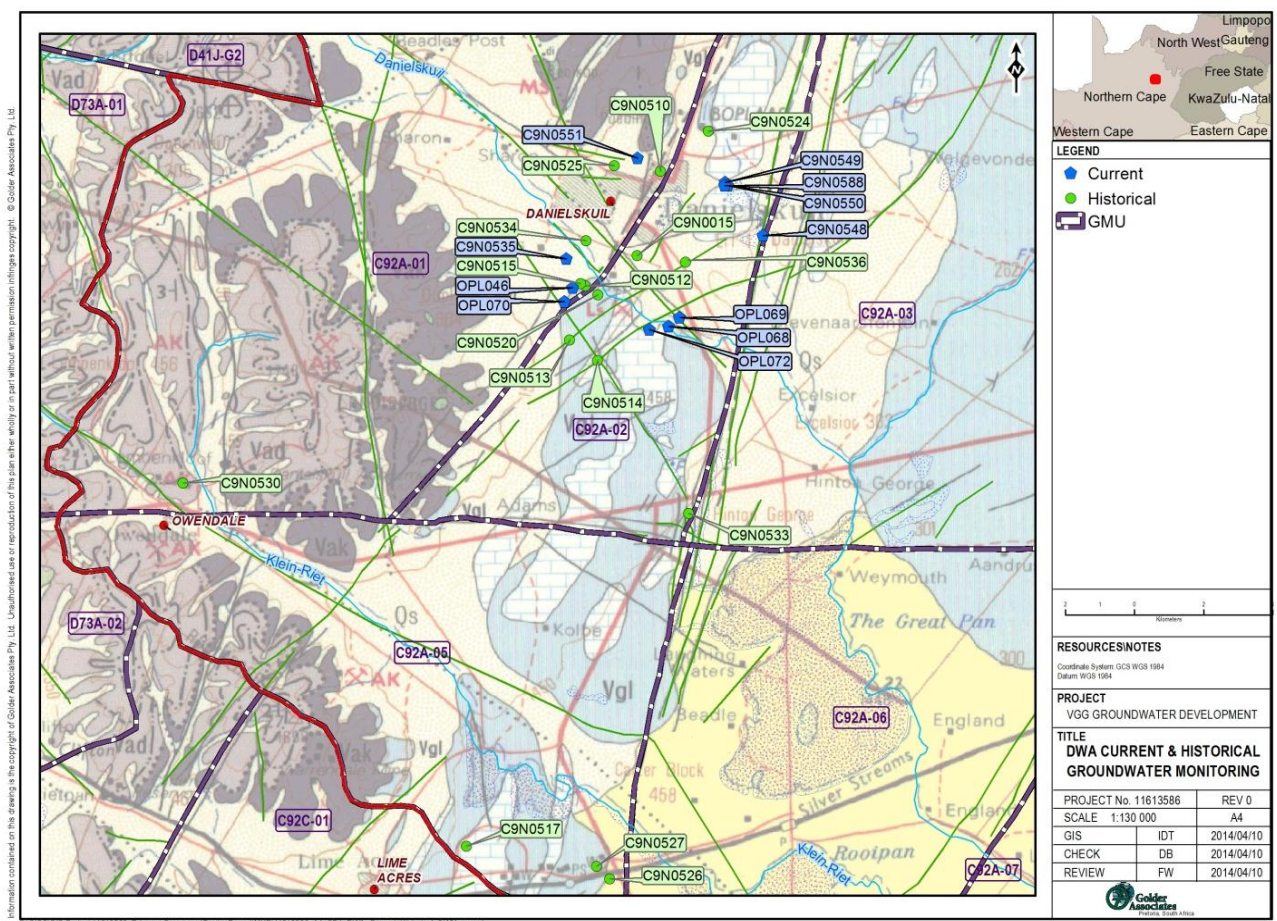


Figure 68: Location of DWA Historical and Current Groundwater Monitoring Points



Historical water level monitoring records of monitoring borehole C9N0535 (OLP034), displaying seasonal water level fluctuations, is shown in Figure 69. The other DWA water levels graphs are presented in Volume II of this report.

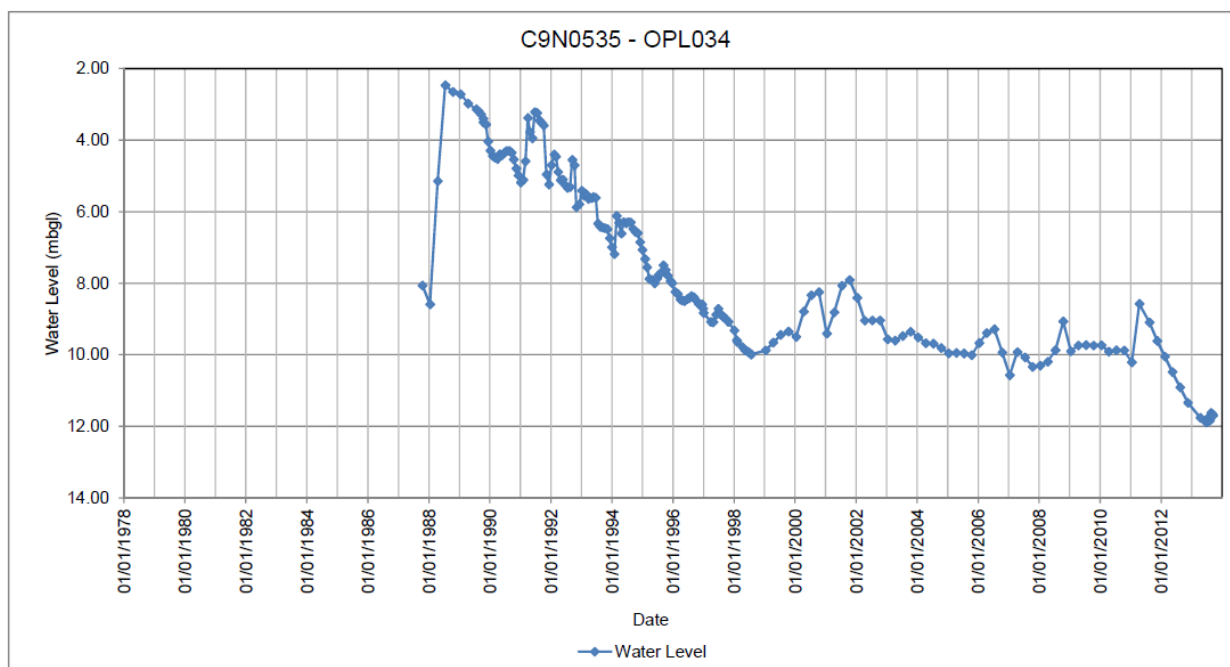


Figure 69: DWA Water Level Record of C9N0535

5.4.4 Proposed Groundwater Monitoring Network

The proposed monitoring network for SD1 well field area is indicated on Figure 70 and entails an initial baseline monitoring period of up to three years and long term monitoring program at implementation of well fields.

The groundwater monitoring programme for SD1 must comprise of:

- Quarterly water level monitoring of all accessible exploration boreholes for period of up to three years;
- Continuous water level monitoring at present installed electronic data loggers for period of up to three years;
- During well field implementation the proposed production and designated monitoring boreholes (Figure 70) must be equipped with real time water level loggers and incorporated with DWA's resource monitoring program;
- After well field implementation, quarterly sampling of well field boreholes and analysis of samples for macro chemical elements as well as bacteriological analysis; and
- Two real-time rainfall monitoring stations must be installed, one each in well field area 1 and 3(Figure 70), to understand and simulate aquifer responses to abstraction and recharge at higher confidence.



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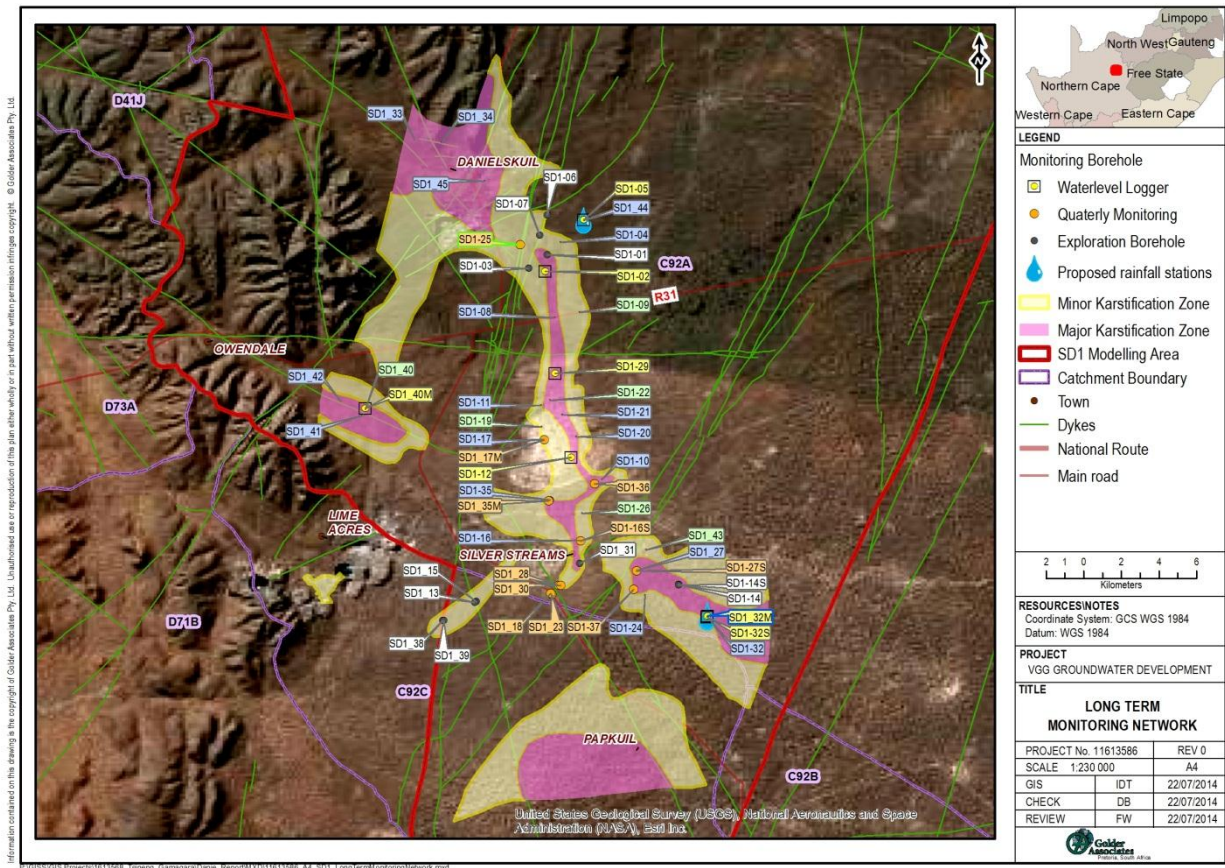


Figure 70: Long Term Monitoring Network

5.5 Groundwater Management Units

Groundwater Management Units (GMU's) were delineated for the entire SD1 modelling area in order to quantify available water resources, estimate recharge volumes and calculate water balances. A total of 11 GMU's were delineated for the SD1 modelling area as shown in Figure 71.

The geological formations, structural information, piezometric surface and water quality indicators were used to delineate groundwater management units. This allows assessment of groundwater recharge at local scale and to assess how much water is locally available for use.

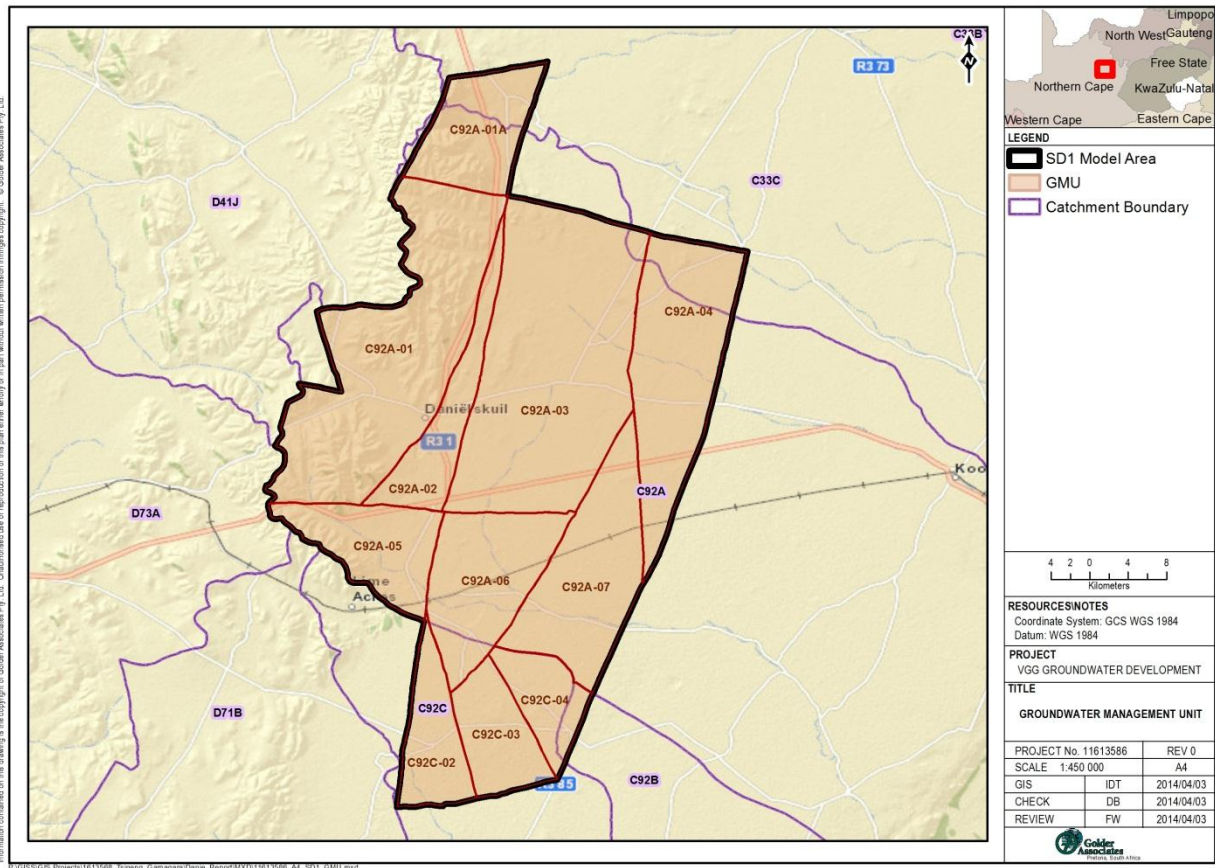


Figure 71: SD1 Groundwater Management Units

5.6 Aquifer Recharge Estimates

The quantity of rainfall and intensity of rainfall (monthly rainfall) are the major drivers of aquifer recharge in the study area. Groundwater recharge (excluding lateral inflows) is sustained by direct rainfall on the surface area and the evaluation thereof is dependent on various factors:

- **Volume of rain** during a rainfall season as well as the rainfall intensity. Larger rainfall intensity effects surface runoff with increased recharge occurring in areas comprising surface depressions;
- **Type of surface cover.** Aquifer recharge increases in areas with outcropping BIF and dolomite geological formations, gravel, and sand cover. Limited to no recharge occurs where Kalahari Group Sediment thicknesses exceed 15 meters;
- **Depth to groundwater level.** Shallow groundwater level areas or areas with relative lower water level depths may represent areas with increased recharge from rainfall;
- **Groundwater quality.** The relative electrical conductivity and chloride content of water can be used to identify areas with increased recharge from rainfall; and
- **Local surface depressions** also represent areas with increased recharge potential due to the accumulation of surface run-off water.

Various recharge estimates methods are available for use, depending on the availability of data. The Chloride Ratio Method was used for this study as the method works well for areas underlain by dolomite and BIF formations.



From the published hydrogeological maps (DWA 1996) the average recharge for the study area is 5mm to 10 mm per annum.

5.6.1 Chloride Ratio Method

Chloride is a conservative tracer, and enters an aquifer by the rainfall recharging the aquifer. The percentage rainfall, representing average annual recharge, can be derived from the ratio of the chloride concentration in rainfall relative to that of groundwater, (Bredenkamp et al, 1995). A specific requirement is that no chloride was added by dissolution of aquifer material, from salts contained within the aquifer matrix, or has entered the aquifer via pollution. It is further required that no evaporation of groundwater occurs up gradient from the groundwater sampling point, and that adsorption of chloride in soils and the vegetation uptake is considered negligible. The chloride concentration should only result from the natural, hydrological, and evaporative processes as expressed below:

$$RE \% = \frac{Cl_r}{Cl_{gw}} \times 100$$

Where: Cl_r is the concentration of chloride in rainfall (mg/l)

Cl_{gw} is the concentration of chloride in the groundwater (mg/l)

In the event that the specific requirement above is not valid, it should be noted that the chloride ratio method will result in an underestimate of rainfall recharge and not an over estimate. Once the mean annual rainfall is determined for a local area, the mean annual recharge can be estimated by means of the chloride ratio method.

The DWA commenced in 2004 with specific measurements of chloride concentrations in rainfall for the Kuruman area from three rainfall sampler sites. The average chloride content of three monthly composite rainfall samples for each site was 0.62, 0.69 and 0.64 mg/l respectively. The value of 0.6 mg/l chloride in rainfall was used as a conservative approach for estimating recharge by Wiegman (2006).

SD1 modelling area was delineated into 5 recharge zones (refer [Figure 72](#)) based on related groundwater chloride values. These recharge estimate zones were delineated using chloride values from higher yielding boreholes and boreholes considered uncontaminated. In areas with sparse or no chloride values, values from similar geological and rainfall terrains were used. These values were used to determine the % recharge from mean annual precipitation (MAP) and mm/a.

The mean annual recharge is the long-term maximum recharge expressed as a long term average. Rainfall variability and intensity (depth) as well as extended droughts are important aspects which determine the sustainability of a resource. Recharge often occurs during episodic recharge events and aquifer storage is important for sustainable abstraction to bridge extended drought periods. The median recharge is the minimum recharge that is available for 5 out of 10 years and considered the volume of water is available for sustainable use.

Based on an extensive regional modelling study conducted on dolomitic terrain for the Zeerust area, an exponential relationship between recharge and rainfall produced acceptable results (FE Wiegman and H van Rensburg). The recharge (mm/month) was derived as a fraction of rainfall based on the following formula (Recharge Fraction = $0.05e^{(0.01 \times \text{Rainfall})}$)

A relationship (median RE = $(0.68 \text{ mean RE} - 3.9)$ mm/a between mean and median annual recharge was determined by Wiegman in 2006 for the D41L catchment located north of the SD1 area. This was used to compile the recharge estimates for various recharge zones as listed in Table 1.



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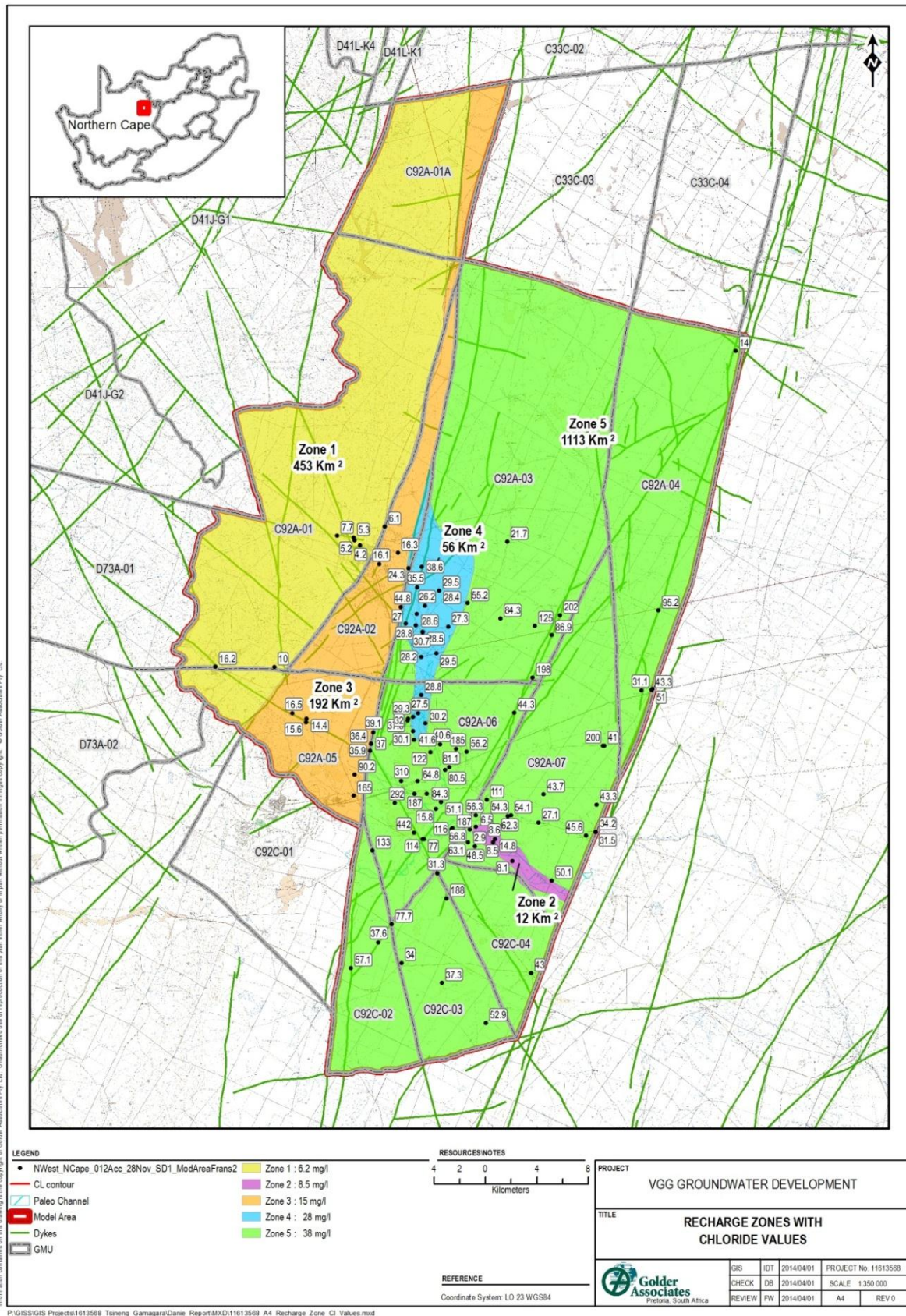


Figure 72: SD1 Recharge Zones - Cl Values



The mean and median annual recharge for the SD1 modelling area recharge zones is presented in Table 24.

The exploitable ground resource (median recharge) for the SD1, C92A catchment for all 11 GMU's as presented in Table 24 amounts 17.0 million m³/a.

Table 24: Summarised Recharges Estimates for SD1 based on the Chloride Ratio Method

Recharge Zone	Representative Cl (mg/l)	% Recharge	Area km ²	Mean (mm/a)	Median (mm/a)	Mean (million m ³ /a)	Median (million m ³ /a)	Quaternary Catchment Area	GMU Number
1	6.2	9.1	453	35	23.8	15.9	10.8	C92A	C92A-01
									C92A-01A
2	8.5	7.0	12	25	17	0.3	0.2	C92A	C92A-07
3	15	4.0	192	15	10.2	2.9	2.0	C92A	C92A-02
									C92A-05
4	28	2.1	56	8	5.4	0.4	0.3	C92A	C92A-03
									C92A-06
5	38	1.6	1113	5	3.4	5.6	3.8	C92A C92C	C92A-03
									C92A-04
									C92A-06
									C92A-07
									C92C-02
									C92C-03
									C92C-04
Total			1826	-	-	25.0	17.0	-	-

5.7 Hydrogeological Conceptualizing

The hydrogeological conceptualizing for SD1 was developed from data gathered during the exploration phase. The conceptualizing forms the basis for the understanding of the groundwater occurrence and flow mechanisms of the study area, and is use as basis for the numerical groundwater model.

Because of the extent of the investigation area the hydrogeology is conceptualise and represented as three hydrogeological sections, the positions of sections are indicated on Figure 73:

- Cross Section A – B;
- Cross Section B – C; and
- Cross Section D – E.

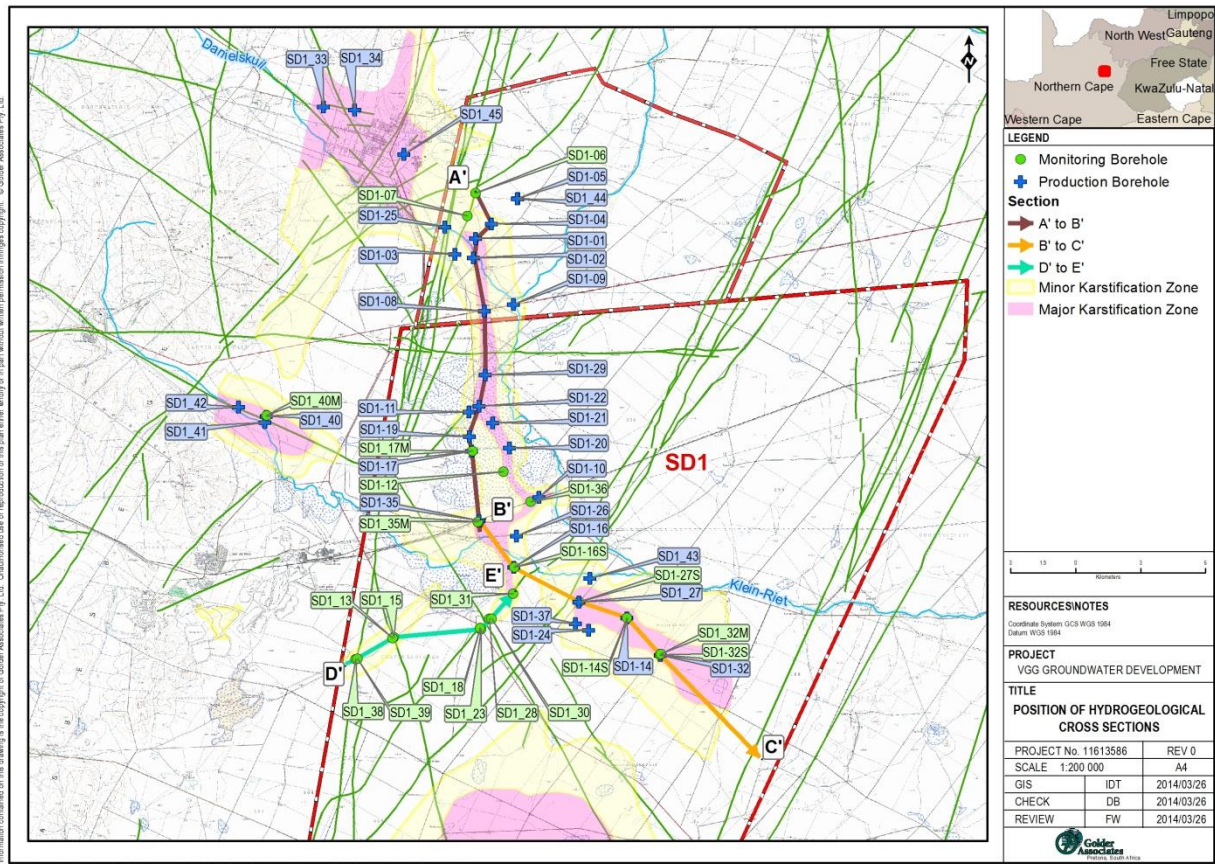


Figure 73: Position of Hydrogeological Cross Sections

5.7.1 Hydrogeological Cross Section A – B

A hydrological cross section was done in a north – south direction to illustrate the geological and hydrogeological information associated with the main karstification zone and the paleo-river channel as delineated by the aerial geophysical survey (Figure 74).

The cross-section shows the presence of a thin calcrete layer (2 to 6m) at surface with a low permeability. Semi conciliated BIF which filled in the paleo-river channel, chert rich dolomite and wad zones is present, with major karstification in the dolomites.

These karstification zones which developed below the paleo channel and along dolerite dyke contact are highly permeable with blow yields intersected as high as 50l/s (SD1-17).

The groundwater flow direction is towards the south, with Transmissivity values ranging from 35 to 2573 (SD1-8).



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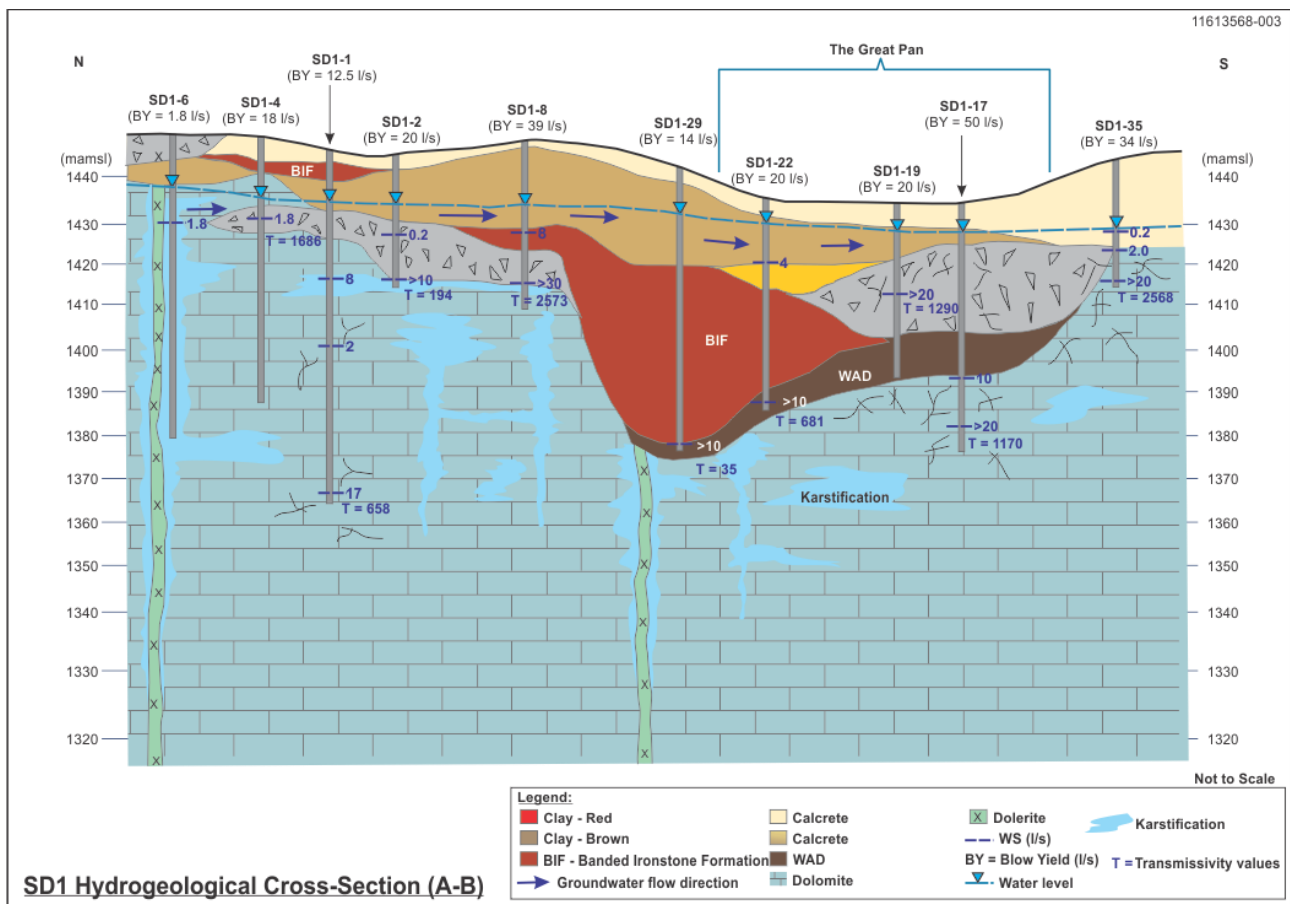


Figure 74: Hydrogeological Cross Section A - B

5.7.2 Hydrogeological Cross Section B – C

A hydrological cross section was done in a northwest – southeast direction to illustrate the geological and hydrogeological information obtained from the borehole drilling and is illustrated in Figure 75

The cross-section shows the presence of a thick calcrete layer (20 to 60m) at surface with a low permeability and is the host formation of the 'Olienhoutboom' forest. Semi conciliated BIF which filled in the paleo river channel is present below the calcrete layer, with major karstification in the dolomites.

These karstification zones which developed below the paleo channel and along dolerite dyke contact are highly permeable with blow yield intersect ranging from 10 to 40l/s.

The groundwater flow direction is towards the south-east, with Transmissivity value as high as 2568 (SD1 - 35).

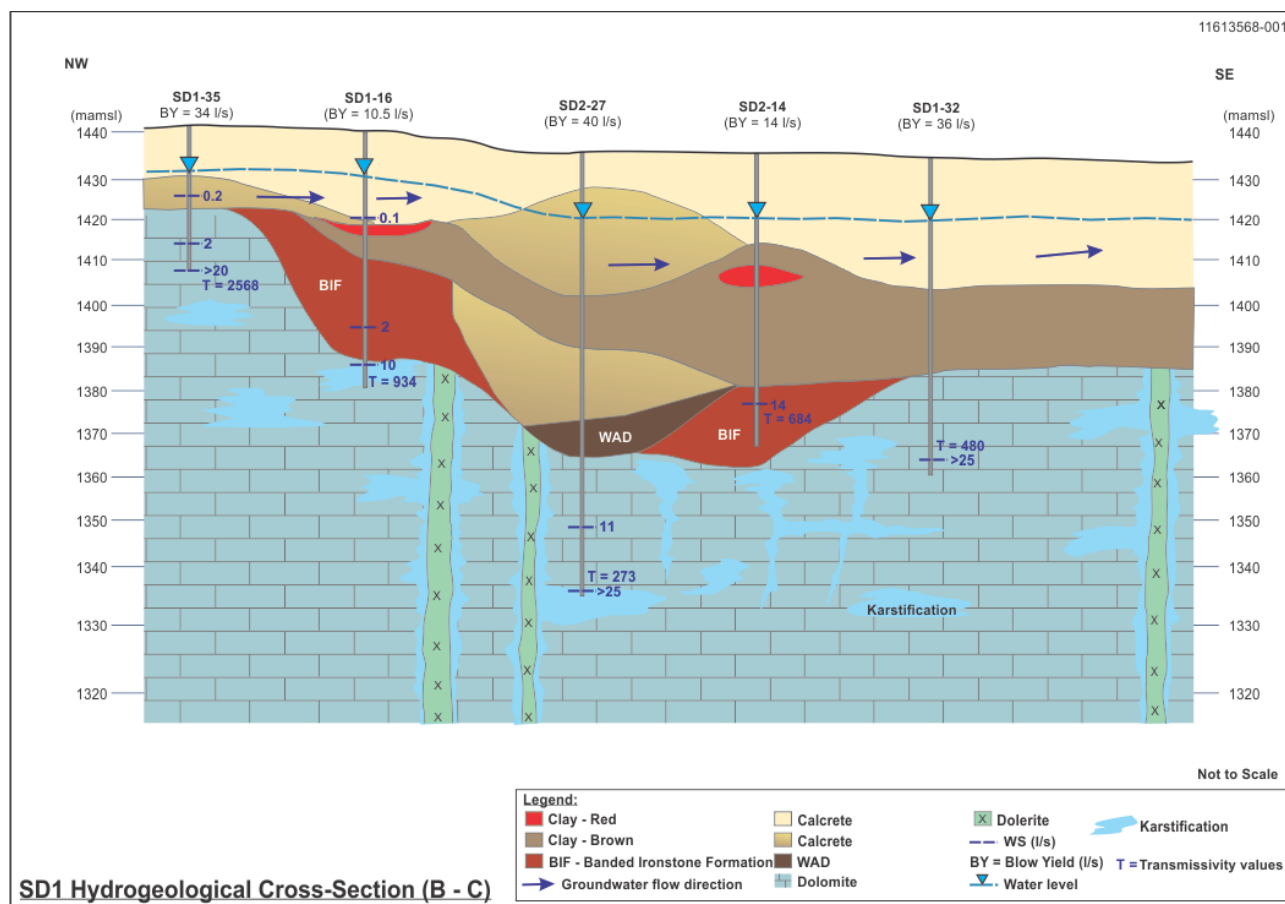


Figure 75: Hydrogeological Cross Section B - C

5.7.3 Hydrogeological Cross Section D – E

A hydrological cross section was also done in a southwest – northeast direction to illustrate the geological and hydrogeological information obtained from the boreholes drilled in this area and illustrated in Figure 76.

The cross-section shows the presence of a calcrete layer 10 to 30m in thickness at surface. This area of calcrete is also the hosting formation of the 'Olienhoutboom' forest.

Minor karstification is dominant in this cross section and is mainly restricted to dolerite and dolomite contact zones. The permeability of the boreholes intersected in this section is low with the highest blow yield intersected 4.4l/s (SD1-13). Transmissivity values range between 35 and 326.

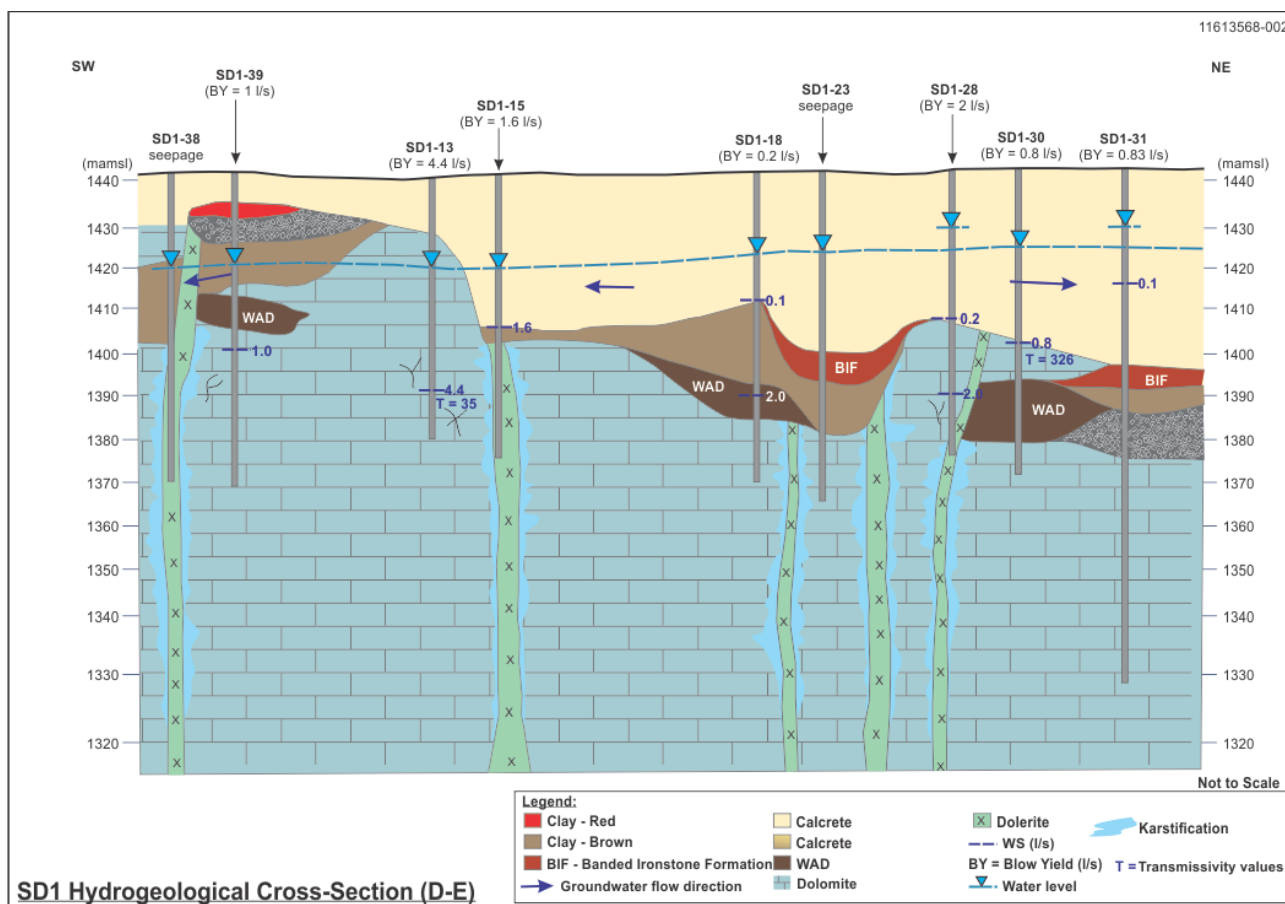


Figure 76: Hydrogeological Cross Section D - E

5.7.4 SD1 Aquifer Zones

From the available drilling and test pumping data of SD1, three aquifer systems were identified in the different geological formations:

- Upper Kalahari Sediments - intergranular unconfined aquifer system comprising mainly out of calcrete, gravel and clay. This aquifer zone has a low permeability retards and restrict water movement and acts as storage unit;
- Fractured and weathered semi consolidated Banded Ironstone Formation (BIF), semi confined aquifer system; and
- Dolomite karst aquifer system, unconfined to semi confined aquifer system, compartmentalised by dolerite dykes and highly permeable;

The hydraulic parameters of the three defined aquifer zones are summarized in Table 25.



Table 25: Summarised Hydraulic Parameters

Aquifer zone	No. of BH'S	Storativity S	Average S	T (m ² /d)	K(m/d)	Average T (m ² /d)	Average K (m/d)
New Exploration Boreholes							
Upper Kalahari Calcrete and Gravel	4	-	-	-	0.00101 to 0.00654	-	0.003498
Fractured and Weathered semi consolidated BIF	6	0.03220	-	35 to 917	-	308	-
Karstification in Dolomite	28	2.24E-08 to 34.90	6.98414	23 to 10273	-	1432	-
Existing Boreholes							
Aquifer Zones not Differentiated	17	0.00001 to 0.38000	0.04178	0.7 to 6526	-	623	-

5.8 Groundwater Reserve

The Africa Geo-Environmental Services (AGES) conducted an intermediate groundwater reserve study in 2008 for the Lower Vaal Water Management Area (WMA). The intermediate groundwater reserve determination was done with using a Groundwater Yield Model for the Reserve (GYMR) and compared with the existing Groundwater Resource Directed Measures (GRDM) method using different scenarios.

Comparing scenario 1 (GYMR – Present Day) and scenario 5 (GRDM – Present Day) of the study, variances are observed in the groundwater balance as shown in Table 26.

Table 26: Comparison of Scenario 1 and 5 Present Day Water Balances in SD1 – C92A (DWA, 2009)

Scenarios	Surface Area (km ²)	Total Inflow (million m ³ /a)	Total Outflow before losses (sinks) million m ³ /a	Total abstraction (WARMS) + calculated (million m ³ /a)	Evapotranspiration flow loss along streams (million m ³ /a)	Net Base Flow (million m ³ /a)	Net Base Flow EWR (million m ³ /a)	Usable GW Component from base flow (million m ³ /a)	GRDM status Category
GYMR Present Day	3913	27.50	-3.19	-0.63	-6.21	-18.10	-5.43	12.67	B
GRDM Present Day	3913	57.91	-1.51	-0.63	0	-56.40	-16.92	39.48	A



Using the scenario 1 (GYMR – Present day 2008) as a representative value for total inflow (recharge) and net base flow, there is a groundwater balance of 12.6 Mm³/a available for use in the C92A quaternary catchment.

6.0 GROUNDWATER MODELLING

A comprehensive 3D numerical groundwater flow model was constructed at quaternary catchment scale to assess the impact of the proposed SD1 well field on the regional groundwater flow, aquifer storage and discharge. The model development, calibration, applied variable recharge rates together with the modelling scenarios are outlined in the SD1 model report by Delta-H presented in Volume II of this report. The objectives of the groundwater flow model are to

- Develop and calibrate a three-dimensional regional numerical groundwater model quantifying the elements of the conceptual model which:
 - Characterises the geological setting;
 - Quantifies and delineates areas of recharge;
 - Establishes the influence of regional structural features (i.e. dykes) on groundwater movement, including the role of fracture zones acting as preferential groundwater flow paths; and
 - Establishes the aquifer hydraulic properties (i.e. Transmissivity and storativity values).
- Apply the numerical groundwater flow model to calculate the impact of the proposed well field on groundwater flow, aquifer recharge and discharge, and the elevation of the water table;
- Develop recommendations to address any shortcomings and data knowledge gaps that need to be addressed in order to improve on the future calibration of the groundwater model and to verify the long-term predictions made in terms of groundwater flow; and
- Delineate aquifer protection zones according to best national practice as outlined by the Department of Water Affairs.

The software code chosen for the numerical finite-element modelling work was the 3D groundwater flow model SPRING. The program was first published in 1970, and since then has undergone a number of revisions. SPRING is widely accepted by environmental scientists and associated professionals. SPRING uses the finite-element approximation to solve the groundwater flow equation. This means that the model area or domain is represented by a number of nodes and elements. Hydraulic properties are assigned to these nodes and elements and an equation is developed for each node, based on the surrounding nodes. A series of iterations are then run to solve the resulting matrix problem utilising a pre-conditioning conjugate gradient (PCG) matrix solver for the current model. The model is said to have “converged” when errors reduce to within an acceptable range. SPRING is able to simulate steady and non-steady flow, in aquifers of irregular dimensions (Delta H; 2014).

6.1 Groundwater Model Construction

6.1.1 Model Domain

The model domain boundaries were established during the conceptualisation phase by Mr Frans Wiegman and adapted accordingly by Delta-H. The model boundaries were chosen along mapped dykes, often coinciding with the quaternary catchment (C92A) boundaries, so as to ensure a dependable water balance for the model with recharge being the main driver of groundwater flow. A number of head dependant boundary conditions were assigned mainly along the eastern and southern edge of the model domain representing potential groundwater outflow towards adjacent aquifer systems (Figure 77).



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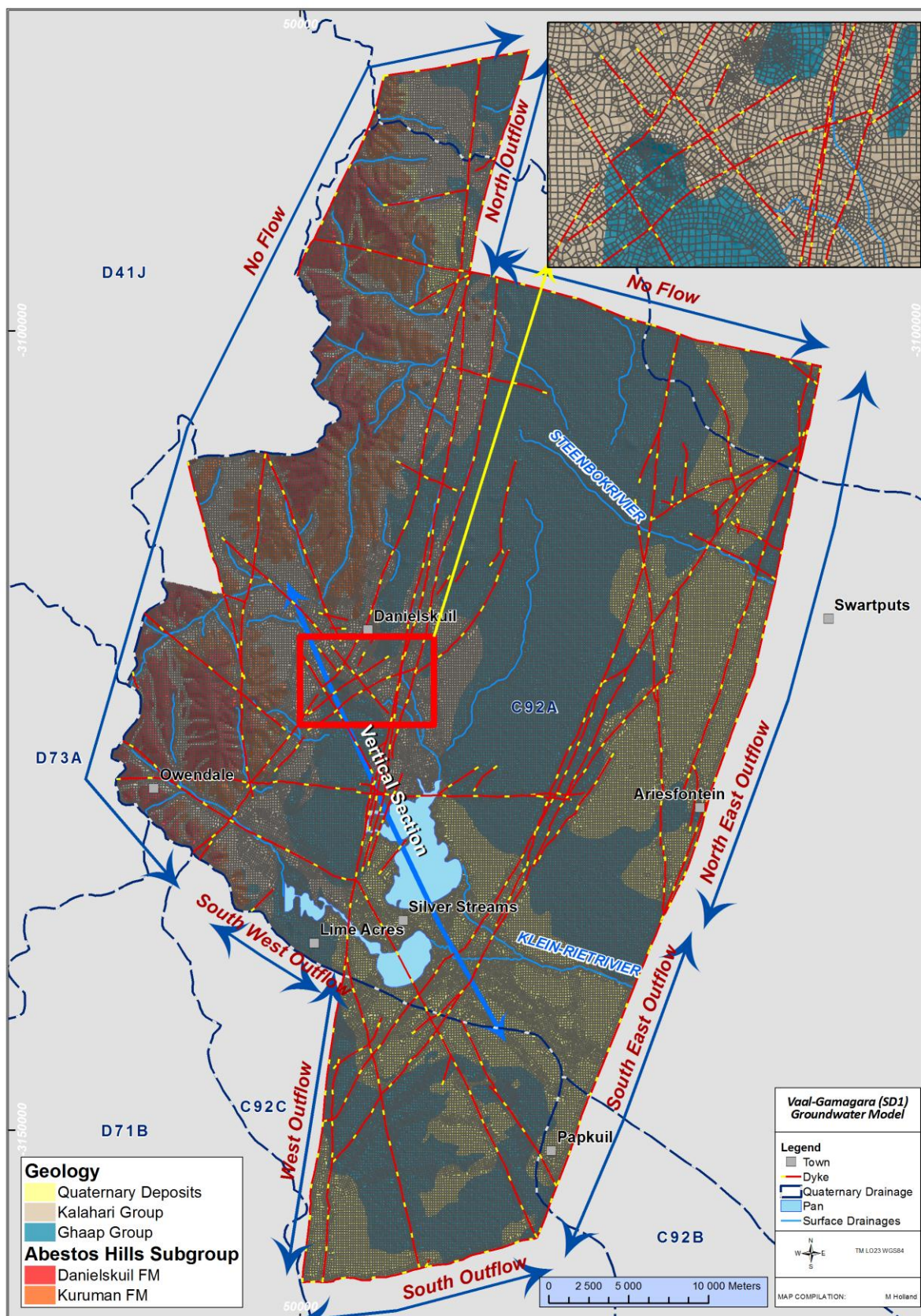


Figure 77: SD1 Groundwater Model Domain



The total model domain covers an area of 1 826 km² and was spatially discretised into 111 512 nodes on 5 node layers, which make up 4 element layers with 121 468 elements (triangles and quadrangles) per layer, to account for the various hydrogeological units underlying the proposed SD1 well fields (Delta H; 2014).

6.1.2 Groundwater Model Layers

The finite-element model was set-up as a three-dimensional four element layer groundwater flow model. The vertical model discretisation respectively model layer coincide with the conceptual hydrogeological model.

The SRTM elevation data were lowered by 2.2m to fit ortho-heights obtained from local trig beacon and compared to gravity survey data and surveyed boreholes elevations.

The upper layer (split into two model layers to increase the accuracy of the unsaturated flow calculations) represent the highly weathered- and karst aquifer to a depth of 4 m below the interpolated groundwater level. The third layer represents the highly karstified hydrogeological unit to a depth of 15 m below the interpolated groundwater level.

The bottom elevation of the groundwater flow system was set at approximately 90 m below the current groundwater level, resulting in a model thickness ranging from 92 to 370 m. The layer arrangement is summarised in Table 27 and shown in a cross-section in Figure 78. The vertical section, chosen along the Idwala Mine Quarry and The Great Pan (north of Silver Streams) (Figure 78) shows the vertical discretisation of the model domain (Delta H; 2014).

Table 27: SD1 Groundwater Model Layer Arrangement

Node layer	Element layer	Map colour	Aquifer feature	Data used for interpolation
1	I, top		Surface elevation	SRTM 90 m Digital Elevation Model (DEM)
2	I, bottom		Weathered- and Karst Aquifer	Divide Layer 1 into 2 (Equal proportion)
3	II, bottom		Weathered- and Karst Aquifer	Fixed offset of 4 m from interpolated water level
4	III, bottom		Karst Aquifer	Fixed offset of 15 m from interpolated water level
5	IV, bottom		Karst Aquifer	90 m below Water Table

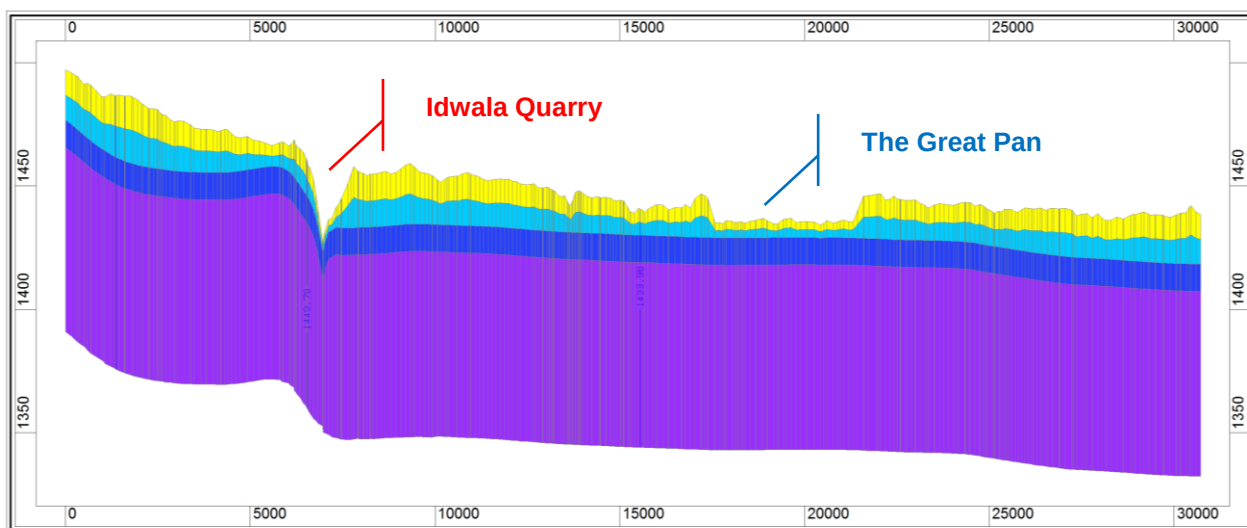


Figure 78: SD1 Vertical Grid Layout Example



6.1.3 Sources and Sinks

6.1.3.1 Groundwater Recharge

Groundwater enters the model domains as direct recharge from rainfall. It was implied that certain areas may have greater recharge potential and may thus contribute a larger proportion of recharge towards the aquifer systems respectively. Based on the conceptual understanding of the SD1 groundwater system, the median annual recharge for different zones varies from 3.5 to 16mm (Figure 79).

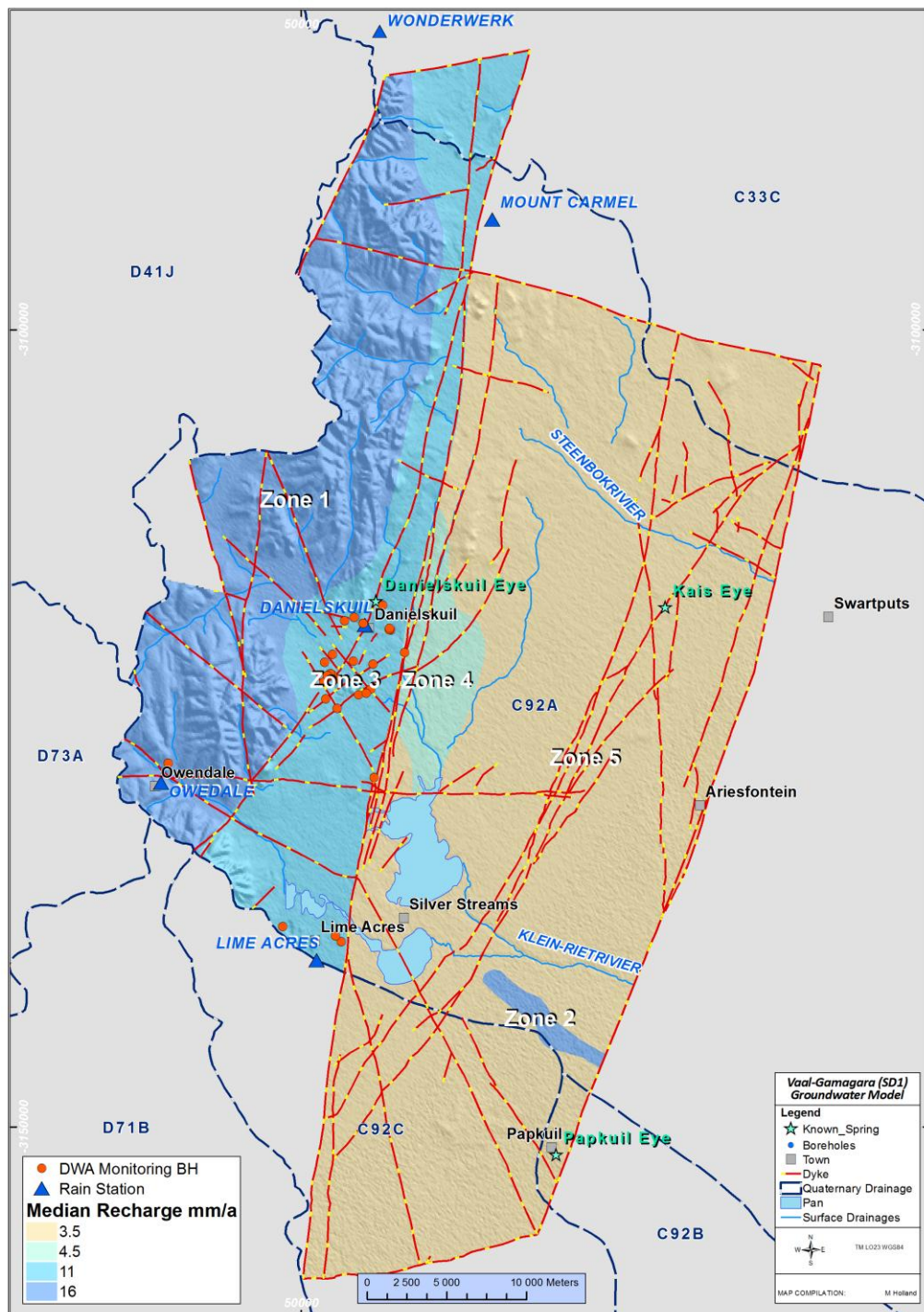


Figure 79: SD1Assigned Recharge Zones and Rates.



The spatial distribution of existing groundwater monitoring boreholes is shown in Figure 79. Available groundwater monitoring data is mainly located within recharge zone 1, 3 and 4, and absent in recharge zone 2 and 5. It must also be noted that not all monitoring boreholes have complete records of water levels, or represent in some cases water levels during pumping conditions and not static (rest) water levels.

Nevertheless, monitoring data show a good relationship between the Cumulative Rainfall Departures (CRD) from the mean rainfall (for the Danielskuil rainfall station) and observed water level fluctuations in the dolomitic aquifer, which indicates dynamic recharge (Figure 80). Since the direct cause/effect relationship between the CRD and water levels was observed, an empirical relationship between rainfall and recharge events can be assumed. Based on earlier modelling studies conducted on dolomitic terrain, an exponential relationship between recharge and rainfall produced acceptable results. The resulting recharge (mm/month) was derived as a fraction of rainfall based on the following formula: $\text{Recharge Fraction} = 0.05e^{(0.01 \times \text{Rainfall})}$ (Delta H; 2014).

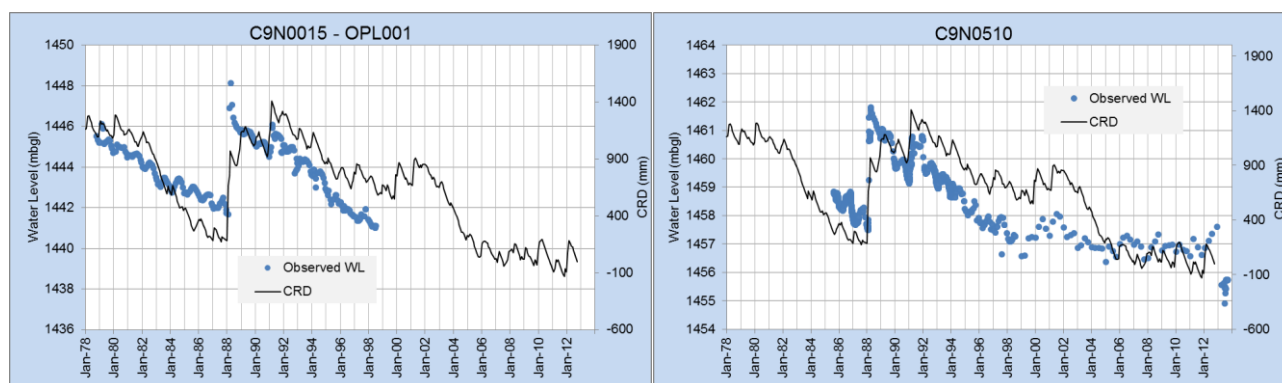


Figure 80: Groundwater level versus the Cumulative Rainfall Departure

6.1.3.2 Groundwater Abstraction

Both steady state and transient borehole abstraction from the model domain was simulated using the withdrawal well boundary condition. Outflow rates were assigned to single nodes (at the appropriate elevation) within the model mesh. For fully penetrating wells, equal heads were prescribed for all applicable well nodes and the inflows for each node automatically calculated by the software. The annual abstraction rate applied to the steady state model amounts to 231,797m³/month or 2,781,564m³/annum.

6.1.3.3 River Courses and Springs

Groundwater within the study area was assumed to originate as spatially distributed rainfall recharge within the model domain. It is thought that a portion of the groundwater recharge occurring within the model domain discharges internally to surface drainage systems via springs or as discharge to the river drainage systems (baseflow).

The interaction between groundwater and surface water courses was simulated under the assumption of continuous gaining river systems (i.e. groundwater is only allowed to discharge into them and not vice versa). These drainages were therefore described within the model using SPRING's 'river package', with no exfiltration of surface water allowed. The stage of each river node was carefully aligned with the height of the Digital Elevation Model (DEM) at that point and an incision the river bottom of 2 m below topography assumed. A river bed conductance of 1E-7 m/s was assumed. Known springs (see section 5.1.2) within the SD1 area were incorporated as leakage boundary conditions at the specific node of the spring location (Delta H; 2014).

6.1.3.4 Mine Quarry

The Idwala open cast mine working (pit) was integrated into the model domain for the predictive simulations by updating the digital elevation model for the pit area and assigning a free seepage boundary to the pit area. It is assumed that any groundwater entering the pit is removed (pumped out) and that the pit bottom



represents therefore the lowest drainage elevation. In other words, groundwater is allowed to seep freely into the pit with a subsequent development of a cone of dewatering. It must be noted that the computation of the free groundwater table and pit inflows consider partially saturated flow conditions using the van Genuchten equation to calculate the relative permeability as a function of the capillary pressure, saturation, residual saturation and entry pressure (Delta H; 2014).

6.2 Model Calibration

6.2.1 Steady State Calibration

Once a reasonable fit of the piezometric contours respectively their gradients was established using the gradient method within the SPRING software package, the measured groundwater levels (in metres above mean sea level) observed in 373 boreholes were used as calibration targets. The regional water level measurements spread over a number of decades and represent therefore by no means a single snapshot of water levels taken under the same climatic conditions and land uses or average conditions. The project team based therefore the steady state calibration towards a reasonable fit of the most recent water levels respectively abstraction and recharge conditions. The three available spring outflows together with the Idwala Pit inflows were considered as secondary targets in the calibration process.

Since the modelled groundwater levels are directly related to the assigned recharge rates and hydraulic conductivities, an independent estimate of one or the other parameter is required to arrive at a potentially unique solution of the model calibration. The estimated recharge rates were therefore considered fixed for the steady state calibration and only hydraulic conductivities considered variable, i.e. adjusted within reasonable boundaries to represent the observed flow system (Delta H; 2014).

The spatial distribution of the calibrated conductivity values for layer I is shown in Figure 81 and the values for all model layers summarised in Table 28.

Table 28: Calibrated Hydraulic Conductivity Ranges for SD1 Groundwater Model

Layer	Aquifer	Hydraulic conductivity (m/s)	
		Min	max
I-IV	Dyke (Barriers to Flow)	1E-9	1E-7
I, II and III	Weathered- and Karst Aquifers	1E-6	4E-4
	BIF	1E-7	5E-6
IV	Deep Karst Aquifer	5E-7	1E-5

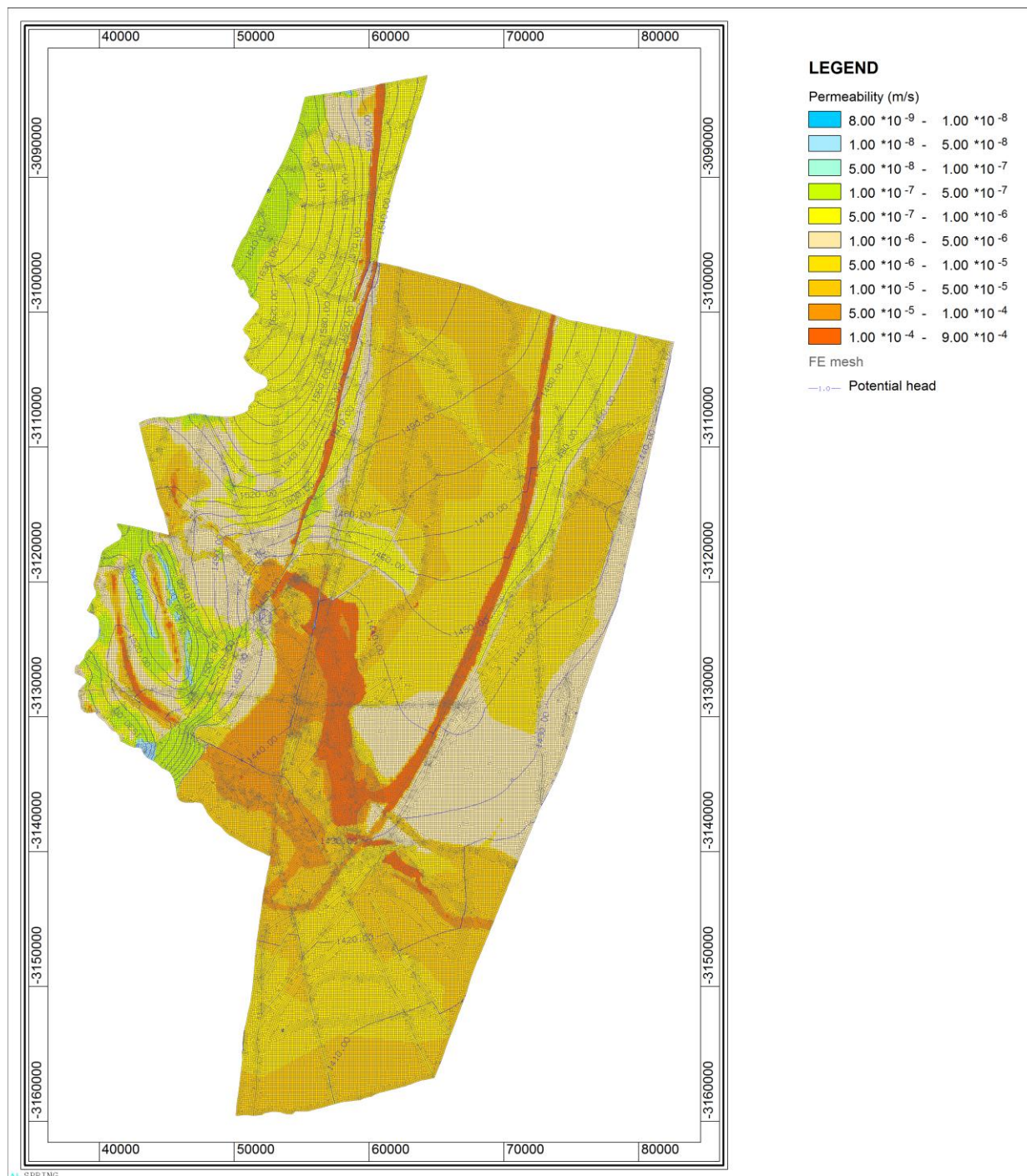


Figure 81: Distribution of Permeability in Layer 1 together with Steady State Heads (10 m Contour Interval)

6.2.2 Transient Calibration

In order to simulate the temporal responses of the aquifers to variable rainfall recharge and external stresses (abstractions), a transient calibration of the steady-state model is required. Although transient calibration introduces another uncertain fitting parameter, namely the storage coefficient S (as a sum of specific storativity and yield for unconfined aquifers), it partially eliminates the non-uniqueness of the steady-state calibration parameters and provides additional insight into the appropriateness of the conceptual model.

Transient simulations require the definition of stress periods, during which boundary conditions remain constant, and time steps, for which model calculations are made. Since the frequency of the rainfall



measurements were provided on a monthly basis the water balance of the model was calculated on a monthly time-step. Stress periods assigned in the present model can be divided into two components:

- The first component covers the transient calibration phase from 1978 to 2012 and entailed 421 (months) stress periods with variable monthly recharge rates; and
- The second component entails stress periods assigned for the predictive model runs considering various aquifer management scenarios for the period 2013 to 2030 (205 stress periods).

The model was further optimised by calibrating the simulated heads to observed pumping test drawdown data for 10 SD1 production boreholes. The pumping tests ranged from 24 to 72 hours and the transient model comprised of 73 one-hour time steps. A summary of the calibration targets is shown in Table 29. The pumping tests however, do not represent the entire the model domain and was limited to the SD1 well field region.

Table 29: SD1 Transient Calibration of Target Boreholes

BH ID	Model Node	L/S	m ³ /hour	Time (Minutes)
SD1-08	69	30	108	1440
SD1-16	77	20	72	2880
SD1-17M	163	30	108	4320
SD1-20	82	30	108	1440
SD1-25	87	30	108	4320
SD1-27	89	30	108	2880
SD1-32M	95	30	108	4320
SD1-35M	101	30	108	4320
SD1-40	105	10	36	4320
SD1-44	109	30	108	4320

For the transient calibration the available long term water level monitoring and 10 (SD1) pumping test datasets were used as calibration. The main aim of the calibration was to match the “signature” or behaviour of temporal water table fluctuations observed, rather than the actual head itself.

Figure 82 shows a comparison of long term trend (1978 to 2012) simulated vs. observed heads for a number of representative boreholes. Based on the results, it is evident that in most cases the “signature” of the temporal water level fluctuations is sufficiently well represented by the model. The “off-set” between observed and simulated heads for some boreholes appears to be a result of the assigned steady state starting water levels, which reflect average and not actual historical water levels at a given point in time. In all cases, this “off-set” is acceptable (within 2 meters) and within the seasonal range of water level fluctuations

At this stage, seasonal monitoring data for the transient model calibration are only available for the catchment area upstream of the SD1 well field (mainly Danielskuil area). Once monitoring data over a full hydrological year become available for the SD1 well fields area, the model should be re-calibrated and predictions updated (Delta H; 2014).



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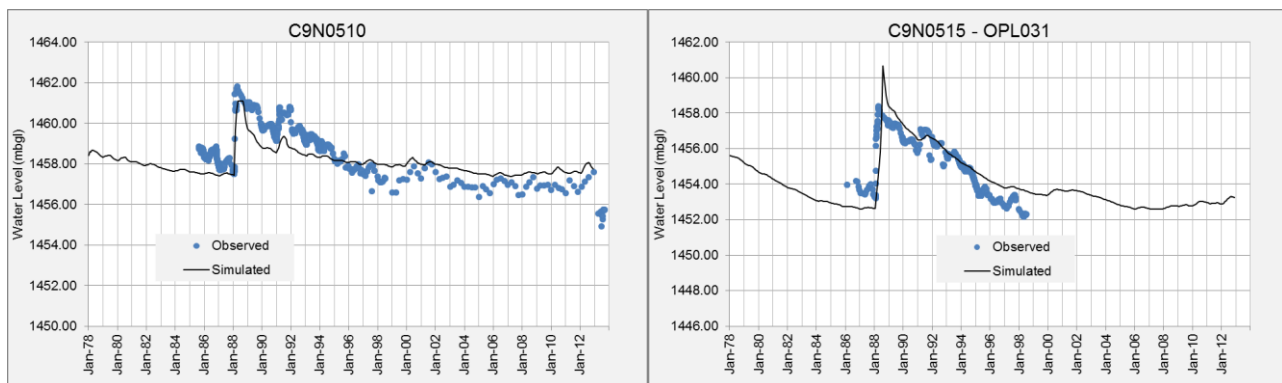


Figure 82: Simulated Versus Observed Groundwater Levels

The transient calibration of pumping test datasets (24 to 72 hours) refines and verifies the steady-state calibration by matching transient hydraulic-head trends which reflect the stresses of pumping from the production boreholes (Figure 83). The transient model calibration was used to optimize the spatial variability of storage coefficients.

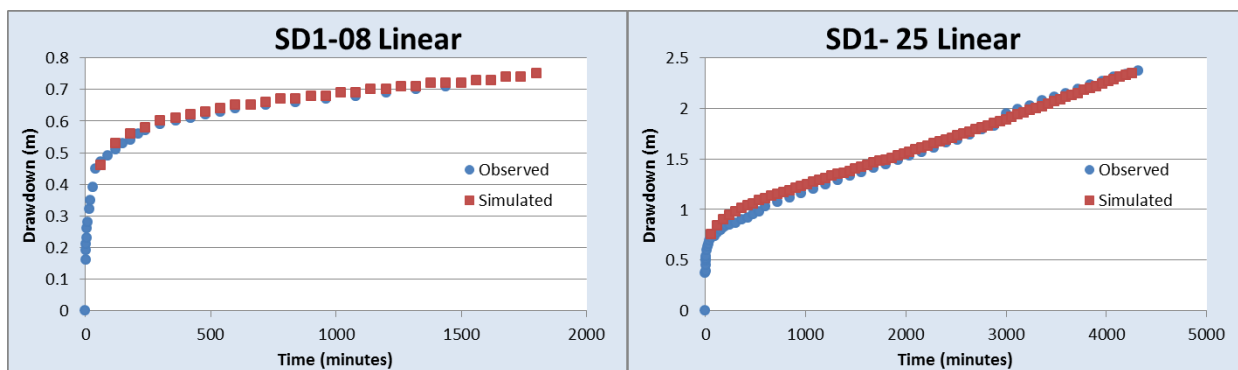


Figure 83: Transient Model Calibration using Normalized (to initial static) Drawdown

An acceptable fit is observed for most pumping test boreholes. However, it is evident that in some cases the drawdown behaviour cannot be accurately represented due to the heterogeneity of fracture distributions and subsequent hydraulic discontinuities proximal to the pumping well (Delta H; 2014).

6.3 Predictive Simulations

6.3.1 Water Balance

A summary of the steady state water balance is provided in Table 30. The steady-state water balance (Table 30) shows that the vast majority of recharge (which is the only model inflow) contributes to baseflow in drainages (including evapotranspiration losses along these drainages and pans) and spring discharges within the model domain, with only around 26 % of the inflow (recharge) reporting to the head dependent outflow boundaries, i.e. towards downstream catchments. Total (steady-state) groundwater abstractions consume for the steady-state scenario around 20% of the total recharge for the area. The Idwala pit inflows was estimated at 26,311 m³/month compared to an alleged inflow of approximately 22,000 m³/month.

Table 30: SD1 Regional Steady State Water Balance

Regional Water Balance		
Inflow	m ³ /month	m ³ /annum
Recharge	1 176 273	14 115 274
Outflow	m ³ /month	m ³ /annum
Spring Discharge	-33 523	-402 276
Boreholes Abstraction	-231 797	-2 781 564



Regional Water Balance		
Contribution to Drainages, pans and potential evapotranspiration	-575 713	-6 908 554
Outflow Boundary	-308 929	-3 707 148
Idwala Pit Inflows	-26 311	-315 732
Total Outflow	-1 176 273	-14 115 274

6.3.2 Applied Rainfall Variability (2013 to 2030)

The calibrated transient model was subsequently used to simulate the impact of proposed abstractions from the SD1 well field on the water levels and water balance of the regional aquifer system. The predictive scenario was simulated based on historically observed rainfall variability. The rainfall/recharge data from 1996 to 2012, which is regarded to be a conservative approach, was used to simulate the rainfall recharge in the predictive scenario (Figure 84).

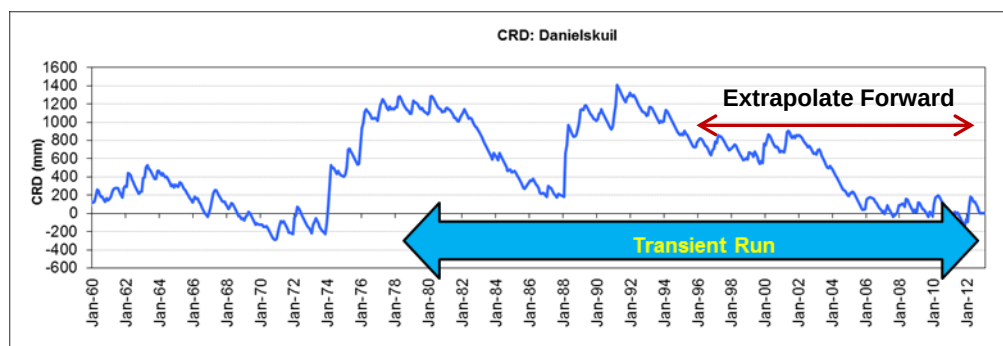


Figure 84: CRD Curve for the Danielskuil Rainfall Station showing the Extrapolated Scenario (red arrow) Interval used for the Predictive Simulations

6.3.3 Applied Abstraction Scenarios (2013 to 2030)

The forward simulations of the proposed SD1 Well field considered four abstraction scenarios, namely:

- Scenario 0 – Base or reference case with no abstractions, i.e. the well field project no-go option.
- Scenario 1 – 22 SD1 and 3 Danielskuil production boreholes:
 - Upper limit abstraction with a combined yield of 724,890 m³/month (8.7 million m³/a) for the SD1 production boreholes and 39,420 m³/month (0.47 million m³/a) for the designated Danielskuil boreholes.
- Scenario 2a – 15 SD1 and 3 Danielskuil production boreholes:
 - Optimised long term abstractions with a combined yield of 444,132 m³/month (5.3 million m³/a) for the SD1 production boreholes and 19,710 m³/month (0.24 million m³/a) for the designated Danielskuil boreholes.
- Scenario 2b – 15 long term SD1 boreholes and 7 short term SD1 boreholes only initiated (into production) from 2015 to 2017 and again from 2024 to 2026 together with the 3 Danielskuil production boreholes:
 - Optimised long- and short term abstractions with a combined yield of 553,632 m³/month (6.6 million m³/a) for the SD1 production boreholes and 19,710 m³/month (0.24 million m³/a) for the designated Danielskuil boreholes (Delta H; 2014).

The various abstraction scenarios are shown in Table 31, while the position of the SD1 well fields and associated (upper limit Scenario 1) abstraction rates is shown spatially in Figure 85.



Table 31: SD1 Abstraction Rates for the Forward Scenario's 1, 2A and 2B

Well field No.	BH no.	Scenario 1 m ³ /month	Scenario 2a m ³ /month	Scenario 2b m ³ /month
Danielskuil	SD1-33	6 570	6 570	6 570
	SD1-34	6 570	6 570	6 570
	SD1-45	26 280	6 570	6 570
Well field No 1	SD1-04	32 850	21 900	21 900
	SD1-08	54 750	43 800	43 800
	SD1-09	32 850	0	21 900
	SD1-25	26 280	0	19 710
	SD1-44	65 700	52 560	52 560
Well field No 2	SD1-10	32 850	32 850	32 850
	SD1-11	32 850	21 900	21 900
	SD1-16	21 900	10 512	10 512
	SD1-17	26 280	19 710	19 710
	SD1-19	26 280	0	19 710
	SD1-20	52 560	52 560	52 560
	SD1-21	26 280	26 280	26 280
	SD1-22	10 950	0	6 570
	SD1-26	21 900	0	21 900
	SD1-35	65 700	52 560	52 560
Well field No 3	SD1-24	52 560	32 850	32 850
	SD1-27	32 850	21 900	21 900
	SD1-32	52 560	32 850	32 850
	SD1-43	21 900	0	10 950
Well field No 4	SD1-40	10 950	0	8 760
	SD1-41	13 140	10 950	10 950
	SD1-42	10 950	10 950	10 950
Total m³/month		764 310	463 842	573 342
Total m³/annum		9 171 720	5 566 104	6 880 104



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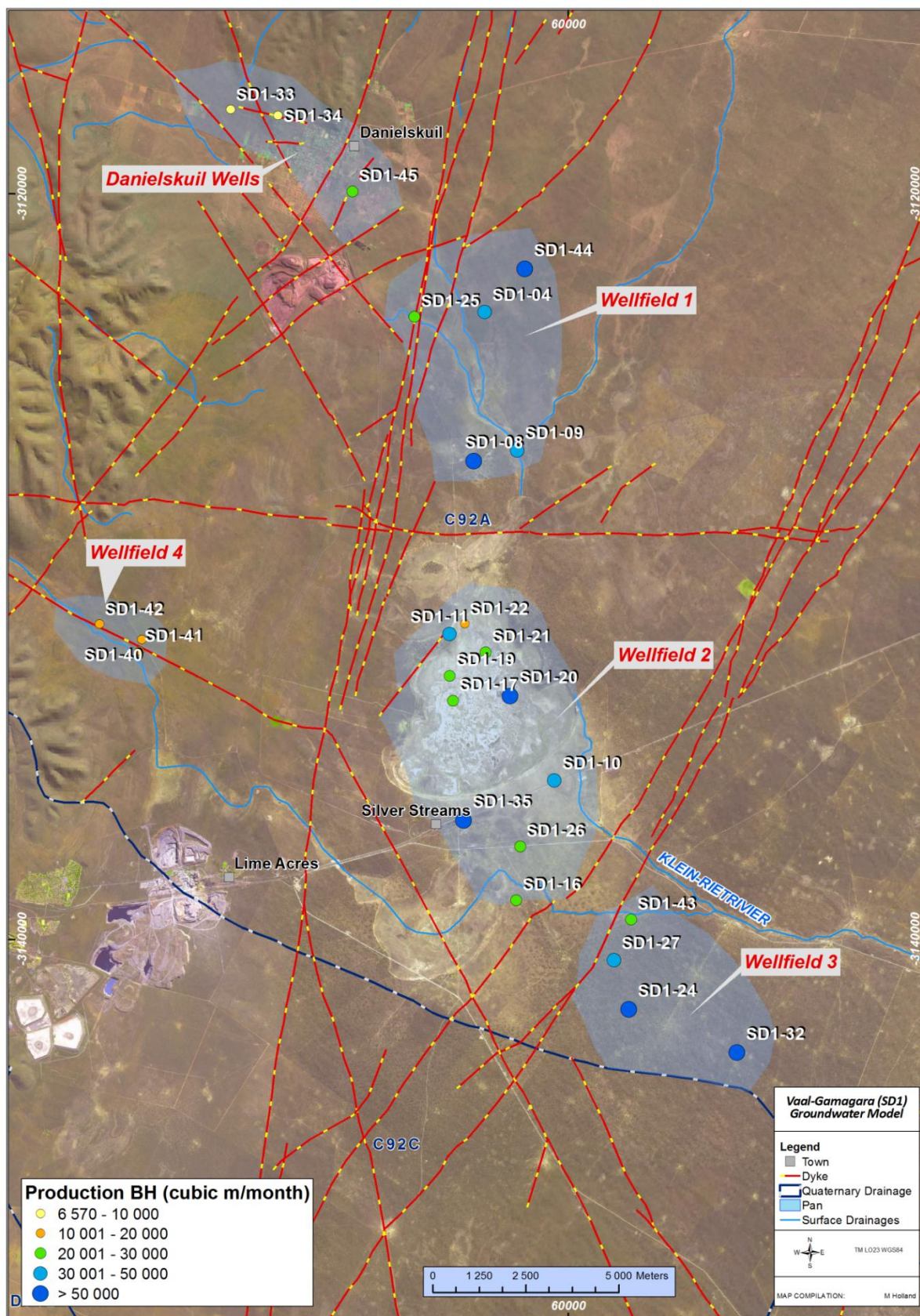


Figure 85: Locality of SD1 Well Fields



6.3.4 SD1 Well Field Scenario 1

Scenario 1 can be considered as a worst case scenario with abstraction rates close to the upper limit of the recommended yields obtained through the local pumping test analysis. As a result, the predictive simulation run reveals a wide-ranging cone of depression, extending approximately 30 km north to south along the well fields and up to 18 km east to west (considering a 2 m cut-off value), due to the distribution of the well fields as shown in Figure 86. The clearly anisotropic zones of influence or groundwater drawdown are due to the presence of dykes with lower permeabilities resulting in the compartmentalisation of the aquifer system.

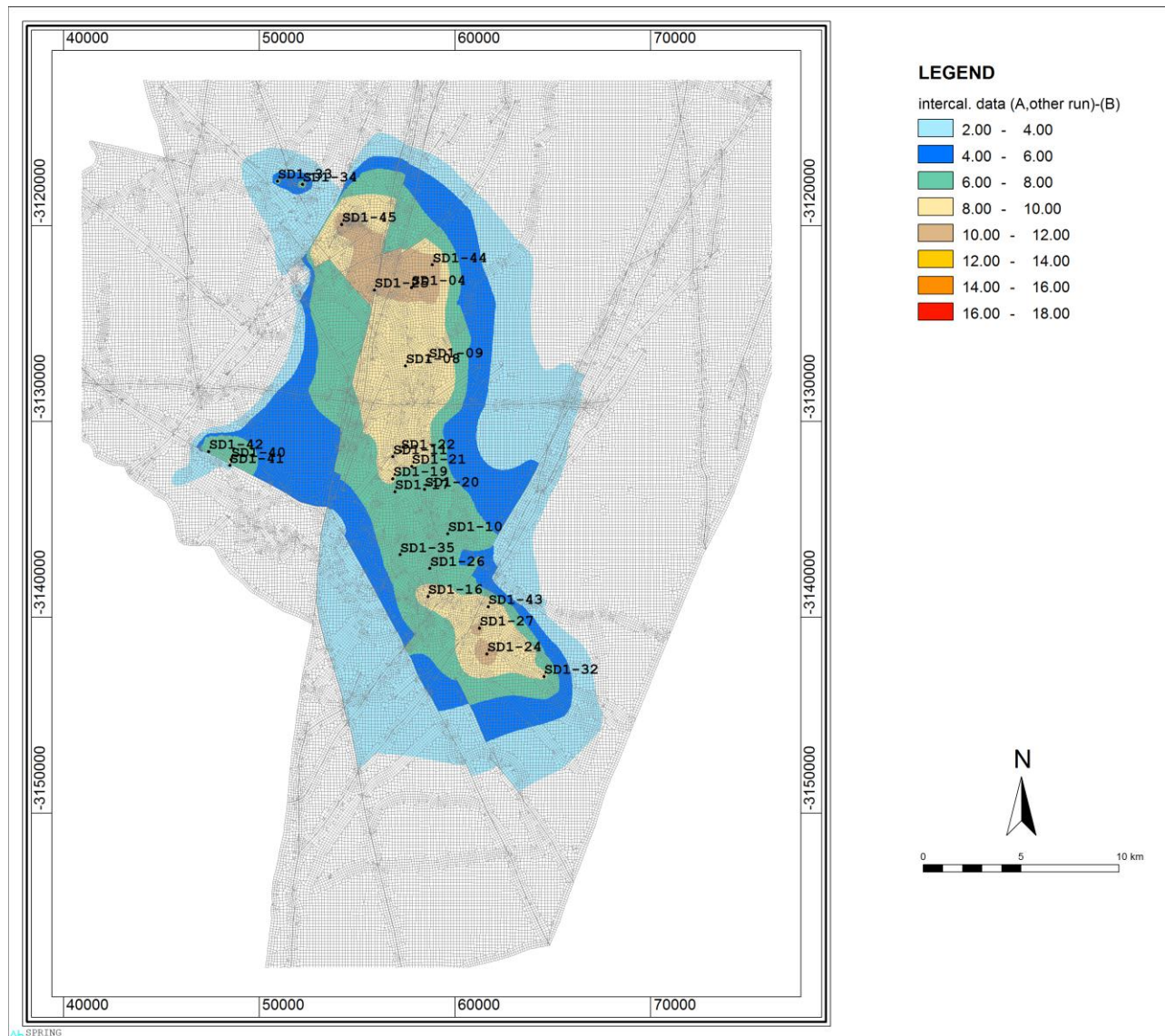


Figure 86: Scenario 1-Cone of Dewatering (m)

6.3.5 SD1 Well Field Scenario 2A

The drawdown cone in the optimised Scenario (2a) is smaller in extent and depth (Figure 87). The cone of dewatering is expectedly more pronounced in the central well fields (No. 2).

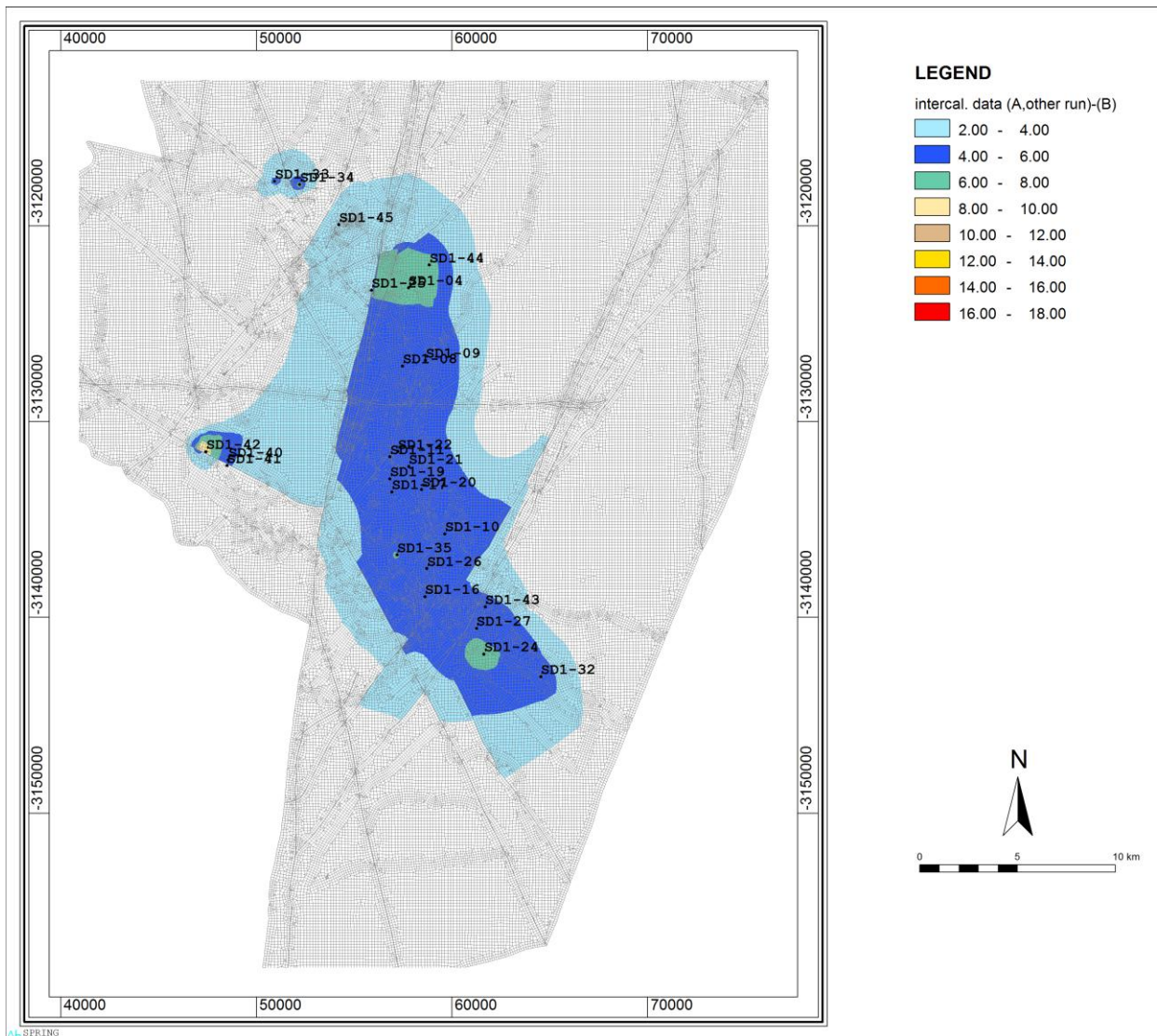


Figure 87: Scenario 2a - Cone of Dewatering (m)

6.3.6 SD1 Well Field Scenario 2B

Based on the outcome of the water level drawdown and extent of the dewatering cone a decision was made by Sedibeng Water to put forward scenario 2b as the recommended well field abstraction rate. The impacts associated with the SD1 well field for the proposed optimal scenario (2b) will be discussed in the following sections in terms of the deviations from the base case scenario 0 (no well field abstractions).

6.3.6.1 Predicted Impact on Water Balance

The change in the predicted water balance compared to the base case (no well field abstractions) for scenario 2b is shown in Table 32.



Table 32: Simulated Water Balance (Transient State - 2030) (Scenario 2b)

Regional Water Balance	Scenario 2b	Base Case	Diff. From Base Case
Inflow	³ m /month	³ m /month	³ m /month
Recharge	870 492	870 492	
Outflow	³ m /month	³ m /month	³ m /month
Spring Discharge	-27 709	-31 102	-3 393
Borehole Abstractions	-695 639	-231 797	463 842
Contribution to Drainages, pans and potential evapotranspiration	-421 928	-452 708	-30 781
Outflow Boundary	-306 442	-354 014	-47 572
Idwala Pit Inflows	-20 472	-25 439	-4 967
Total Outflow	-1 472 189	-1 095 060	
Change In Storage	-601 697	-224 568	377 129
Total Outflow	-870 492	-870 492	

6.3.6.2 Change in Storage

The abstractions from the SD1 well fields results in a change of storage together with a reduction in flows across the outflow boundaries (to downstream catchments) and groundwater contributions to drainages and pans. If the outflows are consistently greater than the inflows, water will be taken from storage, and this manifests itself as an overall decline in groundwater levels. The in- and outflows for the simulation period is shown in Figure 88 while the net change in storage for the base case (no well field abstractions) compared to Scenario 2b is shown Figure 89. The total abstraction from the model domain amounts to approximately 65 % of the average recharge of 1 082 203 m³/month (13 million m³/a) for the simulation period (Delta H; 2014).

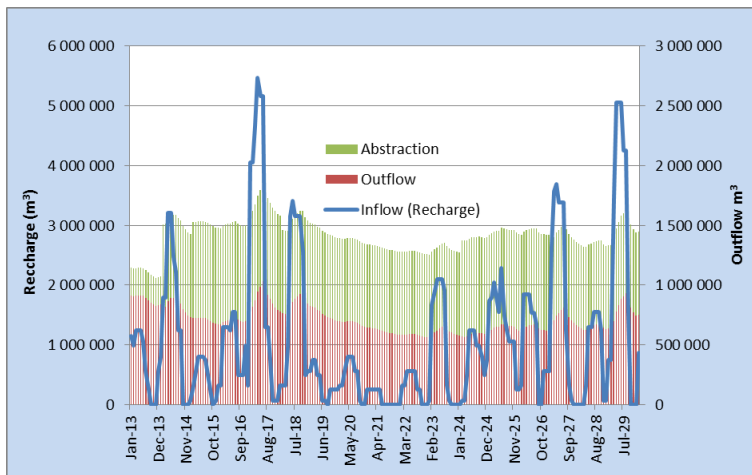


Figure 88: Simulated In- and Outflows for the Modelled Scenario 2B

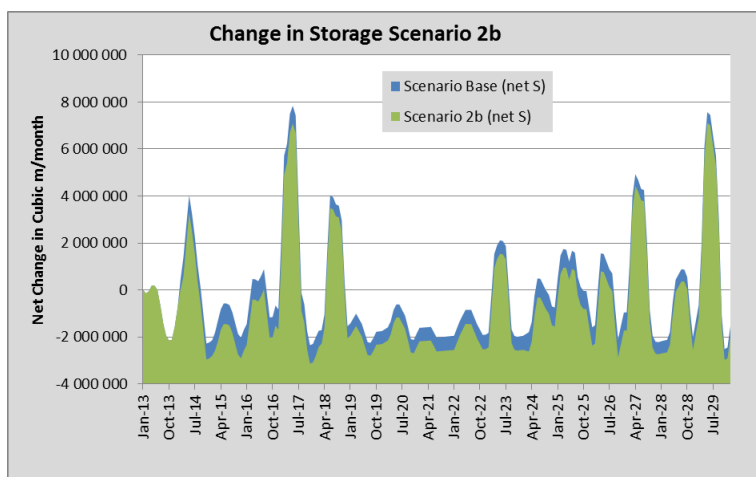


Figure 89: Net change in storage for Scenario 2b compared to the base case

6.3.6.3 Impact on Outflow Boundary

The SD1 well fields (Scenario 2B) will reduce regional groundwater outflow gradually over time until a new (dynamic) equilibrium of recharge and outflow is established (Figure 90). However, it must be emphasised that the change in outflow changes for each time period and that the change in outflow from the first time step (2013) to the last (2030) results in a net change of 2 924 m³/month as a result of the variable recharge and subsequent changes in aquifer storage. The boundaries most affected by the SD1 well fields are the south eastern- and south western outflow (Figure 77) boundaries (Table 33).

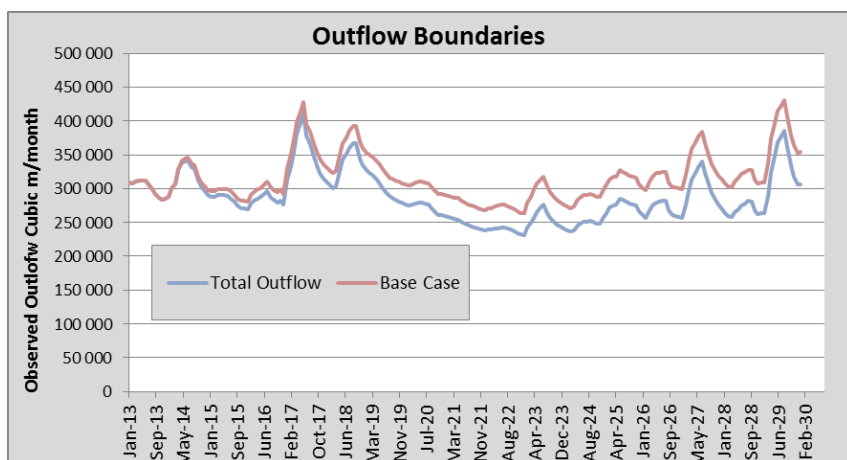


Figure 90: Simulated Mass Flow Rates across the Outflow Boundaries over time for Scenario 2B

Table 33: Simulated reduction in outflow for each outflow boundary (Transient State - 2030) (Scenario 2b)

Outflow Boundary	Scenario 2b in m ³ /month
North Outflow	0
North East Outflow	0
South East Outflow	-15 567
South Outflow	-93
West Outflow	-194
South West Outflow	-31 718
Total	-47 572



6.3.6.4 Impact on Water Levels

The simulated impacts of the groundwater abstraction from the SD1 well field on the regional groundwater levels are shown as a contour map of drawdown by comparing the water levels simulated for the last stress period of the base case (no well field) scenario against the lowered water levels due to abstraction from the SD1 well field (e.g. Scenario 2b). The cone of dewatering for simulation 2b is shown in Figure 91.

No drawdown values below 2 meters are visualised to account for the inaccuracy in the model calibration, which is within the expected seasonal variability of water table elevations. It is likely that any drawdown below 2 meters is within the range of natural water table fluctuations and therefore any potentially affected groundwater dependent ecosystem therefore adapted to it. Similarly, potential groundwater users are unlikely to recognise such drawdown as borehole yields are typically not significantly impacted by such seasonal fluctuations.

The predictive simulation model (scenario 2b) with a maximum abstraction rate of 6.6 million m³/a (from 15 long term and 7 short term SD1 production boreholes) reveals a wide-ranging cone of depression (considering a 2 m cut-off value) due to the distribution of the well fields. Simulated drawdowns for the production boreholes range from 4 to 7 m for the SD1 well field region.

A summary of the drawdown for each abstraction scenario of the production boreholes are given in Table 34.. The designated monitoring boreholes (17) positions are indicated on Figure 92 . The simulated drawdown behaviour for well field boreholes and designated monitoring boreholes behaviour graphs are shown in Appendix B of volume I.

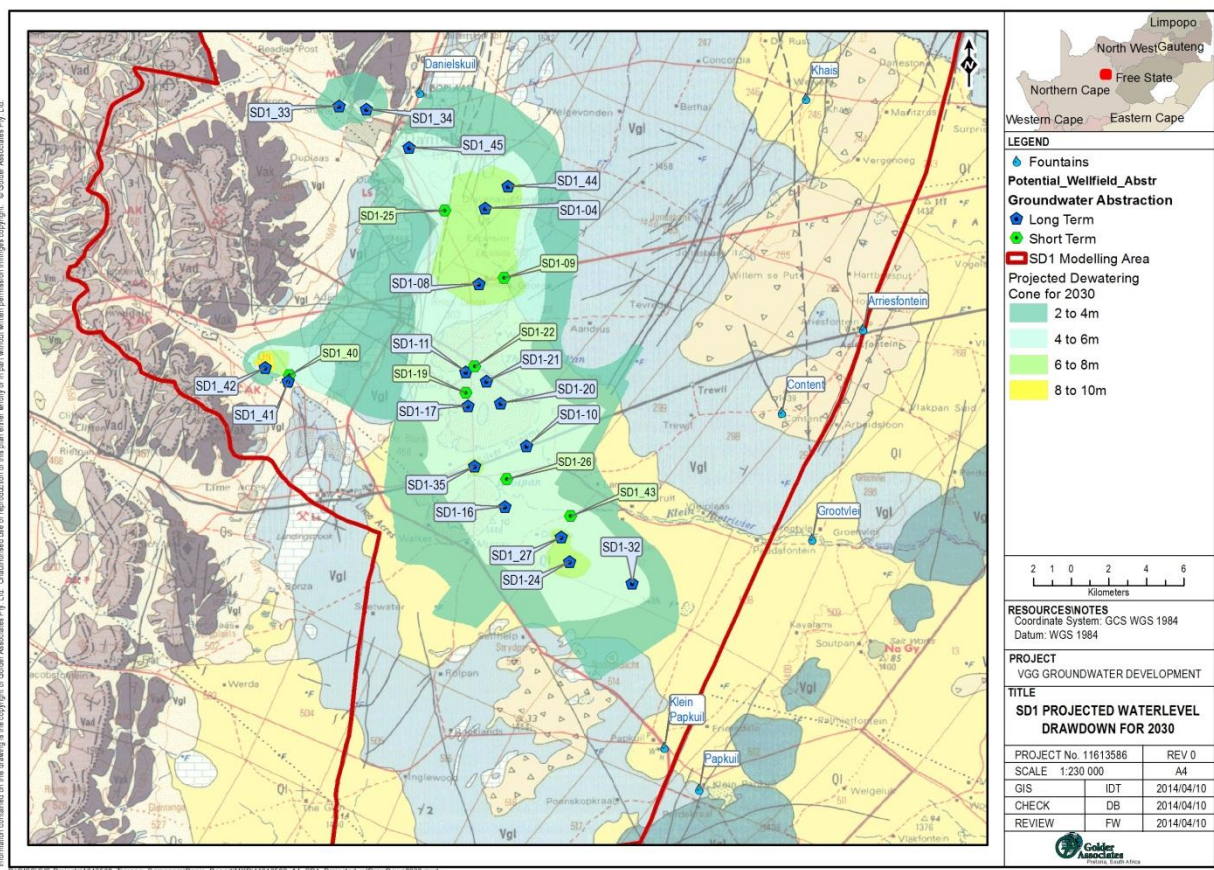


Figure 91: SD1 Projected Water Level Draw Down – 2030



Table 34: Summary of Simulated Total Water Table Drawdown at the end of 2030 for SD1 Well Fields.

Well field No.	BH no.	Scenario 1 Drawdown (m)	Scenario 2a Drawdown (m)	Scenario 2b Drawdown (m)
Danielskuil	SD1-33	11.3	10.2	10.4
	SD1-34	17.3	16.0	16.3
	SD1-45	10.7	3.4	4.5
	-	-	-	-
Well field No 1	SD1-04	10.1	6.0	6.6
	SD1-08	9.4	5.6	6.1
	SD1-09	9.4	5.3	5.8
	SD1-25	11.5	3.3	4.4
	SD1-44	10.5	6.4	7.0
Average Drawdown (m)		10.2	5.3	6.0
Well field No 2	SD1-10	7.3	5.4	5.8
	SD1-11	8.2	5.1	5.5
	SD1-16	8.7	5.4	5.7
	SD1-17	8.3	5.4	5.8
	SD1-19	8.1	4.9	5.3
	SD1-20	7.8	5.3	5.7
	SD1-21	8.1	5.1	5.5
	SD1-22	8.1	5.0	5.4
	SD1-26	7.4	5.2	5.6
	SD1-35	7.1	7.6	8.0
Average Drawdown (m)		7.9	5.4	5.9
Well field No 3	SD1-24	14.3	8.8	8.9
	SD1-27	10.0	5.8	6.0
	SD1-32	9.3	6.0	6.1
	SD1-43	9.8	5.2	5.4
Average Drawdown (m)		10.9	6.4	6.6
Well field No 4	SD1-40	10.5	5.0	5.6
	SD1-41	2.3	1.8	1.9
	SD1-42	6.0	12.7	13.5
Average Drawdown (m)		6.3	6.0	7.0



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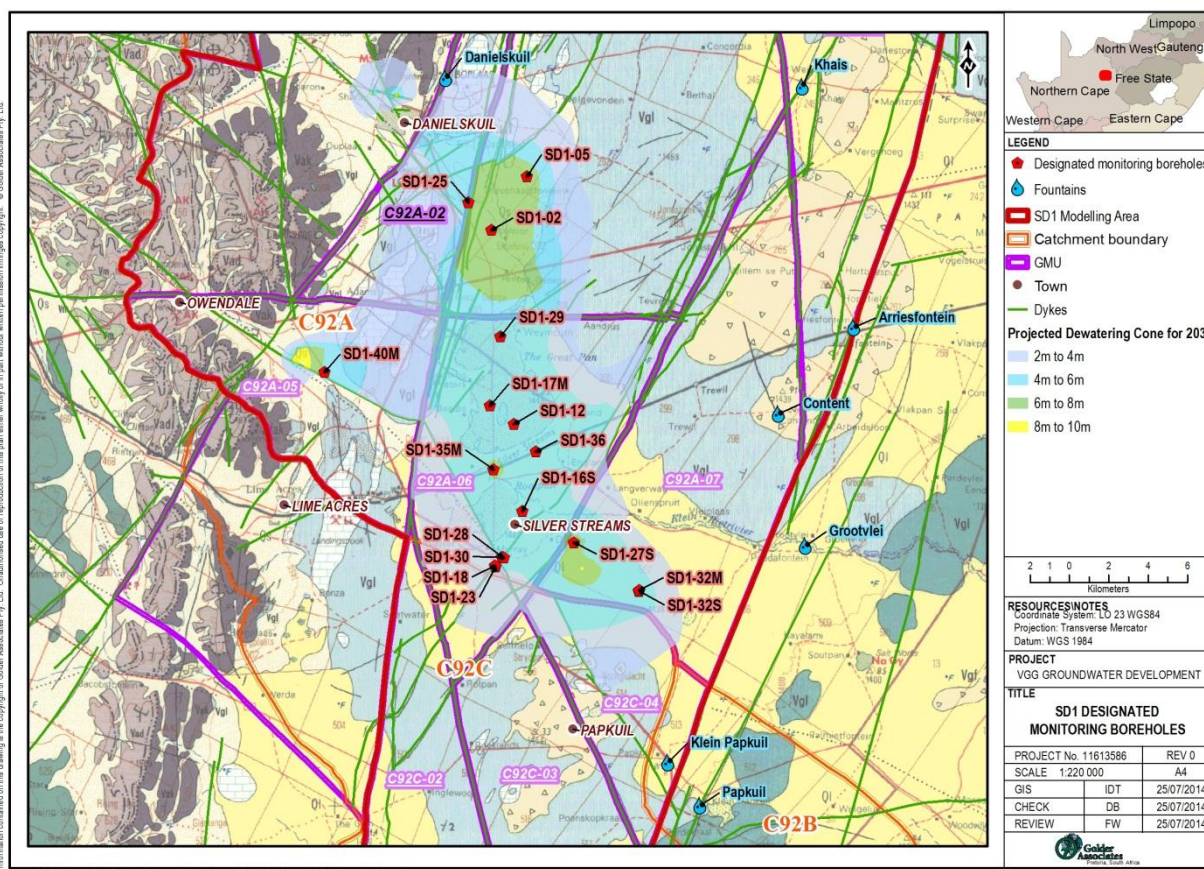


Figure 92: SD1 Designated Monitoring Boreholes

6.3.6.5 Well Field Protection Zone

The approach followed for delineating zones is documented in more detail in the SD1 model report by Delta-H contained in Volume II of this report. The updated model was used in combination with the reverse particle tracking method to delineate the time-of-travel based capture zones of the abstraction wells. The time-of-travel capture zones were used to rank the degree of risk based on the expected travel time of a non-retarded contaminant to reach the water supply wells. The zone 3 outer protection zone (10 year time of travel) is proposed as protection zone for the SD1 well-field scenario 2B comprising of 22 boreholes, as shown in Figure 93.

Any volume of groundwater extracted by pumping in the SD1 production boreholes will be compensated by a reduction in outflow (along the south eastern- and south western outflow boundary) and a reduced volume of groundwater baseflow (towards drainages and springs). Over the long-term a new equilibrium will be reached and in order to maintain this equilibrium, groundwater abstractions must be balanced by increased recharge (increase in the amount of water entering the system) or reduced discharge (reducing the amount of water leaving the system) (Seward et al., 2006). However, some of the water that is pumped comes from a change in amount of water stored in the subsurface (especially in the drier periods where the abstraction is greater than the difference between the inflow and residual outflow, then an additional yield (change in S) is required to maintain the abstraction). During significant recharge events, changes in outflows and contribution to baseflow continue to occur until the water that was removed from storage is replenished (Delta H; 2014).



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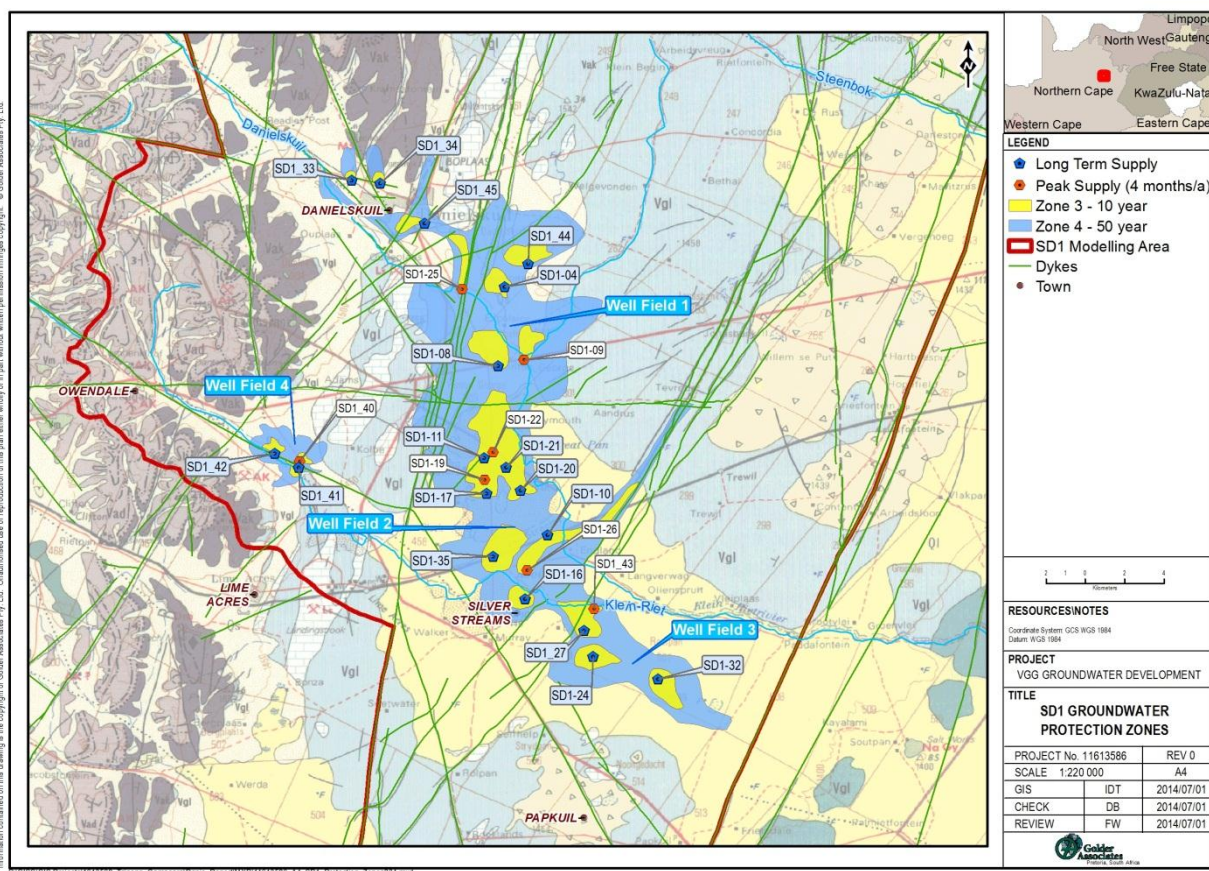


Figure 93: SD1- Groundwater Protection Zones

6.4 Simulated Impact on Water Level of Existing Groundwater Users

The 3D numerical groundwater flow model was conducted to predict the impact of the proposed SD1 well field on the regional groundwater flow, aquifer recharge and discharge.

Due to the intrinsic heterogeneity of the dolomitic groundwater system the potential impact of the groundwater abstractions on other groundwater users may not be equally distributed (spatially) around the proposed abstraction areas. Further, some surface drainages and pans may be perched on a low-permeability substrate (i.e. the calcrete layer), and may not be in hydraulic continuity with the aquifer beneath and therefore not impacted by a drawdown of the water table.

The individual borehole pumping rates for scenario B (22 production boreholes), were optimised through three groundwater model simulations (scenario 1, 2A and 2B) to fall within the recommended critical drawdown level of 6 m, as determined during the pumping test analysis.

The existing ground water users whose boreholes (66) will be impacted by the projected 2030 dewatering cone are indicated on Figure 94. Long term predicted water level draw down (2030) simulations for these boreholes are summarised in Table 35 and the graphs are listed in Appendix C of this document.

From the available borehole information and predicted 2030 water level drawdowns, only SD1-GAA04 will probably dry up. This low yielding borehole has a pump inlet value (PI) of 0.12l/s, has a depth of 16.24m and water level of 12.01m. This borehole has an available drawdown of 4.23m and is currently not in use.

Simulated drawdowns for the existing boreholes range from 0.27m (SD1-GAA071) to 6.05m (SD1-GAA061) with an average drawdown of 4.09 m.

The existing fountains located in the SD1 modelling area fall outside the projected 2030 dewatering cone as indicated on Figure 94 and will not be impacted by the proposed well field.



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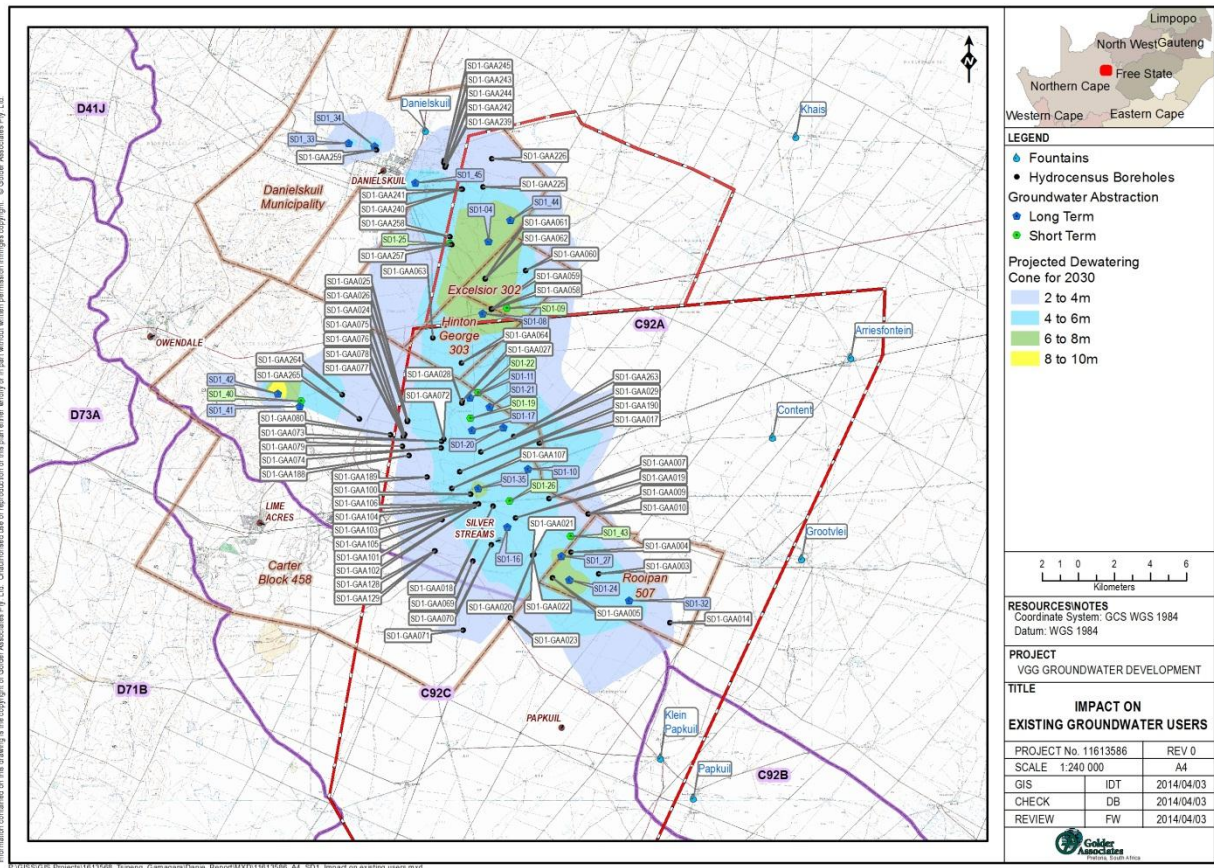


Figure 94: Simulated Impact on Existing Groundwater Users



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Table 35: Predicted Impact on Water Levels of Existing Groundwater Users for 2030

Borehole Number	Land Owner	Farm Name	Depth (m)	Equipment	Test Pumped	Water Level 2013 (mbgl)	Aquifer Yield (l/s)	Predicted Water Level 2030 (mbgl)	Depth-WL-DD(2030) (m)
SD1-GAA071	MR A DE JAGER	CARTER BLOCK PTN. MURRAY	30	W	No	-	-	0.27	-
SD1-GAA014	G.P. DU PLESSIS	ROOIPAN PTN. WITPUT	-	W	No	11.67	-	2.06	-
SD1-GAA023	KOKKIE YORK	CARTER BLOCK PTN. DIKBOS	37.5	W	Yes	11.65	0.54	1.71	24.14
SD1-GAA005	KOKKIE YORK	ROOIPAN PTN. OLIENSPRUIT	38.3	N	Yes	10.9	3.03	5.61	21.79
SD1-GAA003	KOKKIE YORK	ROOIPAN PTN. OLIENSPRUIT	43.1	W	Yes	11.67	0.24(PI)	5.26	26.17
SD1-GAA069	MARIKA DE JAGER	CARTER BLOCK PTN. MURRAY	-	S	No	-	-	1.42	
SD1-GAA021	KOKKIE YORK	CARTER BLOCK PTN. DIKBOS	25.8	S	Yes	14.3	1.25	4.27	7.23
SD1-GAA022	KOKKIE YORK	CARTER BLOCK PTN. DIKBOS	-	W	No	12.07	-	4.28	
SD1-GAA020	KOKKIE YORK	CARTER BLOCK PTN. DIKBOS	37.3	W	Yes	11.4	0.54(PI)	4.32	21.58
SD1-GAA004	KOKKIE YORK	ROOIPAN PTN. OLIENSPRUIT	16.2	N	Yes	12.01	0.12(PI)	5.53	-1.34
SD1-GAA129	JOHAN VISSER	CARTER BLOCK PTN. WALKER	-	W	No	-	-	1.27	-
SD1-GAA128	JOHAN VISSER	CARTER BLOCK PTN. WALKER	41.5	W	No	-	-	1.27	-
SD1-GAA070	MR A DE JAGER	CARTER BLOCK PTN. MURRAY	30	W	No	-	-	4.15	-
SD1-GAA101	JOHAN FAIHST	CARTER BLOCK PTN. SILVER STREAMS	23.7	W	Yes	17.76	0.12(PI)	1.49	4.45
SD1-GAA019	KOKKIE YORK	CARTER BLOCK PTN. DIKBOS	29	W	Yes	9.56	0.51	5.42	14.02
SD1-GAA009	G.P. DU PLESSIS	LANGVERWAGHT	-	W	No	5.22	-	1.95	-



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Borehole Number	Land Owner	Farm Name	Depth (m)	Equipment	Test Pumped	Water Level 2013 (mbgl)	Aquifer Yield (l/s)	Predicted Water Level 2030 (mbgl)	Depth-WL-DD(2030) (m)
SD1-GAA010	G.P. DU PLESSIS	LANGVERWAGHT	-	M	No	4.99	-	1.95	-
SD1-GAA018	KOKKIE YORK	CARTE BLOCK PTN. DIKBOS	30.1	W	Yes	10.21	0.42(PI)	5.67	14.22
SD1-GAA105	JOHAN FAIHST	CARTER BLOCK PTN. SILVER STREAMS	56	S	No	11	1.41	5.01	39.99
SD1-GAA103	JOHAN FAIHST	CARTER BLOCK PTN. SILVER STREAMS	-	W	No	-	-	5.05	-
SD1-GAA104	JOHAN FAIHST	CARTER BLOCK PTN. SILVER STREAMS	-	N	No	-	-	5.02	-
SD1-GAA106	JOHAN FAIHST	CARTER BLOCK PTN. SILVER STREAMS	35	S	No	-	-	5.25	-
SD1-GAA102	JOHAN FAIHST	CARTER BLOCK PTN. SILVER STREAMS	40	W	No	-	-	5.59	-
SD1-GAA007	KOKKIE YORK	CARTERBLOCK PTN. DIKBOS	-	N	No	9.44	-	4.15	-
SD1-GAA107	JOHAN FAIHST	CARTER BLOCK PTN. OUTPOST	30.2	S	Yes	14.69	0.09(PI)	4.13	11.38
SD1-GAA189	DRIES SCHEEPERS	CARTER BLOCK PTN. BEADLE	30	W	No	-	0.4	3.18	-
SD1-GAA190	DRIES SCHEEPERS	CARTER BLOCK PTN. ELIM	-	S	No	1.66	8.3	4.87	-
SD1-GAA188	DRIES SCHEEPERS	CARTER BLOCK PTN. ELIM	40	W	No	21.9	-	2.13	15.97
SD1-GAA029	STEFAANS PRENS	CARTER BLOCK PTN. LAUGHING WATERS	-	N	No	2.4	-	5.48	-
SD1-GAA074	HENNIE VAN ZYL	CARTER BLOCK PTN. BEADLE	50	N	No	0	0.1	4.11	45.89
SD1-GAA079	HENNIE VAN ZYL	CARTER BLOCK PTN. BEADLE	38	M	No	0	5.6	2.22	35.78
SD1-GAA017	KOKKIE YORK	CARTER BLOCK PTN. DIKBOS	23	W	Yes	12.6	0.25(PI)	5.29	5.11
SD1-GAA073	HENNIE VAN ZYL	CARTER BLOCK PTN. BEADLE	50	S	No	0	3.6	4.26	45.74



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Borehole Number	Land Owner	Farm Name	Depth (m)	Equipment	Test Pumped	Water Level 2013 (mbgl)	Aquifer Yield (l/s)	Predicted Water Level 2030 (mbgl)	Depth-WL-DD(2030) (m)
SD1-GAA072	HENNIE VAN ZYL	CARTER BLOCK PTN. BEADLE	50	N	No	6.53	-	4.42	39.05
SD1-GAA078	HENNIE VAN ZYL	CARTER BLOCK PTN. BEADLE	46	M	No	0	27.8	3.27	42.73
SD1-GAA263	KOKKIE YORK	CARTER BLOCK	54.8	N	Yes	2.0	20.0(sdt)	5.42	49.38
SD1-GAA077	HENNIE VAN ZYL	CARTER BLOCK PTN. BEADLE	23	S	No	0	27.8	3.35	19.65
SD1-GAA076	HENNIE VAN ZYL	CARTER BLOCK PTN. BEADLE	24.3	N	Yes	15.46	9.05	3.39	5.45
SD1-GAA080	HENNIE VAN ZYL	CARTER BLOCK PTN. BEADLE	50	S	No	0	5.6	3.91	46.09
SD1-GAA075	HENNIE VAN ZYL	CARTER BLOCK PTN. BEADLE	46	N	No	0	16.7	3.41	42.59
SD1-GAA024	STEFAANS PRENS	CARTER BLOCK PTN. LAUGHING WATERS	0	N	No	0	-	3.87	-3.87
SD1-GAA025	STEFAANS PRENS	CARTER BLOCK PTN. LAUGHING WATERS	25	W	No	16.19	-	3.89	4.92
SD1-GAA026	STEFAANS PRENS	CARTER BLOCK PTN. LAUGHING WATERS	36.4	N	Yes	16.05	0.69(PI)	3.89	16.46
SD1-GAA265	PPC/BOTHA MARKRAM	CARTER BLOCK	-	W	No	0	-	4.05	-
SD1-GAA028	STEFAANS PRENS	CARTER BLOCK PTN. LAUGHING WATERS	-	W	No	0	-	5.4	-
SD1-GAA027	STEFAANS PRENS	CARTER BOX PTN. LAUGHING WATERS	75.2	M	Yes	14.11	6.21	5.41	55.68
SD1-GAA264	PPC/BOTHA MARKRAM	CARTER BLOCK PTN. KOLBE	-	W	No	7.34	-	4.18	-
SD1-GAA064	LENNOX CLOETE	HINTON GEORGE	-	W	No	7.53	-	5.43	-
SD1-GAA063	LENNOX CLOETE	HINTON GEORGE	-	W	No	21.73	-	5.15	-
SD1-GAA058	LENNOX CLOETE	HINTON GEORGE	-	W	No	15.76	-	5.91	-



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Borehole Number	Land Owner	Farm Name	Depth (m)	Equipment	Test Pumped	Water Level 2013 (mbgl)	Aquifer Yield (l/s)	Predicted Water Level 2030 (mbgl)	Depth-WL-DD(2030) (m)
SD1-GAA059	LENNOX CLOETE	HINTON GEORGE	-	W	No	15.84	-	5.91	-
SD1-GAA062	LENNOX CLOETE	EXCELSIOR	-	W	No	12.66	-	6.04	-
SD1-GAA061	LENNOX CLOETE	EXCELSIOR	-	W	No	0	-	6.05	-
SD1-GAA060	LENNOX CLOETE	EXCELSIOR	-	W	No	0	-	4.6	-
SD1-GAA257	MUNICIPALITY BH	OUPLAAS	14.4	N	No	6.93	-	4.26	3.21
SD1-GAA258	MUNICIPALITY BH	DANIELSKUIL	-	W	No	0	-	4.43	-
SD1-GAA241	MUNICIPALITY BH	DANIELSKUIL MEENT PTN. DANLIME 3	33	S	No	9.04	10	4.33	19.63
SD1-GAA240	MUNICIPALITY BH	DANIELSKUIL MEENT PTN. DANLIME 4	60	S	No	9.98	12	4.32	45.7
SD1-GAA225	MUNICIPALITY BH	DANIELSKUIL MEENT	-	W	No	14.86	-	3.46	-
SD1-GAA239	MUNICIPALITY BH	DANIELSKUIL (APIE SE GAT 4) PTN. DANLIME 2	83	S	No	8.07	50	4.27	70.66
SD1-GAA242	MUNICIPALITY BH	DANIELSKUIL (PILOT BH)	-	N	No	0	-	4.23	-
SD1-GAA244	MUNICIPALITY BH	DANIELSKUIL MEENT (APIE SE GAT)	102	N	No	9.31	24	4.11	88.58
SD1-GAA243	MUNICIPALITY BH	DANIELSKUIL(APIE SE GAT2)	90	N	No	9.58	39	4.07	76.35
SD1-GAA245	MUNICIPALITY BH	DANIELSKUIL MEENT (APIE SE GAT3)	90	N	No	9.84	1	3.96	76.2
SD1-GAA226	MUNICIPALITY BH	DANIELSKUIL ALLOTMENT	-	W	No	0	-	2.34	-
SD1-GAA259	MUNICIPALITY BH	DANIELSKUIL ALLOTMENT	70.6	N	Yes	12.6	0.8(PI)	5.42	52.58



7.0 SD1 WELL FIELD ABSTRACTION RATES

7.1.1 SD1 Well fields

Subsequent to the simulated groundwater impacts (Scenario 2B), the recommended abstraction rates for the proposed SD1 well field are listed in **Error! Reference source not found.** and indicated on Figure 95. From the 32 boreholes drilled and constructed as potential production boreholes, 22 (69%) are recommended as well field production boreholes:

- 15 Boreholes can be implemented for long term (continuous) use at a combined monthly abstraction rate of 444,132 m³/month;
- 7 Boreholes can be implemented for short term (3 years on and six years off) or peak supply (4 months/year) use at a combined abstraction rate of 109 500 m³/month.

Detailed well field borehole management recommendations are summarized in Table 38 and listed in Appendix A.

7.2 Danielskuil Municipality Supply Boreholes

Three exploration boreholes were allocated to Danielskuil municipality to help fulfil their future water demand. These boreholes recommended abstraction rates are listed in Table 37 and indicated on Figure 95

The combined monthly abstraction rate for these boreholes is 19 710 m³/month. The management recommendations are listed in Table 38 and in Appendix A.

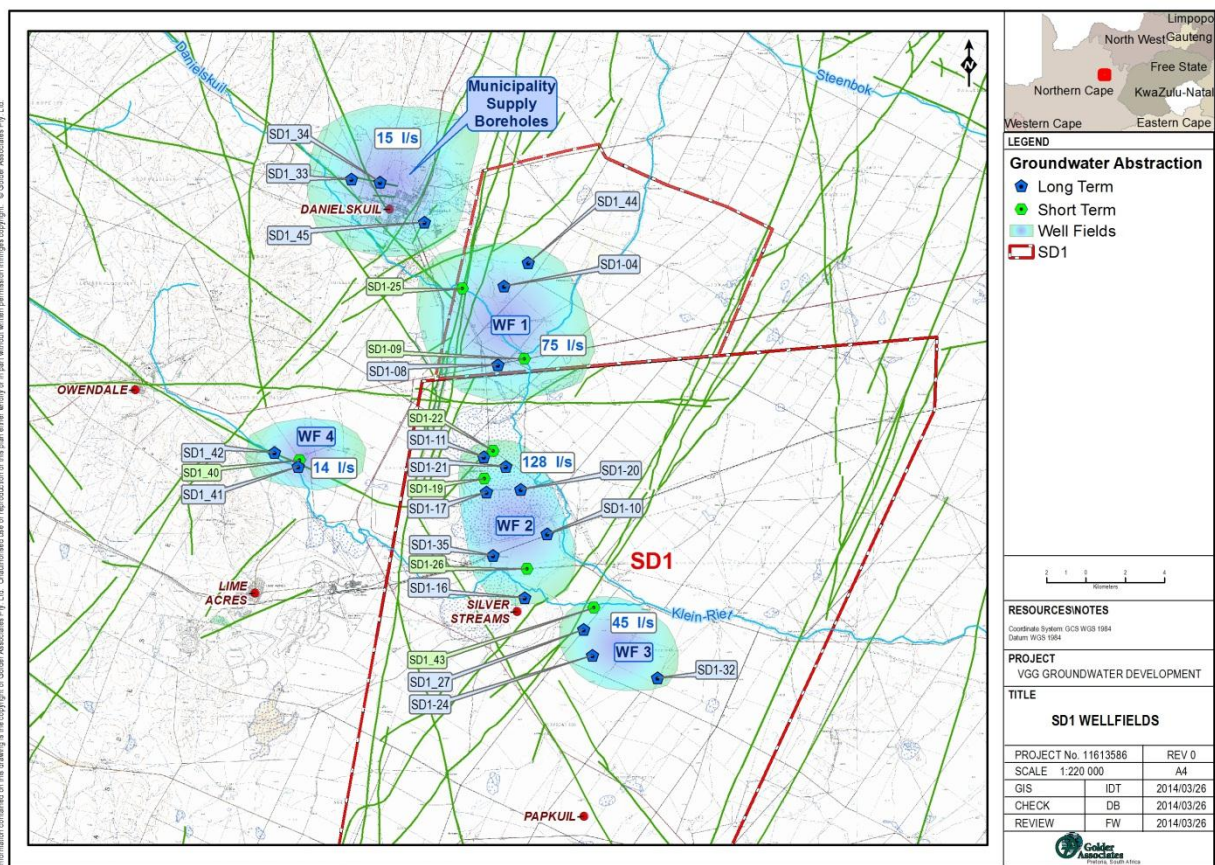


Figure 95: SD1 Well Field Borehole Positions Scenario 2B



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Table 36: SD1 Recommended Well Field Abstraction Rates

Well field	Borehole No.	Latitude	Longitude	Depth (m)	Diameter (mm)	WL (mamsl)	WL (m)	Critical WL Depth (m)	Discharge (l/s)	Pumping Hours Per day	Daily Abstraction M ³ /day	Monthly Abstraction M ³ /Monthly	Long Term M ³ /day	Short Term M ³ /day	Water Quality Class
WF1	SD1-04	-28.22185	23.5884	61	203	1437.41	11.58	18	10	20	720	21900	720	-	0
WF1	SD1-08	-28.25789	23.58555	40	254	1435.47	13.68	26	20	20	1440	43800	1440	-	0
WF1	SD1-09	-28.25527	23.59748	40	203	1435.48	6.84	30	10	20	720	21900	-	720	I
WF1	SD1-25	-28.22309	23.56914	51	203	1439.62	7.02	48	15	12	648	19710	-	648	0
WF1	SD1-44	-28.21134	23.59929	34	203	1439.45	17.83	23	20	24	1728	52560	1728	-	I
WF2	SD1-10	-28.33522	23.60812	28	254	1432.086	11.92	24	15	20	1080	32850	1080	-	II
WF2	SD1-11	-28.29988	23.57918	70	165	1432.93	13.44	42	10	20	720	21900	720	-	0
WF2	SD1-16	-28.36428	23.5978	69	165	1431.525	9.61	39	8	12	345.6	10512	345.6	-	I
WF2	SD1-17	-28.31607	23.58026	58	203	1432.86	2.29	39	15	12	648	19710	648	-	0
WF2	SD1-19	-28.31002	23.57928	40	203	1432.42	2.4	18	15	12	648	19710	-	648	0
WF2	SD1-20	-28.31478	23.59588	48	203	1432.8	2.2	43	20	24	1728	52560	1728	-	I
WF2	SD1-21	-28.30433	23.58906	103	165	1432.82	2.04	72	10	24	864	26280	864	-	0
WF2	SD1-22	-28.29738	23.58331	49	203	1432.94	2.93	37	5	12	216	6570	-	216	0
WF2	SD1-26	-28.35129	23.59879	69	203	1431.406	10.41	55	10	20	720	21900	-	720	I
WF2	SD1-35	-28.34501	23.58328	28	254	1432.748	9.58	25	20	24	1728	52560	1728	-	I
WF3	SD1-24	-28.39055	23.62879	68	203	1424.569	12.7	66	15	20	1080	32850	1080	-	0
WF3	SD1-27	-28.37868	23.6247	104	203	1424.485	12.93	84	10	20	720	21900	720	-	I
WF3	SD1-32	-28.40082	23.65853	73	203	1423.783	12.65	70	15	20	1080	32850	1080	-	II
WF3	SD1-43	-28.36883	23.62928	64	203	1423.016	14.81	59	5	20	360	10950	-	360	I
WF4	SD1-40	-28.30157	23.49494	97	165	1438.482	30.24	51	4	20	288	8760	-	288	0



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WF4	SD1-41	-28.30427	23.49428	97	203	1423.46	43.43	72	5	20	360	10950	288	-	0
WF4	SD1-42	-28.29786	23.48335	112	165	1423.77	53.46	69	5	20	360	10950	360	-	0
Total									262	-	18202	553632	14529	3600	-
Long Term m³/Month												444132			
Short Term m³/Month												109500			
Long Term m³/annum												5329584			
Short Term m³/annum												1314000			
Long + Short Term m³/annum												6643584			

Table 37: Danielskuil Municipality Supply Boreholes

Locality	Borehole No.	Latitude	Longitude	Depth (m)	Diameter (mm)	WL (mamsl)	WL (m)	Critical WL Depth (m)	Discharge	Pumping Hours Per day	Daily Abstraction m3/day	Monthly Abstraction m3/Monthly	Long Term m3/day	Water Quality Class
Danielskuil	SD1-33	-28.173102	23.5186	74	203	1468.05	26.12	72	5	12	216	6570	216	0
Danielskuil	SD1-34	-28.17447	23.53161	137	203	1467.812	25.59	59	5	12	216	6570	216	II
Danielskuil	SD1-45	-28.19284	23.55202	44	203	1432.48	12.82	34	5	12	216	6570	216	I
	Total								15	-	648	19710	648	-
Total m³/a											236 520			



7.3 SD1 Well Field Management Recommendations

The summary of management recommendations for SD1 well field and Danielskuil Municipality supply boreholes is listed in Table 38 and presented in Appendix A of this report.

Table 38: SD1 Well Field Management Recommendations

Well Field	Bh No.	Depth (m)	SWL (mbgl)	T (m ² /d)	S	Water Quality Class	Management Recommendations				
							Yield (l/s)	Duty (hr/day)	Pump Intake (mbgl)	Dynamic Water level (mbgl)	Critical Water level (mbgl)
WF1	SD1-04	61	11.58	1686	0.05	0	10	20	48	14	18
WF1	SD1-08	40	13.68	2573	0.05	0	20	20	36	14.5	26
WF1	SD1-09	40	6.84	987	0.05	I	10	20	36	10.5	30
WF1	SD1-25	51	7.02	2533	0.0197	0	15	12	48	9	48
WF1	SD1-44	34	17.83	748	0.05	I	20	24	30	19.5	23
WF2	SD1-10	28	11.92	917	0.05	II (N – 13.4mg/l) Blend water before use	15	20	26	16	24
WF2	SD1-11	70	13.44	3424	0.05	0	10	20	54	15.5	42
WF2	SD1-16	69	9.61	934	0.05	I	8	12	60	11	39
WF2	SD1-17	58	2.29	855	0.05	0	15	12	42	4	39
WF2	SD1-19	40	2.4	1290	0.05	0	15	12	36	4	18
WF2	SD1-20	48	2.2	3082	0.05	I	20	24	36	5	43
WF2	SD1-21	103	2.04	714	0.05	0	10	24	36	5.5	72
WF2	SD1-22	49	2.93	681	0.05	0	5	12	36	7	37
WF2	SD1-26	69	10.41	747	0.05	I	10	20	60	14	55
WF2	SD1-35	28	9.58	2568	34.9	I	20	24	26	11.5	25
WF3	SD1-24	68	12.7	486	0.05	0	15	20	66	14.5	66
WF3	SD1-27	104	12.93	273	0.05	I	10	20	84	16	84
WF3	SD1-32	73	12.65	1078	0.000321	II (F- 1.21mg/l) Blend Water before use	15	20	70	17	70
WF3	SD1-43	64	14.81	313	0.05	I	5	20	60	16	59
WF4	SD1-40	97	30.24	79	0.0322	0	4	20	54	35	51
WF4	SD1-41	97	43.43	83	0.05	0	5	20	72	49	72



WF4	SD1-42	112	53.46	52	0.05	0	5	20	72	59	69
Danielskuil Municipality Supply Boreholes											
DM	SD1-33	74	26.12	68	0.05	0	5	12	63	31	72
DM	SD1-34	137	25.59	71	0.05	II (F-1.05mg/l) Blend water before use	5	12	60	29	59
DM	SD1-45	44	12.82	1948	0.05	I (Fe- 0.14mg/l) Blend water before use	5	12	33	14	34

8.0 CONCLUSIONS

Based on the desktop studies, field investigations and resource assessment activities undertaken during this project, the following conclusions are made for the SD1 area:

- The Vaal Gamagara Water Supply study area (SD1) is underlain by Kalahari sediments, dolomite and Banded Iron Formation (BIF) aquifers of which the latter two are compartmentalized by intrusive low permeable dolerite dyke structures;
- Thirty two high yielding boreholes were drilled with a combined air-lift yield of 871 l/s. Exploration drilling in SD1 area was completed on 18 August 2013;
- Borehole test pumping in the SD1 area was completed by 10 September 2013, with twenty seven higher yielding exploration boreholes subjected to 24 or 48 or 72 hour CDT's. The combined pumping yield of these tests was 510 l/s;
- The following aquifer systems were confirmed in the SD1 study area:
 - Intergranular Kalahari Sediments, unconfined aquifer system;
 - Banded Ironstone Formation (BIF) - weathered and fractured semi confined aquifer system; and
 - Dolomite karst aquifers – semi confined to confined aquifer system, compartmentalised by dolerite dykes.
- The aquifer testing results and continuous water level monitoring data confirmed that the upper Kalahari sediments (mainly shallow/perched calcrete aquifer) is not hydraulically linked with the deeper bedrock aquifer zones;
- Major karstification zones in the dolomite are the main aquifer system in the SD1 area, with borehole blow yields up to 60 l/s;
- Water level depths of the exploration boreholes range from 2m to 67m with an average of 14m;
- The baseline groundwater quality of SD1 exploration boreholes is based on the macro chemistry analyses of the sampled exploration boreholes. The concentrations are compared to the SANS 241:2011 water quality standard and the baseline quality is represented by the median of the concentrations listed in the Table below:



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Item	Physical Parameters			Macro Determinants (Major Ions)								Minor Determinant		
	pH	EC mS/m	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO4 mg/l	NO3 mg/l	MALK Mg/l	F mg/l	Fe mg/l	Mn mg/l
No. of Records	43	43	43	43	43	43	43	43	43	43	43	43	43	43
10 % Percentile	7.25	26.72	174.40	35.00	12.06	5.34	1.72	8.31	11.20	0.30	143.60	0.10	0.05	0.05
Median Baseline water Quality	7.54	67.1	420	86.3	33.8	11.7	2.49	29.3	28.2	3.325	292	0.1	0.05	0.05
Average	7.52	61.42	410.93	78.87	33.18	17.20	3.45	39.99	34.12	3.48	273.05	0.13	0.08	0.08
90% Percentile	7.72	87.70	588.40	98.72	50.56	35.84	5.96	80.86	66.94	5.99	377.20	0.16	0.05	0.15
Max. Allowable Limit (SANS 241:2011)	<5 >9	<170	<1200	<300	<100	<200	<100	<300	<500	<11	-	<1.5	<0.3	<0.5

The background groundwater classification for SD1 study area is calcium magnesium bicarbonate type of water (Ca, Mg)(HCO₃)₂;

- Borehole management recommendations for the identified well fields, scenario B (22 boreholes) amounts to a combined (long and short term) peak abstraction rate of **6,643,584 m³/a**. The sustainable long term abstraction rate is **5,329,584 m³/a** and the short term / peak supply for four months per annum from 7 boreholes is **1,314,000 m³/a**;
- The recommended abstraction rate for the additional developed Danielskuil Municipality supply boreholes amounts to 236,520m³/a;
- A 3D numerical groundwater flow model was conducted to predict the impact of the proposed SD1 well field on the regional groundwater flow, aquifer recharge and discharge. The predictive simulation for scenario B (22 boreholes) with a combined peak abstraction of 6,643,584 m³/a reveals a shallow extended cone of depression, with a 2 to 6m water level drawdown within the regional aquifer;
- The individual borehole pumping rates for scenario 2B (22 production boreholes), were optimised through three groundwater model simulations(scenario 1, 2A and 2B) to limit water level drawdowns on the regional dolomite aquifer to within 4 to 6m, to limit the risk of sinkhole occurrences. Simulated dynamic water level drawdowns for the production boreholes range from 4.4 (SD1-25, dolomite) to 13.5m (SD1-42, BIF) with an average drawdown of 7m;
- The conceptual assumption is made that dolerite dykes are partially permeable for +/- 4m below SWL, allowing groundwater interflow between compartments. Below 4m the dolerite dykes are impermeable and acts as groundwater flow barriers responsible for compartmentalization in the formations;
- Any volume of groundwater extracted by pumping in the SD1 production boreholes will be compensated by a reduction in outflow (along the south eastern and western outflow boundary) and a reduced volume of baseflow (towards drainages and springs). Over the long-term a new equilibrium will be reached and in order to maintain this equilibrium, groundwater abstractions must be balanced by increased recharge (increase in the amount of water entering the system) or reduced discharge (reducing the amount of water leaving the system);
- Lime Acres form part of the base case scenario with no impact on the groundwater regime; and



- An intermediate groundwater reserve study was completed in 2008 for the Lower Vaal Water Management Area (WMA). The intermediate groundwater reserve determination was done with using a Groundwater Yield Model for the Reserve (GYMR). Using the GYMR (Present day scenario for 2008) as a representative value for total inflow (recharge) and net base flow, there is a groundwater balance of 12.67 million m³/a available for use in the C92A quaternary catchment. Updating the existing water use for 2013 to 4.21 million m³/a, the groundwater balance available for use by the SD1 well field is 8.45 million m³/a.

9.0 RECOMMENDATIONS

Based on the above discussions and conclusions the following is recommended:

- A WULA to implement the 22 production boreholes (scenario B) to abstract **5 329 584m³/a** on a sustainable basis over the long term and **1 314 000m³/a** over a short term / peak supply for four months/a (**6 643 584m³/a** combined peak supply) to augment water supply to the VGWS;
- The recommended well field abstractions for SD1 are summarised in table below:

Well Field	Number of BH's	Yield l/s	Long Term m ³ /m	Long Term m ³ /a	Short Term m ³ /m	Short Term m ³ /a	Long + Short Term m ³ /a
WF1	5	75	118 260	1 419 120	41 610	499 320	1 918 440
WF2	10	128	216 372	2 596 464	48 180	578 160	3 174 624
WF3	4	45	87 600	1 051 200	10 950	131 400	1 182 600
WF4	3	14	21 900	262 800	8 760	105 120	367 920
Total	-	262	444 132	5 329 584	109 500	1 314 000	6 643 584
Danielskuil	3	15	19 710	236 520			

- All 22 well field boreholes should be protected by a 30 m fenced area and equipped with real time water level monitoring facility as well as water sampling facility at the borehole;
- During installation of reticulation network backfilling of all excavations must be compacted to accepted geotechnical standards to avoid creating drains collecting water and generating preferential groundwater flow paths along new manmade constructions increasing the risk for sinkhole development;
- Critical water levels as indicated in the borehole management recommendations in Appendix A, must not be exceeded. Once these levels are reached daily abstraction rates must be reduced;
- No household, agricultural or animal activities must be allowed within 150 m radius of all production boreholes;
- The aquifer protection zone 3 (for ten year period) must be implemented, within which no new developments or activities may be allowed that may contaminate the aquifer;
- The performance of the well field must be evaluated once a year by updating the numerical model;
- The presented model must be used as a tool for identifying a sound management protocol of the aquifer. Recommendations given are:
 - The model must be utilized to develop optimal operational and management rules for the well field, considering their impact on the regional water balance and water levels;



- The model must be re-calibrated once a full hydrological year of monitoring data for the SD1 well field becomes available;
- Annual review of the model predictions and model update if required;
- With minimal further customization, the model can be expanded to a mass transport model to simulate water quality impacts across the entire model domain.
- Proposed groundwater monitoring programme for SD1 area must comprise of:
 - Quarterly water level monitoring of all accessible exploration boreholes for period of up to three years;
 - Continuous water level monitoring at present installed electronic data loggers for period of up to three years;
 - Site-specific groundwater and rainfall monitoring data are vital for a reliable transient calibration of the model and to understand and simulate aquifer responses to abstraction and recharge at higher confidence. Two real-time rainfall monitoring stations must be installed (one each in well field area 1 and 3).
 - The designated monitoring boreholes, must be equipped for real time water level monitoring, to minimize private land access;
 - During well field implementation the proposed production boreholes must be equipped with real time water level loggers;
 - Monthly abstraction from each borehole must also be monitored;
 - After well field implementation, quarterly sampling of well field boreholes and analysis of samples for macro chemical elements as well as bacteriological analysis;
 - All water level, abstraction and water quality monitoring data must be incorporated into DWA's resource monitoring program;
 - Real time water level monitoring data must also be linked to the Tshiping Water User Association's database to be accessible to all groundwater users and interested parties;
 - Regional water level monitoring by DWA needs to be implemented in the modelling area and downstream below the modelling outflow boundary; and
 - As part of the DWA regional water level monitoring, a monitoring borehole must be implemented in the south of the modelling area near Papkuil.

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APPENDIX A

Well Field Management Recommendations

MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BAX0023 Number: SD1-04 Site type: Borehole

Distr./Farm No.: Site Name/Descr.: DANIELSKUIL

Latitude [°]:	28.221849	Alt. No. 1:		Diam. [mm]:	203	Water lev. [m]:	12.99
Longitude [°]:	23.588400	Alt. No. 2:		Depth [m]:	61.55	WL status:	Static
Altitude [m]:	1448.99	Rep. inst.:	GOLD	Col. ht. [m]:	0.51	Date WL meas.:	20130421

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-04	Date sampled:	20130422	Depth sampl. [m]:	28.50	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.25	Na:	10.7	Cl:	26.2	Langel.:	0.09	E.Coli:
EC: [mS/m]	69.5	K:	1.61	NO3 as N:	2.75	Aggr-Ind:	12.17	Faec. co:
TDS:	370	Si:	12.8	SO4:	25.7	Ion-bal:	0.56	Total Co:
T. Alk.:	369	Al:	< 0.05	F:	< 0.1	CaCO3:	422.47	SPC:
Ca:	90.2	Fe:	< 0.05	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ¡ Value exceeds minimum allowable limit				
Mg:	48	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
19.00	19.50	20.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	14.00	305	Steel		Plain casing			
14.00	20.00	305	Steel		Perforated or slotted			
0.00	16.00	254	Steel		Plain casing			
16.00	22.00	254	Steel		Perforated or slotted			
0.00	6.00	203	Steel		Plain casing			
6.00	36.00	203	Steel		Perforated or slotted			
36.00	42.00	203	Steel		Plain casing			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130421	60	28.50	5.09	0.32					
STEP TEST STEP 2	20130421	60	28.50	10.05	0.76					
STEP TEST STEP 3	20130421	60	28.50	15.03	1.04					
STEP TEST STEP 4	20130421	60	28.50	20.09	1.47	100	120			
CONSTANT	20130421	1440	28.50	20.08	1.31	100	960	1686		

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	48.00	Electric motor	20	10.00	CLASS 0	14.00	18.00

Note: 1. Production borehole.
2. Install water level monitoring facility in borehole.



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BCX0178 Number: SD1-08 Site type: Borehole

Distr./Farm No.: 303 Site Name/Descr.: HINTON GEORGE

Latitude [°]:	28.257892	Alt. No. 1:		Diam. [mm]:	254	Water lev. [m]:	14.95
Longitude [°]:	23.585559	Alt. No. 2:		Depth [m]:	39.85	WL status:	Static
Altitude [m]:	1449.15	Rep. inst.: GOLD		Col. ht. [m]:	0.53	Date WL meas.:	20130501

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-08	Date sampled:	20130502	Depth sampl. [m]:	34.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.29	Na:	11.1	Cl:	28.2	Langel.:	0.08	E.Coli:
EC: [mS/m]	66.3	K:	1.89	NO3 as N:	3.55	Aggr-Ind:	12.15	Faec. co:
TDS:	400	Si:	12.8	SO4:	24.2	Ion-bal:	0.58	Total Co:
T. Alk.:	332	Al:	< 0.05	F:	< 0.1	CaCO3:	388.17	SPC:
Ca:	87	Fe:	< 0.05	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ¡ Value exceeds minimum allowable limit				
Mg:	41.6	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
27.00	27.30	30.00	Notch (V- or U-notch)		
22.00	22.50	8.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	1.00	381	Steel		Plain casing			
0.00	18.00	254	Steel		Plain casing			
0.00	18.00	305	Steel		Plain casing			
18.00	24.00	305	Steel		Perforated or slotted			
18.00	36.00	254	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130501	60	34.80	8.02	0.21					
STEP TEST STEP 2	20130501	60	34.80	16.12	0.48					
STEP TEST STEP 3	20130501	60	34.80	24.12	0.77					
STEP TEST STEP 4	20130501	60	34.80	30.21	1.09	0 100	5			
CONSTANT	20130501	1440	34.80	30.08	0.71	0 100	10	2573		

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	36.00	Electric motor	20	20.00	CLASS 0	14.50	26.00

Note: 1. Production borehole.
2. Install water level monitoring facility in borehole.



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BCX0174 Number: SD1-09 Site type: Borehole

Distr./Farm No.: 302 Site Name/Descr.: EXCELSIOR

Latitude [°]:	28.255266	Alt. No. 1:		Diam. [mm]:	203	Water lev. [m]:	8.04
Longitude [°]:	23.597476	Alt. No. 2:		Depth [m]:	40.30	WL status:	Static
Altitude [m]:	1442.32	Rep. inst.: GOLD		Col. ht. [m]:	0.55	Date WL meas.:	20130428

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-09	Date sampled:	20130429	Depth sampl. [m]:	34.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.32	Na:	15.7	Cl:	29.5	Langel.:	0.12	E.Coli:
EC: [mS/m]	73.1 †	K:	1.8	NO3 as N:	3.91	Aggr-Ind:	12.20	Faec. co:
TDS:	450	Si:	13.9	SO4:	26.9	Ion-bal:	1.32	Total Co:
T. Alk.:	370	Al:	< 0.05	F:	< 0.1	CaCO3:	429.50	SPC:
Ca:	82.3	Fe:	< 0.05	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ¡ Value exceeds minimum allowable limit				
Mg:	54.5	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
32.00	36.00	13.00	Notch (V- or U-notch)		
10.00	19.00	25.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	2.00	305	Steel		Plain casing			
0.00	6.00	203	Steel		Plain casing			
0.00	6.00	254	Steel		Plain casing			
6.00	18.00	254	Steel		Perforated or slotted			
6.00	36.00	203	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130428	60	34.80	8.23	0.65					
STEP TEST STEP 2	20130428	60	34.80	16.32	1.34					
STEP TEST STEP 3	20130428	60	34.80	24.14	2.36					
STEP TEST STEP 4	20130428	60	34.80	30.13	3.42	100	30			
CONSTANT	20130429	1440	34.80	25.09	2.11	100	150	987		

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	36.00	Electric motor	20	10.00	CLASS 0	10.50	30.00

Note: 1. Production borehole.
2. Install water level monitoring facility in borehole.



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BCX0192 Number: SD1-10 Site type: Borehole

Distr./Farm No.: 458 Site Name/Descr.: CARTER BLOCK

Latitude [°]:	28.335220	Alt. No. 1:		Diam. [mm]:	220	Water lev. [m]:	12.90
Longitude [°]:	23.608120	Alt. No. 2:		Depth [m]:	27.00	WL status:	Static
Altitude [m]:	1444.01	Rep. inst.: GOLD		Col. ht. [m]:	0.53	Date WL meas.:	20130613

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-10	Date sampled:	20130614	Depth sampl. [m]:	22.80	Comment:	
Main Parameters:		Calculated Parameters:		Bacteriol. Parameters:			
pH:	7.64	Na:	40	Cl:	81.1	Langel.:	0.28
EC: [mS/m]	88.1 †	K:	9.76	NO3 as N:	13.4 †	Aggr-Ind:	12.37
TDS:	594 †	Si:	18.6	SO4:	68.8	Ion-bal:	0.95
T. Alk.:	288	Al:	< 0.05	F:	< 0.1	CaCO3:	432.68
Ca:	75.5	Fe:	< 0.05			SPC:	
Mg:	59.4	Mn:	< 0.05				

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimum allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
22.00	22.50	0.10	Notch (V- or U-notch)		
25.00	28.00	20.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	22.00	254	Steel		Plain casing			
0.00	22.00	305	Steel		Plain casing			
22.00	28.00	254	Steel		Perforated or slotted			
22.00	28.00	305	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	%	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130613	60	22.80	6.21	1.00						
STEP TEST STEP 2	20130613	60	22.80	14.10	2.38						
STEP TEST STEP 3	20130613	60	22.80	24.21	3.88						
STEP TEST STEP 4	20130613	60	22.80	30.21	6.19	100	110				
CONSTANT	20130613	1440	22.80	25.08	3.24	100	150	917			

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	26.00	Electric motor	20	15.00	CLASS 2	16.00	24.00

Note: 1. Production borehole.
2. (N = 13.4 mg/l) Blend water before human consumption.
3. Install water level monitoring facility in borehole.



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BCX0172 Number: SD1-11 Site type: Borehole

Distr./Farm No.: 458 Site Name/Descr.: CARTER BLOCK

Latitude [°]:	28.299879	Alt. No. 1:		Diam. [mm]:	165	Water lev. [m]:	14.61
Longitude [°]:	23.579177	Alt. No. 2:		Depth [m]:	61.00	WL status:	Static
Altitude [m]:	1444.50	Rep. inst.:	GOLD	Col. ht. [m]:	0.52	Date WL meas.:	20130503

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:	
Type of Inst.:	Pulley Diam. [mm]:
Manufacturer:	Depth to Intk. [m]:
Engine:	
Manufacturer:	Power Rating [kW]
Type of Power:	Pulley Diam. [mm]:

USE APPLICATION:

Site Status: Unused
Purpose: Production (water supply)
Consumer: Non-urban
Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-11	Date sampled:	20130504	Depth sampl. [m]:	58.50	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters.		
pH:	7.6	Na:	11.7	Cl:	29.3	Langel.:	0.37	E.Coli:
EC: [mS/m]	63.7	K:	2.33	NO3 as N:	3.93	Aggr-Ind:	12.43	Faec. co:
TDS:	462	Si:	14.8	SO4:	32.3	Ion-bal:	0.19	Total Co:
T. Alk.:	302	Al:	< 0.05	F:	0.137	CaCO3:	364.41	SPC:
Ca:	90.5	Fe:	< 0.05	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit				
Mg:	33.7	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
67.00	70.00	10.20	Notch (V- or U-notch)		
27.00	27.50	0.00100	Notch (V- or U-notch)		SEEPAGE
43.00	43.50	3.80	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m] to Bot. [m]		Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width		Hor. Dist.	Vert. Dist.
0.00	1.00	381	Steel		Plain casing				
0.00	12.00	254	Steel		Plain casing				
0.00	20.00	305	Steel		Plain casing				
0.00	25.00	165	Steel		Plain casing				
12.00	36.00	254	Steel		Perforated or slotted				
25.00	61.00	165	Steel		Perforated or slotted				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130503	60	58.50	5.13	0.13				
STEP TEST STEP 2	20130503	60	58.50	10.10	0.43				
STEP TEST STEP 3	20130503	60	58.50	15.13	0.80				
STEP TEST STEP 4	20130503	60	58.50	20.14	1.41	100	15		
CONSTANT	20130504	1440	58.50	20.08	0.73	100	30	3424	

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	54.00	Electric motor	20	10.00	CLASS 0	15.50	42.00

Note: 1. Production borehole.
2. Install water level monitoring facility in borehole.



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BCX0186 Number: SD1-16 Site type: Borehole

Distr./Farm No.: Site Name/Descr.: LIME ACRES

Latitude [°]:	28.364280	Alt. No. 1:		Diam. [mm]:	165	Water lev. [m]:	10.28
Longitude [°]:	23.597800	Alt. No. 2:		Depth [m]:	59.40	WL status:	Static
Altitude [m]:	1441.14	Rep. inst.: GOLD		Col. ht. [m]:	0.60	Date WL meas.:	20130530

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-16	Date sampled:	20130501	Depth sampl. [m]:	52.80	Comment:	
Main Parameters:		Calculated Parameters:		Bacteriol. Parameters:			
pH:	7.42	Na:	23.3	Cl:	51.9	Langel.:	0.20
EC: [mS/m]	73.1 †	K:	4.16	NO3 as N:	5.41	Aggr-Ind:	12.26
TDS:	504 †	Si:		SO4:	45.2	Ion-bal:	0.96
T. Alk.:	296	Al:	< 0.05	F:	< 0.1	CaCO3:	388.28
Ca:	94.3	Fe:	< 0.05			SPC:	
Mg:	37.2	Mn:	< 0.05				

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimum allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
23.00	23.50	0.10	Notch (V- or U-notch)		
53.00	55.00	10.00	Notch (V- or U-notch)		
40.00	40.50	2.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	2.00	254	Steel		Plain casing			
0.00	47.00	165	Steel		Plain casing			
0.00	51.00	203	Steel		Plain casing			
47.00	59.00	165	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130530	60	52.80	5.16	0.33				
STEP TEST STEP 2	20130530	60	52.80	10.25	0.85				
STEP TEST STEP 3	20130530	60	52.80	15.22	1.21				
STEP TEST STEP 4	20130530	60	52.80	20.52	2.01	100	120		
CONSTANT	20130530	2880	52.80	20.09	3.07	100	240	934	

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	60.00	Electric motor	12	8.00	CLASS 0	11.00	39.00

Note: 1. Production borehole.
2. Install water level monitoring facility in borehole.



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BCX0176 Number: SD1-17 Site type: Borehole

Distr./Farm No.: 458 Site Name/Descr.: CARTER BLOCK

Latitude [°]:	28.316070	Alt. No. 1:		Diam. [mm]:	203	Water lev. [m]:	3.44
Longitude [°]:	23.580260	Alt. No. 2:		Depth [m]:	57.60	WL status:	Static
Altitude [m]:	1435.15	Rep. inst.:	GOLD	Col. ht. [m]:	0.50	Date WL meas.:	20130901

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		
Type of Inst.:		Pulley Diam. [mm]:
Manufacturer:		Depth to Intk. [m]:
Engine:		
Manufacturer:		Power Rating [kW]
Type of Power:		Pulley Diam. [mm]:

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-17	Date sampled:	20130917	Depth sampl. [m]:	34.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.57	Na:	16.4	Cl:	41.6	Langel.:	0.32	E.Coli:
EC: [mS/m]	67.1	K:	2.8	NO3 as N:	3.96	Aggr-Ind:	12.39	Faec. co:
TDS:	462	Si:	14.7	SO4:	41.8	Ion-bal:	-0.38	Total Co:
T. Alk.:	288	Al:	< 0.05	F:	< 0.1	CaCO3:	362.30	SPC:
Ca:	91.8	Fe:	< 0.05	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ‡ Value exceeds minimum allowable limit				
Mg:	32.4	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
40.00	40.50	10.00	Notch (V- or U-notch)		
52.00	52.50	20.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	3.00	254	Steel		Plain casing			
0.00	23.00	203	Steel		Plain casing			
23.00	53.00	203	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery %	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130507	60	34.80	8.49	0.04					
STEP TEST STEP 2	20130507	60	34.80	16.50	0.08					
STEP TEST STEP 3	20130507	60	34.80	24.44	0.24					
STEP TEST STEP 4	20130507	60	34.80	30.54	0.89	100	10			
CONSTANT (1)	20130508	1440	34.80	30.02	0.74	100	90			
CONSTANT (2)	20130901	4320	34.80	30.09	1.25	100	5	855		

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	42.00	Electric motor	12	15.00	CLASS 0	4.00	39.00

Note: 1. Production borehole.
2. Install water level monitoring facility in borehole.



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Project No.: 11613568

MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BCX0179 Number: SD1-19 Site type: Borehole

Distr./Farm No.: 458 Site Name/Descr.: CARTER BLOCK

Latitude [°]:	28.310020	Alt. No. 1:		Diam. [mm]:	203	Water lev. [m]:	3.24
Longitude [°]:	23.579285	Alt. No. 2:		Depth [m]:	40.22	WL status:	Static
Altitude [m]:	1434.82	Rep. inst.:	GOLD	Col. ht. [m]:	0.50	Date WL meas.:	20130505

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-19	Date sampled:	20130506	Depth sampl. [m]:	28.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.6	Na:	11.6	Cl:	30.1	Langel.:	0.36	E.Coli:
EC: [mS/m]	63.9	K:	2.33	NO3 as N:	3.91	Aggr-Ind:	12.43	Faec. co:
TDS:	412	Si:	14.6	SO4:	33.1	Ion-bal:	-0.55	Total Co:
T. Alk.:	302	Al:	< 0.05	F:	< 0.1	CaCO3:	360.59	SPC:
Ca:	89.3	Fe:	< 0.05	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ¡ Value exceeds minimum allowable limit				
Mg:	33.5	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
6.00	6.50	0.00	Notch (V- or U-notch)		DAMP
13.00	13.50	0.00	Notch (V- or U-notch)		
19.00	21.00	0.00	Notch (V- or U-notch)		CAVITY
31.00	31.50	12.50	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	7.00	254	Steel		Plain casing			
0.00	34.00	203	Steel		Plain casing			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130505	60	28.80	8.13	0.14					
STEP TEST STEP 2	20130505	60	28.80	16.22	0.39					
STEP TEST STEP 3	20130505	60	28.80	24.09	0.59					
STEP TEST STEP 4	20130505	60	28.80	30.10	0.84	100	30			
CONSTANT	20130506	1440	28.80	25.02	0.74	100	60	1290		

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	36.00	Electric motor	12	15.00	CLASS 0	4.00	18.00

Note: 1. Production borehole.
2. Install water level monitoring facility in borehole.



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BCX0181 Number: SD1-20 Site type: Borehole

Distr./Farm No.: 458 Site Name/Descr.: CARTER BLOCK

Latitude [°]:	28.314784	Alt. No. 1:		Diam. [mm]:	203	Water lev. [m]:	4.26
Longitude [°]:	23.595877	Alt. No. 2:		Depth [m]:	49.40	WL status:	Static
Altitude [m]:	1435.00	Rep. inst.: GOLD		Col. ht. [m]:	0.54	Date WL meas.:	20130510

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:	
Type of Inst.:	Pulley Diam. [mm]:
Manufacturer:	Depth to Intk. [m]:
Engine:	
Manufacturer:	Power Rating [kW]
Type of Power:	Pulley Diam. [mm]:

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-20	Date sampled:	20140218	Depth sampl. [m]:	46.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.39	Na:	34.1	Cl:	68.8	Langel.:	0.20	E.Coli:
EC: [mS/m]	80.8 †	K:	6	NO3 as N:	1.73	Aggr-Ind:	12.28	Faec. co:
TDS:	580 †	Si:		SO4:	57	Ion-bal:	4.33	Total Co:
T. Alk.:	316	Al:	< 0.05	F:	0.13	CaCO3:	440.36	SPC:
Ca:	97.7	Fe:	< 0.05	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ¡ Value exceeds minimum allowable limit				
Mg:	47.8	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
6.00	6.50	0.10	Notch (V- or U-notch)		
44.00	47.00	20.00	Notch (V- or U-notch)		
32.00	32.50	2.00	Notch (V- or U-notch)		
19.00	19.50	2.00	Notch (V- or U-notch)		

CASING DETAILS:

Diam.		Thickn.	Type of openings	Openings [mm]:		Hor. Dist.	Vert. Dist.
Depth to Top [m]	to Bot. [m]			Length	Width		
0.00	2.00	381	Steel				
0.00	12.00	254	Steel				
0.00	12.00	305	Steel				
0.00	13.00	203	Steel				
12.00	24.00	254	Steel				
13.00	48.00	203	Steel				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	%	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130510	60	46.80	8.51	0.14						
STEP TEST STEP 2	20130510	60	46.80	16.76	0.29						
STEP TEST STEP 3	20130510	60	46.80	24.27	0.55						
STEP TEST STEP 4	20130510	60	46.80	30.33	1.16	0	100	10			
CONSTANT	20130510	1440	46.80	30.13	0.77		100	30	3082		

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	36.00	Electric motor	24	20.00	CLASS 0	5.00	43.00
Note: 1. Production borehole. 2. Install water level monitoring facility in borehole.								



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BCX0173 Number: SD1-21 Site type: Borehole

Distr./Farm No.: 458 Site Name/Descr.: CARTER BLOCK

Latitude [°]:	28.304334	Alt. No. 1:		Diam. [mm]:	165	Water lev. [m]:	3.32
Longitude [°]:	23.589058	Alt. No. 2:		Depth [m]:	103.00	WL status:	Static
Altitude [m]:	1434.86	Rep. inst.:	GOLD	Col. ht. [m]:	0.53	Date WL meas.:	20130512

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:	
Type of Inst.:	Pulley Diam. [mm]:
Manufacturer:	Depth to Intk. [m]:
Engine:	
Manufacturer:	Power Rating [kW]
Type of Power:	Pulley Diam. [mm]:

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-21	Date sampled:	20130531	Depth sampl. [m]:	82.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.56	Na:	12.5	Cl:	30.2	Langel.:	0.34	E.Coli:
EC: [mS/m]	67.1	K:	2.41	NO3 as N:	3.96	Aggr-Ind:	12.42	Faec. co:
TDS:	430	Si:	16	SO4:	25.5	Ion-bal:	-0.38	Total Co:
T. Alk.:	339	Al:	< 0.05	F:	< 0.1	CaCO3:	389.10	SPC:
Ca:	84.9	Fe:	< 0.05	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ¡ Value exceeds minimum allowable limit				
Mg:	43.1	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
101.00	103.00	25.80	Notch (V- or U-notch)		
73.00	73.50	5.20	Notch (V- or U-notch)		
21.00	21.50	2.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m] to Bot. [m]		Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width		Hor. Dist.	Vert. Dist.
0.00	4.00	305	Steel		Plain casing				
0.00	18.00	165	Steel		Plain casing				
0.00	19.00	254	Steel		Plain casing				
0.00	42.00	203	Steel		Plain casing				
18.00	90.00	165	Steel		Perforated or slotted				
19.00	31.00	254	Steel		Perforated or slotted				
31.00	37.00	254	Steel		Plain casing				
42.00	48.00	203	Steel		Perforated or slotted				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130512	60	82.80	5.11	0.58					
STEP TEST STEP 2	20130512	60	82.80	10.32	1.27					
STEP TEST STEP 3	20130512	60	82.80	15.12	1.91					
STEP TEST STEP 4	20130512	60	82.80	21.55	2.56	100	60			
CONSTANT	20130512	1440	82.80	20.11	2.70	100	150	714		

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	36.00	Electric motor	24	10.00	CLASS 0	5.50	72.00



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MANAGEMENT RECOMMENDATIONS

Note: 1. Production borehole.
2. Install water level monitoring facility in borehole.

MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BCX0177 Number: SD1-22 Site type: Borehole

Distr./Farm No.: 458 Site Name/Descr.: CARTER BLOCK

Latitude [°]:	28.297378	Alt. No. 1:		Diam. [mm]:	203	Water lev. [m]:	4.24
Longitude [°]:	23.583311	Alt. No. 2:		Depth [m]:	49.00	WL status:	Static
Altitude [m]:	1435.87	Rep. inst.: GOLD		Col. ht. [m]:	0.57	Date WL meas.:	20130426

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:	
Type of Inst.:	Pulley Diam. [mm]:
Manufacturer:	Depth to Intk. [m]:
Engine:	
Manufacturer:	Power Rating [kW]
Type of Power:	Pulley Diam. [mm]:

USE APPLICATION:

Site Status: Unused
Purpose: Production (water supply)
Consumer: Non-urban
Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-22	Date sampled:	20130515	Depth sampl. [m]:	46.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.49	Na:	11.7	Cl:	27.5	Langel.:	0.23	E.Coli:
EC: [mS/m]	59.8	K:	2.32	NO3 as N:	3.38	Aggr-Ind:	12.29	Faec. co:
TDS:	376	Si:	14.7	SO4:	26.6	Ion-bal:	0.17	Total Co:
T. Alk.:	292	Al:	< 0.05	F:	< 0.1	CaCO3:	343.64	SPC:
Ca:	86.3	Fe:	< 0.05	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ‡ Value exceeds minimum allowable limit				
Mg:	31.2	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
12.00	12.50	1.00	Notch (V- or U-notch)		
19.00	19.50	3.00	Notch (V- or U-notch)		
38.00	38.50	7.00	Notch (V- or U-notch)		
46.00	46.50	10.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m] to Bot. [m]		Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width		Hor. Dist.	Vert. Dist.
0.00	4.00	381	Steel		Plain casing				
0.00	13.00	203	Steel		Plain casing				
0.00	15.00	305	Steel		Plain casing				
0.00	18.00	254	Steel		Plain casing				
13.00	49.00	203	Steel		Perforated or slotted				
18.00	30.00	254	Steel		Perforated or slotted				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130514	60	46.80	6.09	2.06					
STEP TEST STEP 2	20130514	60	46.80	12.09	4.93					
STEP TEST STEP 3	20130514	60	46.80	18.11	6.62					
STEP TEST STEP 4	20130514	60	46.80	25.12	9.59	100	7			
CONSTANT	20130515	1440	46.80	20.04	11.59	100	120	681		

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	36.00	Electric motor	12	5.00	CLASS 0	7.00	37.00
Note: 1. Production borehole. 2. Install water level monitoring facility in borehole.								



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BCX0195 Number: SD1-24 Site type: Borehole

Distr./Farm No.: 507 Site Name/Descr.: ROOIPAN

Latitude [°]:	28.390550	Alt. No. 1:		Diam. [mm]:	203	Water lev. [m]:	14.15
Longitude [°]:	23.628790	Alt. No. 2:		Depth [m]:	68.50	WL status:	Static
Altitude [m]:	1437.27	Rep. inst.:	GOLD	Col. ht. [m]:	0.45	Date WL meas.:	20130615

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-24	Date sampled:	20130616	Depth sampl. [m]:	64.50	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.58	Na:	20	Cl:	48.5	Langel.:	0.35	E.Coli:
EC: [mS/m]	67.6	K:	4.88	NO3 as N:	3.39	Aggr-Ind:	12.42	Faec. co:
TDS:	476	Si:	19.4	SO4:	30.3	Ion-bal:	3.21	Total Co:
T. Alk.:	295	Al:	< 0.05	F:	< 0.1	CaCO3:	384.59	SPC:
Ca:	94.8	Fe:	< 0.05	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ¡ Value exceeds minimum allowable limit				
Mg:	36	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
68.00	68.50	32.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	2.00	305	Steel		Plain casing			
0.00	26.00	203	Steel		Plain casing			
0.00	31.00	254	Steel		Plain casing			
26.00	68.00	203	Steel		Perforated or slotted			
31.00	55.00	254	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	%	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130615	60	64.50	8.32	0.06						
STEP TEST STEP 2	20130615	60	64.50	16.02	0.11						
STEP TEST STEP 3	20130615	60	64.50	24.51	0.63						
STEP TEST STEP 4	20130615	60	64.50	30.21	1.28	100	20				
CONSTANT	20130616	1440	64.50	30.10	1.16	100	180	486			

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	66.00	Electric motor	20	15.00	CLASS 0	14.50	66.00

Note: 1. Production borehole.
2. Install water level monitoring facility in borehole.



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BAX0027 Number: SD1-25 Site type: Borehole

Distr./Farm No.: Site Name/Descr.: DANIELSKUIL

Latitude [°]:	28.223085	Alt. No. 1:		Diam. [mm]:	203	Water lev. [m]:	8.20
Longitude [°]:	23.569143	Alt. No. 2:		Depth [m]:	51.50	WL status:	Static
Altitude [m]:	1446.64	Rep. inst.:	GOLD	Col. ht. [m]:	0.57	Date WL meas.:	20130520

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-25	Date sampled:	20130522	Depth sampl. [m]:	46.80	Comment:	
Main Parameters:		Calculated Parameters:		Bacteriol. Parameters:			
pH:	7.47	Na:	19.6	Cl:	44.8	Langel.:	0.14
EC: [mS/m]	61.1	K:	2.9	NO3 as N:	4.2	Aggr-Ind:	12.20
TDS:	418	Si:	12.4	SO4:	45.3	Ion-bal:	0.86
T. Alk.:	238	Al:	< 0.05	F:	< 0.1	CaCO3:	323.59
Ca:	89.8	Fe:	< 0.05			SPC:	
Mg:	24.2	Mn:	< 0.05				

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit j Value exceeds minimum allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
19.00	19.50	0.20	Notch (V- or U-notch)		
49.00	49.50	50.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	13.00	305	Steel		Plain casing			
0.00	39.00	203	Steel		Plain casing			
39.00	51.00	203	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130520	60	46.80	8.13	0.24				
STEP TEST STEP 2	20130520	60	46.80	16.50	0.54				
STEP TEST STEP 3	20130520	60	46.80	24.31	0.82				
STEP TEST STEP 4	20130520	60	46.80	30.32	1.18	100	10		
CONSTANT	20130521	2880	46.80	30.29	1.83	100	30	2533	0.0197

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	48.00	Electric motor	12	15.00	CLASS 0	9.00	48.00

Note: 1. Production borehole.
2. Install water level monitoring facility in borehole.



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BCX0190 Number: SD1-26 Site type: Borehole

Distr./Farm No.: Site Name/Descr.: LIME ACRES

Latitude [°]:	28.351290	Alt. No. 1:		Diam. [mm]:	203	Water lev. [m]:	10.90
Longitude [°]:	23.598790	Alt. No. 2:		Depth [m]:	69.00	WL status:	Static
Altitude [m]:	1441.82	Rep. inst.:	GOLD	Col. ht. [m]:	0.55	Date WL meas.:	20130603

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-26	Date sampled:	20130605	Depth sampl. [m]:	52.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.49	Na:	23.6	Cl:	51.8	Langel.:	0.26	E.Coli:
EC: [mS/m]	72.9 †	K:	4.41	NO3 as N:	6.24	Aggr-Ind:	12.32	Faec. co:
TDS:	486	Si:		SO4:	44.8	Ion-bal:	1.55	Total Co:
T. Alk.:	293	Al:	< 0.05	F:	< 0.1	CaCO3:	391.96	SPC:
Ca:	93.3	Fe:	< 0.05	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ¡ Value exceeds minimum allowable limit				
Mg:	38.7	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
18.00	18.50	0.00	Notch (V- or U-notch)		DAMP
38.00	39.00	1.00	Notch (V- or U-notch)		
56.00	58.00	3.00	Notch (V- or U-notch)		
66.00	69.00	8.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	1.50	305	Steel		Plain casing			
0.00	25.00	203	Steel		Plain casing			
0.00	37.00	254	Steel		Plain casing			
25.00	61.00	203	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130603	60	52.80	5.32	0.66				
STEP TEST STEP 2	20130603	60	52.80	10.22	2.20				
STEP TEST STEP 3	20130603	60	52.80	15.15	3.81				
STEP TEST STEP 4	20130603	60	52.80	20.21	5.85	100	90		
CONSTANT	20130604	1440	52.80	15.06	3.79	100	210	747	

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	60.00	Electric motor	20	10.00	CLASS 0	14.00	55.00
Note: 1. Production borehole. 2. Install water level monitoring facility in borehole.								



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Project No.: 11613568

MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BCX0198 Number: SD1-27 Site type: Borehole

Distr./Farm No.: 458 Site Name/Descr.: CARTER BLOCK PTN. ROOIPAN

Latitude [°]:	28.378680	Alt. No. 1:		Diam. [mm]:	203	Water lev. [m]:	14.38
Longitude [°]:	23.624700	Alt. No. 2:		Depth [m]:	104.44	WL status:	Static
Altitude [m]:	1437.42	Rep. inst.:	GOLD	Col. ht. [m]:	0.62	Date WL meas.:	20130724

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-27	Date sampled:	20130726	Depth sampl. [m]:	82.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.58	Na:	28.1	Cl:	56.8	Langel.:	0.18	E.Coli:
EC: [mS/m]	72.8 †	K:	5.39	NO3 as N:	3.75	Aggr-Ind:	12.25	Faec. co:
TDS:	532 †	Si:	16.6	SO4:	44.2	Ion-bal:	-1.28	Total Co:
T. Alk.:	289	Al:	< 0.05	F:	0.184	CaCO3:	350.13	SPC:
Ca:	64.5	Fe:	< 0.05	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ¡ Value exceeds minimum allowable limit				
Mg:	46	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
23.00	23.50	0.00	Notch (V- or U-notch)		MOIST
85.00	85.50	11.00	Notch (V- or U-notch)		
101.00	101.50	25.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	2.00	381	Steel		Plain casing			
0.00	30.00	305	Steel		Plain casing			
0.00	49.00	254	Steel		Plain casing			
0.00	50.00	203	Steel		Plain casing			
50.00	104.00	203	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130724	60	82.80	8.20	0.92					
STEP TEST STEP 2	20130724	60	82.80	16.30	1.61					
STEP TEST STEP 3	20130724	60	82.80	24.22	2.10					
STEP TEST STEP 4	20130724	60	82.80	30.12	3.49	100	60			
CONSTANT	20130724	2880	82.80	30.16	4.12	100	300	273		

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	84.00	Electric motor	20	10.00	CLASS 0	16.00	84.00

Note: 1. Production borehole.
2. Install water level monitoring facility in borehole.



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BCX0191 Number: SD1-32 Site type: Borehole

Distr./Farm No.: 507 Site Name/Descr.: ROOIPAN

Latitude [°]:	28.400820	Alt. No. 1:		Diam. [mm]:	190	Water lev. [m]:	14.12
Longitude [°]:	23.658530	Alt. No. 2:		Depth [m]:	73.90	WL status:	Static
Altitude [m]:	1436.43	Rep. inst.:	GOLD	Col. ht. [m]:	0.53	Date WL meas.:	20130727

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-32	Date sampled:	20140218	Depth sampl. [m]:	70.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.2	Na:	4.39	Cl:	9.97	Langel.:	0.05	E.Coli:
EC: [mS/m]	55.6	K:	1.91	NO3 as N:	< 0.3	Aggr-Ind:	12.10	Faec. co:
TDS:	402	Si:		SO4:	3.59	Ion-bal:	-0.69	Total Co:
T. Alk.:	325	Al:	< 0.05	F:	< 0.1	CaCO3:	327.40	SPC:
Ca:	97.1	Fe:	1.21 ‡	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit § Value exceeds minimum allowable limit				
Mg:	20.7	Mn:	0.14 †					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
11.00	12.00	0.00	Notch (V- or U-notch)		DAMP
32.00	33.00	0.00	Notch (V- or U-notch)		DAMP
49.00	49.50	0.00	Notch (V- or U-notch)		SEEPAGE
71.00	73.00	25.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	21.00	305	Steel		Plain casing			
0.00	30.00	254	Steel		Plain casing			
0.00	49.00	203	Steel		Plain casing			
49.00	73.00	203	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130609	60	70.80	8.12	1.25					
STEP TEST STEP 2	20130609	60	70.80	16.10	2.17					
STEP TEST STEP 3	20130609	60	70.80	24.15	4.44					
STEP TEST STEP 4	20130609	60	70.80	30.10	7.04	100	30			
CONSTANT (1)	20130610	2880	70.80	25.08	3.91	100	120			
CONSTANT (2)	20130727	4320	70.80	30.24	5.33	100	40	1078	0.0003	

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	70.00	Electric motor	20	15.00	CLASS 2	17.00	70.00

Note: 1. Production borehole.
2. (F = 1.21 mg/l) Blend water before human consumption.
3. Install water level monitoring facility in borehole.



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BAX0031 Number: SD1-33 Site type: Borehole

Distr./Farm No.: Site Name/Descr.: DANIELSKUIL

Latitude [°]:	28.173100	Alt. No. 1:		Diam. [mm]:	203	Water lev. [m]:	26.20
Longitude [°]:	23.518600	Alt. No. 2:		Depth [m]:	74.80	WL status:	Static
Altitude [m]:	1494.17	Rep. inst.:	GOLD	Col. ht. [m]:	0.60	Date WL meas.:	20130718

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-33	Date sampled:	20130721	Depth sampl. [m]:	64.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.64	Na:	6.39	Cl:	7.65	Langel.:	-0.35	E.Coli:
EC: [mS/m]	22.1	K:	2.17	NO3 as N:	1.23	Aggr-Ind:	11.59	Faec. co:
TDS:	136	Si:	8.35	SO4:	11.5	Ion-bal:	7.38 †	Total Co:
T. Alk.:	103	Al:	< 0.05	F:	< 0.1	CaCO3:	134.54	SPC:
Ca:	34.8	Fe:	< 0.05	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ‡ Value exceeds minimum allowable limit				
Mg:	11.6	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
33.00	33.50	0.20	Notch (V- or U-notch)		
67.00	67.50	2.00	Notch (V- or U-notch)		
73.00	78.00	10.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	3.00	381	Steel		Plain casing			
0.00	21.00	305	Steel		Plain casing			
0.00	31.00	254	Steel		Plain casing			
31.00	37.00	254	Steel		Perforated or slotted			
0.00	26.00	203	Steel		Plain casing			
26.00	74.00	203	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130718	60	64.80	5.55	3.38					
STEP TEST STEP 2	20130718	60	64.80	10.24	13.97					
STEP TEST STEP 3	20130718	60	64.80	15.54	24.37					
STEP TEST STEP 4	20130718	30	64.80	20.10	38.60	100	100			
PUMP INLET	20130718	30	64.80	18.10	38.60					
CONSTANT	20130718	4320	68.80	12.18	15.74	100	1080	68	0.04	

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	63.00	Electric motor	12	5.00	CLASS 0	31.00	72.00
Note: 1. Production borehole. 2. Install water level monitoring facility in borehole.								



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BAX0030 Number: SD1-34 Site type: Borehole

Distr./Farm No.: Site Name/Descr.: DANIELSKUIL

Latitude [°]:	28.174470	Alt. No. 1:		Diam. [mm]:	203	Water lev. [m]:	26.40
Longitude [°]:	23.531610	Alt. No. 2:		Depth [m]:	137.59	WL status:	Static
Altitude [m]:	1493.40	Rep. inst.: GOLD		Col. ht. [m]:	0.44	Date WL meas.:	20130713

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-34	Date sampled:	20130714	Depth sampl. [m]:	76.80	Comment:	
Main Parameters:		Calculated Parameters:		Bacteriol. Parameters:			
pH:	7.46	Na:	5	Cl:	5.34	Langel.:	-0.22
EC: [mS/m]	35.2	K:	2.07	NO3 as N:	< 0.3	Aggr-Ind:	11.76
TDS:	236	Si:	7.46	SO4:	49.2	Ion-bal:	2.37
T. Alk.:	140	Al:	< 0.05	F:	1.05 †	CaCO3:	198.90
Ca:	57.3	Fe:	< 0.05			SPC:	
Mg:	13.6	Mn:	0.29 †				

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit j Value exceeds minimum allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
8.00	8.50	0.00	Notch (V- or U-notch)		MOIST
41.00	41.50	0.20	Notch (V- or U-notch)		
60.00	60.50	6.00	Notch (V- or U-notch)		
76.00	79.00	2.00	Notch (V- or U-notch)		
97.00	97.50	2.00	Notch (V- or U-notch)		
104.00	104.50	2.00	Notch (V- or U-notch)		
128.00	128.50	0.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	2.00	381	Steel		Plain casing			
0.00	22.00	305	Steel		Plain casing			
0.00	48.00	254	Steel		Plain casing			
0.00	53.00	203	Steel		Plain casing			
53.00	107.00	203	Steel		Perforated or slotted			
107.00	125.00	203	Steel		Plain casing			
125.00	137.00	203	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130713	60	76.80	6.24	2.19					
STEP TEST STEP 2	20130713	60	76.80	12.42	8.45					
STEP TEST STEP 3	20130713	60	76.80	16.22	26.30					
STEP TEST STEP 4	20130713	15	76.80	20.14	50.10	0.42	99	300		
PUMP INLET	20130713	25	76.80	18.14	50.40					
CONSTANT	20130713	4320	76.80	12.18	13.47	100	2160	71	0.04	



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MANAGEMENT RECOMMENDATIONS

RECOMMENDATIONS:								
Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	60.00	Electric motor	12	5.00	CLASS 2	29.00	59.00
Note: 1. Production Borehole. 2. (F = 1.05 mg/l) Blend water before human consumption. 3. Install water level monitoring facility in borehole.								

MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BCX0183 Number: SD1-35 Site type: Borehole

Distr./Farm No.: 458 Site Name/Descr.: CARTER BLOCK

Latitude [°]:	28.345005	Alt. No. 1:		Diam. [mm]:	254	Water lev. [m]:	10.68
Longitude [°]:	23.583280	Alt. No. 2:		Depth [m]:	28.70	WL status:	Static
Altitude [m]:	1442.33	Rep. inst.: GOLD		Col. ht. [m]:	0.56	Date WL meas.:	20130803

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-35	Date sampled:	20130526	Depth sampl. [m]:	22.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.53	Na:	26.5	Cl:	64.8	Langel.:	0.28	E.Coli:
EC: [mS/m]	75 †	K:	4.23	NO3 as N:	4.53	Aggr-Ind:	12.36	Faec. co:
TDS:	492 †	Si:	14.1	SO4:	55.7	Ion-bal:	-0.59	Total Co:
T. Alk.:	289	Al:	< 0.05	F:	0.148	CaCO3:	386.54	SPC:
Ca:	93.6	Fe:	< 0.05	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ¡ Value exceeds minimum allowable limit				
Mg:	37.2	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
26.00	26.50	20.00	Notch (V- or U-notch)		
22.00	22.50	2.00	Notch (V- or U-notch)		
16.00	16.50	0.20	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	3.00	305	Steel		Plain casing			
0.00	16.00	254	Steel		Plain casing			
16.00	28.00	254	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery %	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130524	60	22.80	8.13	0.17					
STEP TEST STEP 2	20130524	60	22.80	16.14	0.37					
STEP TEST STEP 3	20130524	60	22.80	24.53	0.59					
STEP TEST STEP 4	20130524	60	22.80	30.22	1.55	0	30			
CONSTANT (1)	20130524	2880	22.80	30.06	1.76	100	120			
CONSTANT (2)	20130803	4320	22.80	30.12	2.37	100	60			

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	26.00	Electric motor	24	20.00	CLASS 0	11.50	25.00

Note: 1. Production borehole.
2. Install water level monitoring facility in borehole.



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Project No.: 11613568

MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823ADX0060 Number: SD1-40 Site type: Borehole

Distr./Farm No.: 458 Site Name/Descr.: CARTER BLOCK

Latitude [°]:	28.301570	Alt. No. 1:		Diam. [mm]:	165	Water lev. [m]:	30.35
Longitude [°]:	23.494940	Alt. No. 2:		Depth [m]:	97.60	WL status:	Static
Altitude [m]:	1468.72	Rep. inst.:	GOLD	Col. ht. [m]:	0.50	Date WL meas.:	20140117

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-40	Date sampled:	20130714	Depth sampl. [m]:	0	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	6.72	Na:	10.1	Cl:	14.4	Langel.:	-0.94	E.Coli:
EC: [mS/m]	34.8	K:	2.36	NO3 as N:	2.01	Aggr-Ind:	11.05	Faec. co:
TDS:	242	Si:	11.7	SO4:	12.8	Ion-bal:	4.09	Total Co:
T. Alk.:	155	Al:	< 0.05	F:	< 0.1	CaCO3:	187.83	SPC:
Ca:	55.5	Fe:	< 0.05	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ¡ Value exceeds minimum allowable limit				
Mg:	12	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
52.00	52.50	2.00	Notch (V- or U-notch)		
60.00	61.00	4.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	5.00	305	Steel		Plain casing			
0.00	34.00	254	Steel		Plain casing			
0.00	43.00	203	Steel		Plain casing			
43.00	61.00	203	Steel		Perforated or slotted			
0.00	39.00	165	Steel		Plain casing			
39.00	93.00	165	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130826	60	82.80	3.54	2.03					
STEP TEST STEP 2	20130826	60	82.80	7.52	7.37					
STEP TEST STEP 3	20130826	60	82.80	12.04	22.30					
STEP TEST STEP 4	20130826	60	82.80	20.04	33.41	100	300			
CONSTANT	20130827	4320	82.80	10.08	14.37	100	1320	79	0.0322	

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	54.00	Electric motor	24	4.00	CLASS 0	35.00	51.00
Note: 1. Production borehole. 2. Install water level monitoring facility in borehole.								



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823ADX0062 Number: SD1-41 Site type: Borehole

Distr./Farm No.: 458 Site Name/Descr.: CARTER BLOCK

Latitude [°]:	28.304270	Alt. No. 1:		Diam. [mm]:	203	Water lev. [m]:	43.71
Longitude [°]:	23.494280	Alt. No. 2:		Depth [m]:	93.00	WL status:	Static
Altitude [m]:	1467.44	Rep. inst.:	GOLD	Col. ht. [m]:	0.55	Date WL meas.:	20140117

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status: Unused
Purpose: Production (water supply)
Consumer: Non-urban
Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-41	Date sampled:	20130823	Depth sampl. [m]:	82.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.54	Na:	9.33	Cl:	15.6	Langel.:	-0.10	E.Coli:
EC: [mS/m]	35.5	K:	2.4	NO3 as N:	1.66	Aggr-Ind:	11.89	Faec. co:
TDS:	224	Si:	9.67	SO4:	13.2	Ion-bal:	1.73	Total Co:
T. Alk.:	162	Al:	< 0.05	F:	0.123	CaCO3:	187.81	SPC:
Ca:	55	Fe:	< 0.05	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ¡ Value exceeds minimum allowable limit				
Mg:	12.3	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
65.00	65.50	0.00	Notch (V- or U-notch)		SEEPAGE
73.00	91.00	12.50	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	5.00	381	Steel		Plain casing			
0.00	28.00	305	Steel		Plain casing			
0.00	55.00	254	Steel		Plain casing			
55.00	67.00	254	Steel		Perforated or slotted			
0.00	49.00	203	Steel		Plain casing			
49.00	91.00	203	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130819	60	82.80	5.06	2.84					
STEP TEST STEP 2	20130819	60	82.80	10.04	7.58					
STEP TEST STEP 3	20130819	60	82.80	15.10	12.96					
STEP TEST STEP 4	20130819	15	82.80	20.06	38.10	100	90			
PUMP INLET	20130819	25	82.80	18.10	38.23					
CONSTANT(1)	20130820	1200	82.80	12.04	10.30	100	210			
CONSTANT(2)	20130821	4320	82.80	12.04	14.21	100	600	83		

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	72.00	Electric motor	20	5.00	CLASS 0	49.00	72.00

Note: 1. Production borehole.
2. Install water level monitoring facility in borehole.



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823ADX0063 Number: SD1-42 Site type: Borehole

Distr./Farm No.: 458 Site Name/Descr.: CARTER BLOCK

Latitude [°]:	28.297860	Alt. No. 1:		Diam. [mm]:	165	Water lev. [m]:	53.32
Longitude [°]:	23.483360	Alt. No. 2:		Depth [m]:	112.00	WL status:	Static
Altitude [m]:	1477.23	Rep. inst.:	GOLD	Col. ht. [m]:	0.52	Date WL meas.:	20140117

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-42	Date sampled:	20130814	Depth sampl. [m]:	0	Comment:	
Main Parameters:		Calculated Parameters:		Bacteriol. Parameters:			
pH:	7.73	Na:	9.01	Cl:	16.5	Langel.:	0.20
EC: [mS/m]	44.5	K:	2.94	NO3 as N:	3.26	Aggr-Ind:	12.22
TDS:	274	Si:	11.8	SO4:	27	Ion-bal:	2.23
T. Alk.:	192	Al:	< 0.05	F:	< 0.155	CaCO3:	243.75
Ca:	63.9	Fe:	< 0.05			SPC:	
Mg:	20.5	Mn:	0.05				

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimum allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
70.00	71.00	2.00	Notch (V- or U-notch)		
107.00	110.00	10.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	23.00	305	Steel		Plain casing			
0.00	51.00	254	Steel		Plain casing			
0.00	55.00	203	Steel		Plain casing			
55.00	73.00	203	Steel		Perforated or slotted			
0.00	50.00	165	Steel		Plain casing			
50.00	110.00	165	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130815	60	76.80	4.04	2.03					
STEP TEST STEP 2	20130815	60	76.80	8.12	9.04					
STEP TEST STEP 3	20130815	60	76.80	12.10	12.11					
STEP TEST STEP 4	20130815	15	76.80	16.30	40.61	100	120			
PUMP INLET	20130815	25	76.80	14.48	40.90					
CONSTANT	20130816	2880	76.80	10.14	10.38	100	360	52		

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	72.00	Electric motor	20	5.00	CLASS 0	59.00	69.00

Note: 1. Production borehole.
2. Install water level monitoring facility in borehole.



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BCX0199 Number: SD1-43 Site type: Borehole

Distr./Farm No.: 458 Site Name/Descr.: CARTER BLOCK

Latitude [°]:	28.368830	Alt. No. 1:		Diam. [mm]:	203	Water lev. [m]:	14.17
Longitude [°]:	23.629280	Alt. No. 2:		Depth [m]:	68.00	WL status:	Static
Altitude [m]:	1437.83	Rep. inst.:	GOLD	Col. ht. [m]:		Date WL meas.:	20140117

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-43	Date sampled:	20130622	Depth sampl. [m]:	64.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.39	Na:	31.7	Cl:	56.3	Langel.:	0.06	E.Coli:
EC: [mS/m]	74.4 †	K:	5.3	NO3 as N:	4.41	Aggr-Ind:	12.14	Faec. co:
TDS:	508 †	Si:	15.5	SO4:	45.2	Ion-bal:	-1.89	Total Co:
T. Alk.:	300	Al:	< 0.05	F:	< 0.1	CaCO3:	350.32	SPC:
Ca:	74.8	Fe:	< 0.05	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ¡ Value exceeds minimum allowable limit				
Mg:	39.8	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
23.00	23.50	0.20	Notch (V- or U-notch)		
60.00	60.50	22.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	4.00	305	Steel		Plain casing			
0.00	16.00	254	Steel		Plain casing			
16.00	40.00	254	Steel		Perforated or slotted			
0.00	40.00	203	Steel		Plain casing			
40.00	64.00	203	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130620	60	64.80	5.50	0.77				
STEP TEST STEP 2	20130620	60	64.80	14.03	5.81				
STEP TEST STEP 3	20130620	60	64.80	24.21	13.04				
STEP TEST STEP 4	20130620	60	64.80	30.21	20.01	0 300			
CONSTANT	20130621	1440	64.80	15.00	6.27	100 1440	313		

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	60.00	Electric motor	20	5.00	CLASS 0	16.00	59.00

Note: 1. Production borehole.
2. Install water level monitoring facility in borehole.



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BAX0032 Number: SD1-44 Site type: Borehole

Distr./Farm No.: Site Name/Descr.: DANIELSKUIL

Latitude [°]:	28.211340	Alt. No. 1:		Diam. [mm]:	203	Water lev. [m]:	18.54
Longitude [°]:	23.599290	Alt. No. 2:		Depth [m]:	34.42	WL status:	Static
Altitude [m]:	1457.28	Rep. inst.:	GOLD	Col. ht. [m]:	0.49	Date WL meas.:	20140117

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-44	Date sampled:	20130810	Depth sampl. [m]:	28.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.73	Na:	10.5	Cl:	28.4	Langel.:	0.46	E.Coli:
EC: [mS/m]	73.9 †	K:	1.46	NO3 as N:	1.99	Aggr-Ind:	12.54	Faec. co:
TDS:	500 †	Si:	14.9	SO4:	23.9	Ion-bal:	-8.76	Total Co:
T. Alk.:	395	Al:	< 0.05	F:	0.185	CaCO3:	367.50	SPC:
Ca:	65.2	Fe:	< 0.05	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ¡ Value exceeds minimum allowable limit				
Mg:	49.8	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
24.00	29.00	10.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	3.00	305	Steel		Plain casing			
0.00	12.00	254	Steel		Plain casing			
12.00	24.00	254	Steel		Perforated or slotted			
0.00	11.00	203	Steel		Plain casing			
11.00	29.00	203	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130807	60	28.80	8.52	0.06					
STEP TEST STEP 2	20130807	60	28.80	16.40	0.12					
STEP TEST STEP 3	20130807	60	28.80	24.30	0.18					
STEP TEST STEP 4	20130807	60	28.80	30.21	0.30	100	10			
CONSTANT	20130807	4320	28.80	30.16	1.14	100	20	748		

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	30.00	Electric motor	24	20.00	CLASS 0	19.50	23.00

Note: 1. Production borehole.
2. Install water level monitoring facility in borehole.



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823BAX0033 Number: SD1-45 Site type: Borehole

Distr./Farm No.: Site Name/Descr.: DANIELSKUIL

Latitude [°]:	28.192840	Alt. No. 1:		Diam. [mm]:	203	Water lev. [m]:	12.86
Longitude [°]:	23.552020	Alt. No. 2:		Depth [m]:	44.90	WL status:	Static
Altitude [m]:	1453.90	Rep. inst.:	GOLD	Col. ht. [m]:	0.40	Date WL meas.:	20140118

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), Hartebeesthoek94 (WGS 84)

EXISTING EQUIPMENT:

Pump:		Pulley Diam. [mm]:	
Type of Inst.:		Depth to Intk. [m]:	
Manufacturer:			
Engine:		Power Rating [kW]	
Manufacturer:		Pulley Diam. [mm]:	
Type of Power:			

USE APPLICATION:

Site Status:	Unused
Purpose:	Production (water supply)
Consumer:	Non-urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	SD1-45	Date sampled:	20140216	Depth sampl. [m]:	40.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.93	Na:	9.34	Cl:	16.6	Langel.:	0.43	E.Coli:
EC: [mS/m]	44.6	K:	3.28	NO3 as N:	3.27	Aggr-Ind:	12.45	Faec. co:
TDS:	282	Si:	10.2	SO4:	23.7	Ion-bal:	3.19	Total Co:
T. Alk.:	201	Al:	< 0.05	F:	0.153	CaCO3:	253.85	SPC:
Ca:	66.3	Fe:	0.14 †	Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption † Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit ! Value exceeds recommended minimum limit ¡ Value exceeds minimum allowable limit				
Mg:	21.5	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
25.00	25.50	2.50	Notch (V- or U-notch)		
35.00	35.50	20.00	Notch (V- or U-notch)		
38.00	42.00	20.00	Notch (V- or U-notch)		

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length Width	Hor. Dist.	Vert. Dist.
0.00	2.00	381	Steel		Plain casing			
0.00	22.00	305	Steel		Plain casing			
22.00	28.00	305	Steel		Perforated or slotted			
0.00	18.00	254	Steel		Plain casing			
18.00	36.00	254	Steel		Perforated or slotted			
0.00	20.00	203	Steel		Plain casing			
20.00	44.00	203	Steel		Perforated or slotted			

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m] %	[min]	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20130811	60	40.80	8.09	0.30					
STEP TEST STEP 2	20130811	60	40.80	16.01	0.69					
STEP TEST STEP 3	20130811	60	40.80	24.04	1.32					
STEP TEST STEP 4	20130811	60	40.80	30.01	1.66	100	15			
CONSTANT (1)	20130812	2880	40.80	30.04	2.05	100	540	1948	0.03	
CONSTANT (2)	20140117	120	40.80	30.05	1.49	100	3			

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	Mono-type pump	33.00	Electric motor	12	5.00	CLASS 1	14.50	34.00



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MANAGEMENT RECOMMENDATIONS

Note: 1. Production borehole.
2. (Fe 0.14 mg/l) Blend water before human consumption.
3. Install water level monitoring facility in borehole.



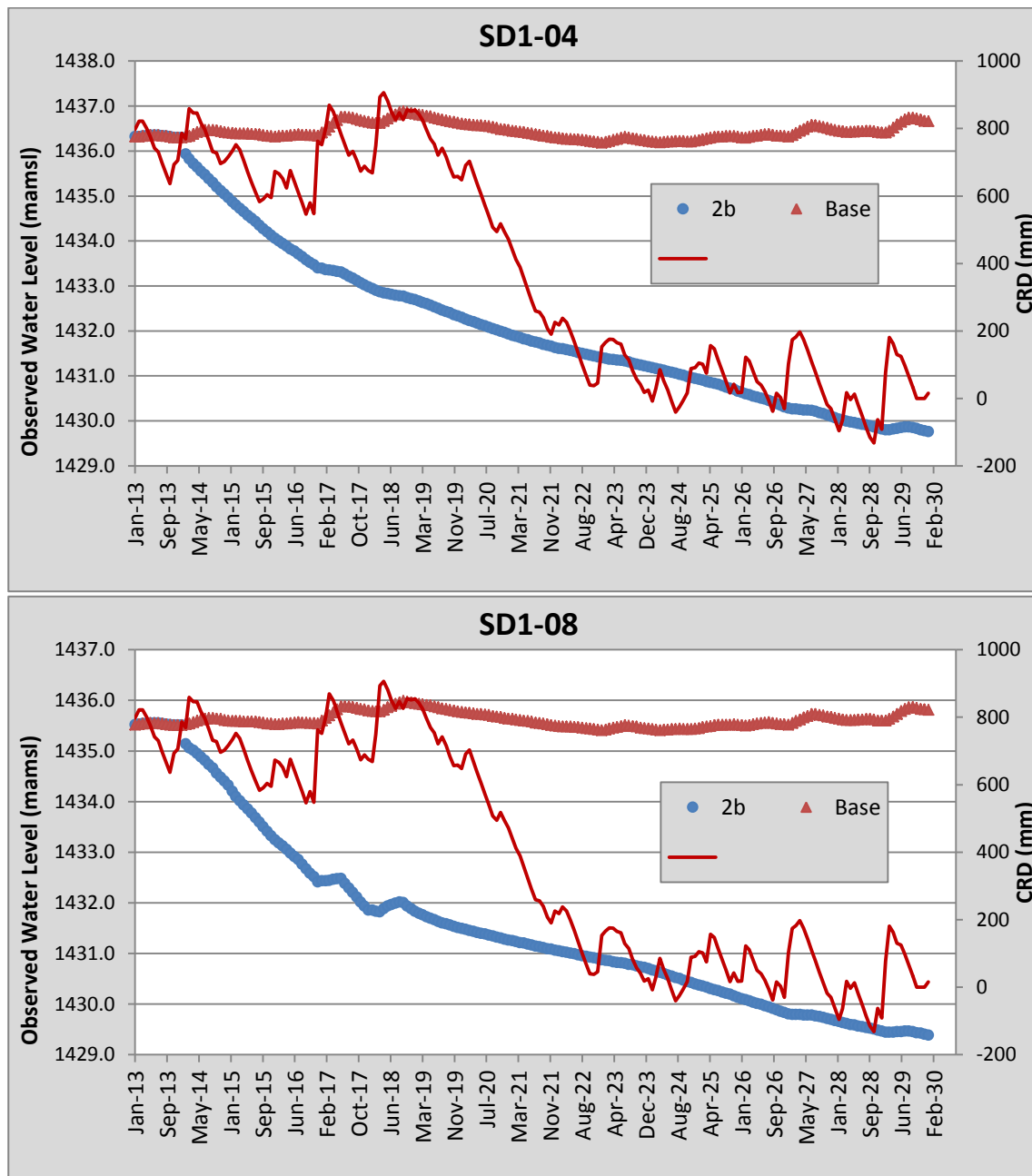
APPENDIX B

Long-Term Water Level Drawdown Simulations for Production and Monitoring Boreholes



APPENDIX B

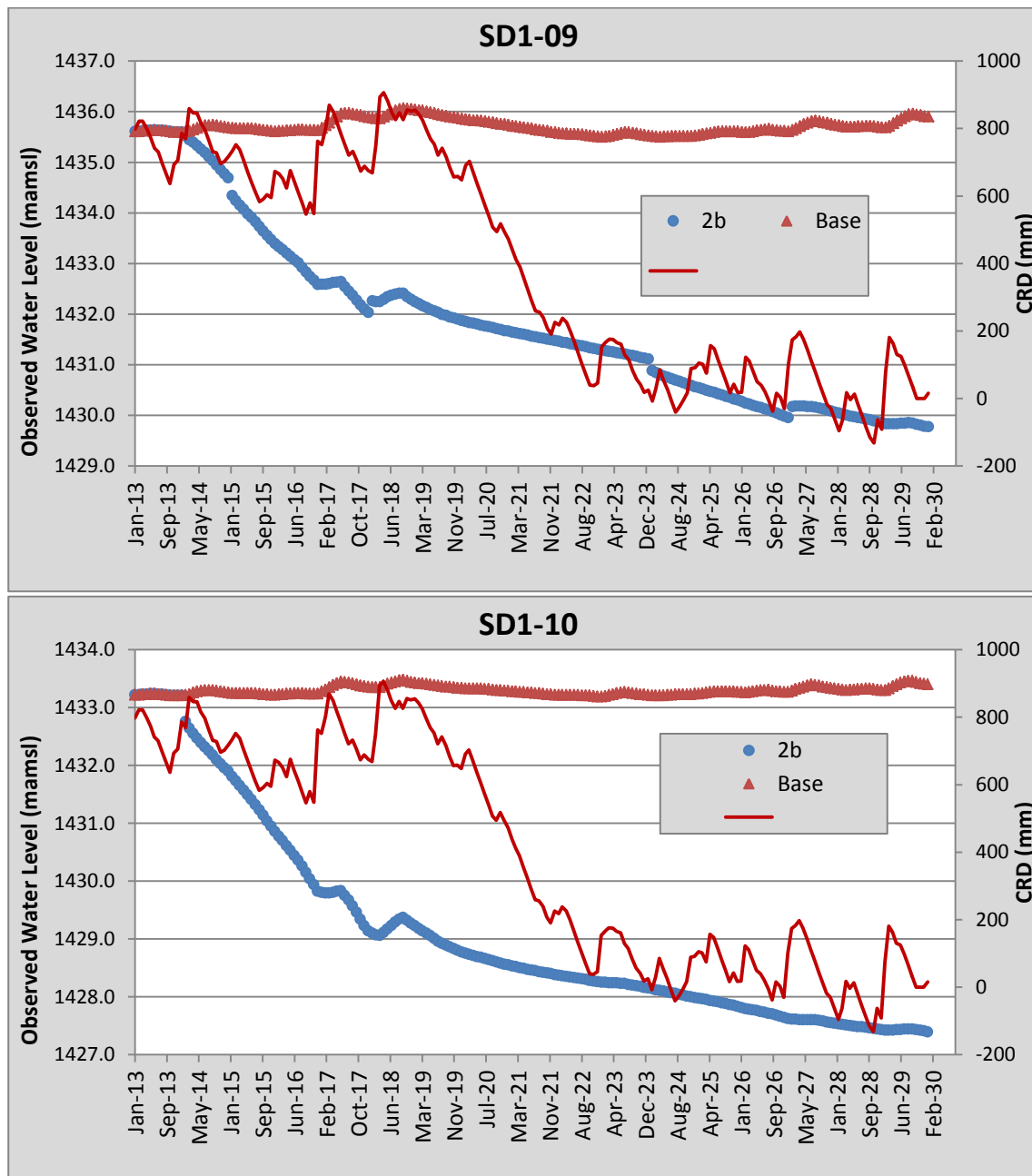
VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I





APPENDIX B

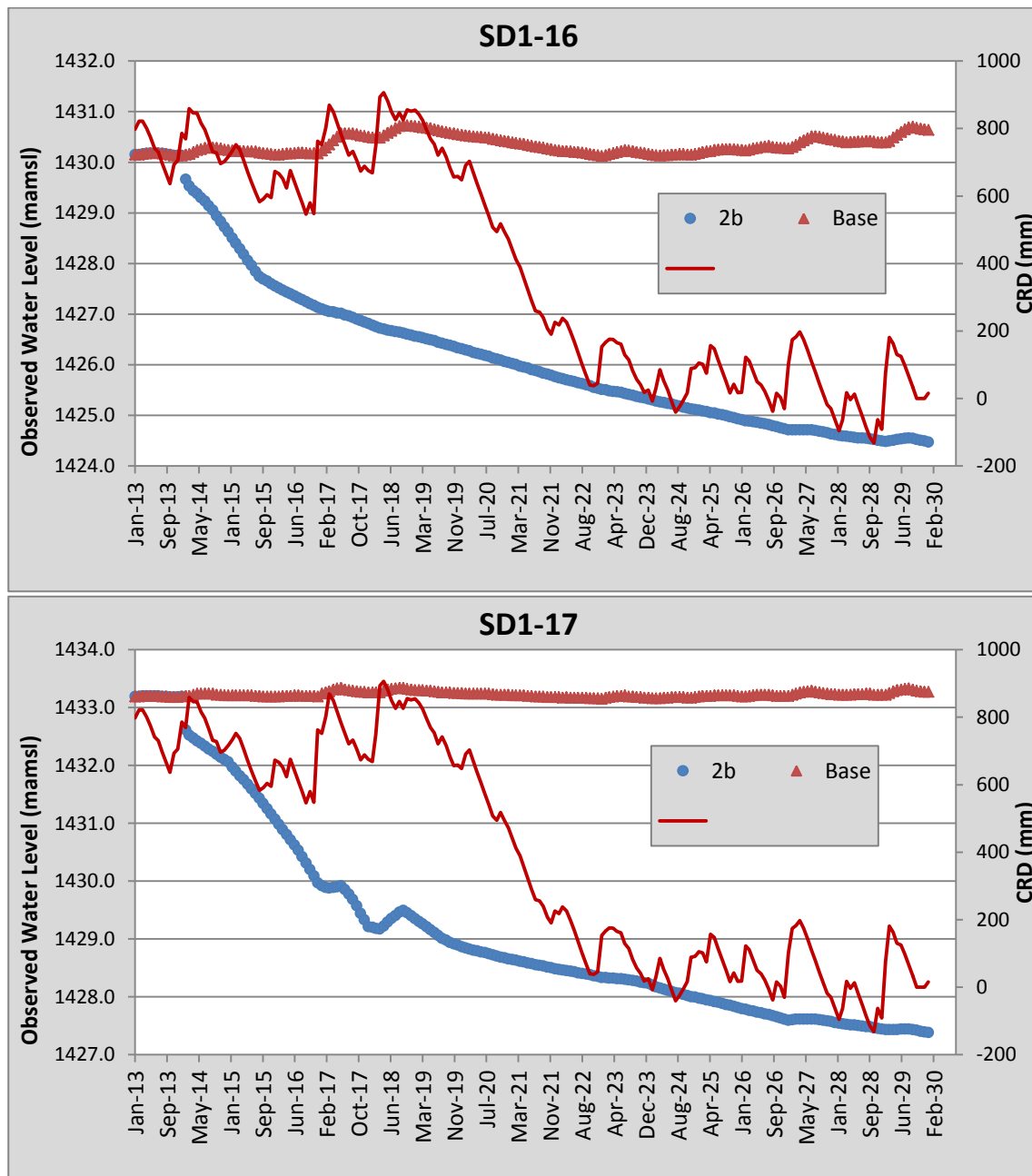
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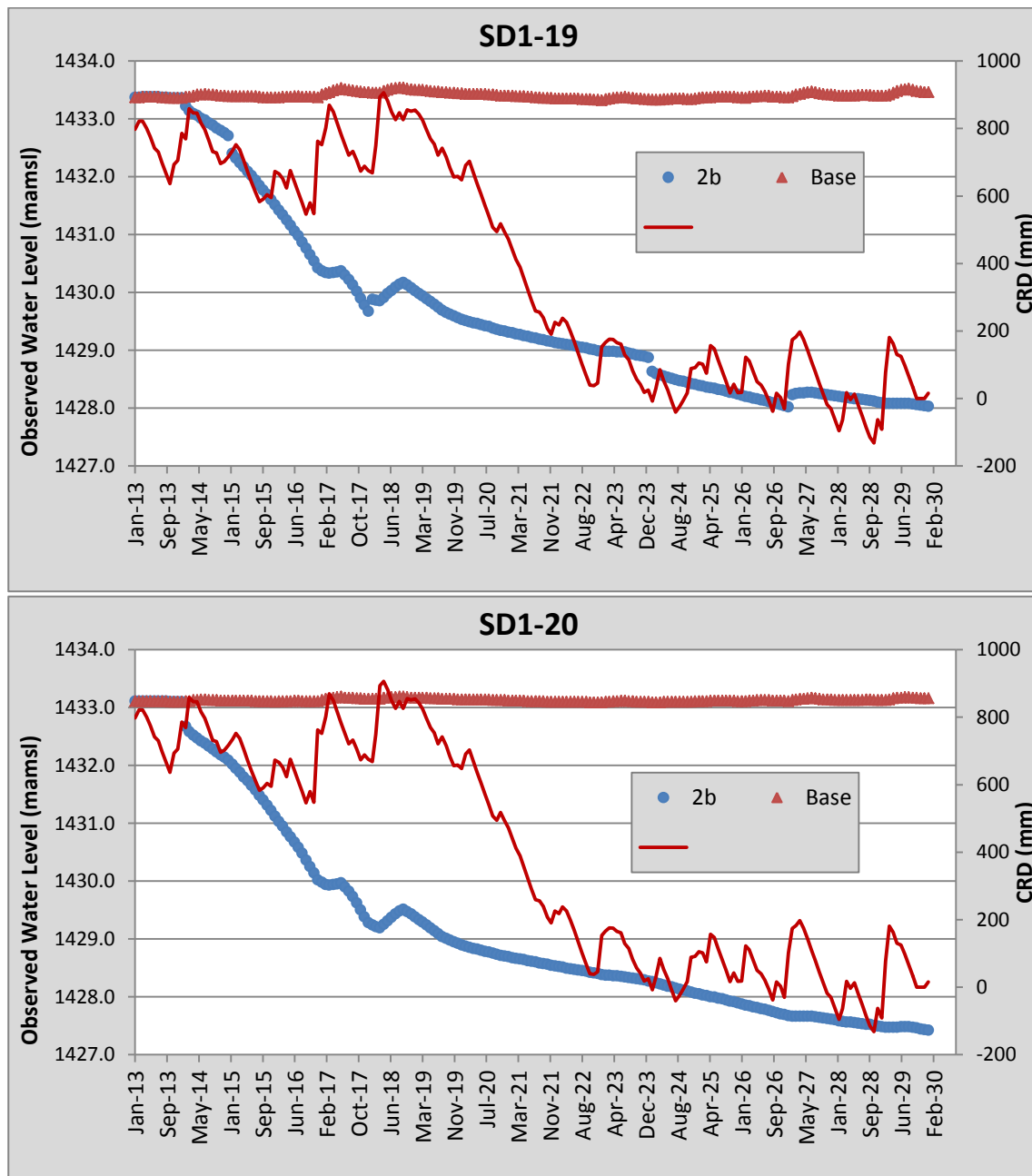
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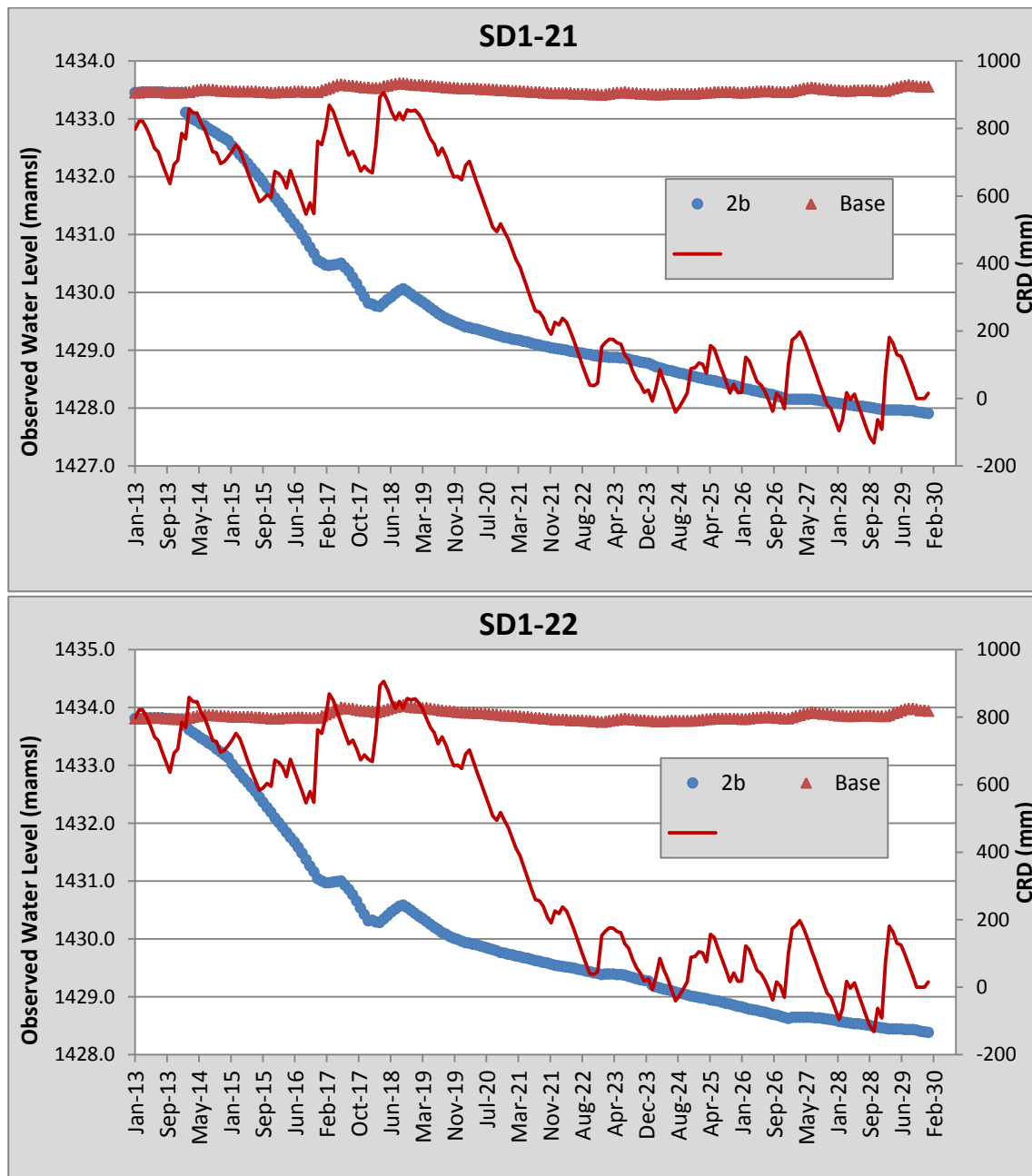
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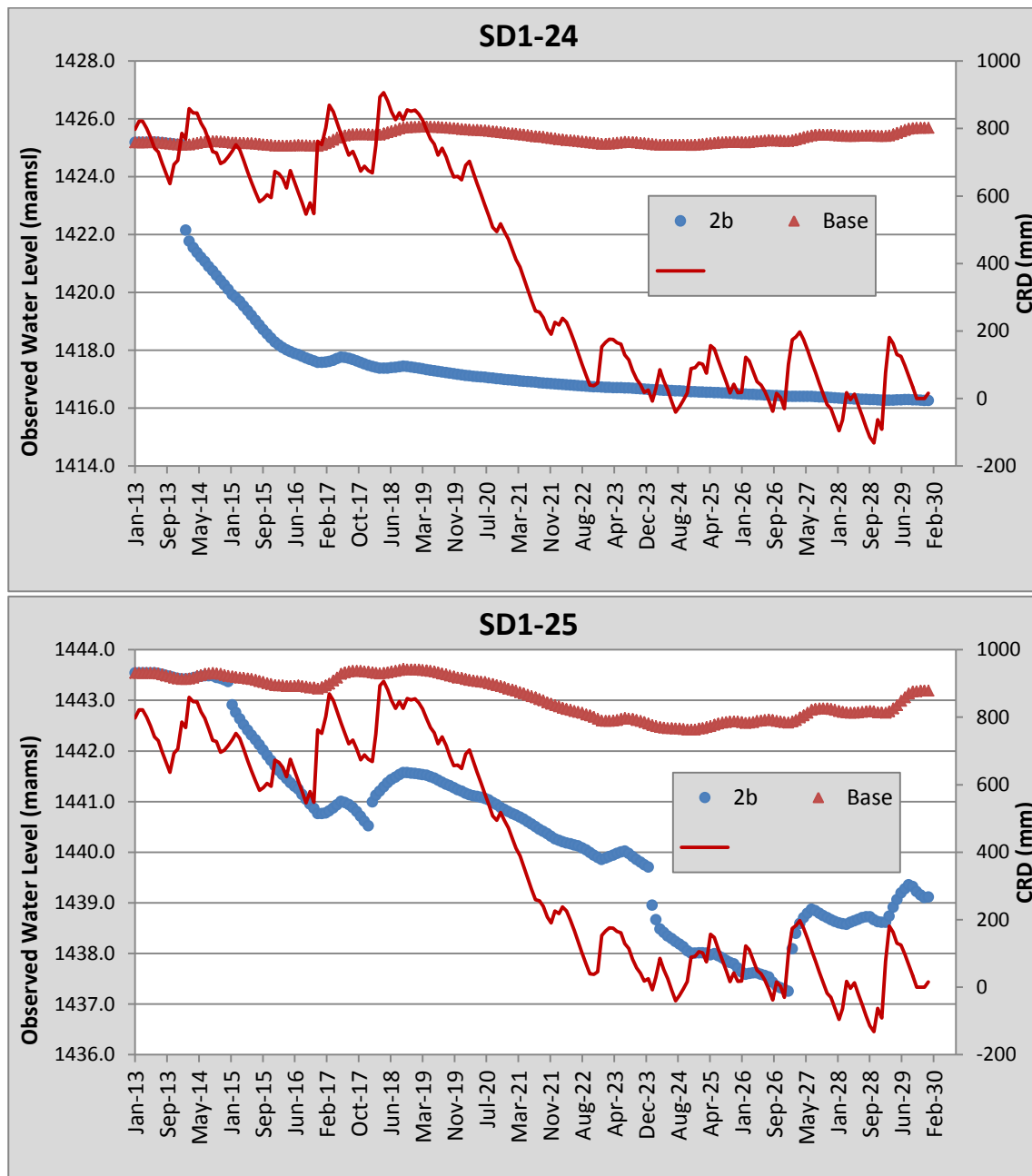
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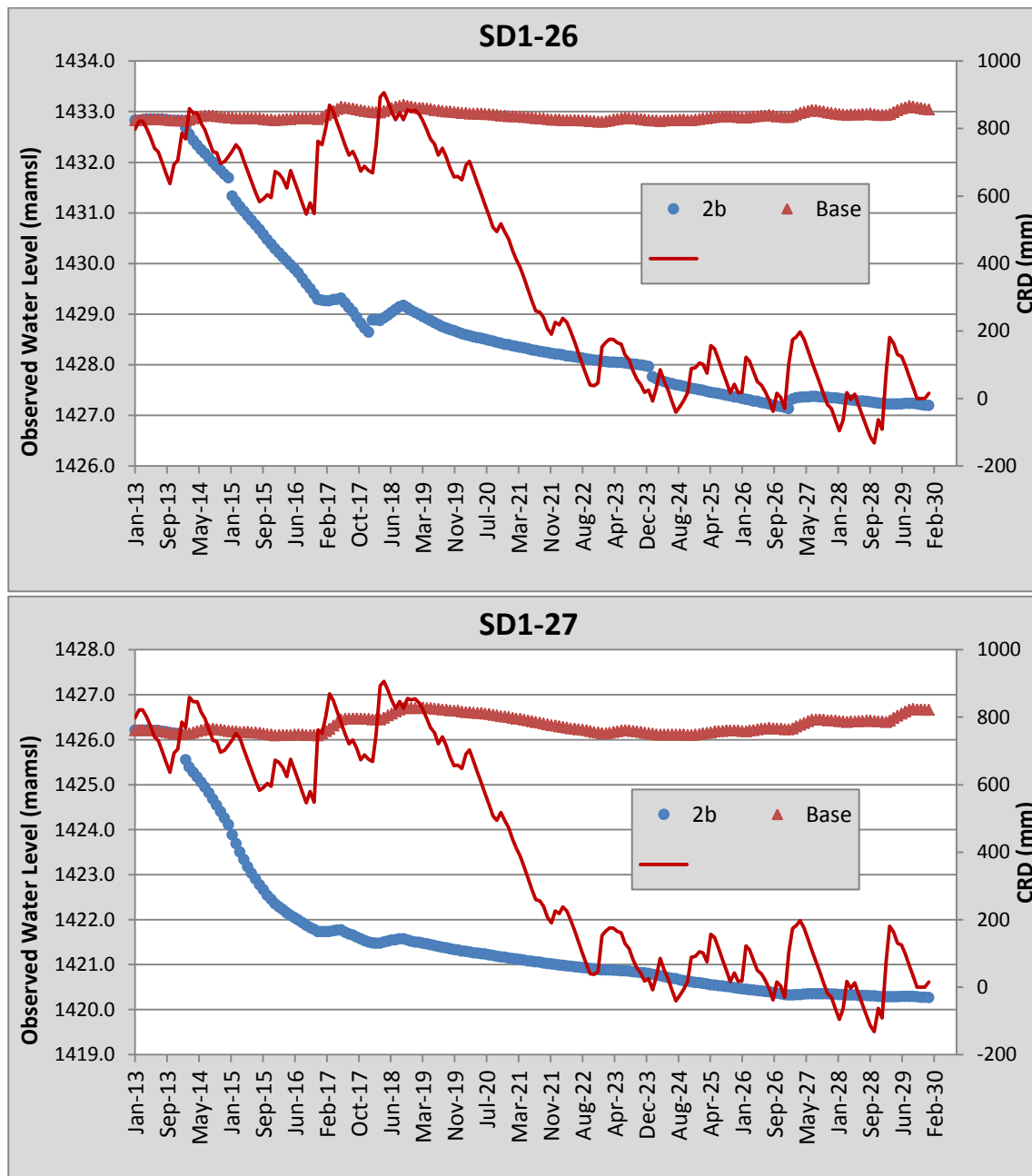
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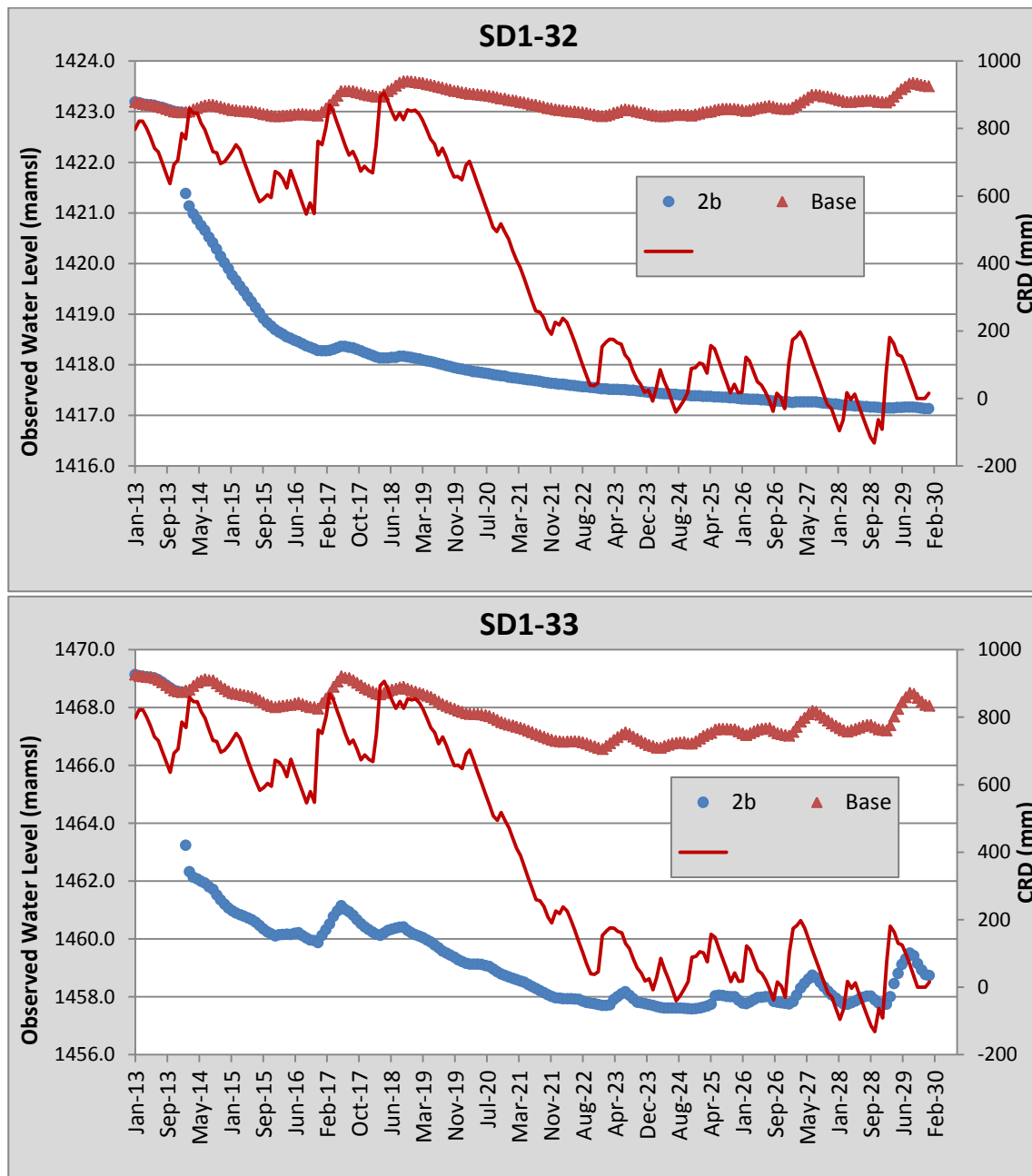
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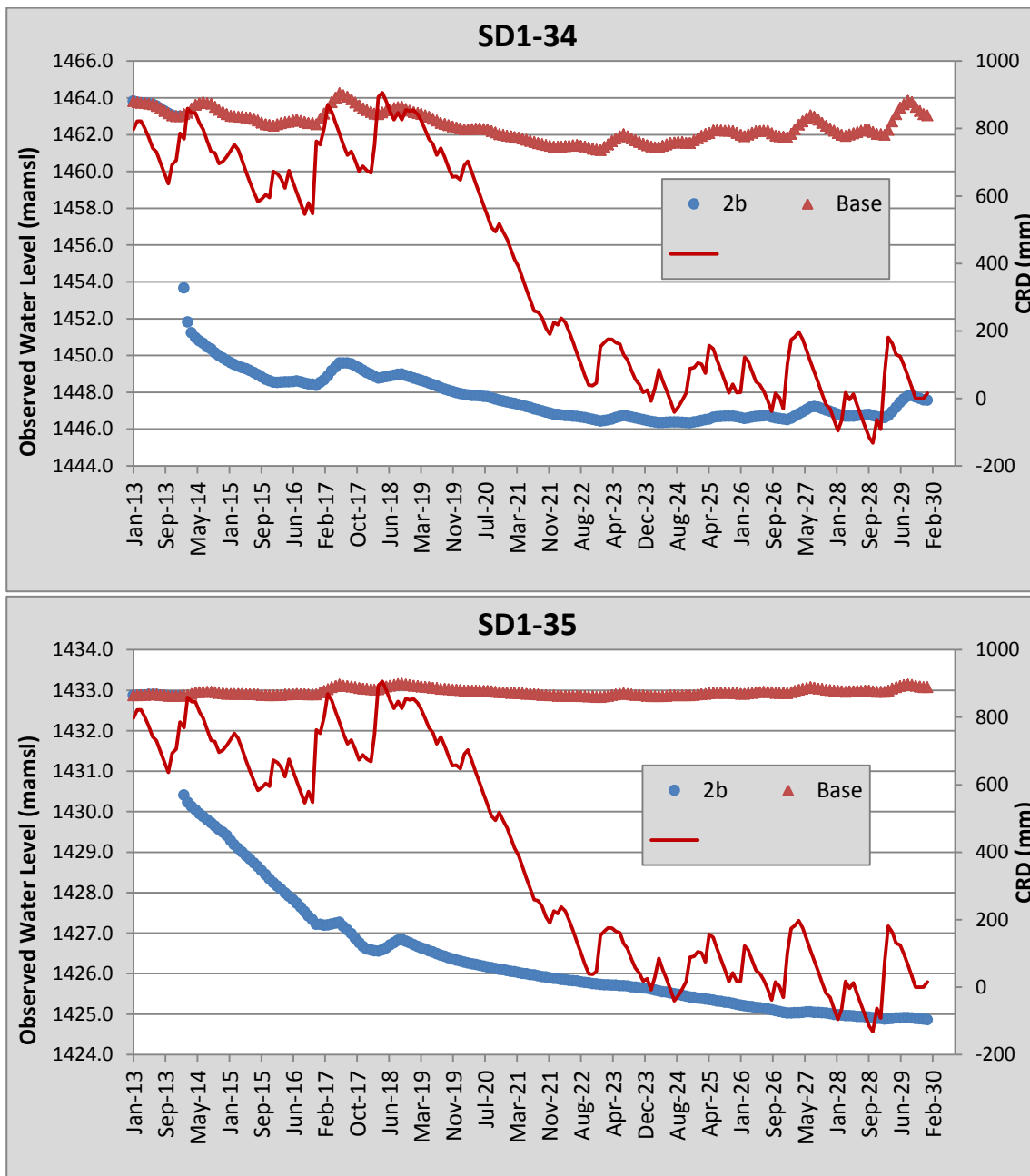
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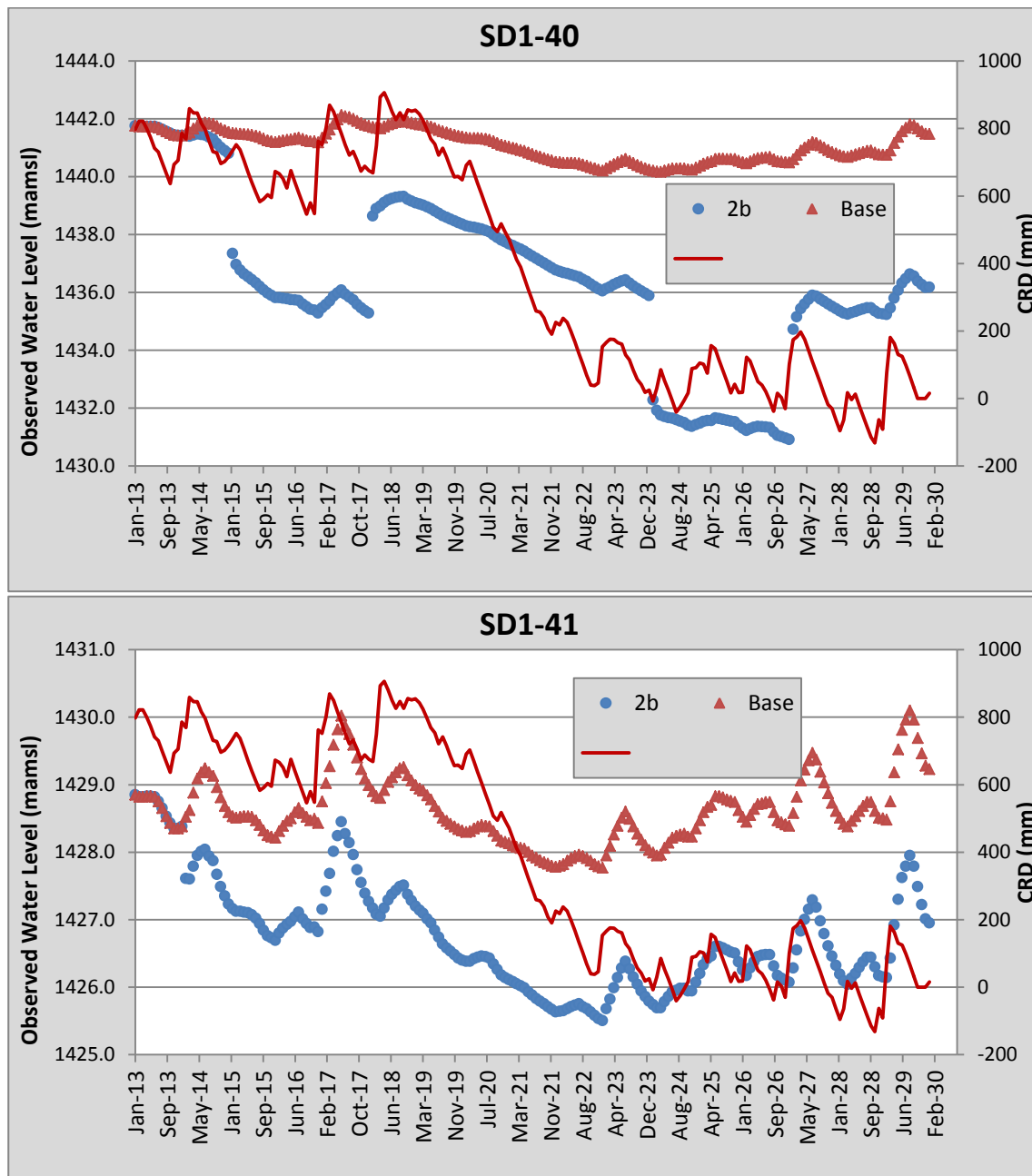
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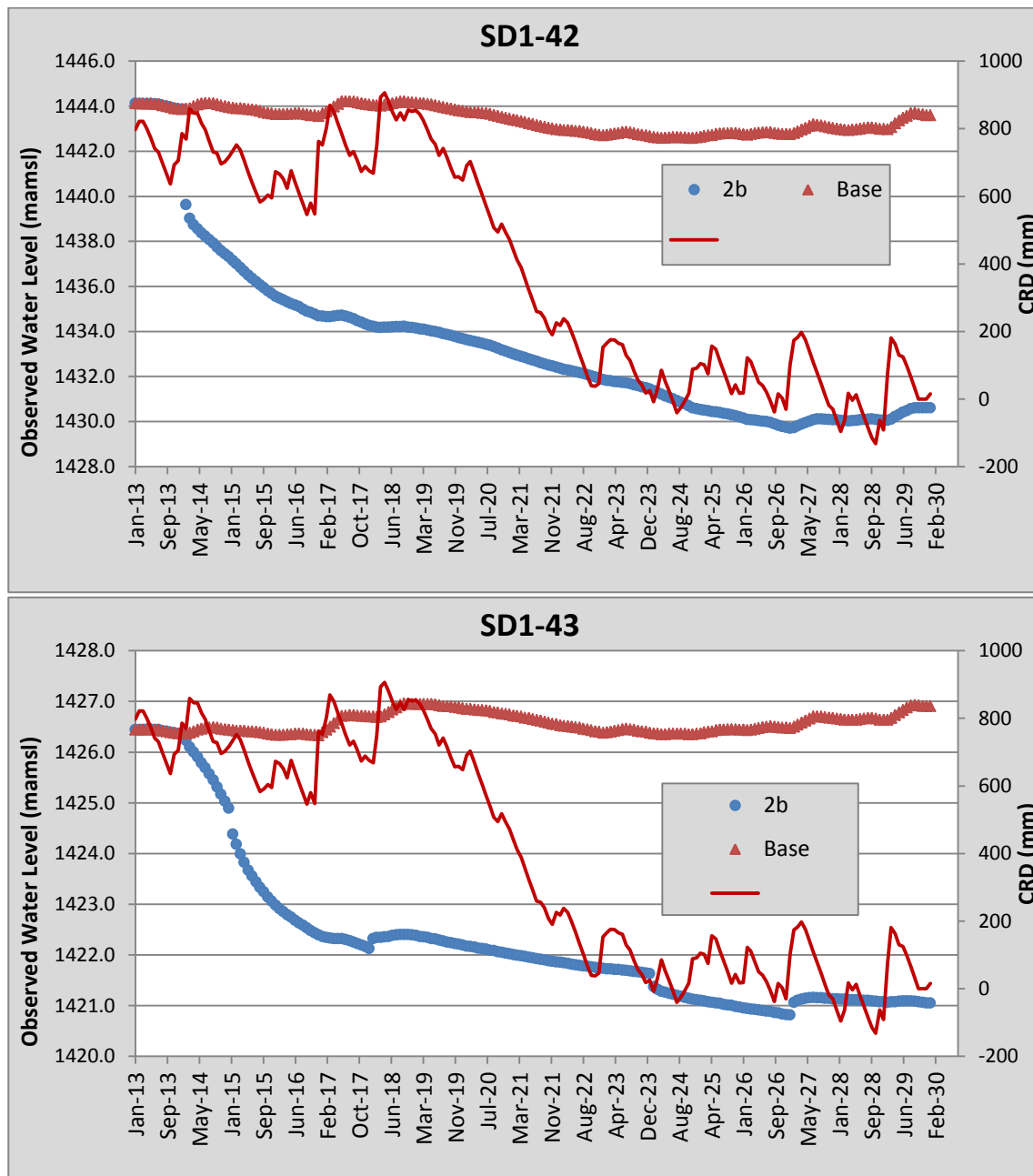
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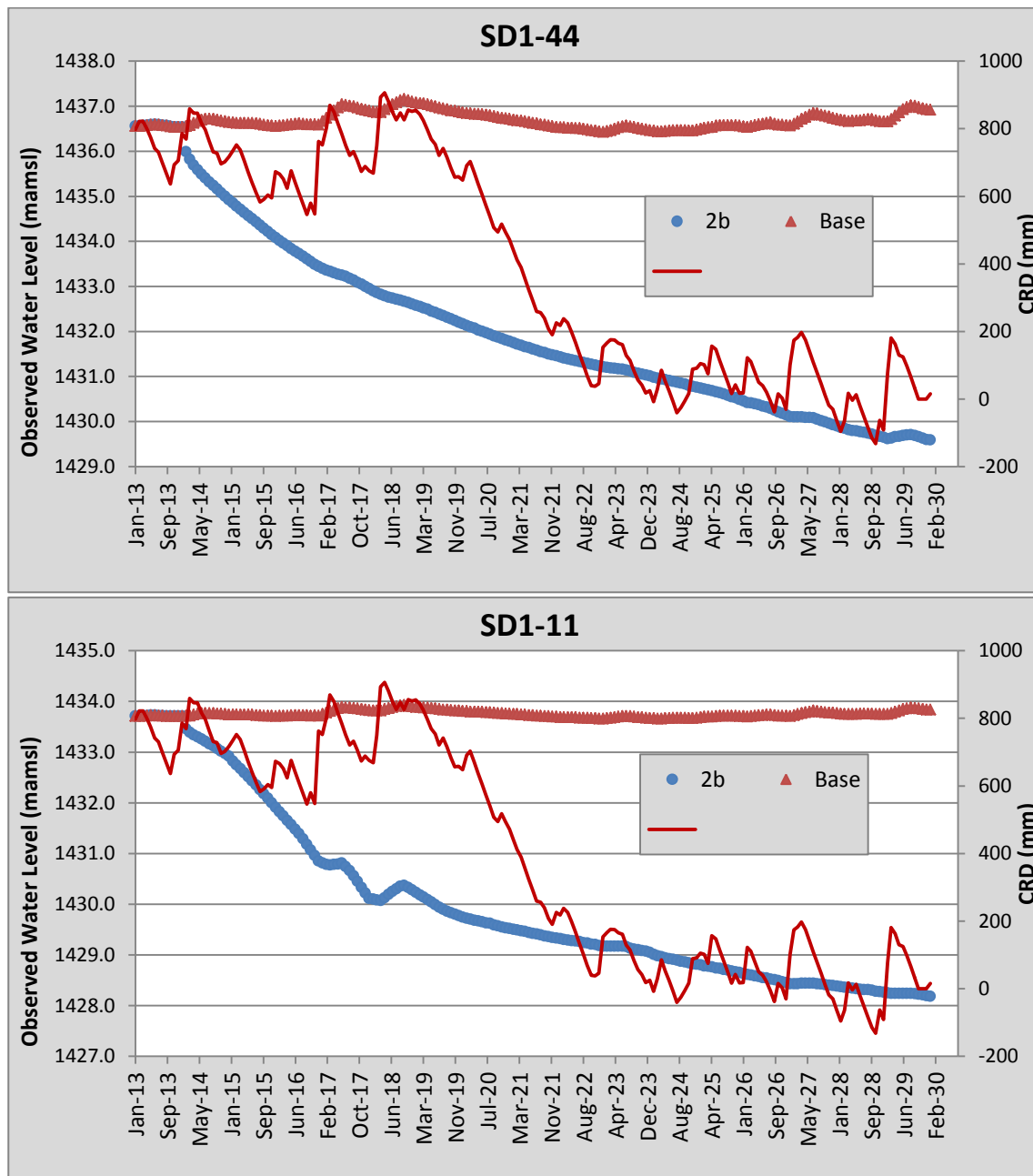
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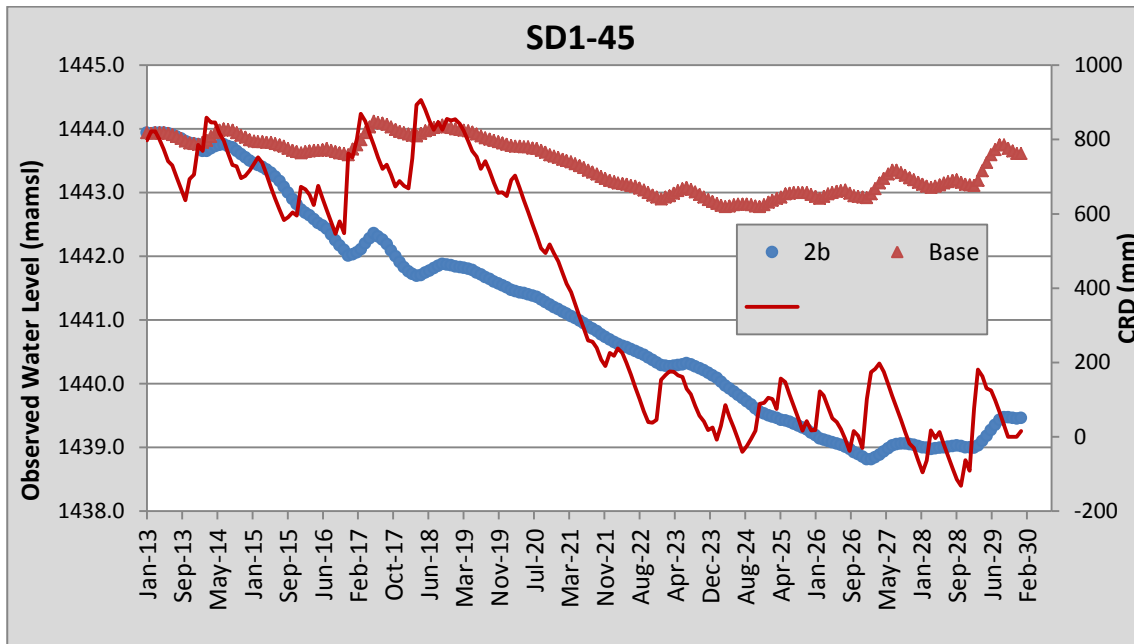
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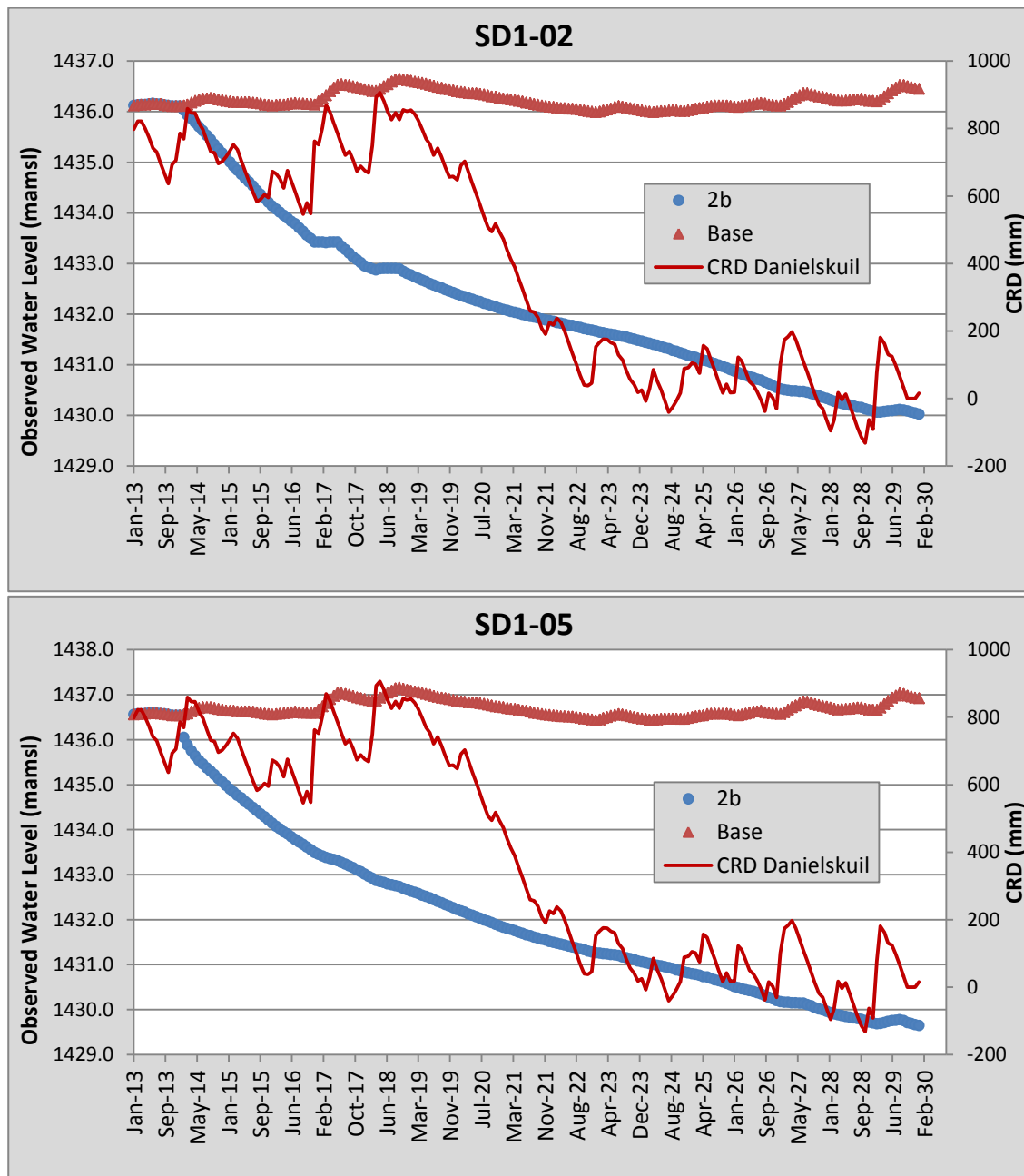
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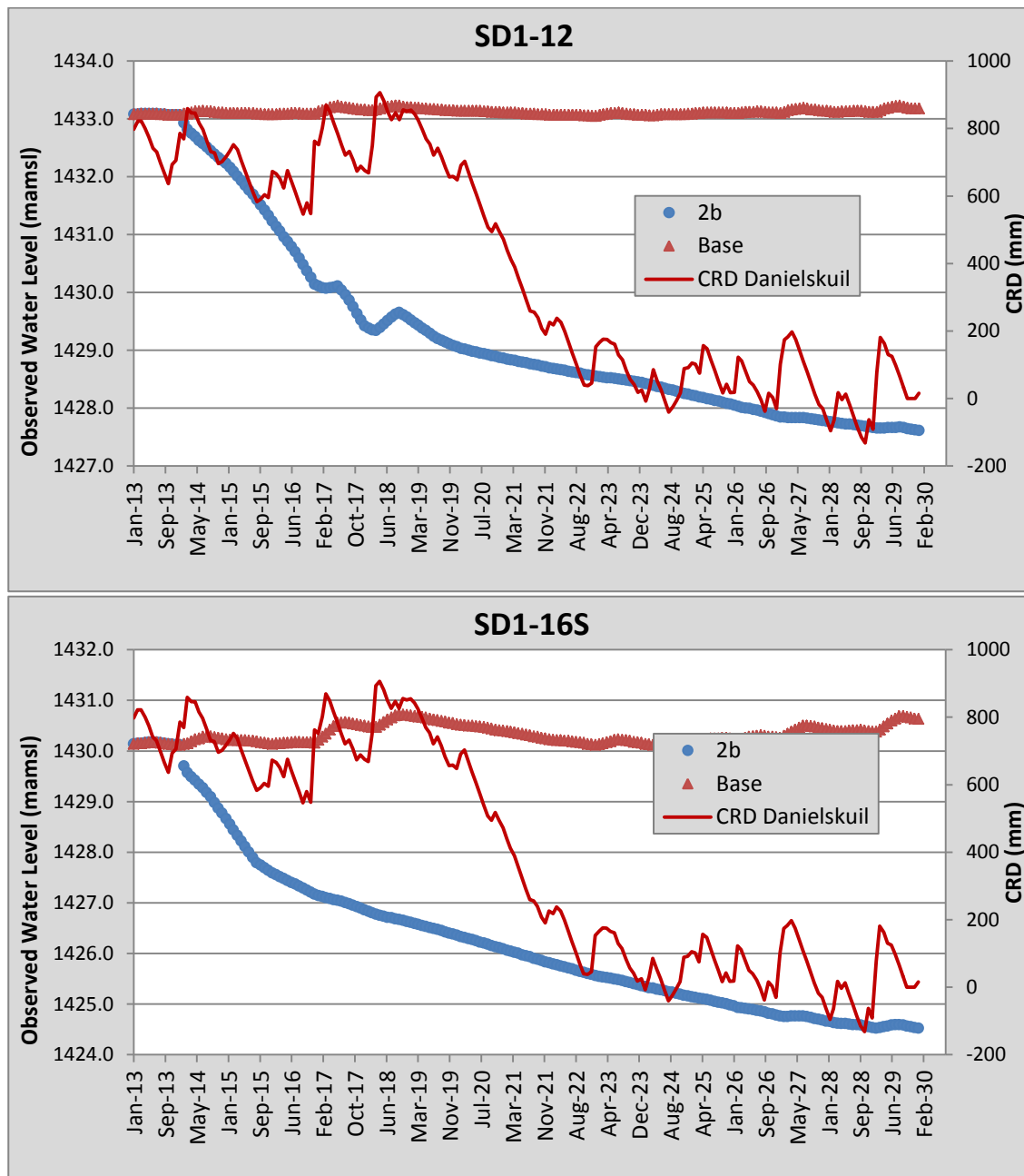
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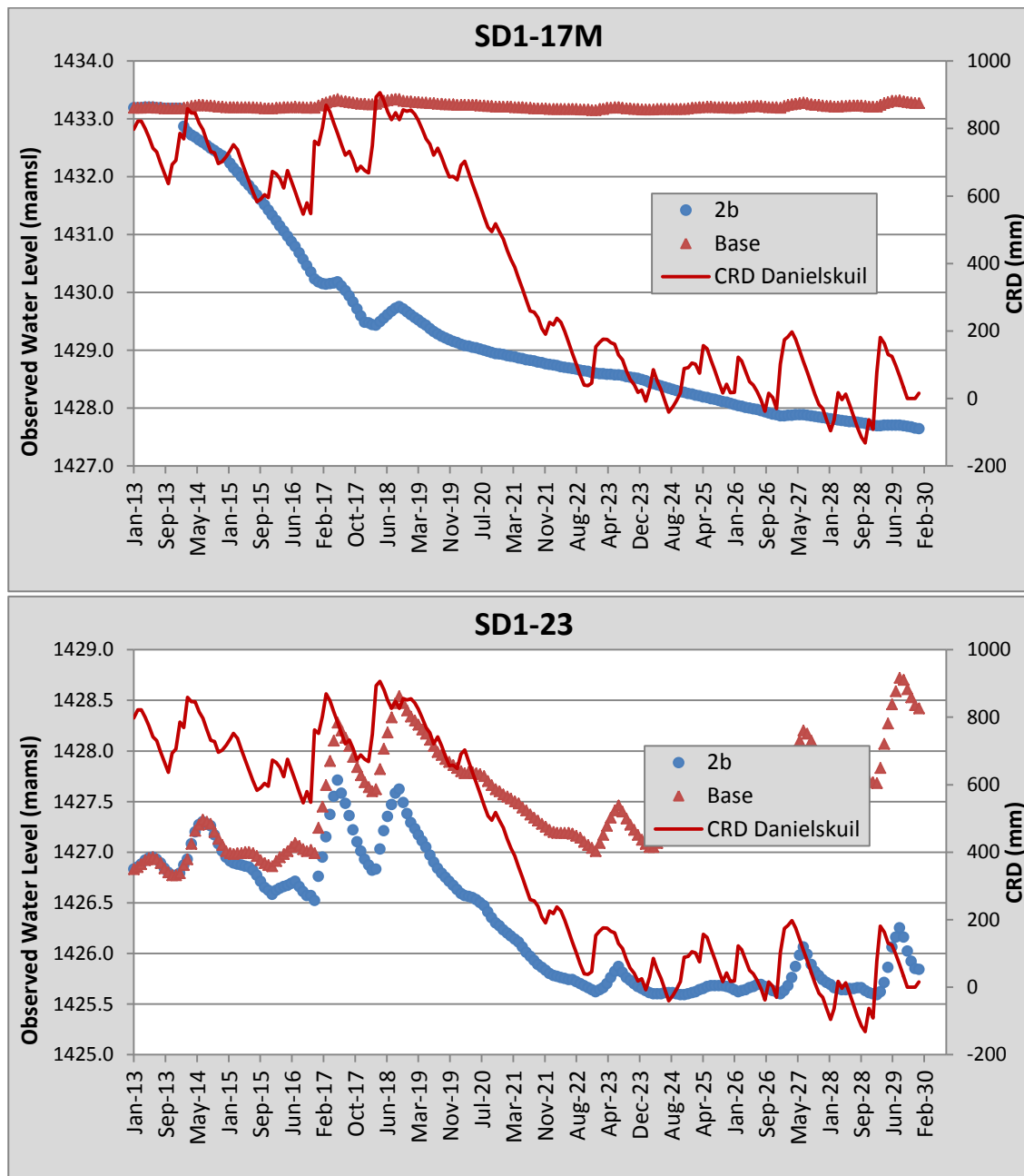
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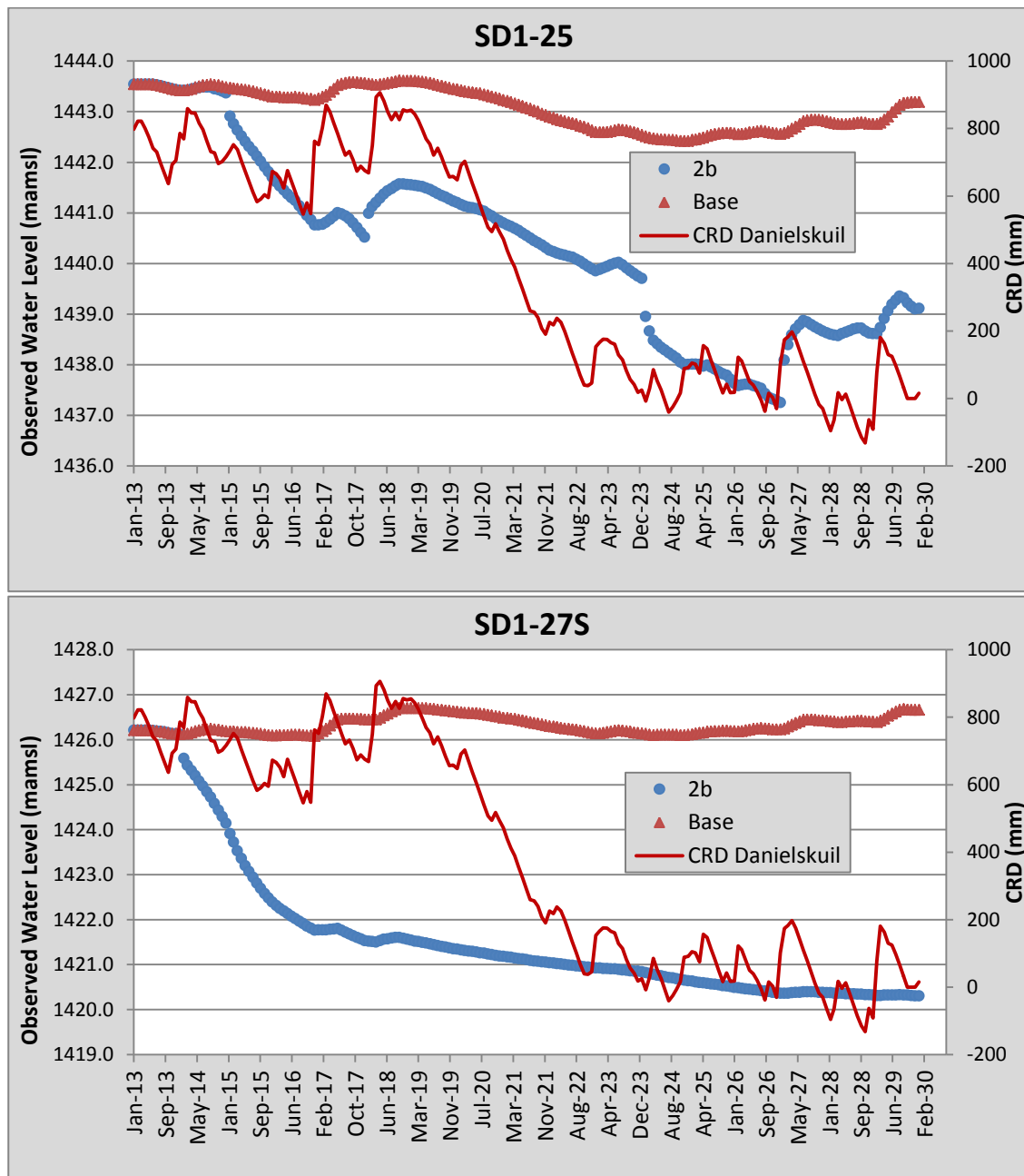
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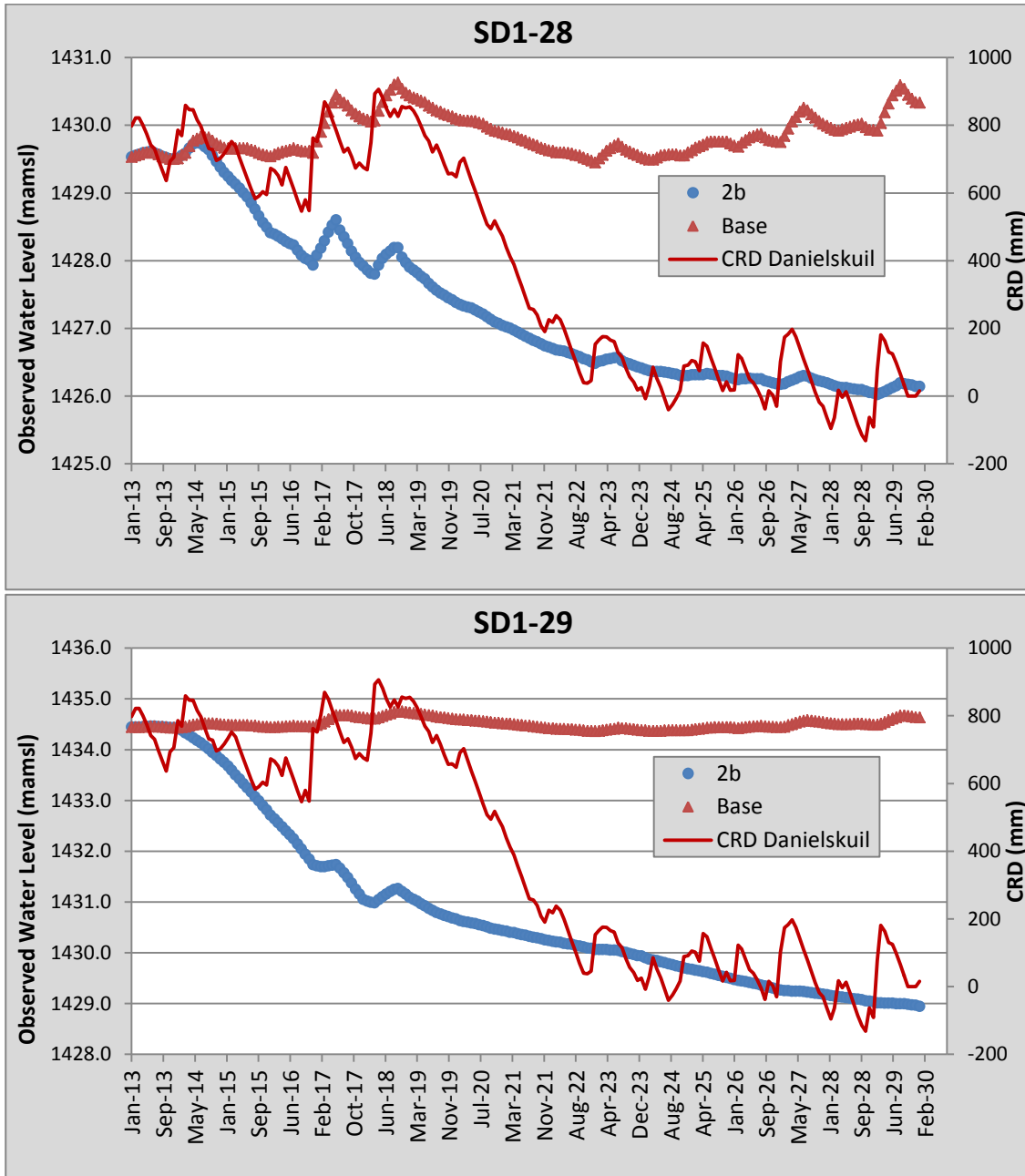
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APPENDIX B

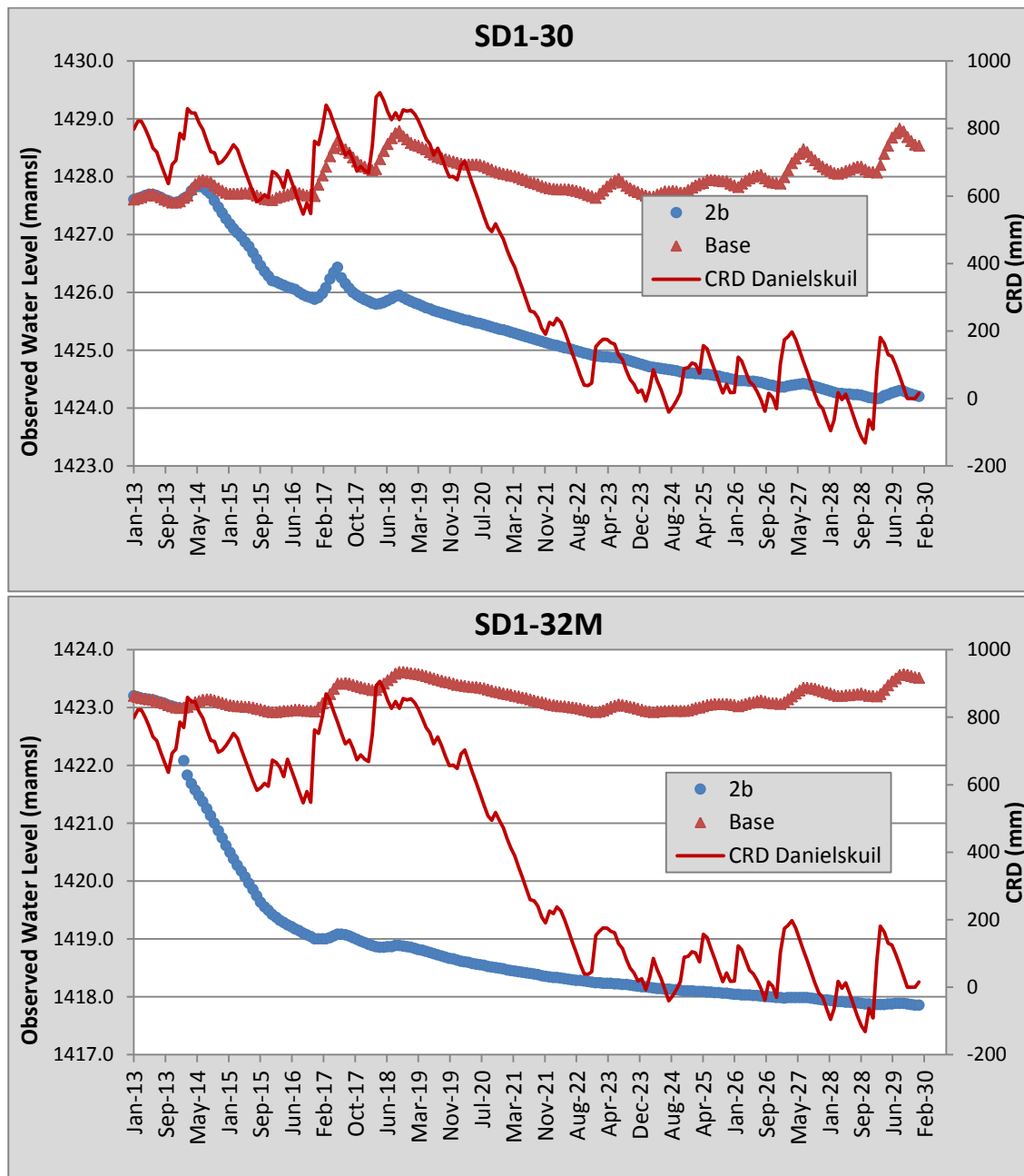
VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I





APPENDIX B

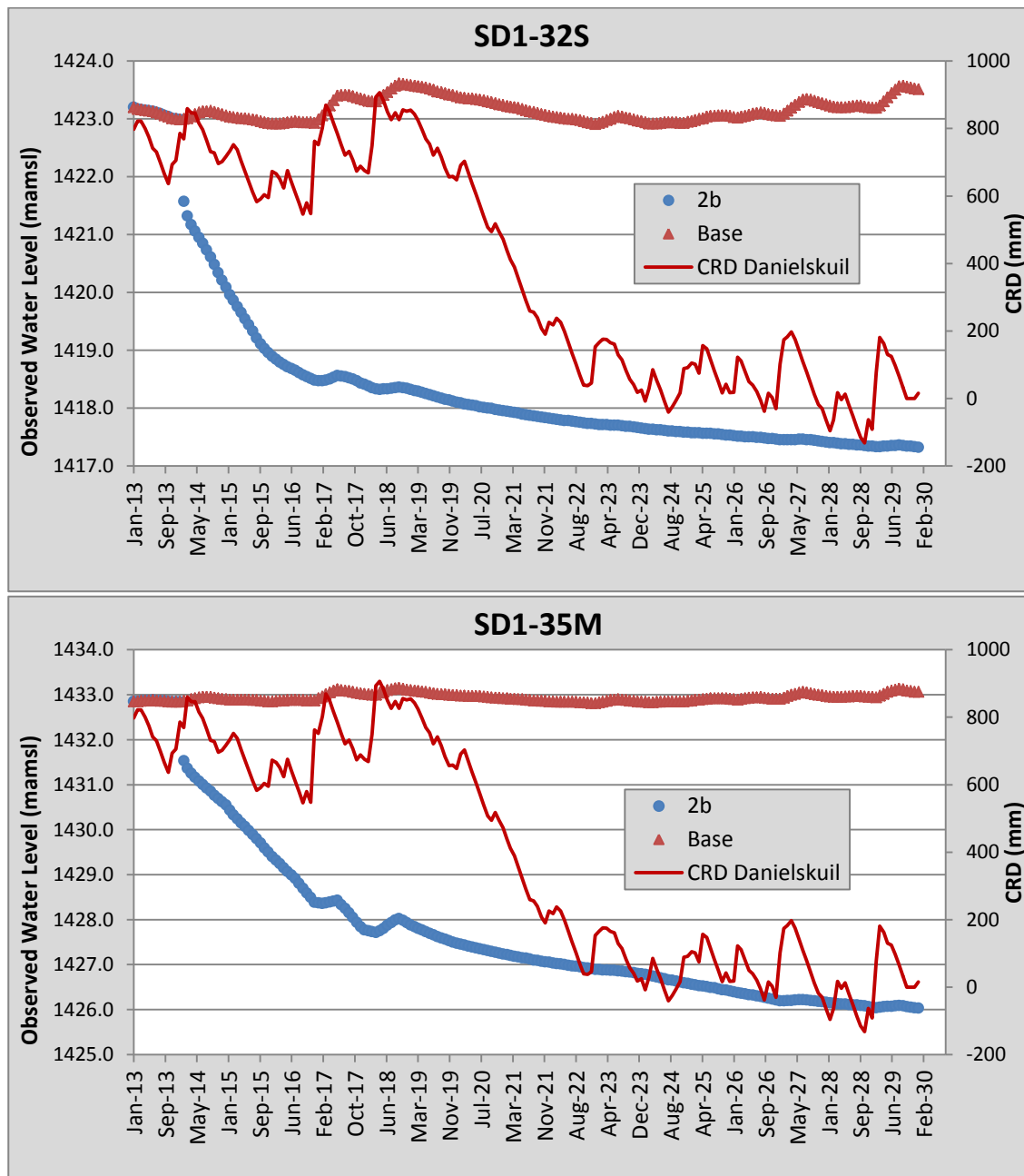
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APPENDIX B

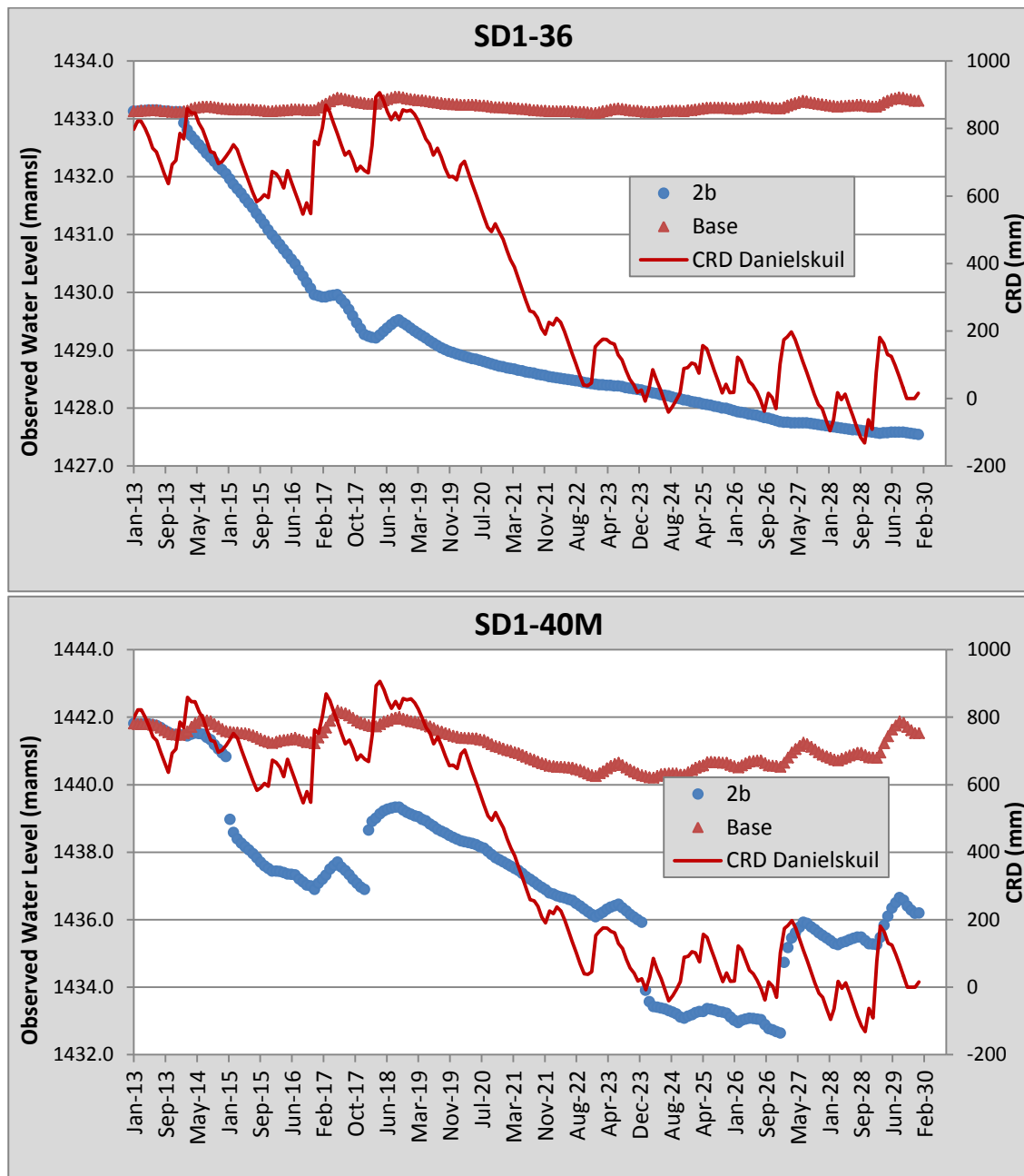
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APPENDIX B

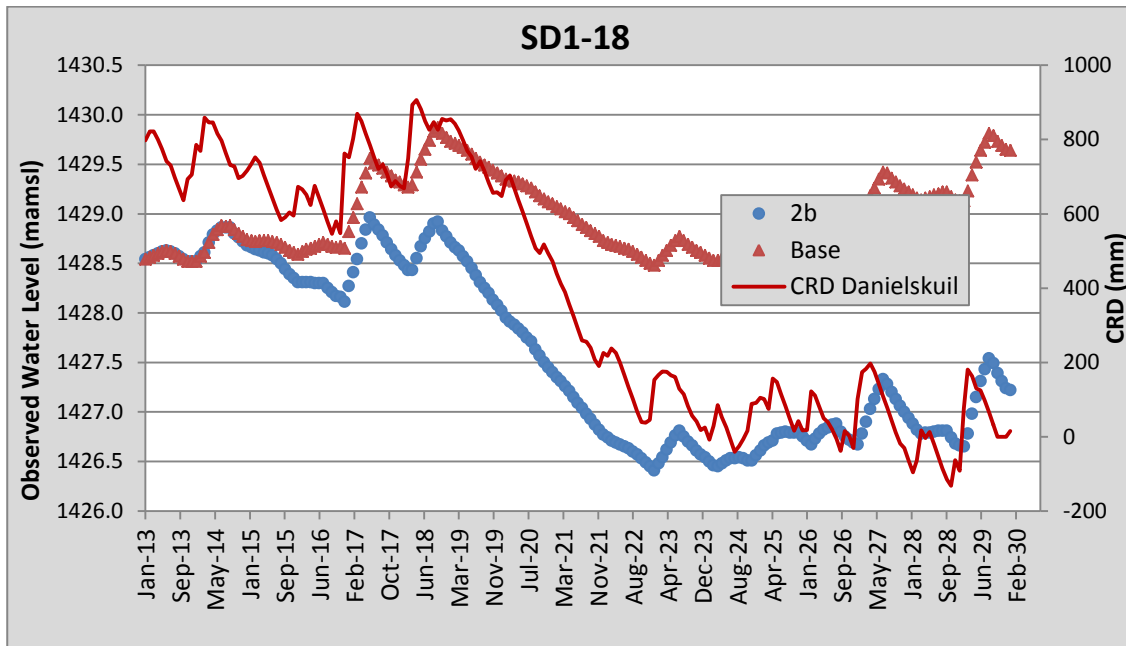
VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I





APPENDIX B

VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I





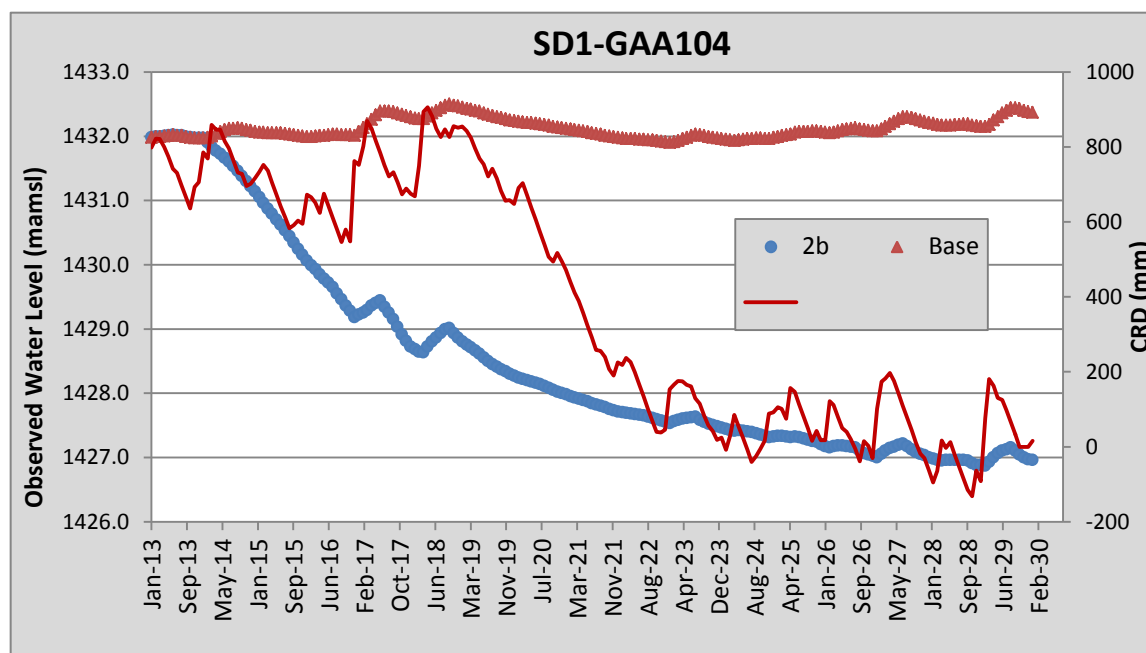
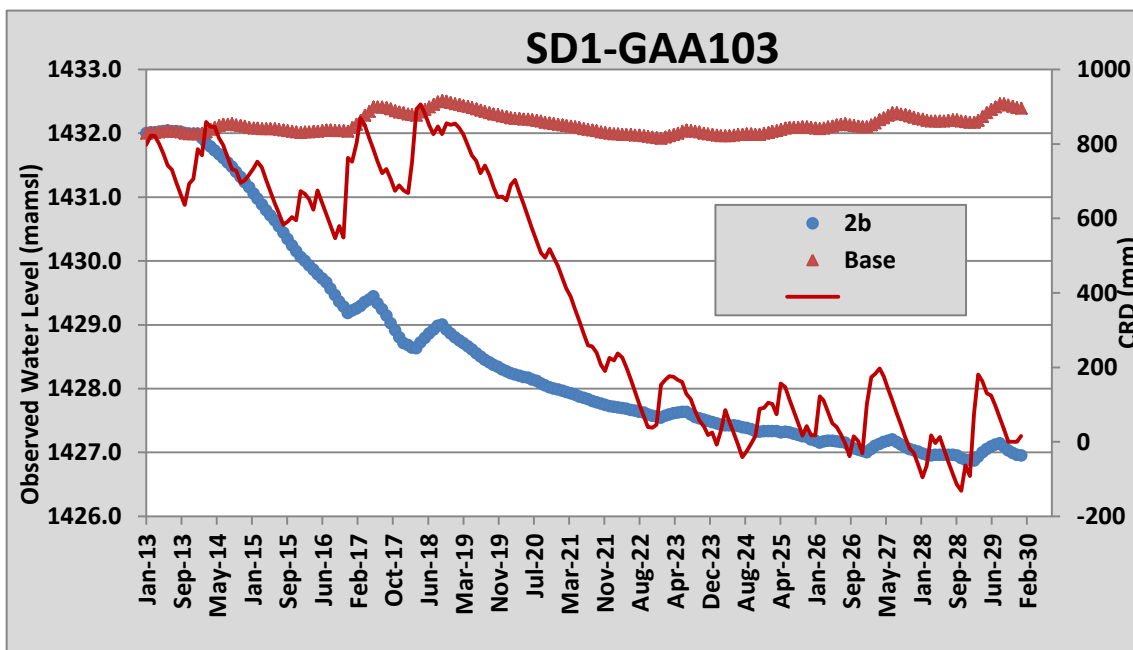
APPENDIX C

Long-Term Water Level Drawdown Simulations for Existing Boreholes



APPENDIX C

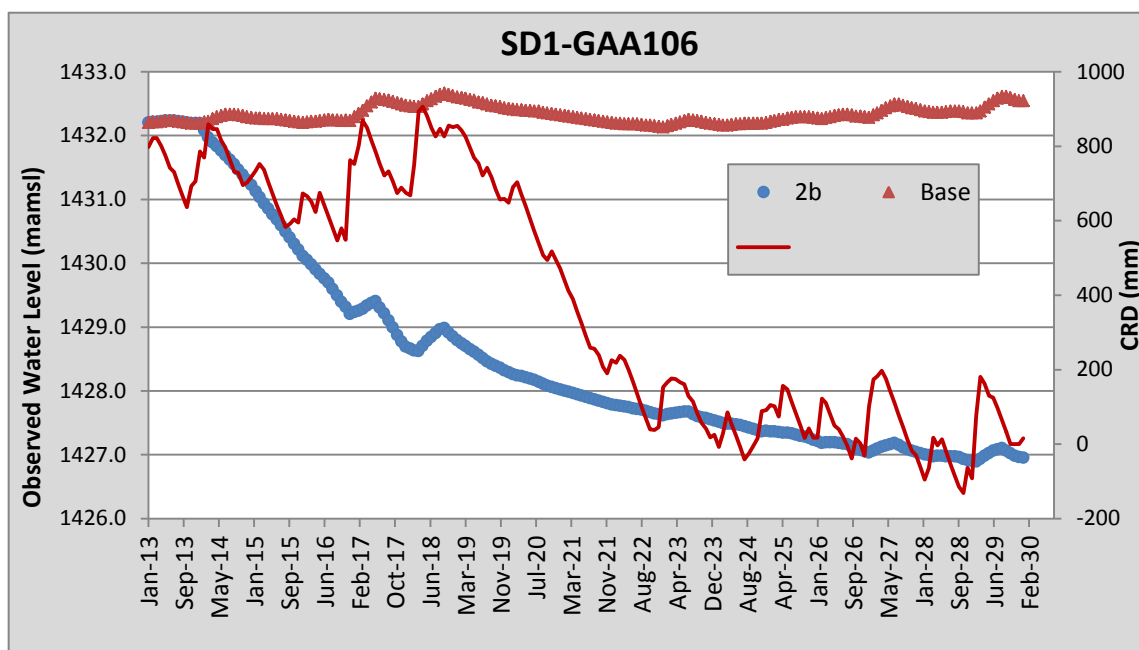
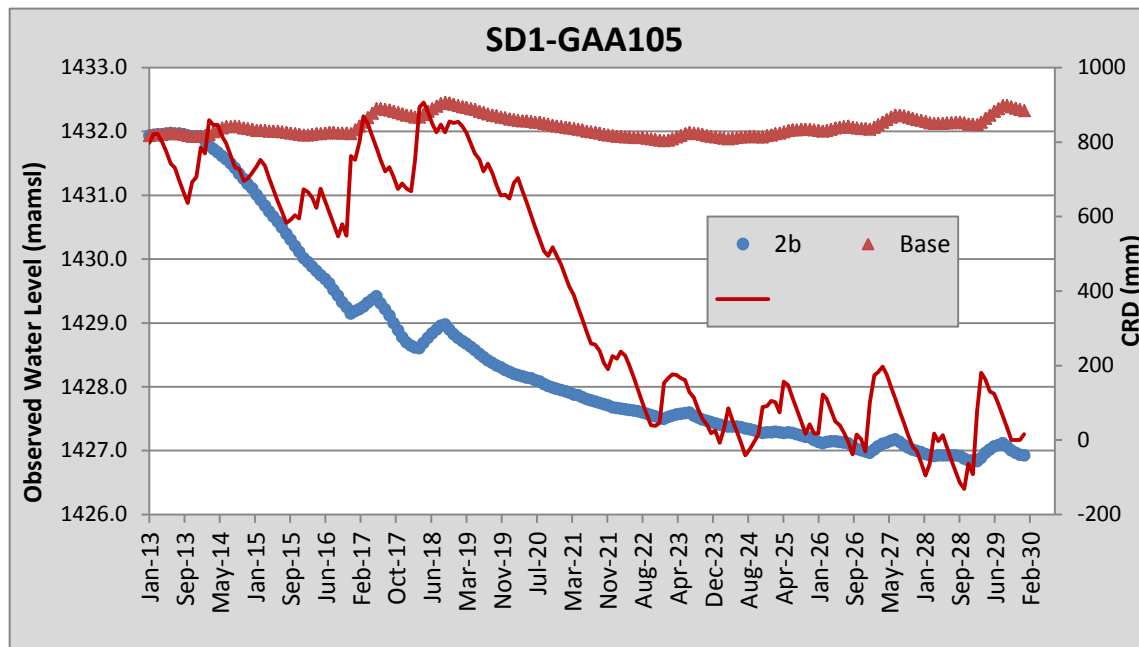
VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I





APPENDIX C

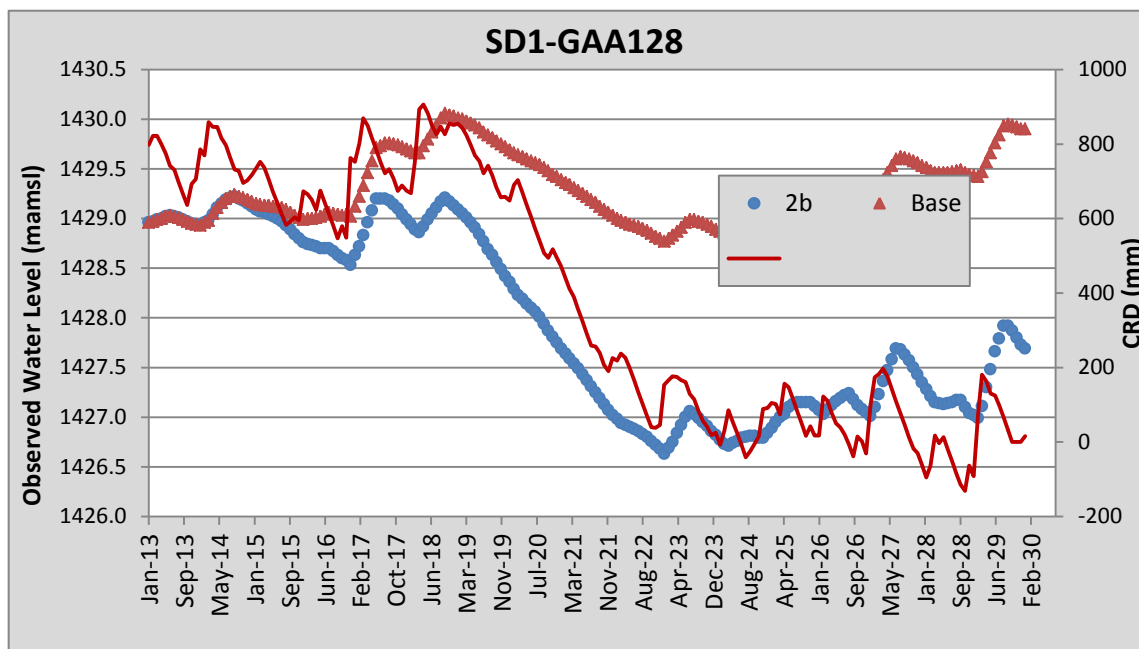
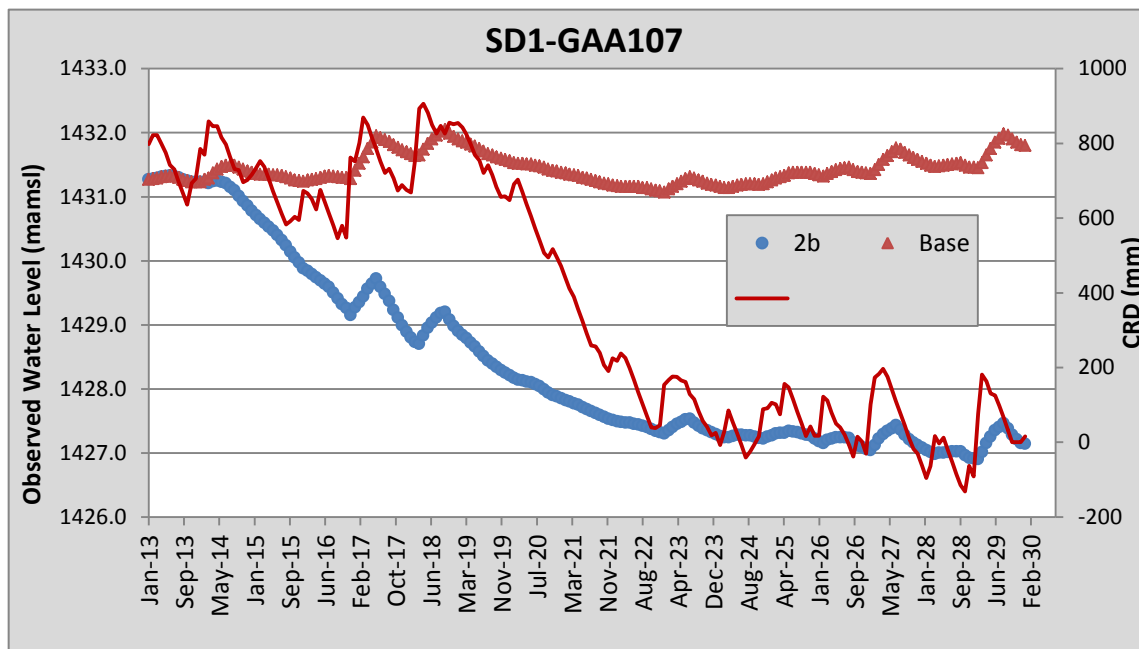
VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I





APPENDIX C

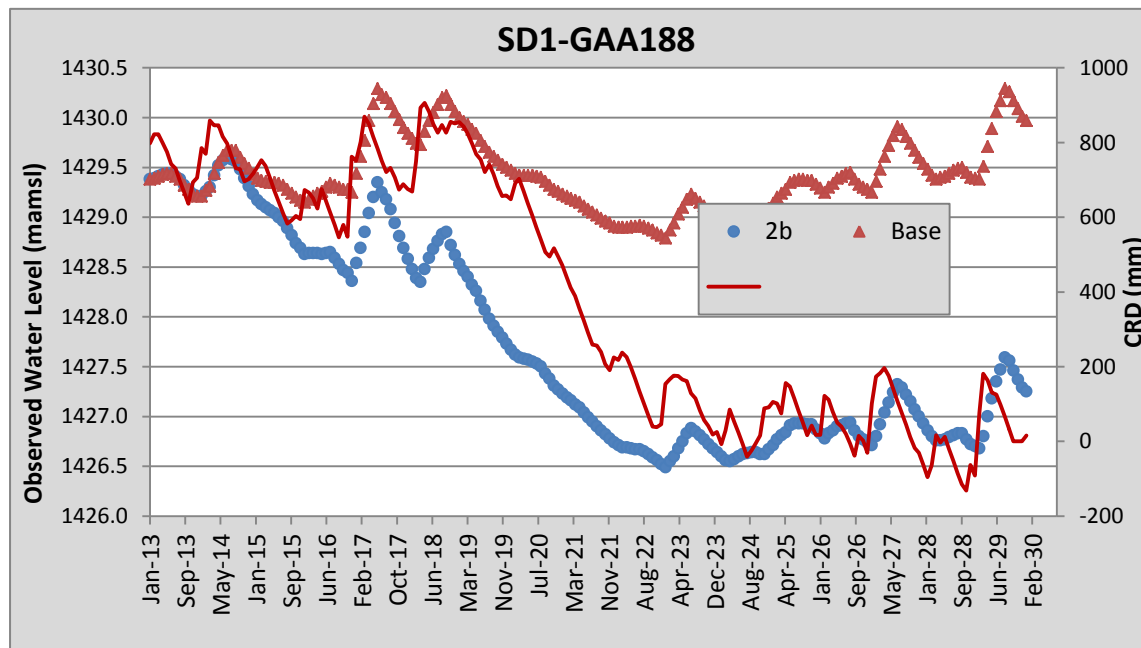
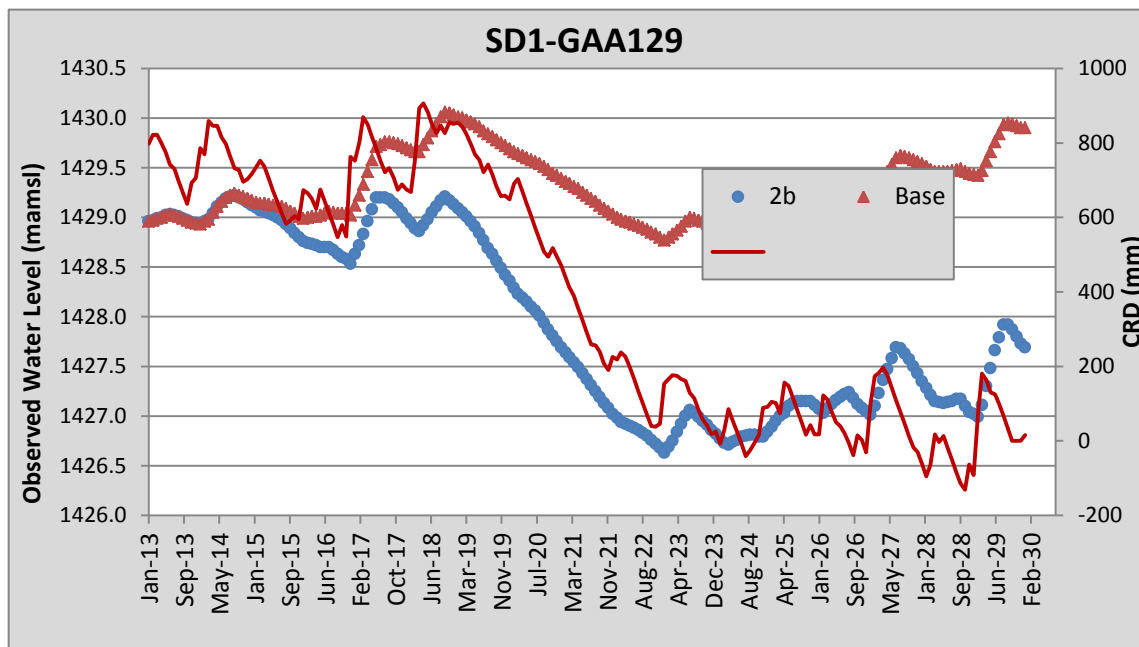
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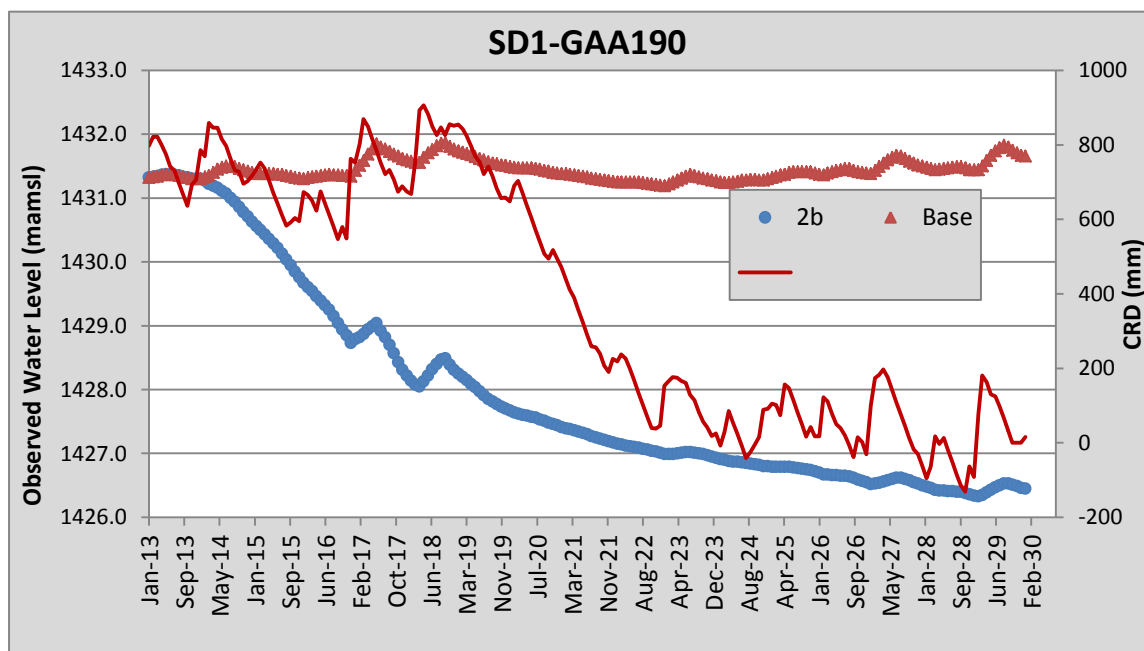
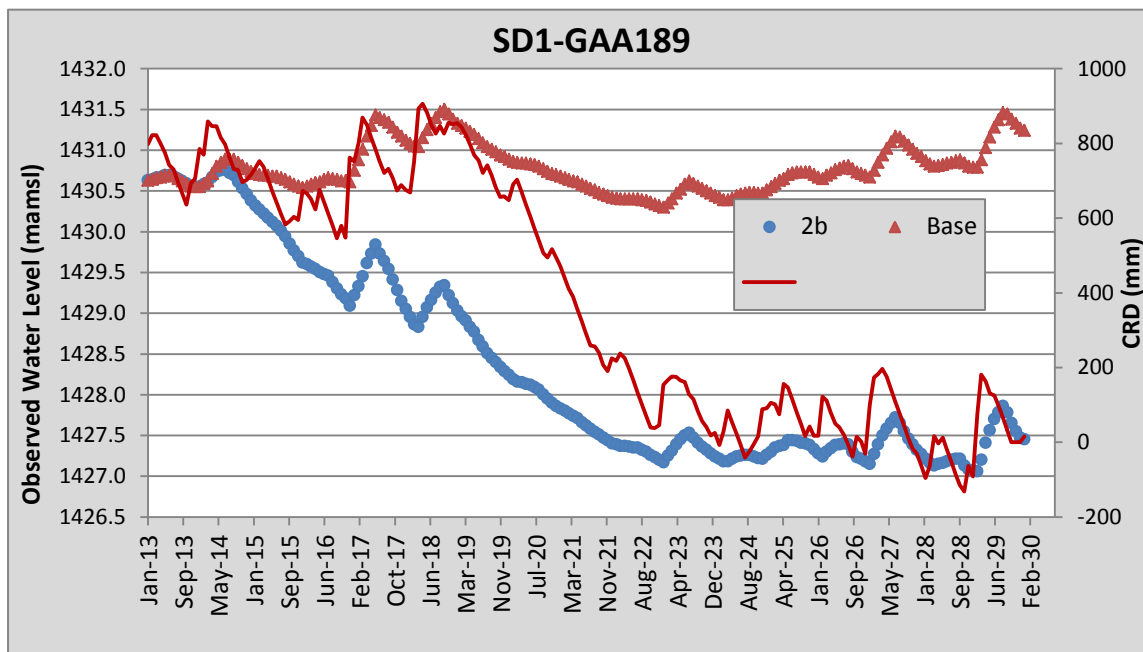
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APPENDIX C

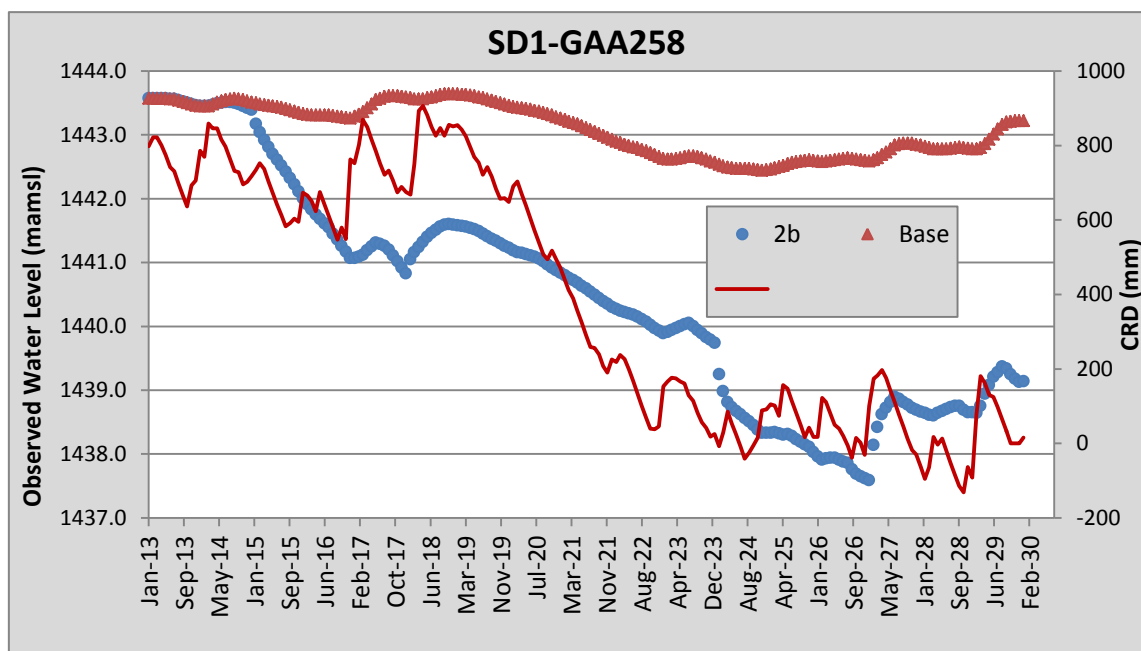
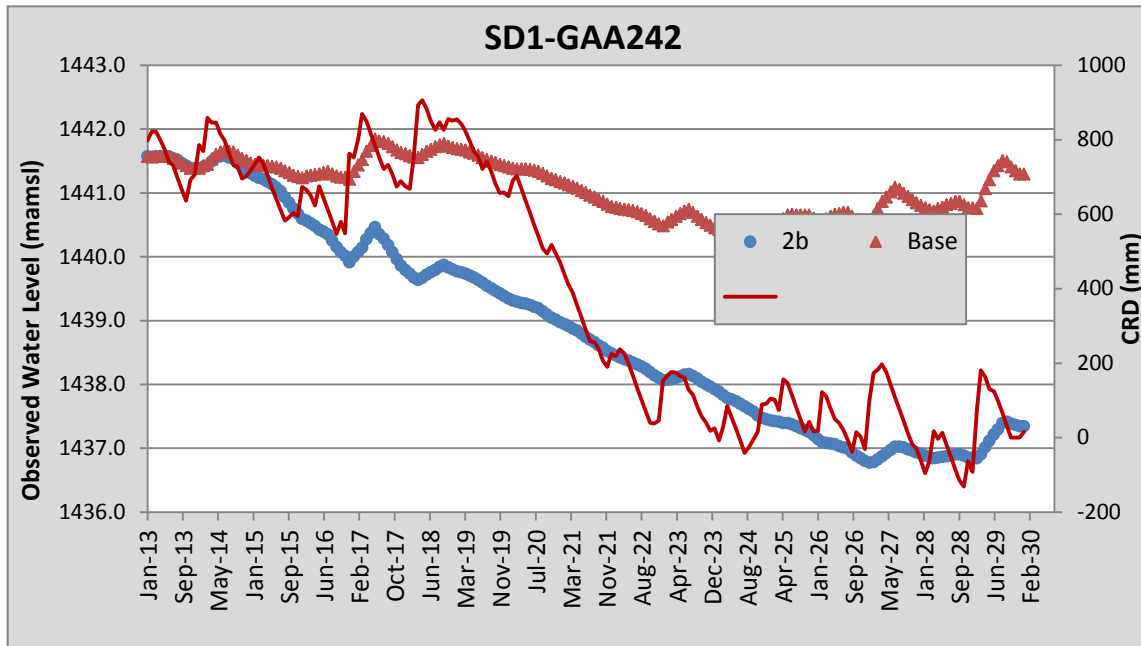
VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I





APPENDIX C

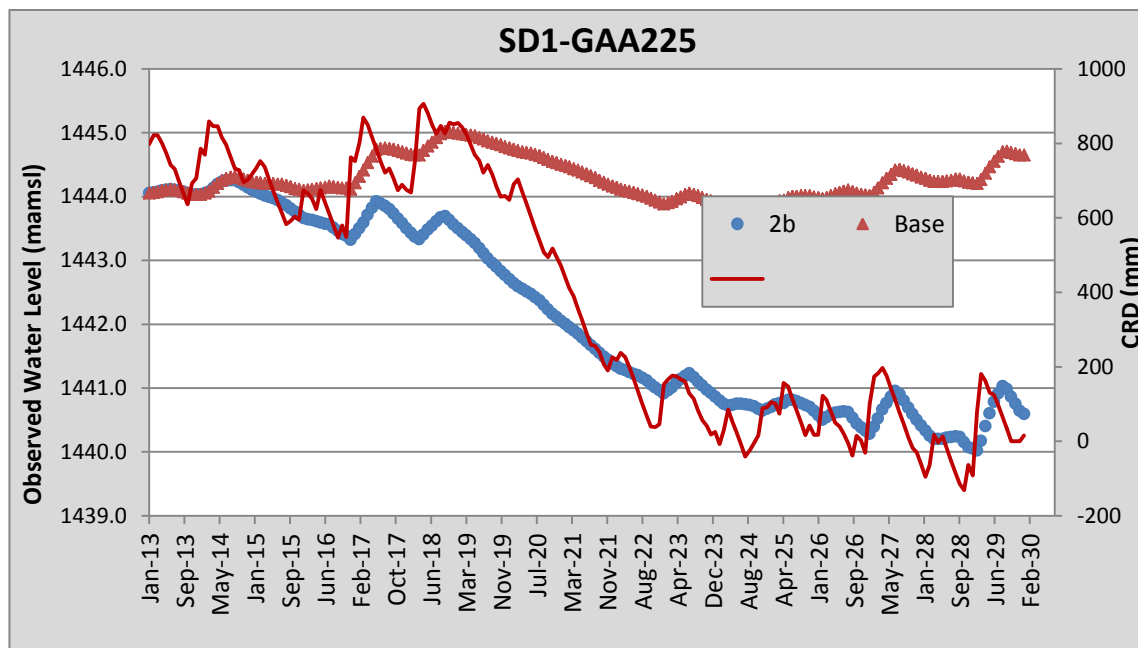
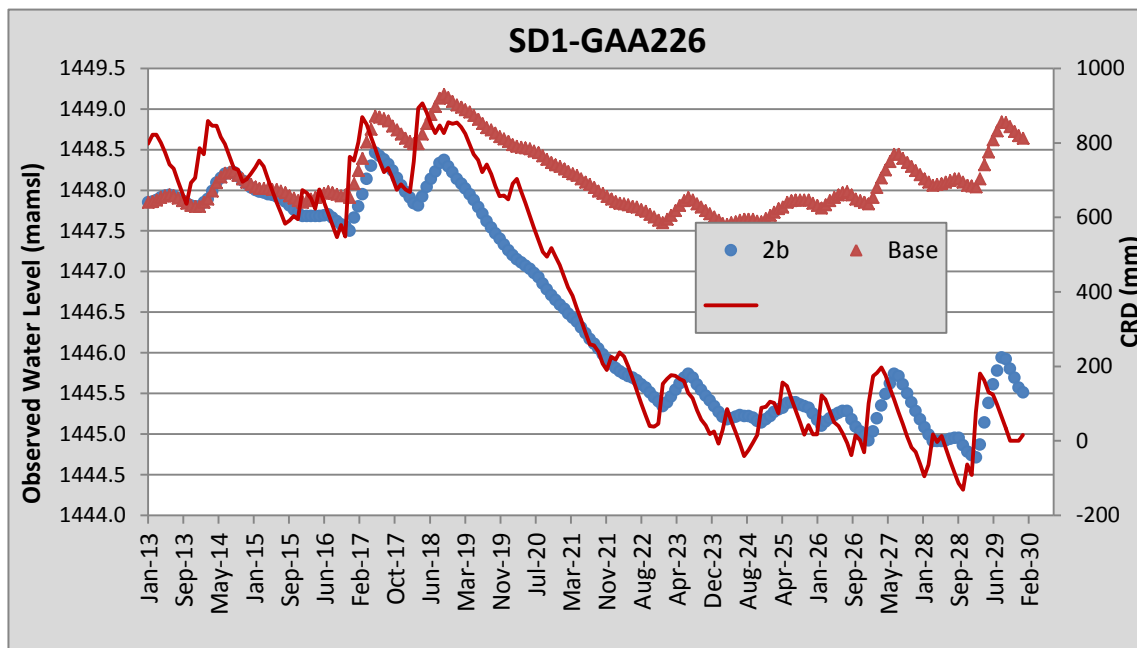
VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I





APPENDIX C

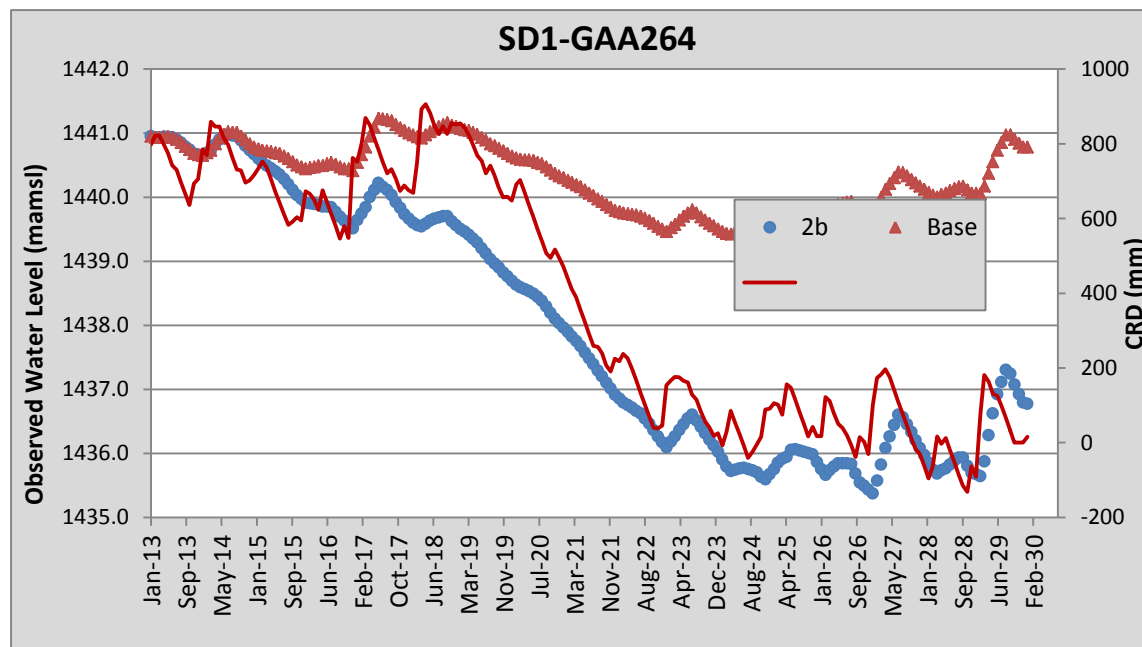
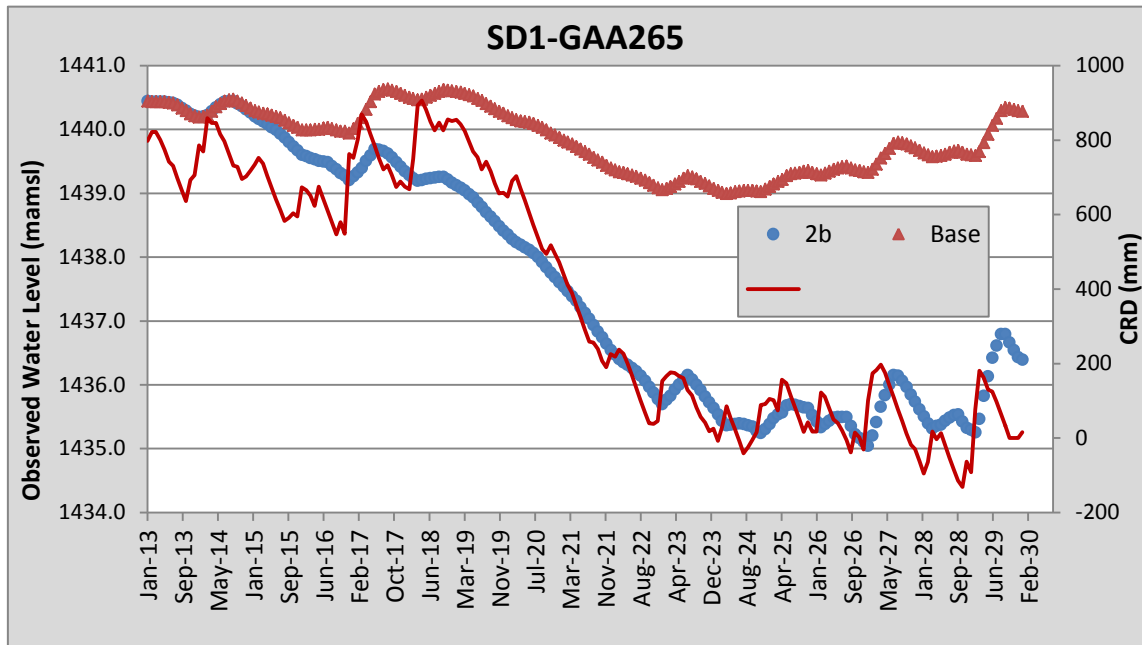
VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I





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APPENDIX D

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