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MAIN REPORT: VOLUME I

Groundwater Assessment and Development for the Vaal Gamagara Pipeline Scheme - SD2 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. 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 VGWS scheme four large scale groundwater source development areas were identified (SD1 to SD4).

This report documents the exploitability and sustainable potential of SD2 (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 Delporthoop, 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 assessment 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 2 (SD2) and establish the sustainable yield that can augment the Vaal Gamagara Pipeline scheme.

Description of Study Area

SD2 investigation area falls under the jurisdiction of Tsantsabane Local Municipality (LM), of the ZF Mgcawu District Municipality (formerly Siyanda District) and is located in the Northern Cape Province. The study area is located north east of Postmasburg and extends north east to Jen Haven community.

The recorded MAP for SD2 is 328mm/a, as recorded at Postmasburg rainfall stations for the period 1917 to 2014, rainfall is predominantly in the summer months and mainly occurs as isolated thunderstorms.

The SD2 area is situated on the southeastern flank of the Maremane Dolomite Dome and the surface is mostly covered by Quaternary sand and calcrete. The Ongeluk Lava Formation overlies the Makganyane Formation, Danielskuil Formation and Kuruman Formations which are underlain by the Campbell Rand Subgroup.

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 142 existing boreholes and verification of existing groundwater use and selective sampling of 37 boreholes to characterized water quality of exiting groundwater users;



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- 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 from very near surface to depths of 200 to 250 metres;
- Detailed remote sensing and assessment of airborne geophysical data to identify linear structures of potentially enhanced groundwater occurrence;
- Ground geophysical surveys: gravity surveys were conducted over a large portion of the study area to optimize selection of drilling targets in the dolomite and banded ironstone formations(BIF);
- Test pumping of 20 existing boreholes consisting of Step Draw-down Tests (SDT) to characterize aquifer parameters and for water sampling;
- Drilling of 47 exploration/test boreholes using air percussion drilling method according to but not limited to DWA minimum standards and requirements;
- Groundwater sampling on 39 newly drilled exploration boreholes to confirm groundwater quality and potability;
- Aquifer test pumping of 39 exploration boreholes:
 - Short term test (SDT and 24 hour CDT) to assess borehole yield capacity and aquifer sustainability;
 - Long term test of 72hours to confirm aquifer sustainability and obtain aquifer hydraulic parameters for modelling.
- Conceptualizing of hydrogeological model
- Numerical 3D modelling, to simulate the aquifers of the D73A quaternary catchment area and predict long term sustainability of groundwater supply and test feasibility of implementing development in SD2;
- Confirm management recommendations for production holes designed to ensure long term sustainability, taking the buffer effect of the aquifer into account; and
- Compile investigation report.

Groundwater Resources Assessment

Groundwater use

The existing groundwater users are divided into two main water user category's namely municipality and private use.

The estimate groundwater abstraction rates for SD2 modelling area is summarised in the table below.

Groundwater use	Borehole number	Abstraction Rate m ³ /Month	Abstraction Rate m ³ /Year
Postmasburg Municipality	SD2-GAA036; SD2-GAA037	41472	497664
Municipality Jen Haven Community	SD2-GAA002; SD2-GAA004	10368	124416
Private	226 Boreholes and fountains	51840	622080
Total Use		172 186.56	2 066 238.72

Groundwater Levels and Flow Direction

The regional groundwater flow direction for the SD2 study area is south west towards Postmasburg. 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.



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Groundwater Quality

The baseline water quality is based on macro chemical analysis of sampled exploration 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 for the new exploration boreholes complies with long term potable water quality standards and is summarised in the table below.

Item	Physical Parameters			Macro Determinants (Major Ions and Trace Metals)								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	39	39	39	39	39	39	39	39	39	39	39	39	39	33
10 % Percentile	7.24	43.2	308	42.5	22.6	12.1	2.27	20.3	13.4	1.93	166	0.1	0.05	0.05
Median Baseline water Quality	7.71	57.20	378	64.60	35.40	19.0	2.90	28.70	19.90	2.97	272.00	0.18	0.05	0.05
Average	7.70	58.29	414.54	65.14	37.09	22.02	3.34	39.89	22.06	4.05	258.82	0.21	0.06	0.16
90% Percentile	8.13	75.6	512	87.3	53.1	35	5.47	54.5	32.3	7.26	347	0.351	0.05	0.47
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 quality representative for SD2 study area are calcium magnesium bicarbonate type of water (Ca, Mg)(HCO₃)₂, representing unpolluted groundwater.

Aquifer Recharge

Eight recharge zones were delineated for the SD2 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	25	2.4	95	7.8	5.3	0.7	0.5	D73A	D73A-01
2	14.4	4.2	64	13.8	9.4	0.9	0.6	D73A	D73A-02
3	20	3	64	9.8	6.7	0.6	0.4	D73A	D73A-02
4	6	10	137	32.8	22.3	4.5	3.1	D73A	D73A-02
5	15	4	190	13.1	8.9	2.5	1.7	D73A	D73A-02
									D73A-03
									D73A-04
6	20	3	231	9.8	6.7	2.3	1.5	D73A	D73A-02
									D73A-03
									D73A-04
7	26	4	80	13.1	8.9	1.0	0.7	D73A	D73A-03
									D73A-04
8	29	2.1	91	6.9	4.7	0.6	0.4	D73A	D73A-04
Total			952	-	-	13.2	9.0	8	-



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The median recharge from rainfall (sustainable resource potential) for the SD2 study area is estimated at 9 million m³/annum and the long term mean annual recharge (inclusive of major rainfall events) at 13.2million m³/annum.

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 the GRDM methodology. Using the GRDM (Present day scenario for 2008) as a representative value for total inflow (recharge) and net base flow, there is a groundwater balance of 22.46 million m³/a available for use in the D73A 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
GRDM Present Day	3234	33.91	-1.82	-0.56	0	-32.08	-9.62	22.46	A

Groundwater Modelling

A numerical groundwater flow model was constructed for SD2 investigation area 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 during the study was converted into a 3D numerical model with 8 element layers, with discrete consideration of hydraulic conductivity zones and geological units in the SD2 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 (1999 to 2014).

The calibrated model was subsequently used to simulate the impacts of the proposed SD2 well fields on the groundwater environment. The historical rainfall period from 1997 to 2014 was extrapolated forward for the simulation period from 2014 to 2031 (17 years). To determine the optimal well field pumping rates while taking into consideration potential impacts on the groundwater system, three scenarios were assessed, namely an upper limit scenario (1), an optimised scenario (2) and scenario (3). These scenarios were compared against a base case or no-go scenario (0) of no future well field abstractions.

The predictive simulation model (scenario 3) with a maximum peak yield of 5.5Mm³/annum (from 21 boreholes, including 8 short term production boreholes) reveals a wide cone of water table drawdown due to the substantial abstraction in comparison to the regional recharge rate. Simulated drawdowns for the production boreholes range from 2 to 11 m, with an average of 7 m for the SD2 well field region. The cone of dewatering is in some areas clearly limited by the presence of dykes, which compartmentalise the aquifer system.

The volume of the proposed groundwater extracted by the SD2 production boreholes will largely originate from storage depletion and recharge rather than a reduction in the volume of groundwater reporting towards drainages and springs or to downstream catchments. Over the long-term, a new dynamic 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 by e.g. reduction in evapotranspiration losses or artificial recharge,) or reduced discharge (reducing the amount of water leaving the system). In drier or drought years the proposed abstractions exceed recharge and deplete the aquifer storage (amount of water stored in the subsurface), resulting in a significant drop of water table elevations. During significant recharge events in wetter years, changes in outflows and contribution to baseflow continue to occur until the water that was removed from storage is partially replenished.

Due to the intrinsic heterogeneity of the dolomitic groundwater system the potential impact of the groundwater abstractions on other groundwater users is not 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.

Conclusions

Based on the desktop studies, field investigations and resource assessment activities undertaken during this project, the following conclusions are made for the SD2 area:

- The Vaal Gamagara Water Supply study area (SD2) 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;
- Twenty eight high yielding boreholes were drilled with a combined air-lift yield of 503 l/s;
- Borehole test pumping in the SD2 area included twenty six higher yielding exploration boreholes subjected to 24 to 72 hour CDT's. The combined constant discharge rate of these tests was 456l/s;
- The following major aquifer systems were confirmed in the SD2 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.
- Major karstification zones in the dolomite are the main aquifer system is SD2 area, with borehole blow yields of up to 40.0l/s (SD2-26);
- Water level depths of the exploration boreholes range from to 5m to 60 with an average of 28m;
- Borehole management recommendations for the proposed well fields, scenario 3 (21 production boreholes) amounts to a short term (four months per annum) peak abstraction rate of **5 497 776m³/a**;
- The 3D numerical groundwater flow model was conducted to predict the impact of the proposed SD2 well field on the regional groundwater flow, aquifer recharge and discharge. The predictive simulation for scenario 3 (21 boreholes) with a combined abstraction of 5 497 776m³/a reveals an extended cone of depression with a 2m to 14.7m drawdown of the aquifer at production boreholes in the SD2 area;
- The individual borehole pumping rates for scenario 3 were optimised to limit water level drawdowns on the regional dolomite aquifer to within 4 to 6 m, to limit the additional risk of sinkhole occurrences as a result of lowering the water level depth. The average simulated dynamic water level drawdown for the 21 production boreholes is 7m. The cone of dewatering is in some areas clearly impacted on by the presence of dykes, which compartmentalise the aquifer system;
- The assumption is made that the dolerite dykes are permeable for +/- 4m below the current static water level, allowing groundwater interflow between compartments. Below 4m the dolerite dykes are



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impermeable and acts as groundwater flow barriers responsible for compartmentalization in the formations;

- Any volume of groundwater extracted by pumping in the SD2 production boreholes will be compensated by a reduction in outflow losses. 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);
- An intermediate groundwater reserve study was completed in 2008 for the Lower Vaal Water Management Area (WMA). The intermediate groundwater reserve determination was done using the GRDM methodology. Using the GRDM (Present day scenario for 2008) as a representative value for total inflow (recharge) and net base flow, there is a groundwater balance of 22.46 million m³/a available for use in the D73A quaternary catchment.

Recommendations

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

- A WULA to implement the 21 production boreholes to abstract **3 689 712m³/a** on a continuous basis over the long term and an additional **1 808 064m³/a** for a four months annual peak supply (**5 497 776m³/a combined**) to augment water supply to the VGWS. This represents an average annual abstraction of **4 292 400m³/a**.
- The recommended well field abstractions for SD2 are listed in table below:

Well Field	Number of BH's	Yield l/s	Long Term m ³ /m	Long Term m ³ /a	Peak Supply m ³ /m	Peak Supply m ³ /a	Long + Peak Supply Term m ³ /a
South	12	119	241776	2901312	57816	693792	3595104
South-West	1	10	0	0	21900	262800	262800
North	6	37	52560	630720	44676	536112	1166832
North-West	2	15	13140	157680	26280	315360	473040
Total	21	181	307 476	3 689 712	150 672	1 808 064	5 497 776

- All 21 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 SD2 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 SD2 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 north and south).
 - 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 DWS 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; and
 - Regional water level monitoring by DWS needs to be implemented in the modelling area and downstream below the modelling outflow boundary.



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
S	Storativity
GU	Groundwater Unit
GMU	Groundwater Management Unit
GMA	Groundwater Management Area
MAP	Mean Annual Precipitation
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water Affairs and Sanitation
NWRS	National Water Resource Strategy
T	Transmissivity
BIF	Banded Iron Stone Formation
WMA	Water Management Area
WRC	Water Research Commission
SANS	South African National Standard
RE	Recharge Estimates
PI	Pump Inlet
SD	Source Development
DD	Draw Down
a.m.s.l.	Above Mean Sea Level
BHN	Basic Human Need



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 development 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 an sufficient and sustainable manner towards achieving South Africa's development and socio-economic priorities in an equitable manner next five to 10 years.

This report documents the exploitability and sustainable potential of SD2 (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.



VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I

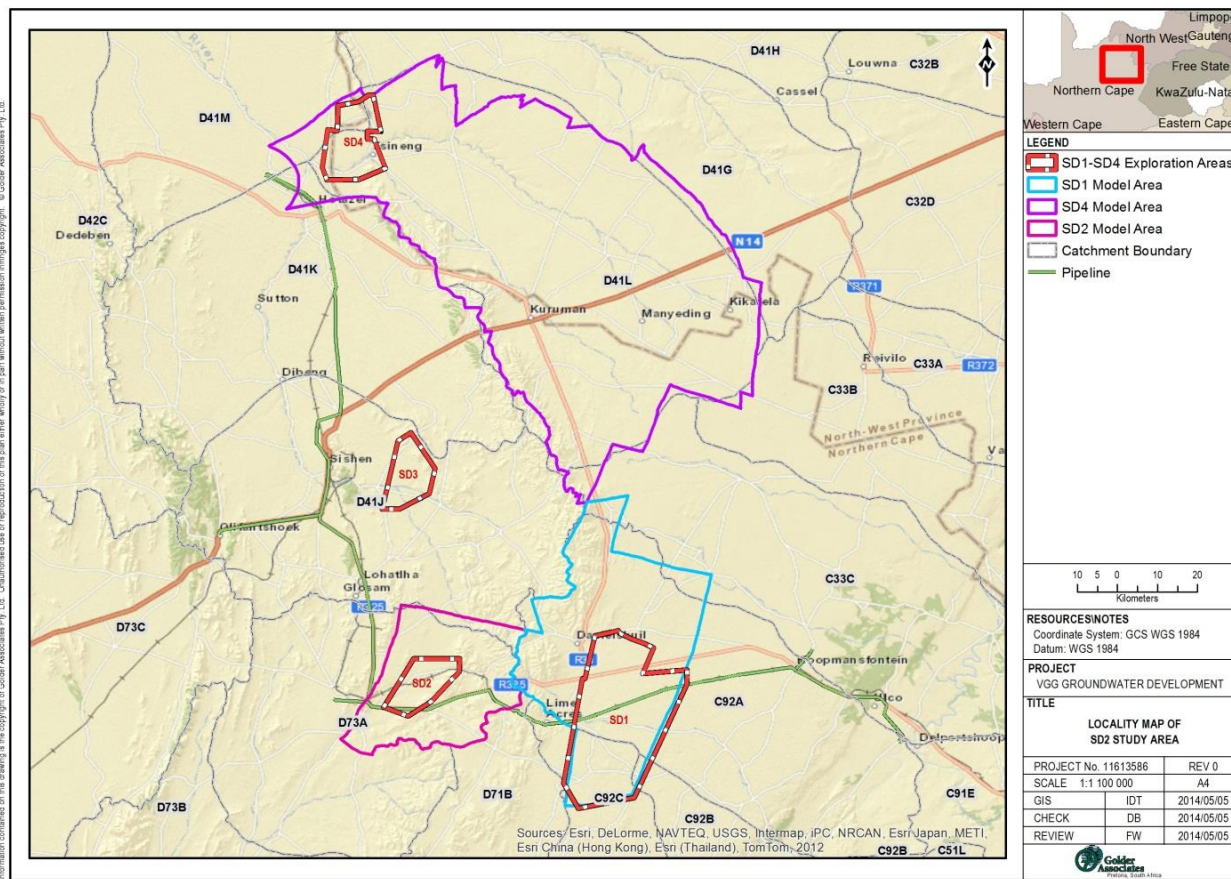


Figure 1: Locality Map of Source Development Areas

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 exiting 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) to characterize aquifer parameters;
- 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 SD2 modelling area and predict long term sustainability of groundwater supply and test feasibility of implementing development in SD2;
- Confirm management recommendations for production holes designed to ensure long term sustainability, taking the buffer effect of the aquifer into account; and
- Compile investigation report.

3.0 DESCRIPTION OF STUDY AREA

3.1 Location

SD2 investigation area falls under the jurisdiction of Tsantsabane Local Municipality (LM), of the ZF Mgcawu District Municipality (formerly Siyanda District) and is located in the Northern Cape Province. The study area is located north east of Postmasburg and extends north east to Jen Haven community.

The SD2 groundwater modelling area falls mainly onto the D73A quaternary catchment area and D41J quaternary catchment to the north, with the size of the modelling area (Figure 2) as 951km².

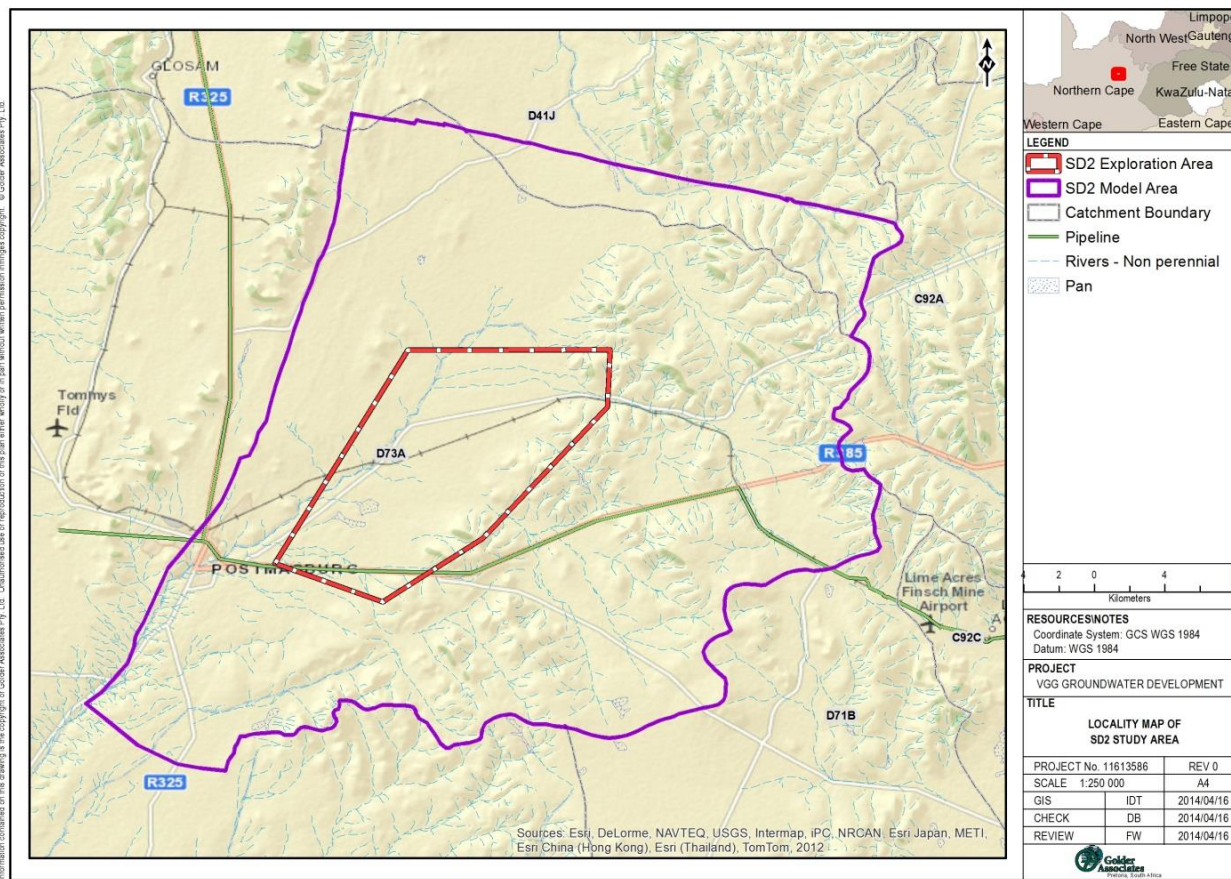


Figure 2: Locality Map of SD2 Study Area

3.2 Topography

The SD2 study area is situated on the southeastern flank of the Maremane Dome and the surface is fairly flat, apart from low irregular hills north east of Postmasburg and Asbestos Mountains in the east.

Most of the SD2 study area topography is characterized by the flat featureless Maremane Dome. Elevations gradually decline from Jen Haven community in the north east (approximately 1490mamsl) towards Postmasburg in the south west to 1320 mamsl.

The SD2 investigation area is bounded to the east by a broken mountain ridge, namely the Asbestos 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 1577mamsl at the highlands to 1320mamsl at the south-west of the investigation area. The irregularities on the escarpment are caused mostly by extensive mechanical erosion of various geological structures.

3.3 Surface Drainage

The SD2 study area fall into the Lower Vaal WMA, D73A quaternary catchment and is situated on the south-eastern flank of the Maremane Dome with no major drainage systems towards the Vaal River. Small localised pans exist and form part of a series of interior drainage basins which overflow occasionally during extremely high rainfall seasons, like during 1974 to 1976 period.

The study area is situated within the upper Groenwaterspruit catchment (Figure 3). Numerous streams collect runoff from the Asbestos Hills and flow westwards where they tend to disappear in the Kalahari



sands. Run-off accumulation in surface depressions can persist for several weeks until water has evaporated or infiltrated into the ground. The main drainage, namely the ephemeral Groenwaterspruit, drains towards the southwest until it's confluence with the non-perennial Southloop. While the Groenwaterspruit is for most parts of the year dry, it flows during rainfall periods and the lush vegetation along the stream channel indicate constant damp soil conditions.

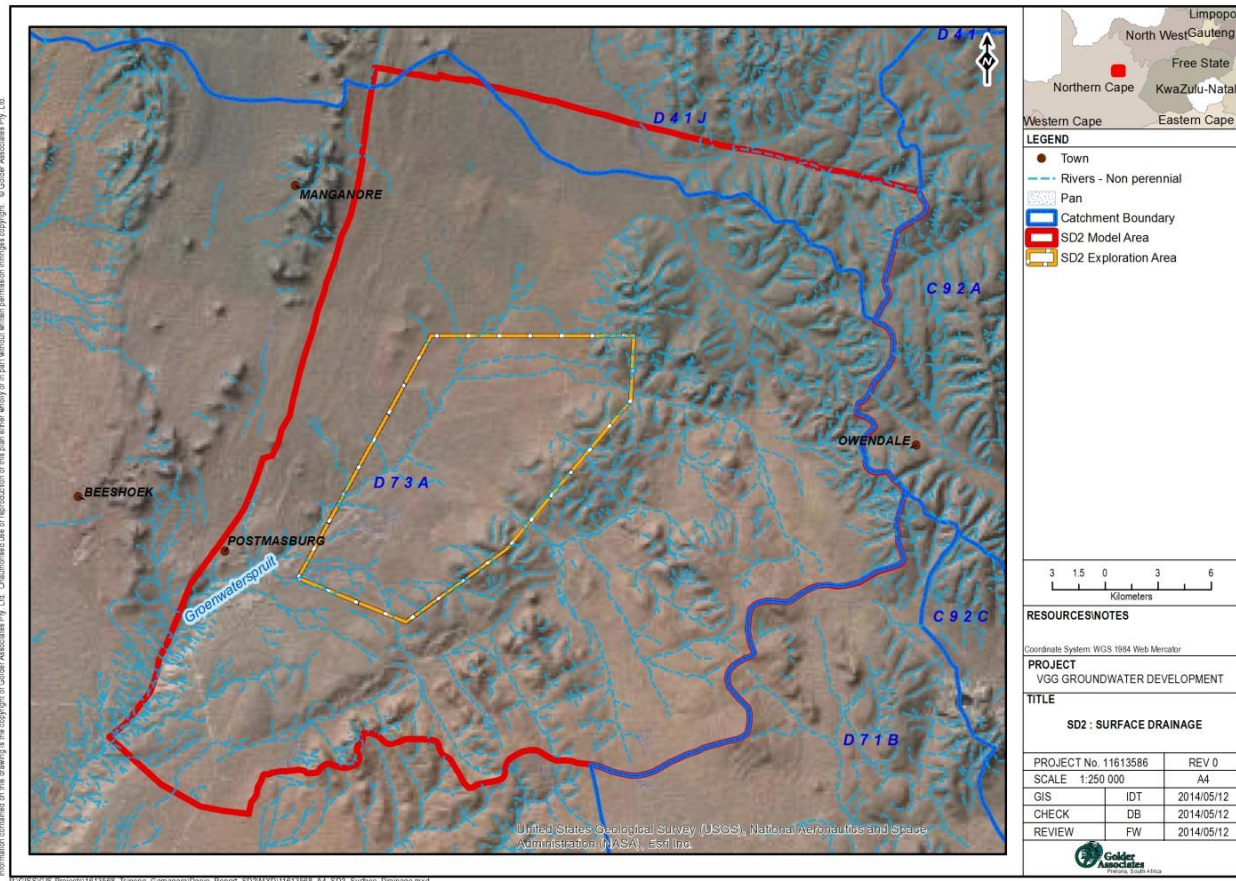


Figure 3: SD2 Surface Drainage

3.4 Vegetation

The SD2 study area is generally covered with natural grass lands, shrubs (Figure 4) and some thorn trees. The occurrence of shrubs and trees is determined by the availability of deeper soil moisture for more extensive root systems.

Generally the bedrock outcrop areas are sparsely vegetated, with greater abundance of shrubs and trees occurring along drainage areas and pans, along dykes and along the edge of scree slopes surrounding mountains to the east of the study area.

The 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.



Figure 4: Typical Grasslands and Shrubs in SD2 – Area

3.5 Climate and Rainfall

The SD2 study area lies in a semi – arid area. The climate of SD2 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.

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. 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 SD2 study area lies in the Lower Vaal WMA, in a summer rainfall region, with an irregular rainfall pattern and occurs mostly in the form of thunderstorms during January, February and March (Figure 6) 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 SD2 area is portrayed by Postmasburg rainfall stations. The MAP rainfall for Postmasburg rainfall station for the period 1917 to 2014 is indicated in Figure 5, with the MAP for the period as 328mm/a. The MAP distribution for the Lower Vaal WMA area is indicated in Figure 6 , indicating a decrease in rainfall from east to west.

The amount of annual rainfall and rainfall intensity (monthly rainfall) are the major driving forces of groundwater recharge.

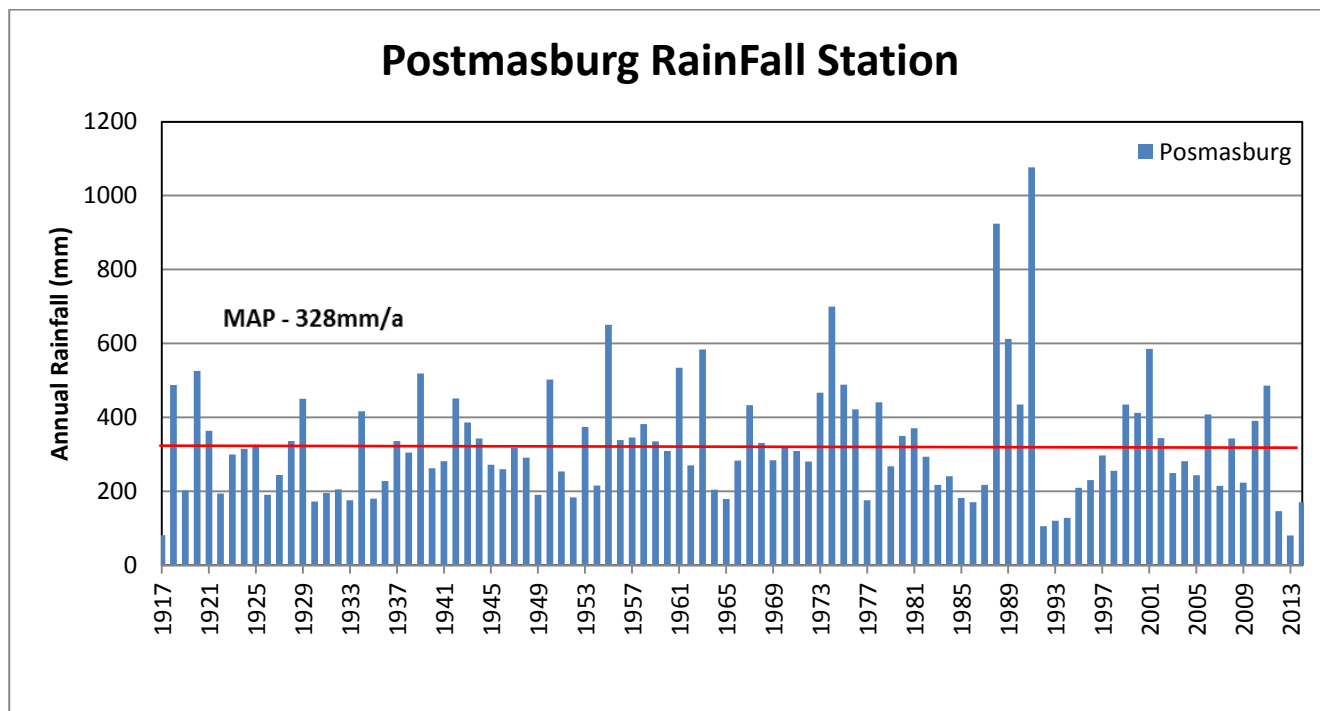


Figure 5: Postmasburg MAP (mm/a)

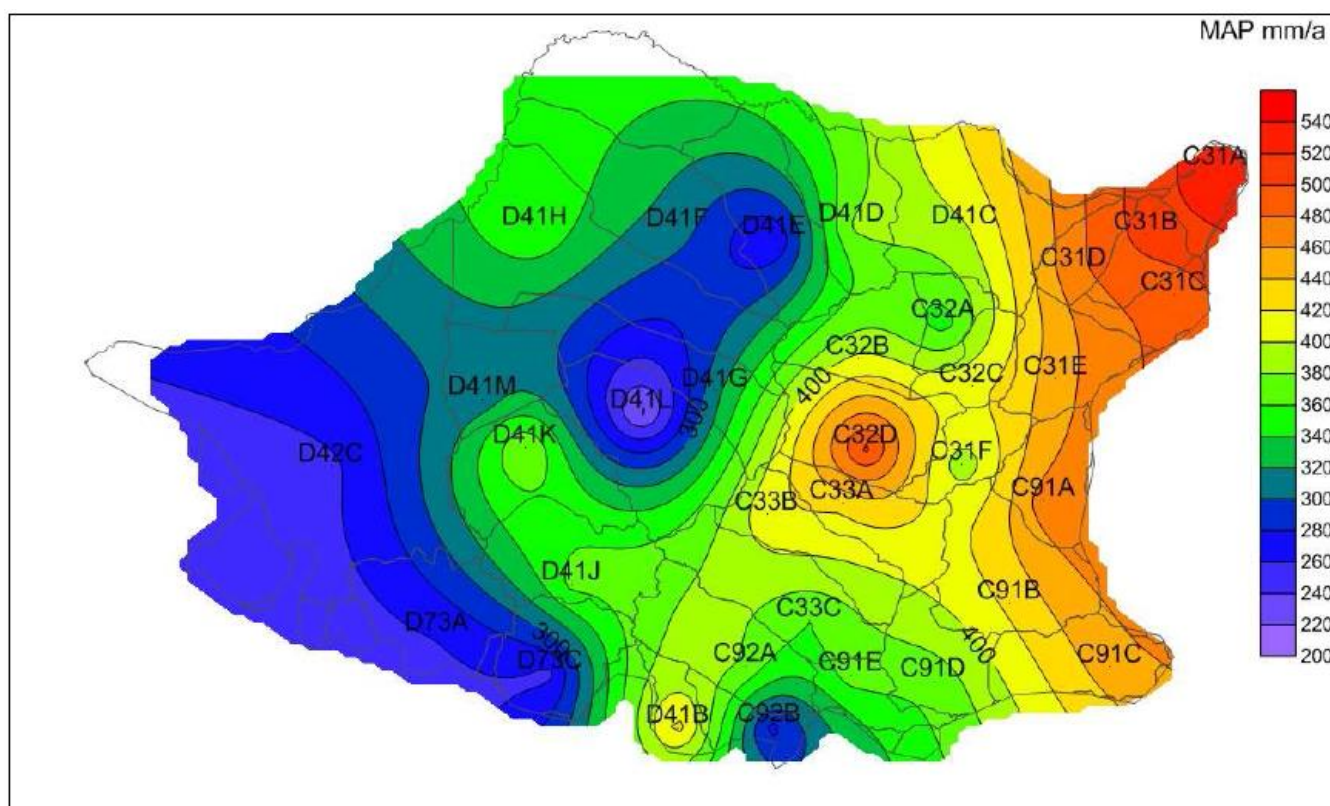


Figure 6: Lower Vaal Mean Annual Precipitation mm/a (MAP)



3.6 Local Geology

SD2 falls onto the Council of Geoscience 1:250 000, (2822 Map Reference) Postmasburg geology map and is shown in Figure 7.

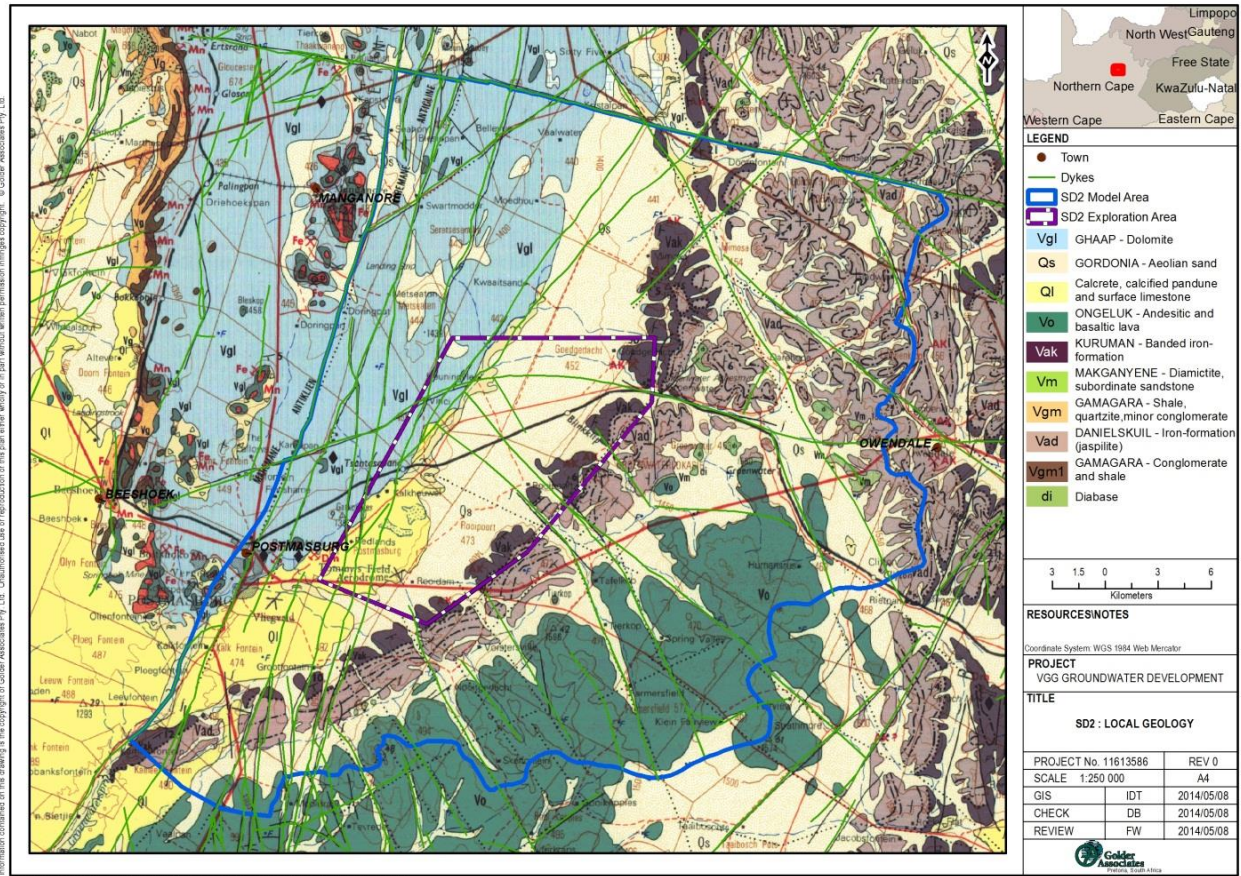


Figure 7: Local Geology

The Ventersdorp Supergroup overlies the basement granite and is unconformably overlain by the Vryburg and Schmidtsdrift Formations 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).



The Gamagara Formation was deposited on the Maremane Anticline and rests unconformably on dolomite and banded iron stone of the underlying formations. It consists of a basal conglomerate with pebbles of jasper, ironstone, shale with lenses of conglomerate, iron-rich flagstone and quartzite. The Formation has a thickness of 300m and when resting on banded ironstone are ferruginised and manganised where they lie on dolomite (Stettler 2013).

The Makganyane Formation lies unconformably on the Gamagara Formation, where the latter is developed and elsewhere it overlies the Asbesberge Subgroup conformably. The max thickness is less than 470m. A tillite occurs at the base of the formation and contains fragments of chert and jasper. Higher up in the succession alternating layers of grit, tillite, silicified mudstone and feldspathic quartzite occur. Dolomite or limestone occurs interbedded in the mudstone (Stettler 2013).

The Ongeluk Formation forms the lower part of the Olifantshoek Group. Andesitic lava belonging to this Formation crops out in the Dimoten Syncline and southeast of the Maremane Anticline and disappears under the sand cover further north. The Formation consists of grey-green lava with jasper amygdalae and lenses of red jasper (Stettler 2013).

The SD2 area specifically, it is situated on the southeastern flank of the Maremane Dome and the surface is mostly covered by Quaternary sand and calcrete, which overlies the Ongeluk lava Formation of the Olifantshoek Group. The Ongeluk Lava Formation overlies the Makganyane formation, Danielskuil (also named the Griquaastad Iron Formation) and Kuruman Formations which are underlain by the Campbell Rand Subgroup. The Kuruman and Danielskuil formation's may have a thrust contact with the Campbell Rand dolomite as will be discussed later in this report, but this has to be tested by field observations. The current geology map used in this report does not indicate this. The units targeted for groundwater are major faults in the Danielskuil and Kuruman formation's and low density highly permeable areas in the Campbell Rand dolomites (Stettler 2013).

Kalahari and Quaternary Deposits

The bedrock geology in the SD2 study area is partially concealed by sediments of the Kalahari group and Quaternary deposits. The Kalahari formation consists primarily of calcrete, gravel and clay beds. In the eastern parts of the study area the superficial cover becomes thin and patchy and large areas of bedrock are exposed.

Kalahari sediments with roughly a NE to SW strike direction (Figure 7 and Figure 31), which varies in thickness from millimetres to a few metres covers the middle part of the study area. Relatively thick deposits of calcrete occur as cappings of the dolerite rocks and normally causes a higher relief due to the expansion mechanism present in the calcification process.

Intrusive Structures

Intrusive dolerite dykes are a common feature in the SD2 study area but seldom outcrop. Dolerite dykes are typically observed as major linear structures and intersect the geological formations perpendicular. These dykes are subject 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 with low permeability compartmentalize the dolomite aquifer. The dyke/bedrock contact zones themselves represent on the other hand preferential groundwater flow paths.

The dykes act near surface as aquitards, restricting lateral water flow. At depth, the dykes become fresh rocks and act as aquicludes, preventing water flow across them.



3.7 Hydrogeology

3.7.1 Aquifer Types and Groundwater Occurrence

Groundwater resources occur throughout the SD2 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.

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 and springs.

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 and Sanitation (DWS) National Groundwater Archive (NGA). The NGA is a National groundwater database initiated and driven by DWS. Groundwater information is captured from numerous government and private projects. This borehole information is available through data request to DWS and some of the borehole information is online obtainable;
 - Borehole information from Golder's in-house database (Aquabase); and
 - Monitoring data from the DWS Kimberley office.
- Previous hydrogeological reports consisting out of resource assessment, development, and monitoring studies from DWS 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

A GIS mapping exercise was conducted, using 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 assist with the preparation of a Communication and Stakeholder Engagement Strategy to secure and sustain stakeholder involvement during the project assessment phase through pro-active and transparent 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 SD2 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 SD2.

4.4 Hydrocensus

An extensive hydrocensus was conducted within the SD2 investigation area during 2012 and 2013. The hydrocensus also included groundwater users with high abstraction rates, namely Postmasburg municipality boreholes and Jen Haven community production boreholes.

During the hydrocensus, 142 boreholes were surveyed in the SD2 study area with the co-operation of the land owners. The hydrocensus survey could not be conducted on some private land areas as some farmers not allowing access. To maintain good relationships with landowners access was not forced as alternative options were available.

Only one fountain SD2-GAA083 was confirmed within the SD2 investigation area.

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;
- Identify borehole use and equipment;
- Estimate abstraction – existing use;
- Land owners;
- Record GPS coordinates of boreholes;
- Measure static water levels;
- Collect representative groundwater samples to determine reference groundwater quality;
- Collect water samples at fountains; and
- Measure field parameters (pH, EC) of samples.



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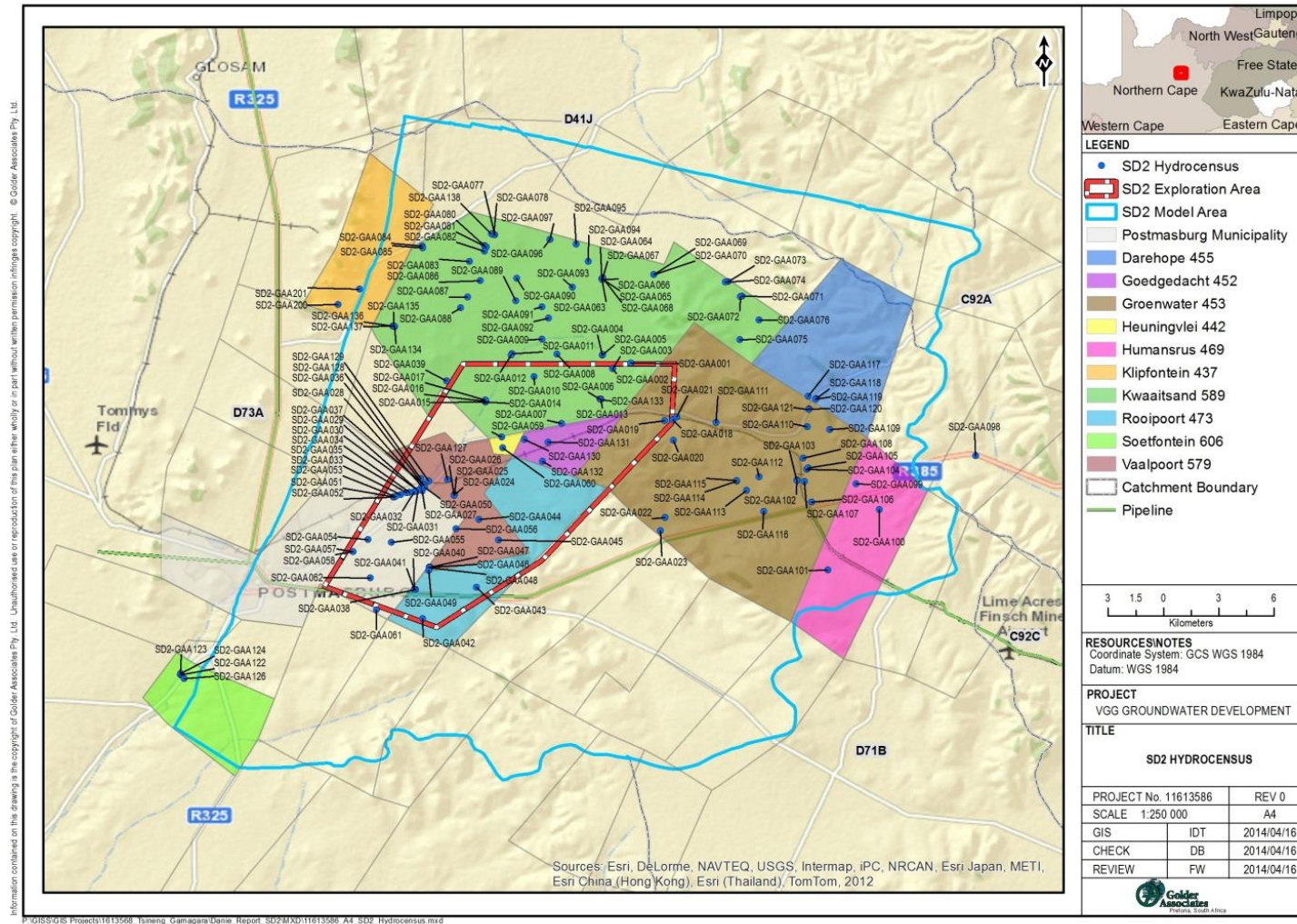


Figure 8: SD2 Hydrocensus Borehole Positions



4.4.1 Discussion

From the borehole information obtained during the hydrocensus the recorded borehole depths of the existing boreholes vary between 2.8m and 176m with an average depth of 67.3m.

From the 142 boreholes listed in Table 1 water levels were measured at 111 existing boreholes. The groundwater levels of SD2 range between 0.32m (SD1-GAA098) along the Groenwaterspruit and 64.12m (SD2-GAA069), with an average water level of 20.12mbgl (metre below ground level).

The reported borehole discharge rates for the investigation area range between 0.37l/s (SD2-GAA042) to 30l/s (SD2-GAA200 Sedibeng mine) with an average discharge rate of 4.4l/s.

Field parameters including pH and EC were measured in the field 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 field values range between 6.43 (SD2-GAA019) and 9.39 (SD2-GAA083) with an average of 7.81(alkaline). The measured pH values are within the accepted quality range of 5 to 10 and is typical of the host formations comprising out of dolomite, BIF and calcrete of the investigation area; and
- The measured EC values range between 9.0 (SD2-020) and 362mS/m (SD2-GAA015) with an average of 85.13mS/m. Only SD2-GAA015 and SD2-019 exceeds the DWAF 1998 Class 1 drinking water limit of 150mg/l. Both of these boreholes are open boreholes and unprotected at surface and with elevated EC concentration are probably related local point source pollution.

A total of 37 water samples were collected at existing boreholes during the hydrocensus and test pumping of existing boreholes 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 domestic all purpose (DA) and stock watering (AS).



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Table 1: Summarised Hydrocensus Borehole Information

Borehole Number	Farm Name/Property	Owner/Representative	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
SD2-GAA001	GOEDGEDACHT PTN. JEN-HAVEN	JEN HAVEN COMMUNITY	-28.21998	23.25417	113.00	-	-	36.52	-	-	M	DA	2013/01/18
SD2-GAA002	GOEDGEDACHT PTN. JEN-HAVEN	JEN HAVEN COMMUNITY	-28.22272	23.24516	86.00	-	-	41.74	68	7.63	S	DA	2012/05/17
SD2-GAA003	GOEDGEDACHT PTN. JEN-HAVEN	JEN HAVEN COMMUNITY	-28.22123	23.24266	-	-	-	46.64	61	7.68	N	-	2012/04/13
SD2-GAA004	GOEDGEDACHT PTN. JEN-HAVEN	JEN HAVEN COMMUNITY	-28.21604	23.24010	88.55	20.41	-	45.34	-	-	N	-	2014/04/01
SD2-GAA005	GOEDGEDACHT PTN. JEN-HAVEN	JEN HAVEN COMMUNITY	-28.21577	23.24045	80.00	-	-	44.5	-	-	N	-	2012/04/13
SD2-GAA006	GOEDGEDACHT PTN. JEN-HAVEN	JEN HAVEN COMMUNITY	-28.23760	23.23915	-	-	-	48.2	-	-	W	AS	2012/04/13
SD2-GAA007	GOEDGEDACHT PTN. JEN-HAVEN	JEN HAVEN COMMUNITY	-28.24943	23.22040	-	-	-	53.73	35	8.1	W	AS	2012/04/13
SD2-GAA008	FARM 442 PTN. GELUK	C OLIVIER	-28.21557	23.21815	60.96	-	-	-	-	-	W	DA	2012/04/13
SD2-GAA009	FARM 442 PTN. GELUK	C OLIVIER	-28.20826	23.21069	-	-	-	12.65	74	7.77	W	AS	2012/04/13
SD2-GAA010	FARM 442 PTN. ELLENDALE	WILLIAM JARVIS	-28.22652	23.20682	79.24	4.02	-	32	-	-	W	DA	2014/04/01
SD2-GAA011	FARM 442 PTN. ELLENDALE	WILLIAM JARVIS	-28.21529	23.19622	69.00	1.02	-	14.51	66	7.19	W	AS	2014/04/01
SD2-GAA012	FARM 442 PTN. ELLENDALE	WILLIAM JARVIS	-28.21611	23.19569	-	-	-	9.42	-	-	N	-	2012/04/13
SD2-GAA013	GOEDGEDACHT PTN. JEN-HAVEN	JEN HAVEN COMMUNITY	-28.23764	23.23948	88.20	0.84	-	49.05	-	-	N	-	2014/04/01
SD2-GAA014	FARM 442 PTN. HEUNINGVLEI	J.A. CLOETE	-28.23902	23.18340	-	-	-	-	91	7.14	W	DA	2012/04/13
SD2-GAA015	FARM 442 PTN. HEUNINGVLEI	J.A. CLOETE	-28.23891	23.18299	75.00	-	-	7.44	362	7.18	N	-	2012/04/13
SD2-GAA016	FARM 442 PTN. HEUNINGVLEI	J.A. CLOETE	-28.23857	23.18257	60.00	-	-	7.47	-	-	N	-	2012/04/13
SD2-GAA017	FARM 442 PTN. HEUNINGVLEI	J.A. CLOETE	-28.23791	23.18299	-	-	-	-	-	-	N	-	2012/04/13
SD2-GAA018	GROENWATER	Groenwater Community(James Koloje)	-28.24769	23.27466	110.00	-	3.3	44.64	72	7.84	N	-	2013/01/18
SD2-GAA019	GROENWATER	Groenwater Community(James Koloje)	-28.24812	23.27069	-	-	-	54.22	159	6.43	N	-	2012/04/13
SD2-GAA020	GROENWATER	Groenwater Community(James Koloje)	-28.25769	23.27490	-	-	-	26.83	9	7.01	N	-	2012/05/17
SD2-GAA021	GROENWATER	Groenwater Community(James Koloje)	-28.24604	23.27655	-	1.0	-	39.43	40	7.5	Q	DA	2013/01/18
SD2-GAA022	GROENWATER PTN. TAFELKOP	Groenwater Community(James Koloje)	-28.29536	23.27086	-	-	-	19.75	-	-	Q	DA	2012/04/13
SD2-GAA023	GROENWATER	Groenwater Community(James Koloje)	-28.30173	23.26853	-	-	-	18.10	77	7.25	W	AS	2013/01/17
SD2-GAA024	VAALPOORT	ROUX VAN DER MERWE	-28.28436	23.16785	-	-	-	19.89	-	-	S	-	2012/04/16
SD2-GAA025	VAALPOORT	ROUX VAN DER MERWE	-28.28426	23.16801	-	-	-	20.04	-	-	S	DA	2012/04/16
SD2-GAA026	VAALPOORT	ROUX VAN DER MERWE	-28.28450	23.16786	-	-	-	-	-	-	W	DA	2012/04/16
SD2-GAA027	POSTMASBURG GATKOPPIES	NOENOE FOURIE	-28.28233	23.15231	-	2.0	-	-	108	7.85	S	DA	2012/05/17



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Borehole Number	Farm Name/Property	Owner/Representative	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
SD2-GAA028	POSTMASBURG GATKOPPIES	NOENOE FOURIE	-28.28005	23.15207	12.00	-	-	6.35	-	-	N	-	2013/01/18
SD2-GAA029	POSTMASBURG PTN. KLEIN SION	BERTIE MULLER	-28.28210	23.15022	100.00	-	-	-	-	-	M	DA	2012/04/16
SD2-GAA030	POSTMASBURG PTN. DIE NAWEEK	PIET LE ROUX	-28.28217	23.15024	36.00	-	-	8.11	-	-	S	DA	2013/01/18
SD2-GAA031	POSTMASBURG PTN. DIE NAWEEK	PIET LE ROUX	-28.28218	23.15030	176.00	-	-	-	-	-	N	-	2013/01/18
SD2-GAA032	POSTMASBURG PTN. KLEIN SION	BERTIE MULLER	-28.28276	23.14827	50.00	-	-	8.67	-	-	S	DA	2012/04/16
SD2-GAA033	POSTMASBURG PTN. DIE GREWE	JOHAN GREEFF	-28.28422	23.14174	30.00	-	-	7.63	-	-	S	DA	2012/04/16
SD2-GAA034	POSTMASBURG PTN. DIE GREWE	JOHAN GREEFF	-28.28292	23.14616	-	-	-	4.2	-	-	S	DA	2012/04/16
SD2-GAA035	POSTMASBURG PTN. DIE GREWE	JOHAN GREEFF	-28.28315	23.14461	-	-	-	6.11	-	-	W	AS	2012/04/16
SD2-GAA036	VAALPOORT (GATKOPPIES1)	Postmasburg municipality borehole	-28.27968	23.15286	50.00	-	-	9	-	-	S	DA	2013/01/17
SD2-GAA037	VAALPOORT	W COETZEE - Municipality Use BH	-28.27928	23.15313	15.00	-	-	9.69	69	7.27	N	DA	2013/01/16
SD2-GAA038	VINCI	AUTHER OLIVIER(Jen Haven Community)	-28.22853	23.16411	-	-	-	-	79	7.41	W	AS	2012/04/13
SD2-GAA039	ROOIPOORT PTN. ROOIDAM	BENNIE BREDENKAMP	-28.33045	23.14897	-	0.8	-	19.65	-	-	W	DA	2012/05/17
SD2-GAA040	ROOIPOORT PTN. ROOIDAM	BENNIE BREDENKAMP	-28.33037	23.14840	51.81	1.26	-	19.54	-	-	W	DA	2012/04/16
SD2-GAA041	ROOIPOORT PTN. ROOIDAM	BENNIE BREDENKAMP	-28.33056	23.14827	36.57	-	-	16.12	-	-	Q	DA	2012/04/16
SD2-GAA042	ROOIPOORT PTN. ROOIDAM	BENNIE BREDENKAMP	-28.34478	23.15257	51.81	0.37	-	28.43	67	6.98	W	AS	2012/05/17
SD2-GAA043	ROOIPOORT PTN. ROOIDAM	BENNIE BREDENKAMP	-28.32947	23.17871	71.62	2.52	-	48.47	-	-	W	AS	2012/04/16
SD2-GAA044	ROOIPOORT PTN. VAALPOORT	ROUX VAN DER MERWE	-28.29630	23.18000	-	-	-	-	65	7.25	M	AS	2012/05/17
SD2-GAA045	ROOIPOORT PTN. VAALPOORT	ROUX VAN DER MERWE	-28.30635	23.18943	-	-	-	-	-	-	W	AS	2012/04/16
SD2-GAA046	ROOIPOORT PTN. VAALPOORT	ANDRIES CORDIER	-28.31966	23.15574	30.48	-	-	21.35	-	-	S	-	2012/04/16
SD2-GAA047	ROOIPOORT PTN. VAALPOORT	ANDRIES CORDIER	-28.31950	23.15625	51.80	-	-	19.96	-	-	N	-	2012/04/16
SD2-GAA048	ROOIPOORT PTN. VAALPOORT	ANDRIES CORDIER	-28.31981	23.15598	-	-	-	24.69	-	-	W	DA	2012/04/16
SD2-GAA049	ROOIPOORT PTN. VAALPOORT	ANDRIES CORDIER	-28.32107	23.15547	-	-	-	23.74	62	7.28	W	DA	2012/05/17
SD2-GAA050	POSTMANSBURG	MUNICIPALITY BOREHOLE	-28.28048	23.15353	30.00	-	-	-	-	-	N	-	2014/04/02
SD2-GAA051	POSTMASBURG PTN. GATKOPPIES	MARIANNA MATHEE	-28.28522	23.13888	-	-	-	0.32	-	-	N	-	2012/04/16
SD2-GAA052	POSTMASBURG PTN. GATKOPPIES	MARIANNA MATHEE	-28.28534	23.13804	-	-	-	5.32	-	-	N	-	2012/04/16
SD2-GAA053	POSTMASBURG PTN. GATKOPPIES	MARIANNA MATHEE	-28.28508	23.13914	-	-	-	5.96	103	6.56	S	DA	2012/05/17
SD2-GAA054	POSTMASBURG	Postmasburg Municipality - NOOI DE BRUIN	-28.30610	23.12586	30.00	-	5.56	16.17	-	-	S	DA	2013/01/18



VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I

Borehole Number	Farm Name/Property	Owner/Representative	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
SD2-GAA055	POSTMASBURG	Postmasburg Municipality - HANS VAN WYK	-28.30746	23.13713	-	-	-	-	65	7.34	W	DA	2012/04/16
SD2-GAA056	POSTMASBURG	Postmasburg Municipality - VYTJIE NEELS	-28.30083	23.16884	-	-	-	21.33	-	-	W	AS	2012/04/16
SD2-GAA057	POSTMASBURG PTN. REDLANDS	PIETER STAFFORD	-28.31209	23.11838	-	-	-	11.59	-	-	S	-	2012/04/16
SD2-GAA058	POSTMASBURG PTN. REDLANDS	PIETER STAFFORD	-28.31212	23.11843	-	8.19	-	-	-	-	M	DA	2012/04/16
SD2-GAA059	FARM 442 PORTION 5 KLEIN GOEDGEDACHT	ATTIE BRITS	-28.25612	23.19102	-	-	-	33.36	-	-	N	-	2013/01/18
SD2-GAA060	FARM 445 PORTION 5 KLEIN GODEGEDACHT	ATTIE BRITS	-28.26128	23.19161	83.00	1.39	-	-	77	7.6	M	DA	2012/10/23
SD2-GAA061	POSTMASBURG	Postmasburg Municipality - BOOI PIETERSE	-28.34024	23.12997	-	-	-	-	120	7.58	W	DA	2012/10/23
SD2-GAA062	POSTMASBURG	TOWNSON	-28.32473	23.12700	-	-	-	-	84	7.77	W	DA	2012/10/23
SD2-GAA063	PLAAS 441 PTN. JO-DIEN	JOHNNY CLOETE	-28.17880	23.23988	-	-	-	17.18	65	9.21	W	AS	2013/07/08
SD2-GAA064	GOEDGEDACHT PTN. JO-DIEN	JOHNNY CLOETE	-28.17888	23.23999	-	-	-	32.65	-	-	W	-	2013/06/06
SD2-GAA065	GOEDGEDACHT PTN. JO-DIEN	JOHNNY CLOETE	-28.17894	23.24010	-	-	-	21.85	-	-	N	-	2013/06/06
SD2-GAA066	GOEDGEDACHT PTN. JO-DIEN	JOHNNY CLOETE	-28.17929	23.24013	-	-	-	-	-	-	N	-	2013/06/06
SD2-GAA067	FARM 441	MARTIENS WILLEMSE	-28.17843	23.24040	-	-	-	-	-	-	N	-	2013/06/06
SD2-GAA068	FARM 441	MARTIENS WILLEMSE	-28.17841	23.24042	-	-	-	-	-	-	W	DA	2013/06/06
SD2-GAA069	FARM 441 PTN. 5	MARTIENS WILLEMSE	-28.17681	23.26721	76.20	-	-	64.12	-	-	N	-	2013/06/06
SD2-GAA070	FARM 441	MARTIENS WILLEMSE	-28.17686	23.26540	146.00	0.51	-	56.26	73	9.34	M	DA	2014/04/01
SD2-GAA071	MIMOSA	JACOLIEN MATHYS	-28.18727	23.30852	-	-	-	-	-	-	W	DA	2014/03/10
SD2-GAA072	MIMOSA	JACOLIEN MATHYS	-28.18756	23.30760	-	-	-	-	-	-	N	-	2013/06/06
SD2-GAA073	MIMOSA PTN. KOEDOSHOCK	JACOLIEN MATHYS	-28.18026	23.30169	-	-	-	10.46	-	-	W	-	2013/06/06
SD2-GAA074	MIMOSA PTN. KOEDOSHOCK	JACOLIEN MATHYS	-28.18052	23.30025	-	-	-	-	19	9.19	W	DA	2013/07/08
SD2-GAA075	MIMOSA PTN. MICH-WILL	MICHEAL WILLEMSE	-28.20852	23.30737	-	-	-	33.39	-	-	W	AS	2013/06/06
SD2-GAA076	MIMOSA PTN. MICH-WILL	MICHEAL WILLEMSE	-28.19886	23.31667	-	-	-	6.77	-	-	W	DA	2013/06/06
SD2-GAA077	SERETSESENCHO PTN. SION	JOHN STAPLETON	-28.15734	23.18757	138.38	1.01	-	12.46	-	-	N	-	2014/04/01
SD2-GAA078	SERETSESENCHO PTN. SION	JOHN STAPLETON	-28.15735	23.18725	81.76	0.74	-	16.36	-	-	N	-	2014/04/01
SD2-GAA080	SERETSESENCHO PTN. SION	JOHN STAPLETON	-28.16254	23.18262	39.70	0.4	-	31.22	-	-	N	-	2014/04/01
SD2-GAA081	SERETSESENCHO PTN. SION	JOHN STAPLETON	-28.16328	23.18346	76.80	4.05	-	32.07	-	-	W	AS	2014/04/01
SD2-GAA082	SERETSESENCHO PTN. SION	JOHN STAPLETON	-28.16546	23.18267	68.56	1.23	-	5.95	148	9.22	M	DA	2014/04/01



VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I

Borehole Number	Farm Name/Property	Owner/Representative	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
SD2-GAA083	SERETSESENCHO PTN. SION	SAMUEL WILLEMSE	-28.17045	23.17517	-		-		88	9.39	N	-	2013/07/08
SD2-GAA084	SERETSESENCHO PTN. SWARTMODDER	SAMUEL WILLEMSE	-28.16276	23.15214	-	4.44	-	10.57	73	8.89	W	DA	2014/04/01
SD2-GAA085	SERETSESENCHO PTN. SWARTMODDER	SAMUEL WILLEMSE	-28.16388	23.15252	-	0.92	-	14.06	-	-	N	-	2014/04/01
SD2-GAA086	SERETSESENCHO PTN. SWARTMODDER	SAMUEL WILLEMSE	-28.17986	23.18057	78.68	0.52	-	8.47	-	-	N	-	2014/04/01
SD2-GAA087	SERETSESENCHO PTN. SWARTMODDER	SAMUEL WILLEMSE	-28.18767	23.17433	45.90	1.06	-	9.36	-	-	W	AS	2014/04/01
SD2-GAA088	SERETSESENCHO PTN. WELTEVREDEN	ANDRIES WILLEMSE	-28.19296	23.17101	-	-	-		-	-	W	DA	2013/06/06
SD2-GAA089	FARM 442 PTN. (8) GELUK	Christo OLIVER	-28.18957	23.19783	-	-	-	5.75	-	-	W	AS	2013/06/06
SD2-GAA090	FARM 442 PTN. KWAAITSAND	JANIE NEELS	-28.17862	23.19847	-	-	-		-	-	W	AS	2013/06/06
SD2-GAA091	FARM 442 PTN. KWAAITSAND	JANIE NEELS	-28.19255	23.21065	-	-	-	11.46	-	-	W	DA	2013/06/06
SD2-GAA092	FARM 442 PTN. KWAAITSAND	JANIE NEELS	-28.19797	23.21387	-	-	-	26.07	65	8.54	W	DA	2013/07/09
SD2-GAA093	FARM 442 PTN. JO-DIEN	JOHNNY CLOETE	-28.18300	23.22549	-	-	-	11.63	-	-	W	AS	2013/06/06
SD2-GAA094	FARM 440 PTN. MOEDHOU	WINSTON/VAUGHN AYTON	-28.17041	23.23339	-	-	-	13.32	-	-	W	AS	2013/06/06
SD2-GAA095	FARM 440 PTN. MOEDHOU	WINSTON/VAUGHN AYTON	-28.16184	23.22736	-	-	-		-	-	W	DA	2013/06/06
SD2-GAA096	FARM 440 PTN. MOEDHOU	WINSTON/VAUGHN AYTON	-28.15974	23.21468	41.50	-	-	3.69	-	-	N	-	2013/06/06
SD2-GAA097	FARM 440 PTN. MOEDHOU	WINSTON/VAUGHN AYTON	-28.15966	23.21461	-	-	-		95	8.69	M	DA	2013/07/08
SD2-GAA098	FARM 457 PTN. OWENDALE	PIET DU TOIT	-28.26528	23.42261	80.00	0.63	-	25.50	-	-	S	DA	2014/01/22
SD2-GAA099	FARM 469 PTN. HUMANSRUS	ALAN SCHOLTZ	-28.27900	23.36409	-	-	-	42.65	-	-	S	DA	2013/07/03
SD2-GAA100	FARM 469 PTN. HUMANSRUS	ALAN SCHOLTZ	-28.29153	23.37533	-	-	-	35.37	-	-	W	AS	2013/07/03
SD2-GAA101	FARM 469 PTN. HUMANSRUS	ALAN SCHOLTZ	-28.32083	23.35034	20.33	-	-	20.15	-	-	W	-	2013/07/03
SD2-GAA102	GROENWATER	Groenwater Community(C Hatting)	-28.27703	23.33520	-	-	-	6.64	-	-	H	DA	2013/07/03
SD2-GAA103	GROENWATER	Groenwater Community(C Hatting)	-28.27719	23.33526	10.66	-	-	6.52	-	-	W	DA	2013/07/03
SD2-GAA104	GROENWATER	Groenwater Community(C Hatting)	-28.27188	23.34001	79.24	18.94	-	5.20	-	-	N	-	2013/07/03
SD2-GAA105	GROENWATER	Groenwater Community(C Hatting)	-28.27122	23.34066	27.43	-	-	6.14	-	-	N	-	2013/07/03
SD2-GAA106	GROENWATER	Groenwater Community(C Hatting)	-28.28774	23.34242	-	-	-	8.15	-	-	N	-	2013/07/03
SD2-GAA107	GROENWATER	Groenwater Community(C Hatting)	-28.27771	23.33893	27.43	-	-	4.04	-	-	W	AS	2013/07/03
SD2-GAA108	GROENWATER	Groenwater Community(C Hatting)	-28.26626	23.33827	8.53	-	-	3.63	-	-	H	DA	2013/07/03



VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I

Borehole Number	Farm Name/Property	Owner/Representative	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
SD2-GAA109	GROENWATER	Groenwater Community(C Hatting)	-28.25240	23.35118	51.81	10.1	-	25.48	-	-	W	AS	2013/07/03
SD2-GAA110	GROENWATER	Groenwater Community(C Hatting)	-28.25111	23.34034	48.76	-	-	11.34	-	-	M	DA	2013/07/03
SD2-GAA111	GROENWATER	Groenwater Community(C Hatting)	-28.24887	23.29572	-	-	-	13.92	-	-	S	AS	2013/07/03
SD2-GAA112	GROENWATER	Groenwater Community(C Hatting)	-28.27539	23.31678	54.86	-	-	23.98	-	-	H	DA	2013/07/03
SD2-GAA113	GROENWATER	Groenwater Community(C Hatting)	-28.28211	23.31066	64.00	-	-	26.32	-	-	S	DA	2013/07/03
SD2-GAA114	GROENWATER	Groenwater Community(C Hatting)	-28.27742	23.30573	-	-	-	14.96	-	-	S	AS	2013/07/03
SD2-GAA115	GROENWATER	Groenwater Community(C Hatting)	-28.27740	23.30571	-	-	-	14.84	-	-	N	-	2013/07/03
SD2-GAA116	GROENWATER PNT 4	Groenwater Community(C Hatting)	-28.29228	23.31897	73.00	-	4.0	24.35	-	-	N	AD	2013/07/03
SD2-GAA117	FARM 455 PTN. DAREHOPE	MIENKIE STEENKAMP	-28.23607	23.34082	-	-	-	23.03	-	-	M	DA	2013/07/03
SD2-GAA118	FARM 455 PTN. DAREHOPE	MIENKIE STEENKAMP	-28.23735	23.34450	-	-	-	27.44	-	-	W	DA	2013/07/03
SD2-GAA119	FARM 455 PTN. DAREHOPE	MIENKIE STEENKAMP	-28.23753	23.34429	-	-	-	21.69	-	-	S	DA	2013/07/03
SD2-GAA120	GROENWATER	Groenwater Community(C Hatting)	-28.24237	23.34112	102.00	-	-	21.89	-	-	N	-	2013/07/03
SD2-GAA121	GROENWATER	Groenwater Community(C Hatting)	-28.24259	23.34100	150.00	-	-	19.9	-	-	N	AD	2013/07/03
SD2-GAA122	SOETFONTEIN	ALBERTUS VILJOEN	-28.37205	23.03445	128.00	-	-	5.08	-	-	S	DA	2013/07/03
SD2-GAA123	SOETFONTEIN	ALBERTUS VILJOEN	-28.37197	23.03421	-	-	-	5.94	-	-	S	DA	2013/07/03
SD2-GAA124	SOETFONTEIN	ALBERTUS VILJOEN	-28.37150	23.03444	-	-	-	5.73	-	-	S	DA	2013/07/03
SD2-GAA125	ROOIPAN	ALBERTUS VILJOEN	-28.37155	23.63461	-	-	-	5.5	-	-	N	-	2014/01/22
SD2-GAA126	SOETFONTEIN	ALBERTUS VILJOEN	-28.37401	23.03591	-	-	-	6.74	-	-	N	-	2013/07/03
SD2-GAA127	VAALPOORT	LOEKIE VAN DER MERWE	-28.27681	23.16467	-	-	-	15.89	-	-	S	AS	2013/11/04
SD2-GAA128	VAALPOORT	LOEKIE VAN DER MERWE	-28.27637	23.15168	-	-	-	-	-	-	S	DA	2013/11/04
SD2-GAA129	VAALPOORT	LOEKIE VAN DER MERWE	-28.27753	23.15546	-	-	-	10.33	-	-	S	DA	2013/11/04
SD2-GAA130	GOEDGEDACHT	LOEKIE VAN DER MERWE	-28.25723	23.20215	-	5.556	-	-	-	-	W	AS	2014/01/27
SD2-GAA131	GOEDGEDACHT	LOEKIE VAN DER MERWE	-28.25864	23.21376	-	5.556	-	46.04	-	-	S	AS	2014/01/27
SD2-GAA132	GOEDGEDACHT	LOEKIE VAN DER MERWE	-28.26804	23.21092	-	-	-	41.73	-	-	N	-	2014/01/27
SD2-GAA133	GOEDGEDACHT PTN. JEN-HAVEN	JEN HAVEN COMMUNITY	-28.23768	23.23951	88.00	-	-	48.78	-	-	N	-	2013/11/1
SD2-GAA134	METSEATEN	JOSEPH ISAACS	-28.20203	23.13888	28.60	0.74	-	13.95	-	-	W	DA	2014/04/01
SD2-GAA135	METSEATEN	JOSEPH ISAACS	-28.20202	23.13838	54.60	1.06	-	13.18	-	-	W	DA	2014/04/01



VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I

Borehole Number	Farm Name/Property	Owner/Representative	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
SD2-GAA136	METSEATEN	JOSEPH ISAACS	-28.20200	23.13788	36.80	4.0	-	10.89	-	-	M	DA	2014/04/01
SD2-GAA137	METSEATEN	JOSEPH ISAACS	-28.20198	23.13844	-	-	-	-	-	-	M	DA	2014/01/31
SD2-GAA138	SERETSESENCHO PTN. SION	JOHN STAPLETON	-28.15685	23.18598	119.80	0.62	-	6.57	-	-	W	AS	2014/04/01
SD2-GAA139	VINCI	JEN HAVEN COMMUNITY	-28.22712	23.16404	90.60	1.56	-	12.04	-	-	N	-	2014/04/01
SD2-GAA140	METSEATEN	LUCAS KOTZE	-28.21038	23.13560	58.20	0.5	-	14.21	-	-	N	DA	2014/04/02
SD2-GAA141	METSEATEN	LUCAS KOTZE	-28.21363	23.16592	2.80	-	-	-	-	-	N	-	2014/04/02
SD2-GAA200	SEDIBENG MINE	SEDIBENG MINE	-28.19149	23.11113	94.16	30	-	39.18	-	-	N	-	2012/04/13
SD2-GAA201	SEDIBENG MINE	SEDIBENG MINE	-28.18380	23.12162	103.08	15.12	-	35.79	-	-	N	-	2012/04/13
Min					2.8	0.37	3.33	0.32	9.0	6.43			
Max					176.0	30.0	5.56	64.12	362.0	9.39			
Average					67.30	5.04	4.30	20.12	85.13	7.81			
SANS 241:2011 Max Allowable Limit									<170	5 - 9.7			
DWAF 1998 Class I Drinking									70-150	5-10			



4.5 Geophysical Survey

The geophysical survey at SD2 comprised of:

- SkyTEM conducted a high resolution combined airborne magnetic and Time Domain Electromagnetic (TDEM) survey to obtain resistivity data from 2 to over 250 m deep; and
- 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 the survey flight lines conducted by SkyTEM is indicated on Figure 9.

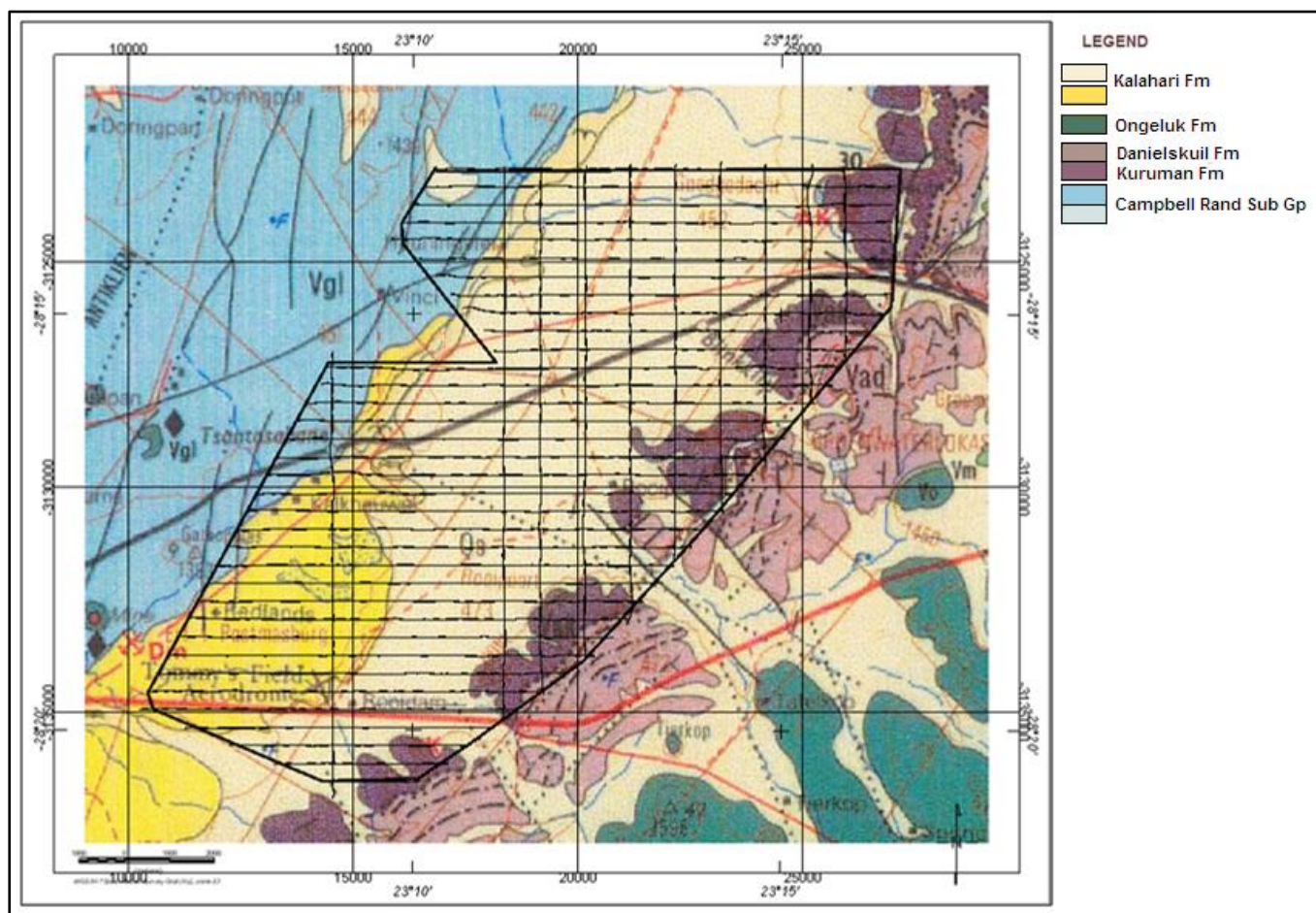


Figure 9: SD2 Airborne Survey Flight Lines

The gravity survey was conducted by EEGS of Centurion within the confines of the SD2 in order to optimize the selection of drilling targets in the leached karst formation.

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 10 .

Apart from the area over the Danielskuil and Kuruman Formations the remainder over the Campbell Rand Subgroup dolomite is fairly flat with little ridges in the center of the Maremane anticline. Most of the valleys and ridges have an approximate NW-SE strike.

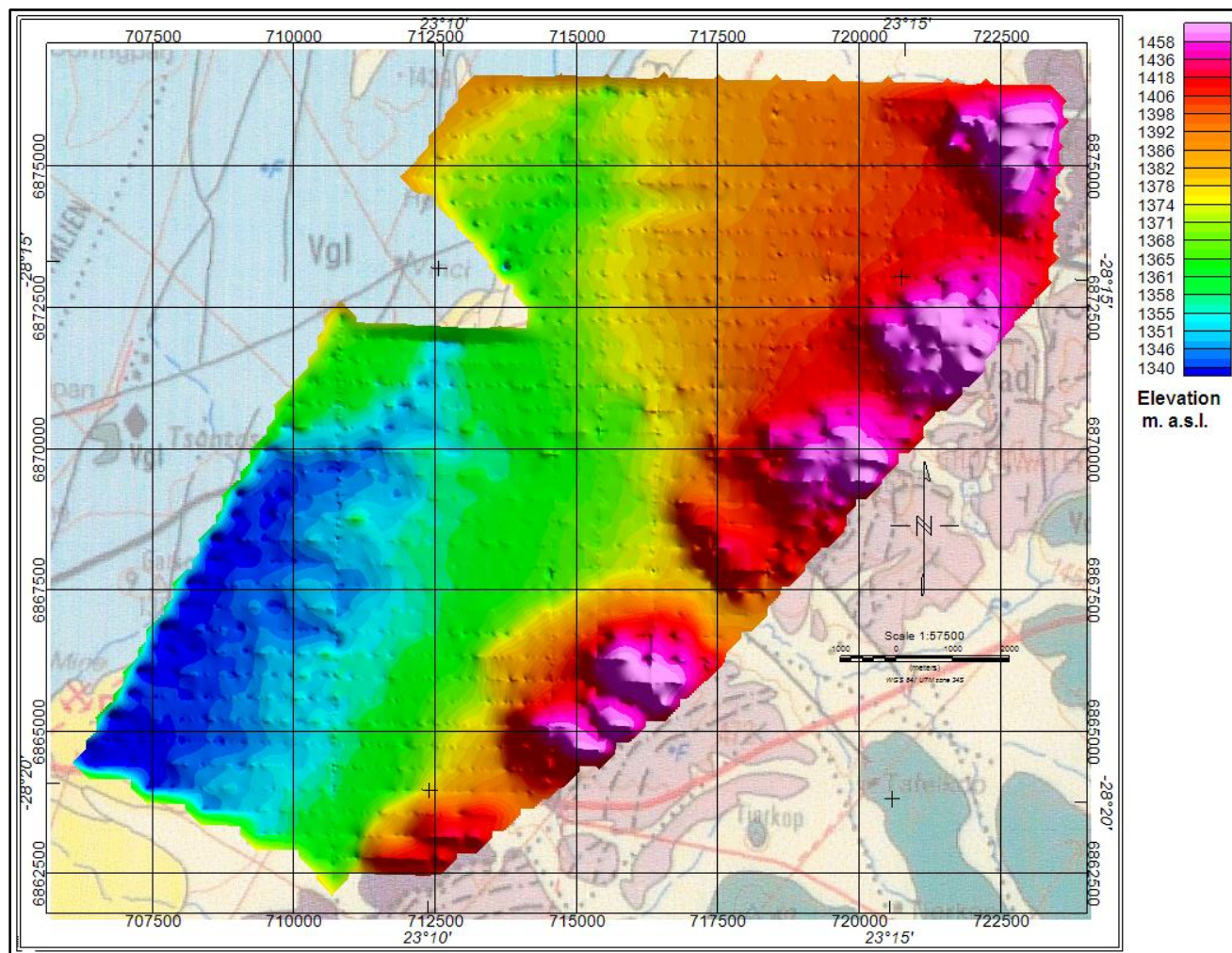


Figure 10: SD2 Digital Elevation Model

4.5.2 Aeromagnetic Data

The total magnetic field for SD2 is shown in Figure 11 as an artificially sun shaded color image and the warm colors indicate the magnetic highs. The data is somewhat noisy which stems from the magnetic and TDEM measurements having been done from the same airborne platform, almost simultaneously, and the presence of the Sishen-Saldanah railway line cutting through the area adding man made noise (Stettler 2013).

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 (Stettler 2013).

Spectacular and most obvious is the broad broken-up pattern of purple-red and blue colors that strike NW-SE on the eastern edge of the magnetic image. This pattern is due to the iron-rich Danielskuil and Kuruman Formations that also form the hills in the area. The deep blue blocks between the red and purples indicate faulting. The significant magnetic lows (light to dark blues) along the western side on the SD2 area are due to the Campbell Rand dolomite formation. Not well visible in the western part of the magnetic data shown in Figure 11 is a roughly north trending, cross cutting, lineament probably due to a diabase dyke or a fault intruded by a diabase dyke (Stettler 2013).

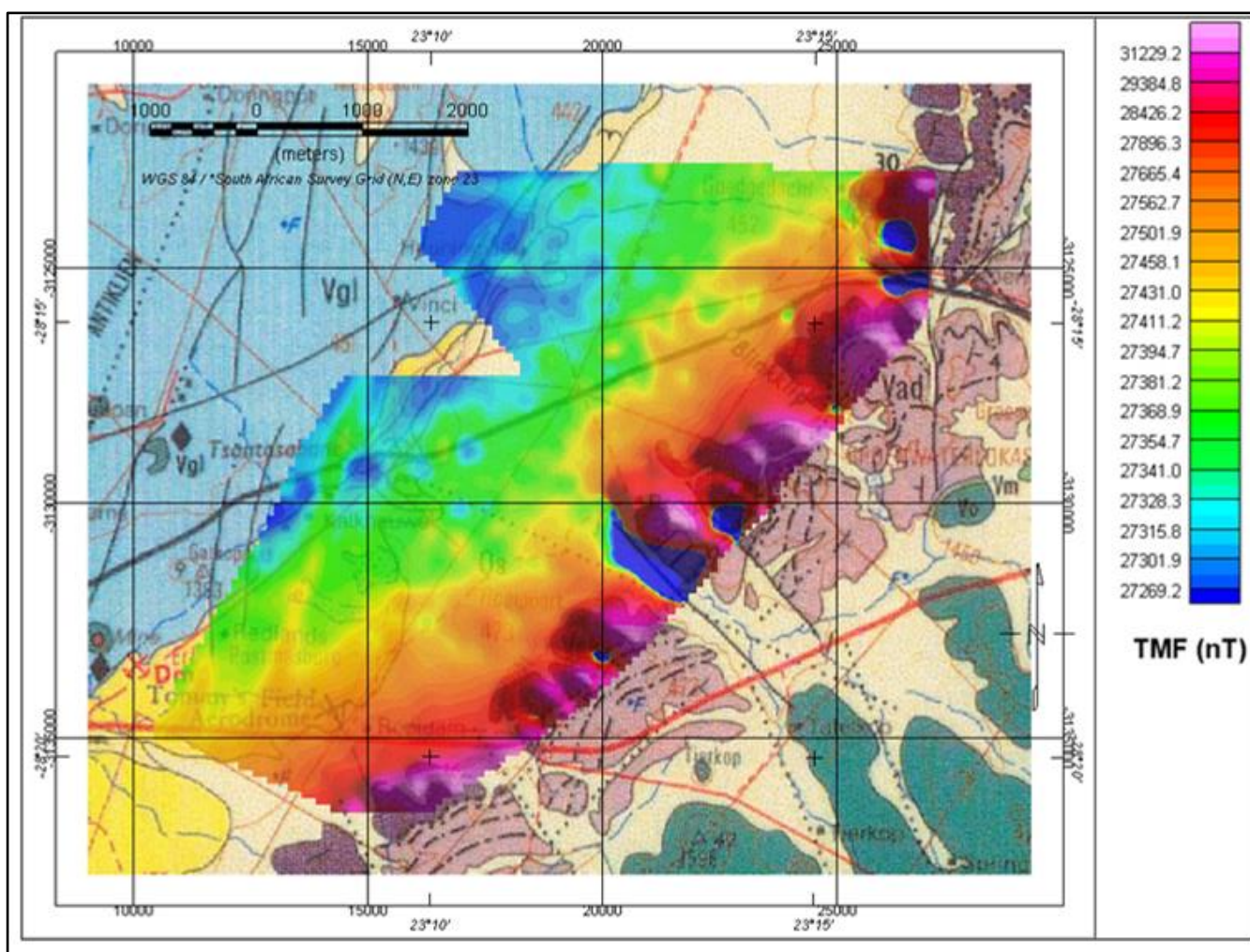


Figure 11: SD2 Total Magnetic Field

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 12. The magnetic bodies occur under the yellow-green-black colored hues except if they exhibit strong remanent magnetism when they are marked by the strong blue hues. The ternary image figure shows the roughly north trending dyke along the western margin of the dataset more clearly than the total magnetic field image. The dyke is represented in dark pink to purple and can be identified by its linear nature. Smaller features are also highlighted by the ternary image. For example



multiple faults can be seen as bright green lines along the eastern margin of the dataset. Some of these faults correlate to the observed faults on the geological map (Stettler 2013).

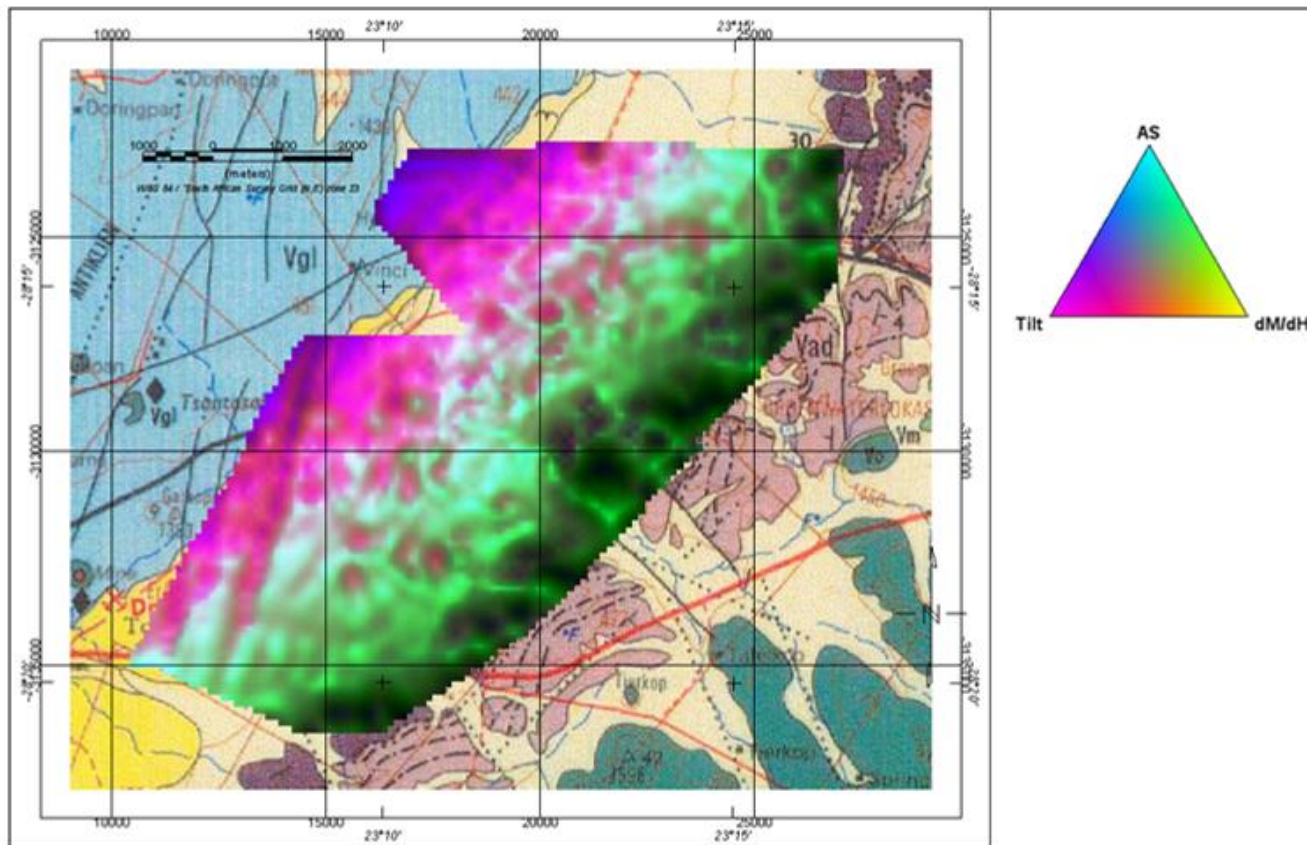


Figure 12: Ternary Plot of the Magnetic Data combining the Analytical Signal, $\partial M/\partial h$ and the Magnetic Tilt Angle

A comparison of the magnetic lineaments and the geology map demonstrates a good correlation between some of the lineaments and mapped faults in the dolomite. The identified magnetic lineaments are shown in the relative Bouguer anomaly map (Figure 14).

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 lines flown as indicated in Figure 9 were flown both N-S and E-W with a line spacing of 300m to sample all possible directions. Since TDEM has the advantage that a depth sounding is recorded every ~1 s which enables the formulation of a 3D resistivity voxel that can be constructed representing the subsurface and this voxel can be dissected in any X, Y, Z direction.

Numerous plots can be generated to show how the electrical resistivity changes as a function of depth and position. Just as an example Figure 13 depicts the apparent resistivities at an elevation of 1300m above sea level. The high resistivity areas on the western perimeter at this particular elevation (1300m) correlate to the underlying Campbell Rand dolomite that is covered by Kalahari age deposits (sand). In the eastern part of the survey area the low resistivity blue colored areas correlate with the banded iron stone of the Danielskuil and Kuruman formations. The three higher resistivity blobs in the central part of SD2 are due to the dolomite being present nearer to surface, i.e. the Quaternary Kalahari Formation is thinnest here, strengthening the possibility that the large gravity low in the center of SD2 is due to a karst area filled with Quaternary, Tertiary and perhaps even Karoo age sediments.

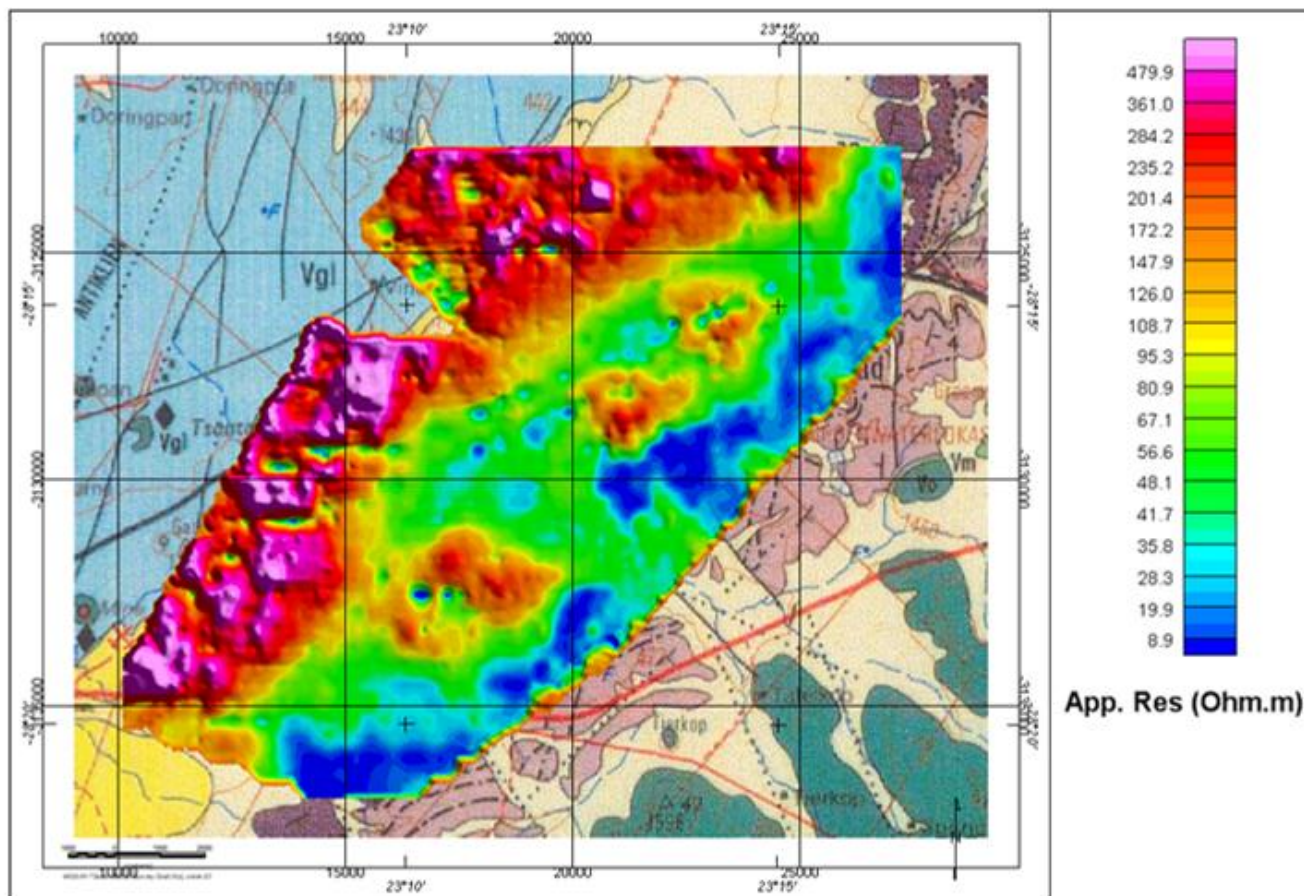


Figure 13: Apparent Resistivity over SD2 at an elevation of 13000 (mamsl)

The apparent resistivity map (Figure 13) shows N-S striking structures on the southwestern perimeter of SD2 that correlate with the mapped faults shown on the geology and the magnetic data set (Stettler 2013).

The discontinuous nature of the resistivity high values in the east (the Kuruman and Danielskuil Formation's) is due to the presence of several roughly NW-SE trending faults. These again correlate well with faults shown on the Kuruman geological map (Stettler 2013).

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 14. Figure 14 also depicts the relative Bouguer anomaly map, which surprisingly indicates a gravity low over the Banded Iron Formations of the Danielskuil and Kuruman Formation's in the northeastern corner of the SD2 area and the maximum gravity high in the opposite northwestern corner. This could indicate that the underlying Campbell Rand dolomite thins considerably in the northeastern direction and



thickens in the northwestern counterpart. Also shown in Figure 14 are residual gravity values along the gravity traverses and the residual here was obtained by subtracting the upward continued (by 500m) relative Bouguer map (regional gravity – shown in Figure 15) from the relative Bouguer map. The slightly thicker lines on Figure 14 indicate the identified magnetic lineaments as identified from the magnetic tilt-angle.

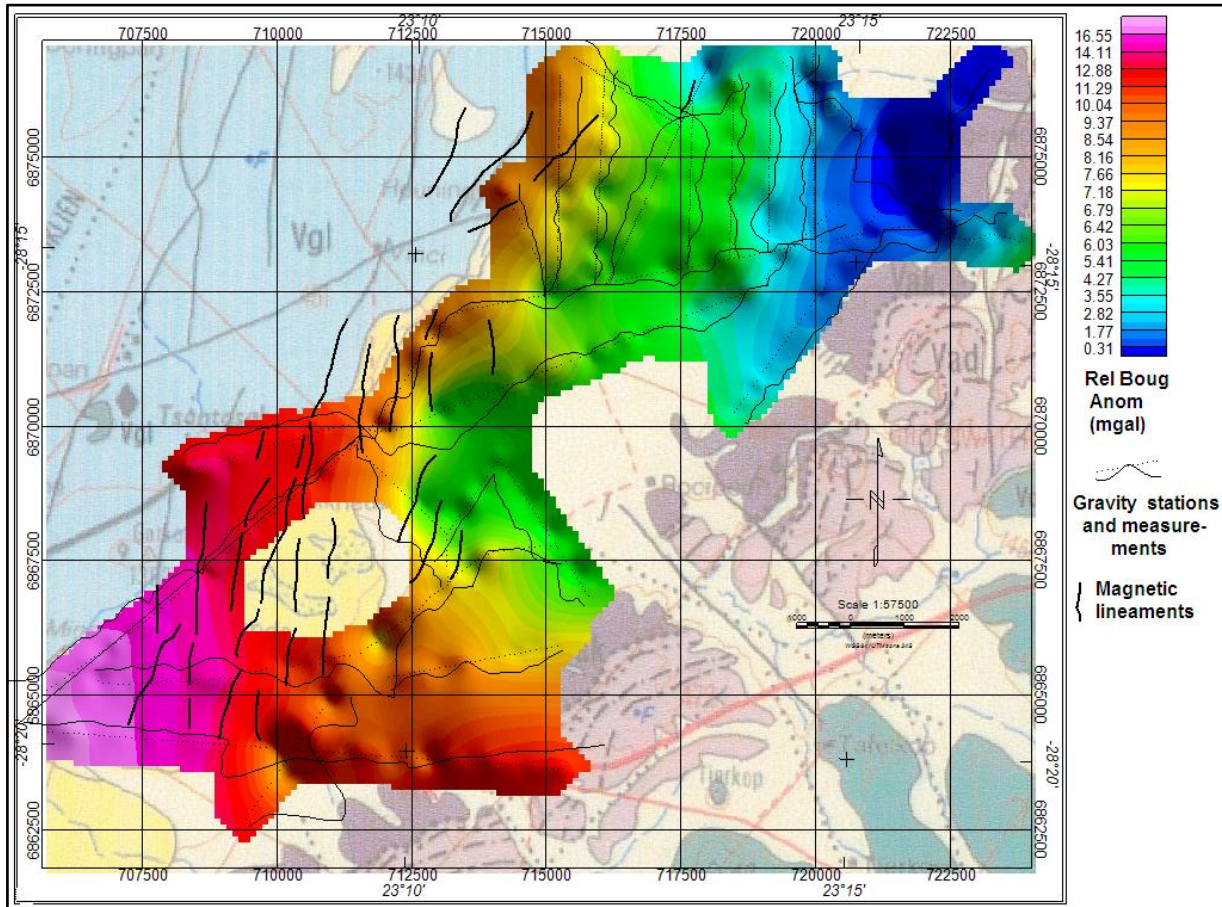


Figure 14: Relative Bouguer Anomaly Map

The residual gravity map is shown in Figure 16 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.

The advantage of the gravity data is that it indicates possible leached, permeable water-bearing zones and the central large gravity low (blue color) is covered with Quaternary age sediments. This could be fill-in of an old karst area in the dolomite and the perimeter of the gravity low may be a good target area for ground water extraction. The other deep gravity lows are also to be considered as indicating target areas and are those in the northeastern and southwestern corners of the gravity coverage for SD2 (Stettler 2013).



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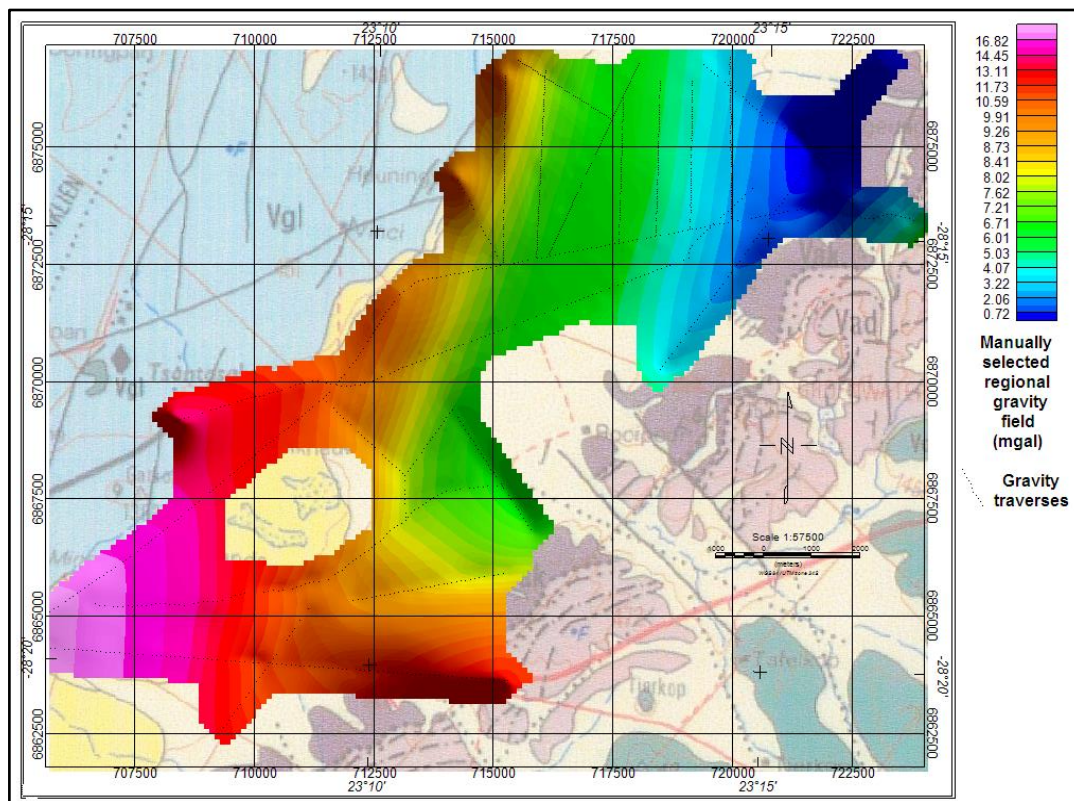


Figure 15: Regional Gravity Map

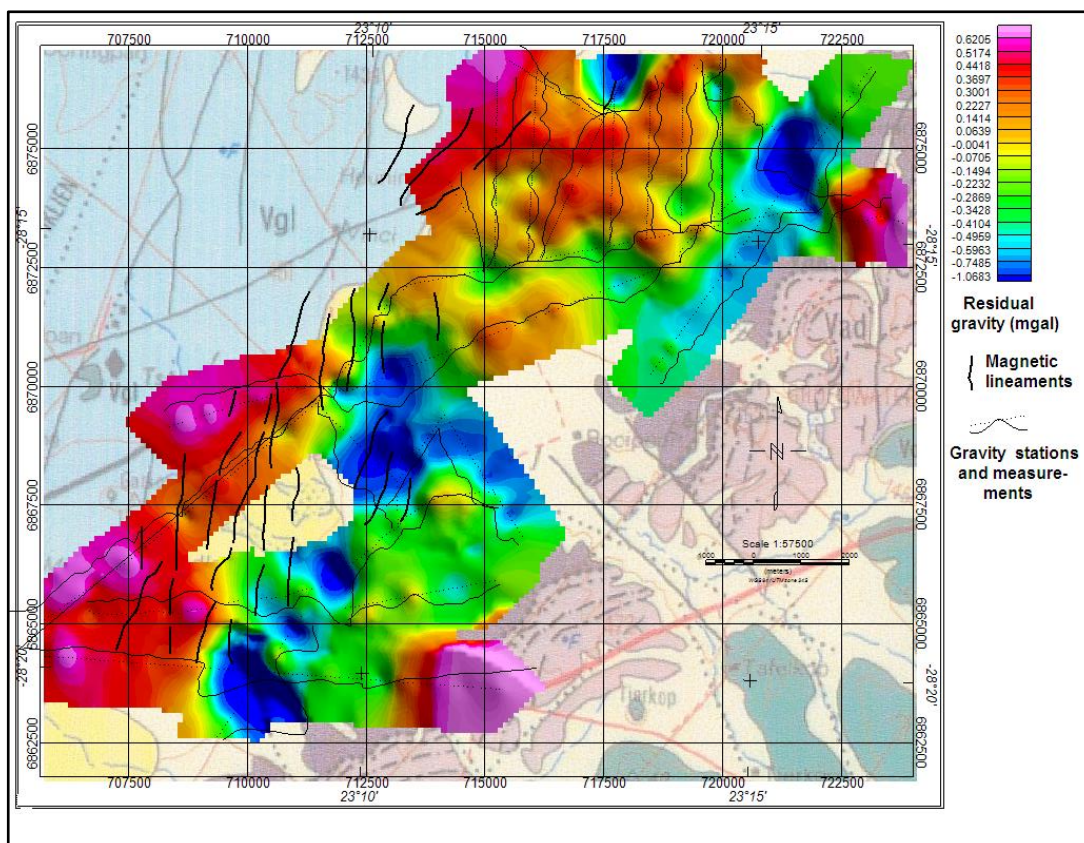


Figure 16: Residual Gravity Map



4.5.5 Geophysical Survey Conclusions

From a collection of three geophysical data sets, namely magnetics, gravity and time domain electromagnetic (TDEM), a better understanding of the geology in SD2 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 could be thrust but this has to be tested.

The iron stones, contrary as expected, are resistive at surface and only become conductive at depth. The resistive upper part is ~100m thick. The lower conductive part is still visible at -400m below surface and may also include the thrust zone plane which is also expected to be conductive, and this may make the thickness of the Danielskuil and Kuruman Formation's to appear more than it actually is.

The magnetic lineaments can be subdivided into two groups, N-S striking lineaments in the dolomites and NW-SE striking lineaments amongst the iron formations and these lineaments curve around into the contact zone of the iron formations with the underlying dolomite. This curvature is taken as evidence to support the thrust contact.

The conductive lineaments noted on the TDEM with a NW-SE strike coincide with the magnetic lineaments in the iron formations (correlating also with Kalahari sediments orientation) while the numerous magnetic lineaments along the western boundary of SD2 don't show clearly on the TDEM data indicating that if they are dykes then the dykes are not weathered. A strongly conductive lineament strikes NNE-SSW across the central part of SD2 and its origin is unknown.

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 faults in the iron formations are considered to constitute the best targets for groundwater abstraction and due to the weather resistant nature of the iron stones the water quality is expected to be good.

The water quality in the karst area of the dolomite could be influenced by the presence of Kalahari sediments.

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 (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 SD2 study area.

The geophysical drill sites selected and drilled are shown in Table 3 as Traverse No/Station No.

The positions of gravity survey traverses with final residual gravity values are indicated on Figure 17.

Examples of linear gravity graphs indicating drill sites, exploration borehole and blow yield are listed as Figure 18 to Figure 19 with the remaining of the graphs listed in the appendices volume II of the report.



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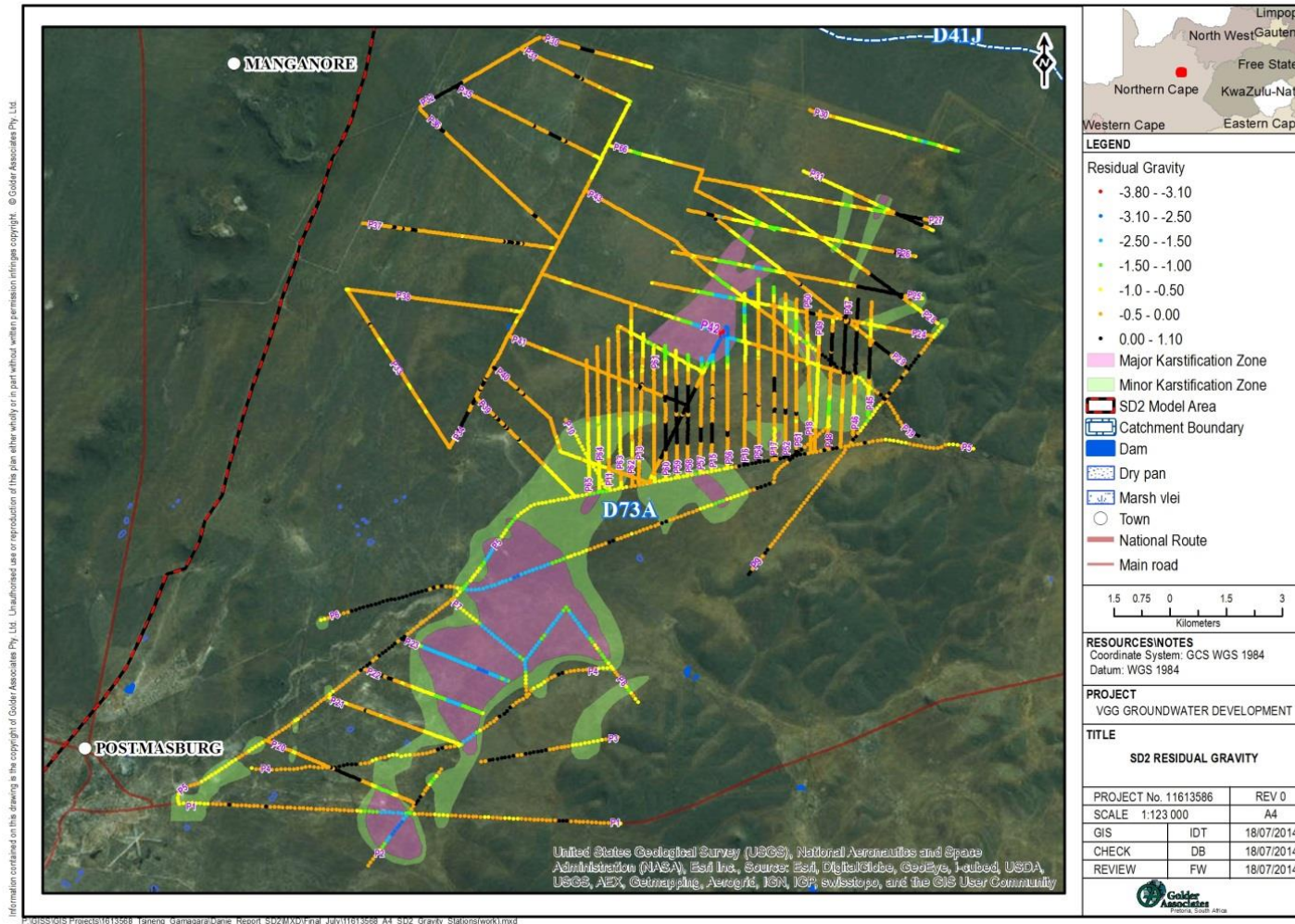


Figure 17: Geophysical Traverses and Residual Gravity Values

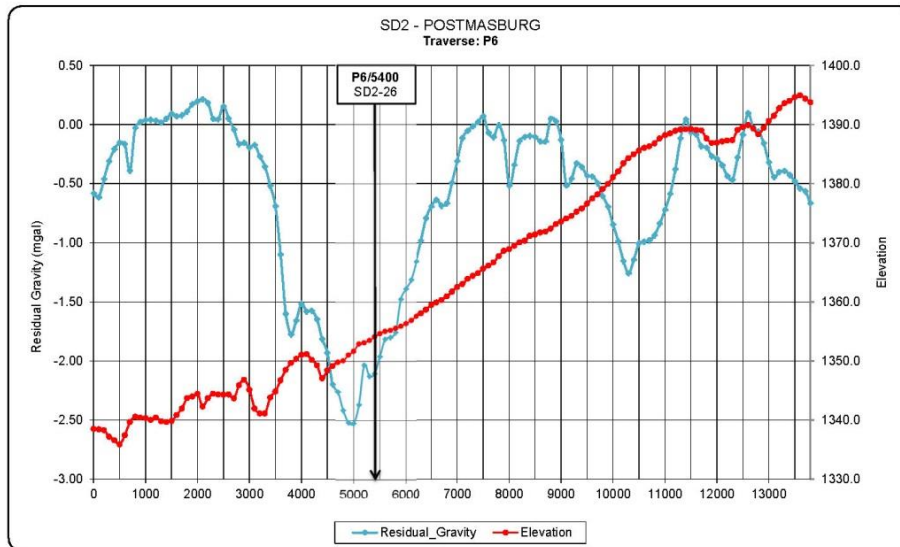


Figure 18: Drill Site P6 – Borehole SD2-26

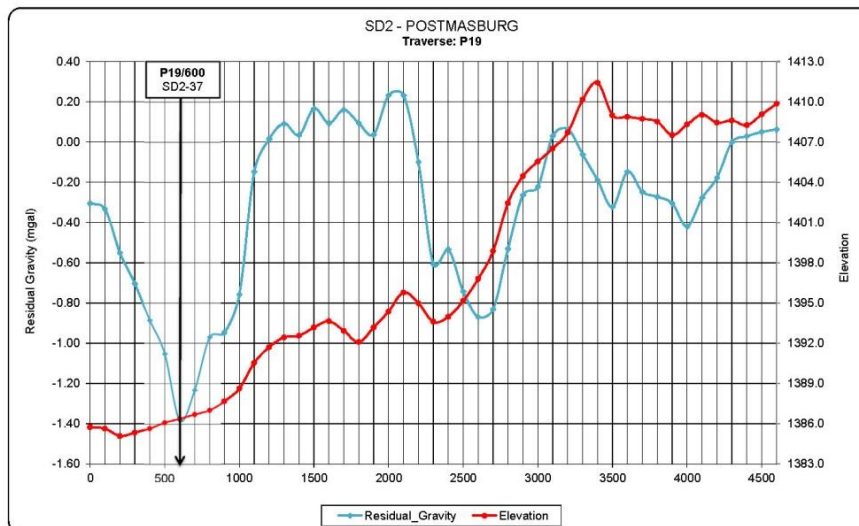


Figure 19: Drill Site P19 – Borehole SD2-37



4.6 Exploration Drilling

The drilling programme was conducted by three air percussion drilling rigs (Figure 20) of Environmental Drilling & Remediation Services (EDRS). The exploration drilling programme started 19 August 2013 and was completed 8 March 2014 with a total of 47 exploration boreholes installed as indicated on Figure 23.



Figure 20: Air Percussion Drilling Rig - SD2-09

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 were 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 SD2 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 (>10l/s) boreholes (Figure 21). This approach is contradictory to a mining approach of de-watering, where deep (>100m) production boreholes are concentrated in an area in order to lower/dewater the water table.

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

The new exploration boreholes were drilled by air percussion drilling rigs (Figure 24), 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 and low yielding boreholes were constructed to serve as potential monitoring boreholes.



Figure 21: Drilling of SD2-30- BY 30.0 l/s

One monitoring borehole (SD2-16M) was drilled within 20m distance from high yielding borehole SD2-16 (Figure 22). The purposes of this monitoring borehole apart from a monitoring facility are to determine the hydraulic parameters of the major karstification zone during long term test pumping. This monitoring borehole was marked using the after-fix “M” after the borehole number (SD2-16M).



Figure 22: Drilling of SD2-16 with SD2-16M in Background.



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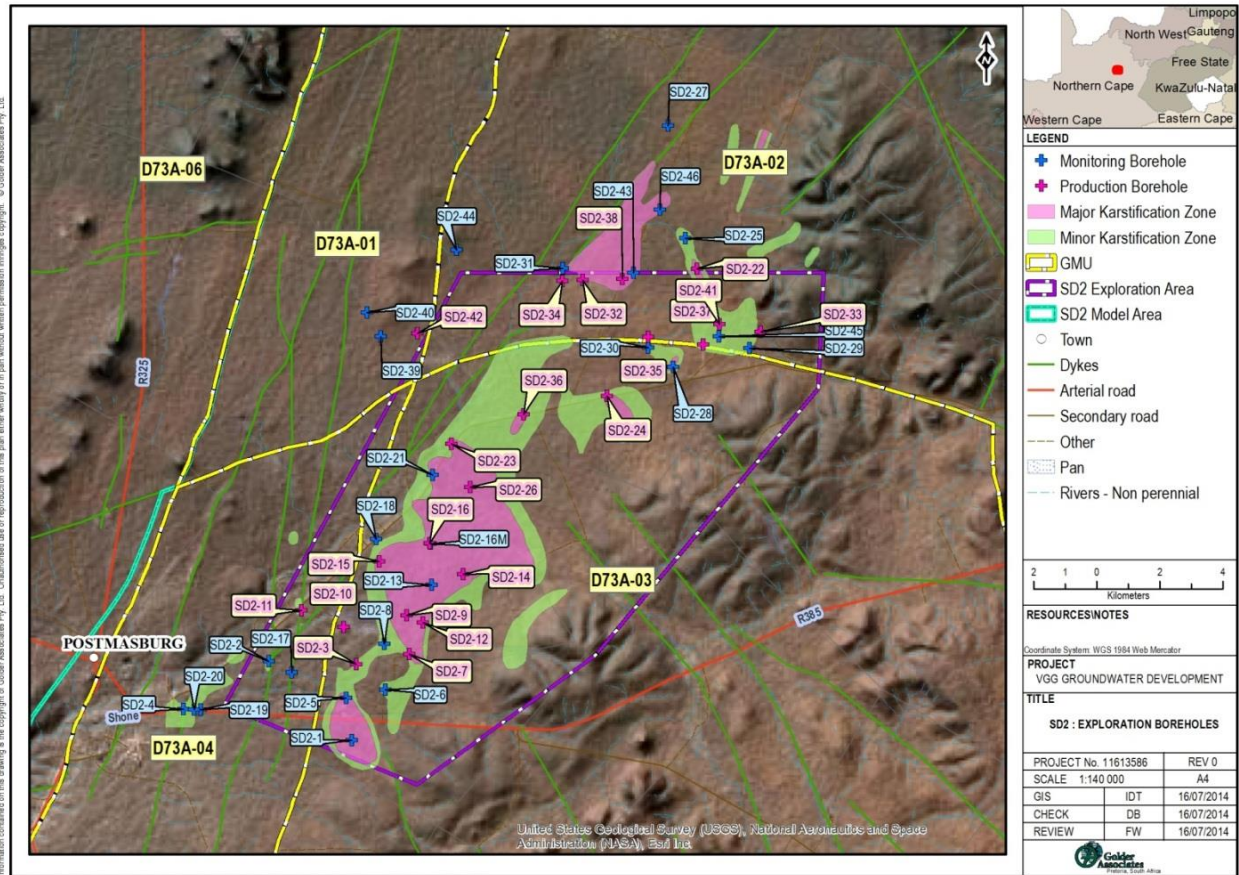


Figure 23: SD2 Exploration Borehole Positions



Figure 24: Drilling of SD2 -11



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 25) 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 25: SD2-16 Completed Headwork's

Drill cuttings were sampled at 1m intervals (Figure 26) and were used to compile geological borehole logs as listed in appendices volume II of the report.



Figure 26: SD2-8 Borehole Drill Samples/Cuttings



4.6.1 Drilling Results

The drilling results are summarised in Table 3 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 47 exploration boreholes were drilled, from which 28 boreholes were constructed as potential production status and 19 as monitoring status.

The drilling results for SD2 are summarised as follows:

- The drilling depth range between 34m (SD2-11) and to 130m (SD2-45) with an average depth of 81m;
- Groundwater strike depths intersected range between 13m and 119m with an average strike depth of 57.4m;
- The final blow yield range between 0.1l/s and 40l/s (SD2-26) with an average blow yield of 13.7l/s; and
- The recorded water level range between 5.21m (SD2-42) and 59.86m (SD2-33) with the average water level as 28.1mbgl.

The final blow yields of the exploration boreholes are indicated in Figure 27 and summarised as:

- Seepage intersected – 10 exploration boreholes – 21.3%;
- Yields 0.1l/s to 2.0l/s - 9 exploration boreholes – 19.1%;
- Yields >2.0l/s to 10.0l/s - 5 exploration boreholes – 10.7%;
- Yields <10.0l/s to 20.0l/s - 14 exploration boreholes – 29.8%; and
- Yields >20l/s – 9 exploration boreholes – 19.1%.

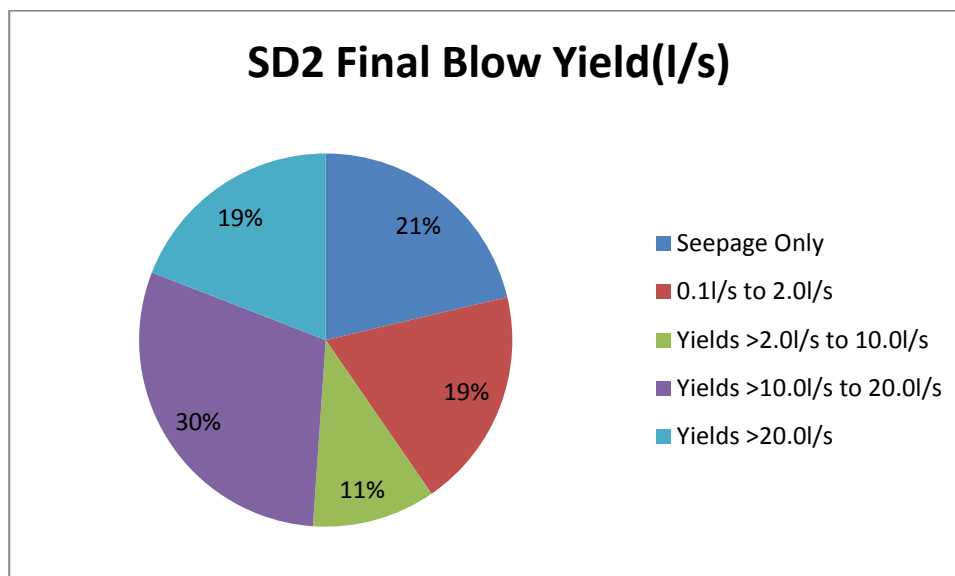


Figure 27: SD2 Final Blow Yields (l/s)

4.6.2 Land Owners Included by SD2 Drilling Programme

The landowners in SD2 area, on whose farms exploration drilling was conducted are summarised in Table 2 and indicated on Figure 28.



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Table 2: Land Owners Included by Drilling Programme in SD2

Land Owner	Farm Name	Number BH	Production Status	Monitoring Status
Postmasburg Municipality	Municipality Land	21	10	11
Jen Haven Community	Goedgedaght 452	14	8	6
Loekie van der Merwe	Vaalpoort	3	3	0
Arthur Olivier	Vinci 580	1	1	0
Johnny Cloete	Farm 589	1	1	0
Lucas Kotze	Farm 589	4	2	2
William Jarvis	Farm 589	3	3	0
Total		47	28	19

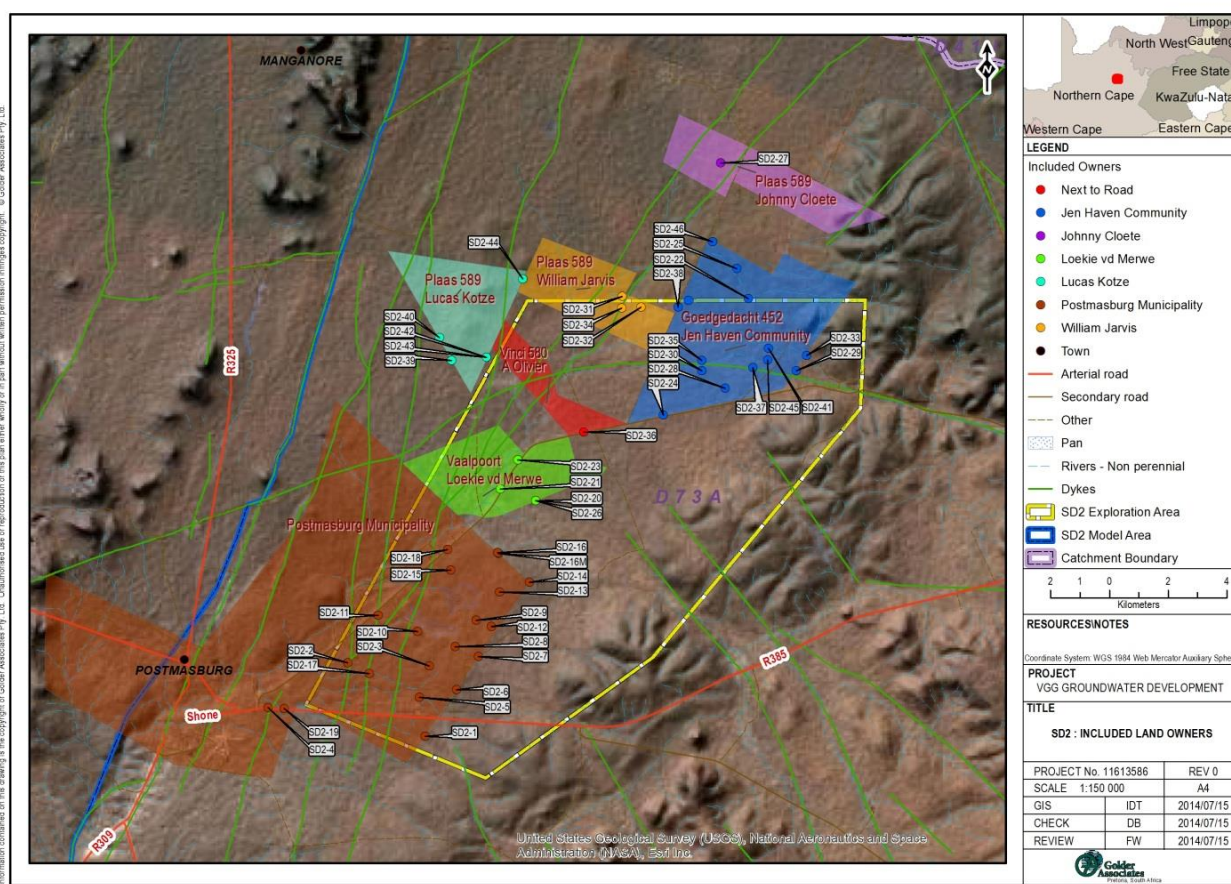


Figure 28: SD2 Land Owners Included by Exploration Drilling Programme

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 using a differential GPS system. The differential GPS system was tied 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 SD2 exploration boreholes and the SkyTEM resistivity map for four depth horizons (10m –shown in Figure 29, 20m, 30m and 40m) were used to delineate and contour the thickness of the Kalahari sediments (calcrete and clay) as indicated on Figure 31.

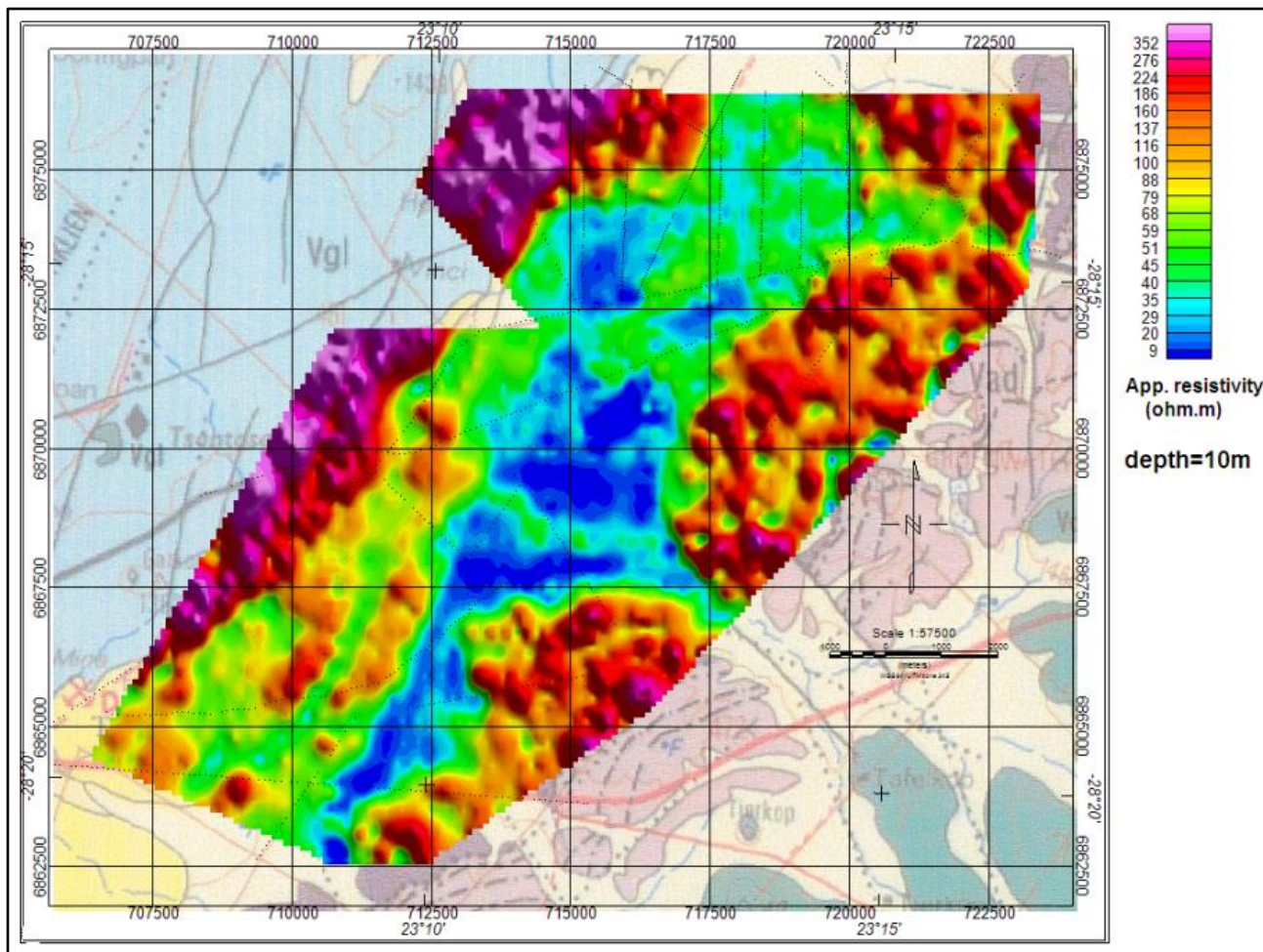


Figure 29: Resistivity distribution at 10m depth

These inferred Kalahari sediments thickness exceeds 60mbgl in certain areas, have a low permeability, restrict groundwater movement and acts as storage unit. At exploration borehole SD2-1 (Figure 30) Kalahari sediments and clay were encountered up to 106m below surface. These delineated Kalahari sediment thicknesses correlate well with the residual gravity values outlining areas of low formation density.



Figure 30: SD2-1 Intersected Kalahari Sediments and Clay



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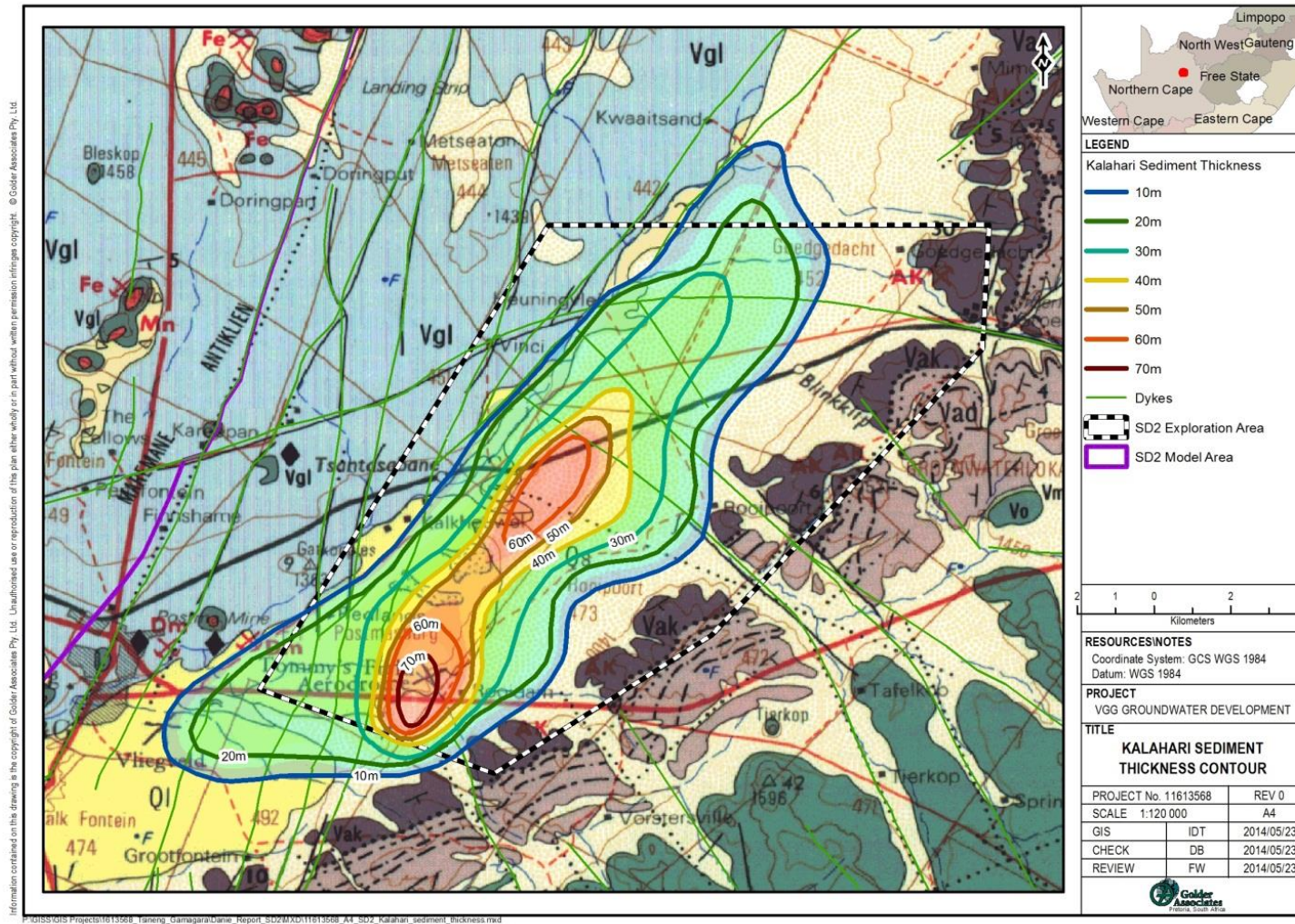


Figure 31: Kalahari Sediment Thickness



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Table 3: 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)	Geological Formation/Aquifer Type	Date Completed	BH Status
SD2-1	Municipality	Postmasburg	-28.337554	23.140891	1354.66	P2/1000	106	60	254	Seepage only	Seepage only	Seepage only	21.63	1333.03	Khalahari sediments	25/08/2013	Monitoring
SD2-2	Municipality	Postmasburg	-28.317828	23.117227	1339.53	P20/720	74	3	254	Seepage only	Seepage only	Seepage only	20.79	1318.74	Khalahari sediments/dolerite	19/08/2013	Monitoring
SD2-3	Municipality	Postmasburg	-28.318590	23.142107	1351.84	P4/3500	118	106	165	23;68;73;99;110	0.1;0.3;2;10;6	22.00	19.02	1332.82	Khalahari sediments/dolomite	23/08/2013	Production
SD2-4	Municipality	Postmasburg	-28.329855	23.092867	1320.11	P1/300	74	60	165	Seepage only	Seepage only	Seepage only	13.78	1306.33	Khalahari sediments/dolomite	21/08/2013	Monitoring
SD2-5	Municipality	Postmasburg	-28.327050	23.139120	1348.07	P20/3100	105	104	165	52;97	0.2;4	4.00	15.24	1332.83	Khalahari sediments/dolomite	03/09/2013	Monitoring
SD2-6	Municipality	Postmasburg	-28.324972	23.150426	1353.38	P2/2700	89	84	165	Seepage only	Seepage only	Seepage only	20.48	1332.90	Khalahari sediments	07/09/2013	Monitoring
SD2-7	Municipality	Postmasburg	-28.316072	23.157200	1353.88	P21/3350	52	52	203	37-42;50-52	3;23	26.00	21.13	1332.75	Khalahari sediments/dolomite	05/09/2013	Production
SD2-8	Municipality	Postmasburg	-28.313490	23.150118	1353.62	P21/2600	120	61	165	51	0.2	0.20	20.67	1332.95	Khalahari sediments/dolomite	09/09/2013	Monitoring
SD2-9	Municipality	Postmasburg	-28.306271	23.156516	1351.26	P22/2350	66	64	165	39-40;53-54;61	0.6;1.0;20	20.00	18.52	1332.74	Khalahari sediments/dolomite	12/09/2013	Production
SD2-10	Municipality	Postmasburg	-28.309325	23.138496	1345.85	P21/1370	60	70	165	39;43;58;62;67-70	0.2;0.3;6;4;10	23.00	13.00	1332.85	Khalahari sediments/dolomite	13/09/2013	Production
SD2-11	Municipality	Postmasburg	-28.304981	23.126510	1337.65	P21/100	34	33	203	22;27-28	20;10	33.00	10.99	1326.66	Dolomite	12/09/2013	Production
SD2-12	Municipality	Postmasburg	-28.308063	23.161201	1353.00	P22/2850	75	75	165	41;72	1.3;20	20.00	20.51	1332.49	Khalahari sediments/dolomite	14/09/2013	Production
SD2-13	Municipality	Postmasburg	-28.298704	23.163611	1353.17	P23/2150	55	52	203	30;38;50	2;10;4	16.00	20.28	1332.89	Khalahari sediments	24/09/2013	Production
SD2-14	Municipality	Postmasburg	-28.296017	23.172748	1357.17	P7/2450	100	100	165	98	15.5	14.00	24.26	1332.91	Khalahari sediments/dolomite	26/09/2013	Production
SD2-15	Municipality	Postmasburg	-28.292804	23.148754	1349.10	P23/550	83	82	165	79-83	20.0	20.00	16.28	1332.82	Khalahari sediments/dolomite	28/09/2013	Production
SD2-16M	Municipality	Postmasburg	-28.288303	23.163341	1352.48	P7/1100	74	56	203	40	2.0	1.70	19.75	1332.73	Khalahari sediments	02/10/2013	Monitoring
SD2-16	Municipality	Jen Haven -	-28.288158	23.163097	1352.45	P7/1070	97	97	165	97	30.0	23.0	19.75	1332.70	Khalahari sediments/dolomite	20/10/2013	Production
SD2-17	Municipality	Postmasburg	-28.320661	23.123741	1339.81	P20/1430	59	59	165	19;32;43	0.2;2;8	8.00	13.46	1326.35	Khalahari sediments/dolomite	30/09/2013	Production
SD2-18	Municipality	Postmasburg	-28.287230	23.147742	1345.35	P5/7700	73	3	254	43;63	0.1;01	0.20	12.41	1332.94	Khalahari sediments/dolomite	30/09/2013	Monitoring
SD2-19	Municipality	Postmasburg	-28.330032	23.097718	1324.82	P1/780	61	61	165	Seepage only	Seepage only	Seepage only	18.21	1306.61	Khalahari sediments/dolomite	02/10/2013	Monitoring
SD2-20	Municipality	Jen Haven -	-28.330009	23.095777	1319.07	P1/600	61	61	165	35-39	0.2	0.20	13.44	1305.63	Khalahari sediments/dolomite	05/10/2013	Monitoring
SD2-21	Vaalpoort	Loekie van	-28.270995	23.163933	1352.7	P5/10200	94	94	165	89	20	20.0	19.81	1332.92	Khalahari sediments/dolomite	17/10/2013	Production
SD2-22	Goedgedaght	Jen Haven -	-28.219793	23.239764	1388.8	P19/600	73	73	165	53;68-73	2;5	4.30	45.8	1342.96	BIF/Dolomite	19/10/2013	Production
SD2-23	Vaalpoort	Loekie van	-28.263208	23.169254	1354.7	P5/11300	73	73	203	50;72	0.2;20	20.00	21.79	1332.88	Khalahari sediments/dolomite	21/10/2013	Production
SD2-24	Goedgedaght	Jen Haven -	-28.25106	23.21368	1381.5	P5/16100	119	119	165	94;119	2;10	15.50	48.01	1333.45	BIF/Dolomite	27/10/2013	Production
SD2-25	Goedgedaght	Jen Haven -	-28.21163	23.23613	1385.10	P24/3300	66	61	203	60-66	0.7	0.70	42.17	1342.93	BIF/Dolomite	25/10/2013	Monitoring
SD2-26	Vaalpoort	Loekie van	-28.27414	23.17470	1356.3	P6/5400	75	75	203	50;68;72	1;5;15	40.0	23.23	1333.10	BIF/Dolomite	26/10/2013	Production
SD2-27	Farm 442	Jen Haven -	-28.18323	23.23123	1385.0	P27/1650	61	61	165	25;57;59	0.2;2;10	13.50	16.84	1368.14	Khalahari sediments/dolomite	28/10/2013	Production
SD2-28	Goedgedaght	Jen Haven -	-28.24391	23.23268	1391.2	P17/2700	85	53	203	Seepage only	Seepage only	Seepage only	50.52	1340.70	BIF	10/11/2013	Monitoring
SD2-29	Goedgedaght	Jen Haven -	-28.23921	23.25441	1401.5	P9/4800	73	73	165	61	0.2	0.20	48.33	1353.21	BIF	14/11/2013	Monitoring
SD2-30	Goedgedaght	Jen Haven -	-28.23913	23.22550	1387.12	P16/2150	98	98	165	66;91	2;25	30	52.79	1334.33	BIF/Dolomite	15/11/2013	Production
SD2-31	Farm 442	Jen Haven -	-28.21907	23.20114	1368.5	P13/150	85	66	203	16;27;39	0.2; 4	4.10	11.38	1357.15	Dolomite	15/11/2013	Production
SD2-32	Farm 442	Jen Haven -	-28.22200	23.20683	1374.8	P12/1300	90	90	203	80-84	11.0	11.00	31.63	1343.12	BIF/Dolomite	21/11/2013	Production
SD2-33	Goedgedaght	Jen Haven -	-28.23506	23.25756	1402.96	P9/5350	104	102	165	84;90	1.0;4.0	1.50	59.86	1343.10	BIF	05/12/2013	Production
SD2-34	Farm 442	Jen Haven -	-28.22229	23.20101	1369.54	P13/500	34	32	203	23;29	20;7.0	26.00	12.31	1357.23	BIF/Dolomite	28/11/2013	Production



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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)	Geological Formation/Aquifer Type	Date Completed	BH Status
SD2-35	Goedgedaght	Jen Haven -	-28.23638	23.22553	1384.4	P16/1850	100	82	203	68;73;86	0.8;21.2;2.0	22	50.5	1333.87	BIF/Dolomite	04/12/2013	Production
SD2-36	Farm 442	Jen Haven -	-28.25574	23.18940	1367.00	P5/13600	97	97	203	83;95	8.0;12.0	20	33.92	1333.08	BIF/Dolomite	02/12/2013	Production
SD2-37	Goedgedaght	Jen Haven -	-28.23833	23.24114	1394.02	P18/2625	85	85	165	71;83	1;3	4.00	57.47	1336.55	BIF/Dolomite	07/02/2014	Production
SD2-38	Goedgedaght	Jen Haven -	-28.22198	23.21828	1381.44	P14/3600	89	89	165	88	10.0	10.80	37.95	1343.49	BIF/Dolomite	25/02/2014	Production
SD2-39	Metseaten	Jen Haven -	-28.23636	23.14901	1386.70	P33/4225	70	70	203	34;41	0.1;1.0	1.10	16.1	1370.60	Dolomite	22/02/2014	Monitoring
SD2-40	Metseaten	Jen Haven -	-28.23020	23.14522	1392.31	P33/3450	60	14	203	Seepage only	Seepage only	Seepage only	52.99	1339.32	Dolomite	22/02/2014	Monitoring
SD2-41	Goedgedaght	Jen Haven -	-28.23316	23.24583	1394.32	P48/1300	72	72	203	63;67	2;11	13.00	51.04	1343.28	BIF/Dolomite	28/02/2014	Production
SD2-42	Metseaten	Jen Haven -	-28.23549	23.15964	1375.8	P34/1150	39	39	165	13;20;26;28;29;37;39	10;12	17.00	5.21	1370.55	Dolomite	25/02/2014	Production
SD2-43	Metseaten	Jen Haven -	-28.22022	23.22136	1382.20	P56/3250	121	35	203	Seepage only	Seepage only	Seepage only	38.46	1343.74	BIF/Dolomite	05/03/2014	Monitoring
SD2-44	Metseaten	Jen Haven -	-28.21448	23.17077	1397.80	P34/3725	60	13	203	seepage only	seepage only	Seepage only	28.23	1369.57	Dolomite	01/03/2014	Monitoring
SD2-45	Goedgedaght	Jen Haven -	-28.23630	23.24567	1395.5	P48/950	130	48	203	94	0.1	0.10	52.18	1343.36	BIF/Dolomite	06/03/2014	Monitoring
SD2-46	Goedgedaght	Jen Haven -	-28.20446	23.22878	1382.8	P54/4850	125	32	254	Seepage only	Seepage only	Seepage only	39.4	1343.37	BIF/Dolomite	07/03/2014	Monitoring
Min						-	34	3	-	13.0	0.1	0.1	5.21	1305.6	-	-	28 Production
Max						-	130	119	-	119.0	30.0	40	59.86	1370.6	-	-	19 Monitoring
Average						-	81.1	65.7	-	57.4	6.8	13.7	28.12	1337.6	-	-	47 Total



4.7 Aquifer Testing

Aquifer testing was performed on 20 existing boreholes (Figure 34) and 34 newly drilled exploration boreholes (Figure 35). The testing programme in SD2 area was completed 16 March 2014.

The aquifer testing programme was conducted by AB Pumps testing contractor using a positive displacement pump (Figure 32) under the supervision of Golder. The objective of the aquifer testing at SD2 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 32: Aquifer Testing SD2-3

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

Pumping rates varied from 0.1 l/s to 30.0 l/s (Figure 33). 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.



In the case of existing boreholes only SDT was conducted for yield determinations.

Five high yielding exploration boreholes (SD2-9, SD2-12, SD2-15, SD2-34 and SD2-35) were subjected to second long term 72hour CDT. These long terms CDT's are not only essential to determine hydraulic parameters and aquifer boundaries, but are of fundamental importance for groundwater model calibration and water level time simulation.

The number of aquifer test pumping completed for SD2 Area is summarized Table 4.

Table 4: Summarised Aquifer Tests Completed at SD2

Total BH's Tested	No. SDT Only	No. SDT and CDT	CDT Pumping Time (Hours)	CDT Yield (l/s)
Existing Boreholes				
20	20	0	No CDT	No CDT
Exploration Boreholes				
34	8	31	12 to 72	2.4 to 30.2



Figure 33: Aquifer Testing of SD2-26 (20l/s)



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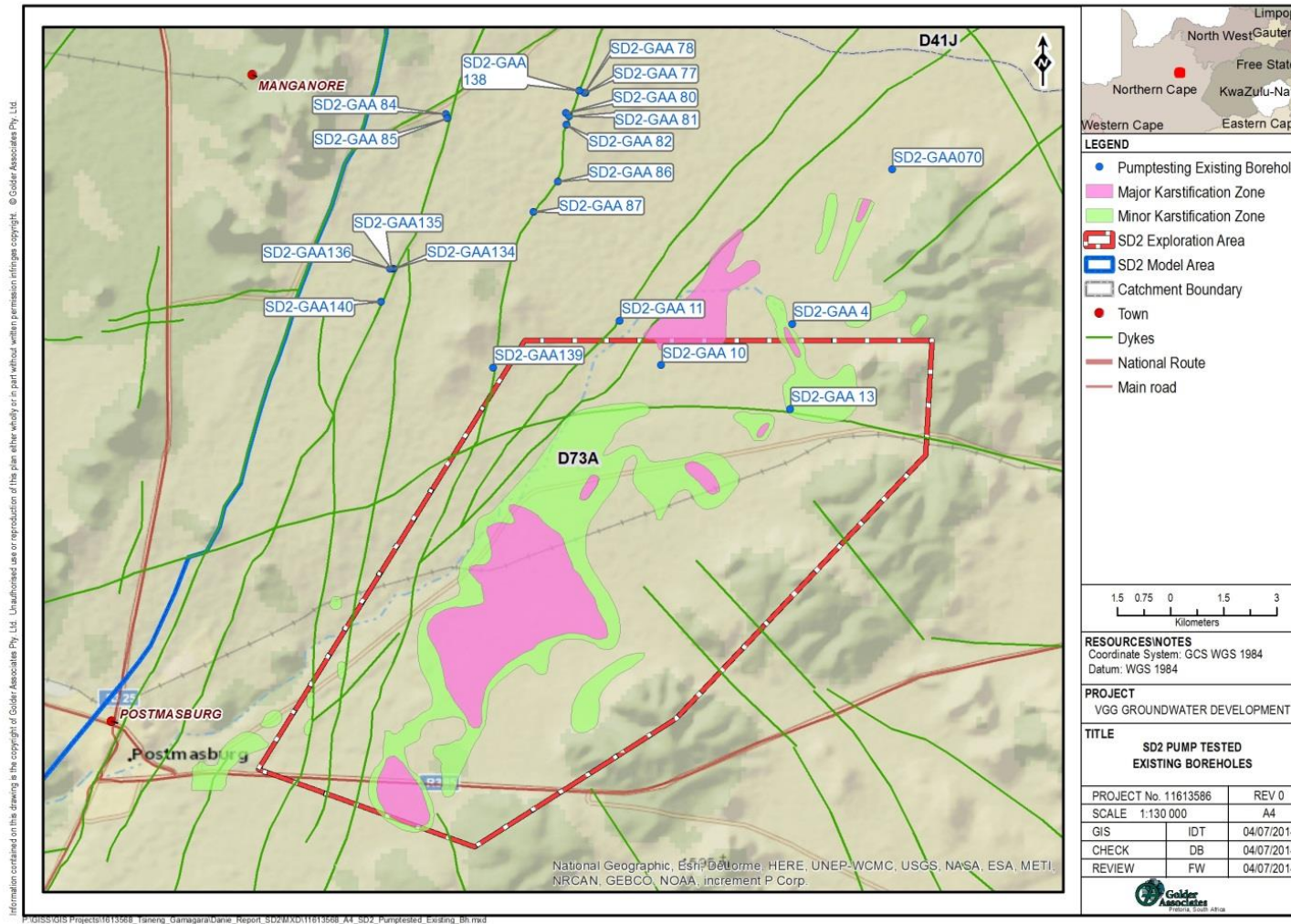


Figure 34: Position of Existing Boreholes Test Pumped



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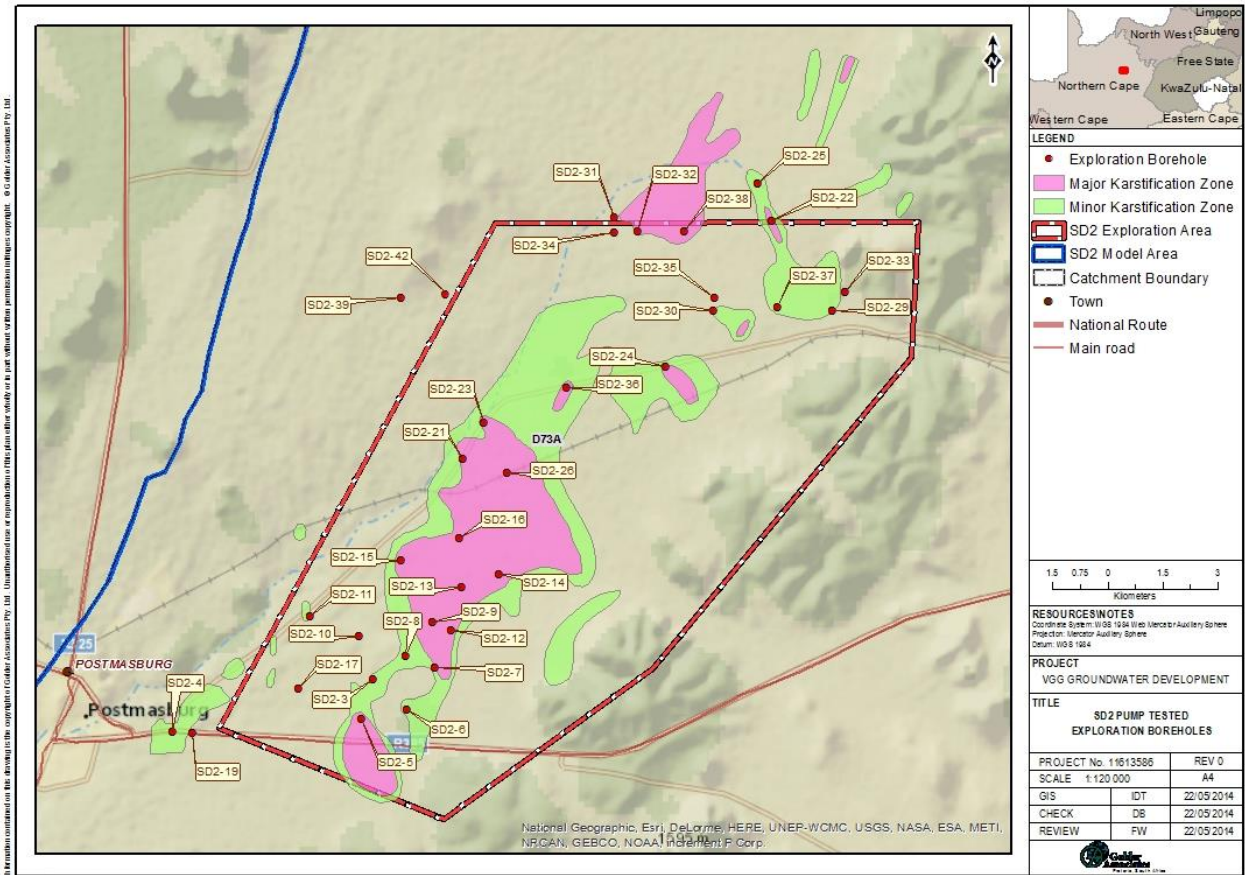


Figure 35: Position of Exploration Boreholes Test Pumped

The aquifer testing programme of the existing boreholes are summarised in Table 5 and of the exploration boreholes in Table 6. 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 36.



Figure 36: Volumetric Measurement of Yield SD2-7 (30l/s)



Table 5: SD2 Existing Boreholes Pump Tested

Borehole Number	Borehole Depth (m)	Static Water level (mbgl)	No of SDT's	Final Yield (l/s)	DD (m)	PI Yield (l/s)
SD2-GAA 4	88.55	44.25	3	20.4	0.68	No PI
SD2-GAA 10	69.1	31.75	3	4.03	13.92	No PI
SD2-GAA 11	69	14.13	2	1.02	47.82	0.44
SD2-GAA 13	88.2	49.05	1	0.84	27.05	No PI
SD2-GAA070	146	56.51	1	0.5	36.83	0.34
SD2-GAA 77	138.38	11.94	2	1.01	85.17	No PI reached
SD2-GAA 78	81.76	16.13	2	0.74	57.10	No PI
SD2-GAA 80	39.7	31.17	1	0.4	6.28	-
SD2-GAA 81	76.8	32.07	4	4.03	36.65	3.30
SD2-GAA 82	68.56	5.38	2	1.24	57.14	0.70
SD2-GAA 84	28.8	9.8	4	4.46	5.10	No PI
SD2-GAA 85	59.63	13.56	2	0.92	37.40	0.63
SD2-GAA 86	78.68	8.28	1	0.52	54.34	No PI
SD2-GAA 87	45.9	9.16	2	1.06	29.53	0.70
SD2-GAA134	28.6	13.75	2	0.71	13.0	0.41
SD2-GAA135	54.6	12.88	2	1.06	37.88	0.40
SD2-GAA136	36.8	11.14	4	4	0.92	No PI
SD2-GAA 138	119.8	6.5	1	0.62	86.0	0.21
SD2-GAA139	90.6	12.24	3	1.5	68.97	1.00
SD2-GAA140	58.2	14	1	0.5	36.82 sdt)	0.30



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Table 6: SD2 Exploration Boreholes Pump Tested

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 (Hours)	Yield of CDT (l/s)	CDT Drawdown (m)	WL Recovery (m)	WL Recovery (Min)
Exploration Boreholes														
SD2-03	-28.31856	23.14214	2013/09/08	118	18.6	101	4	-	20.1	48	20.1	18.7	0	480
SD2-04	-28.32982	23.09288	2014/01/22	74	13.38	62	2	0.13	0.6	-	-	-	36.5	120
SD2-05	-28.32705	23.13926	2013/09/09	104	14.3	101	3	1.3	2.5	-	-	-	0	110(sdt)
SD2-06	-28.32501	23.15042	2014/01/24	77	20.0	62	1	-	0.51	-	-	-	32.34	60
SD2-07	-28.31605	23.15721	2013/09/13	52	20.8	47	4	-	30.3	48	30.0	15.8	0	10
SD2-08	-28.31349	23.15012	2014/01/25	121	20.3	85	3	0.43	1.3	-	-	-	6.48	180
SD2-09	-28.30627	23.15653	2013/09/16	66	18.2	59	4	-	20.6	24	20.1	1.0	0	90
SD2-09(2)	-28.30627	23.15653	28/02/2014	66	18.19	53.15	-	-	-	72	20	0.28	0	90
SD2-10	-28.30932	23.13851	2013/10/13	71	12.3	59	4	-	20.3	24	15.0	9.8	0	40
SD2-11	-28.30498	23.12651	2013/09/23	34	10.6	29	4	-	30.4	48	30.1	1.3	0	1440
SD2-12	-28.30806	23.16122	2013/09/19	74	20.2	71	4	-	21.2	24	20.1	5.0	0	300
SD2-12(2)	-28.30806	23.16122	22/02/2014	74	20.38	70	-	-	-	72	20	4.8	0	1
SD2-13	-28.29871	23.16361	2013/10/21	52	19.8	47	4	28.4	30.0	48	20.0	16.6	1.43	2880
SD2-14	-28.29601	23.17271	2013/10/16	100	23.9	89	4	-	20.4	24	15.2	12.2	0	90
SD2-15	-28.29281	23.14875	2013/10/21	82	16.1	77	4	-	20.0	24	20.0	3.4	0	30
SD2-15(2)	-28.29281	23.14875	05/03/2014	82	16.4	59.15	-	-	-	72	20	3.58	0	720
SD2-16	-28.28816	23.16310	2013/10/31	97	19.2	89	4	-	20.2	48	20.0	5.8	0	3
SD2-17	-28.32063	23.12369	2013/10/18	60	13.2	58	4	-	16.2	24	15.0	9.4	0	960
SD2-19	-28.33002	23.09772	2014/01/21	62	17.7	56	2	0.16	0.7	-	-	-	18.21	120
SD2-21	-28.27099	23.16394	2013/11/06	94	19.4	83	4	18.4	20.0	48	13.0	24.2	0	2
SD2-22	-28.21927	23.23948	2013/10/25	73	45.0	71	4	18.8	20.0	48	13.0	9.3	0	1200
SD2-23	-28.26321	23.16927	2013/11/02	71	21.1	58	4	-	20.0	24	15.0	6.7	0	3
SD2-24	-28.25125	23.21373	2013/11/15	119	47.4	95	4	-	20.2	48	15.0	8.5	0.22	2880
SD2-25	-28.21161	23.23614	2013/11/12	61	41.3	58	2	4.4	4.5	-	-	-	0.21	80



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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 (Hours)	Yield of CDT (l/s)	CDT Drawdown (m)	WL Recovery (m)	WL Recovery (Min)
SD2-26	-28.27414	23.17470	2013/11/10	72	23.3	64	4	-	25.0	48	20.0	13.6	0	720
SD2-29	-28.23921	23.25444	2014/01/25	70	47.74	62	2	0.21	0.74	-	-	-	6.42	70
SD2-30	-28.23913	23.22551	2013/11/29	98	52.5	88	3.5	15.4	17.0	24	10.0	15.2	0	210
SD2-31	-28.21906	23.20117	2013/11/21	85	10.7	77	4	10.0	15.0	24	7	2.3	0	600
SD2-32	-28.22203	23.20685	2013/12/02	90	31.3	83	3	10.7	12.3	24	8	32.8	0	180
SD2-33	-28.23505	23.25757	2014/01/14	102	59.3	94	4	13.2	19.0	48	9	12.9	0	840
SD2-34	-28.22227	23.20102	2013/12/05	34	11.9	29	4	-	30.1	24	20.1	1.4	0.04	1440
SD2-34(2)	-28.22227	23.20102	27/02/2014	34	19.68	29	-	-	-	72	30	2.7	0	1560
SD2-35	-28.23638	23.22553	2013/12/11	100	50.4	76	6	-	30	24	25	0.3	0	15
SD2-35(2)	-28.23638	23.22553	23/02/2014	100	50.12	70.84	-	-	-	72	30	0.43	0	1200
SD2-36	-28.20202	23.13838	20-13/12/08	97	33.9	88	4	-	20	24	15	2.3	0	480
SD2-37	-28.23835	23.24119	20/02/2014	83.86	59.8	76.5	4	-	20.5	48	20	0.77	0	10
SD2-38	-28.22186	23.21807	05/03/2014	88.75	38.08	82.04	4	-	20.3	56	15	27.43	0	20
SD2-39	-28.23631	23.14913	10/03/2014	70	16.1	64.8	4	-	-	-	-	-	0	90
SD2-42	-28.23549	23.15964	12/03/2014	39	5.21	33.34	4	-	20.58	72	15	4.62	0	360



4.7.1 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 7.

Table 7: SD2 Storativity Values

Borehole Number	Date Tested	Borehole Depth (m)	Static Water level (mbgl)	Monitor Borehole	Monitor borehole Aquifer Test - T	Draw Down (m)	Storativity (S)	Storativity (S)
SD2 Exploration Boreholes								
SD2-11	20/09/2013	34	11.52	SD2-GAA054	4750	0.77	1.58 X 10 ⁻⁶	0.00000158
SD2-16	27/10/2013	97	19.64	SD2-16M	1910	0.58	1.57 X 10 ⁻⁴	0.000157
SD2-35	23/02/2013	98.85	50.12	SD2-30	1240	0.1	7.38 X 10 ⁻⁴	0.000738
SD2-42	13/03/2014	38.70	5.21	SD2-39	600	0.11	3.48 X 10 ⁻⁵	0.0000348
Mean								0.00031
Median								0.00016

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.



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Table 8: Calculated Transmissivity Values of SD2 Exploration Boreholes

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)	%					
SD2-3	118	19.47	2880	20.1	18.68	480	100	898	591	165	Dolomite	Production
SD2-7	52.4	20.83	2880	30.22	8.42	10	100	500	431	203	Dolomite	Production
SD2-9	66.3	19.23	1440	20.64	0.52	90	100	965	998	165	Dolomite	Production
SD2-9(2)	66.44	18.19	4320	20.08	0.28	2	100	6180	-	165	Dolomite	Production
SD2-10	70.5	12.35	1440	15.0	9.43	40	100	3788	756	165	Dolomite	Production
SD2-11	34	11.52	2880	30.1	1.68	1440	100	834	946	203	Dolomite	Production
SD2-12	74.4	21.10	1440	20.1	4.63	300	100	683	-	165	Dolomite	Production
SD2-12(2)	74.06	20.38	4320	20.12	4.8	1	100	4120	-	165	Dolomite	Production
SD2-13	52.6	19.75	2880	20.0	16.58	2880	91	570	-	203	Gravel	Production
SD2-14	100.0	23.94	1440	15.2	12.16	90	100	472	-	165	Dolomite	Production
SD2-15	81.8	16.11	1440	20.0	3.36	30	100	476	-	165	Dolomite	Production
SD2-15(2)	80.44	16.4	4320	20.08	3.58	720	100	12360	-	165	Dolomite	Production
SD2-16	97.0	19.64	4320	20	5.84	3	100	892	1020	165	Dolomite	Production
SD2-17	59.6	13.24	1440	15.0	9.43	960	100	191	-	165	Dolomite	Production
SD2-21	94.0	19.81	4320	13.0	24.24	2	100	203	-	165	Dolomite	Production
SD2-22	73.0	45.8	2880	13.0	9.32	1200	100	80.0	-	165	Dolomite	Production
SD2-23	73.0	21.79	1440	15.0	6.78	3	100	1338	-	203	Dolomite	Production
SD2-24	119.0	48.01	1440	15.0	8.64	2880	97	220	-	165	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)	%					
SD2-26	75.0	23.3	4320	20.0	13.56	720	100	1500	-	203	BIF/Dolomite	Production
SD2-30	98.0	52.52	1440	10.03	15.25	210	100	184	-	165	Dolomite	Production
SD2-31	85.0	11.38	1440	7.0	2.34	600	100	438	-	203	Dolomite	Monitoring
SD2-32	90.0	31.63	1440	8.0	32.70	180	100	61	-	203	Dolomite	Production
SD2-33	101.96	59.3	2880	9	12.89	840	100	119	-	165	BIF	Production
SD2-34	34.0	12.31	1440	20.0	1.4	1440	97	872	-	203	Dolomite	Production
SD2-34(2)	34.46	12.31	4320	30.04	2.77	1440	100	842	-	203	Dolomite	Production
SD2-35	100.48	50.36	1440	25	0.28	15	100	1342	-	203	Dolomite	Production
SD2-35(2)	98.85	50.12	4320	30.02	0.43	1200	100	4635	8530	203	Dolomite	Production
SD2-36	97.5	33.92	1440	15	1.54	480	100	1013	-	203	Dolomite	Production
SD2-37	83.86	59.8	2880	20.17	0.77	10	100	2528	-	165	Dolomite	Production
SD2-38	88.75	38.08	3240	15	27.43	20	100	63	-	165	Dolomite	Production
SD2-42	39	5.21	4320	20.0	4.62	360	100	269	265	165	Dolomite	Production



5.0 GROUNDWATER RESOURCE ASSESSMENT

5.1 Groundwater Use

5.1.1 Existing Groundwater Users

The existing groundwater use for the SD2 modelling area was calculated from data and abstraction rates required during the hydrocensus and groundwater database. The groundwater use and abstraction rates are summarised in Table 9.

The existing groundwater users are divided into two main use categories namely municipality/community use and private use with a combined abstraction rate of 172 186m³/Month.

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

- Windmill 0.3l/s for 8 hours/day;
- Solar pump 0.2l/s for 6 hours/day;
- Hand pump 0.1l/s for 8 hours/day;
- Fountains 0.5l/s for 24 hours/day; and
- Motorized pumps at 0.5l/s for 8 hours/day.

Table 9: SD2 Existing Groundwater Use and Abstraction Rates - 2013

Groundwater use	Borehole number	Abstraction Rate m ³ /Month	Abstraction Rate m ³ /Year
Postmasburg Municipality	SD2-GAA036; SD2-GAA037 and calculated average of existing production BH's	46 673	560 079
Municipality Jen Haven Community	SD2-GAA002; SD2-GAA004	10 368	124 416
Groenwater Community	Boreholes in use (12)	3 957	47 485
Private	226 Boreholes and fountains	111 188	1 334 258
Total Use		172 186	2 066 238

Postmasburg Production Boreholes

Postmasburg municipality production boreholes in use were verified during June 2014, and are listed in Table 10 and indicated on Figure 37. The verified production boreholes are shown as a photo gallery in Table 11.

A total of nine production boreholes were verified from which two were confirmed during the hydrocensus in 2012. The new production borehole Dam1 located at the municipality reservoir fall in GMU D73A-06, outside the SD2 groundwater modelling area.

Subsequent to the upgrading of pump equipment within four production boreholes, the Postmasburg municipality abstraction rates need to be quantified.



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Table 10: Postmasburg Municipality Production Boreholes in Use

GMU	Nr. On Map	Alt/Site Name	Latitude	Longitude	Depth(m)	Latest Water Level (mbgl)	Equipment	Comment
D73A-03	SD2-GAA036	Vaalpoort/Gat1	-28.27968	23.15286	50	9.7	Submersible	-
	SD2-GAA037	Vaalpoort/Gat2	-28.27928	23.15313	15	9	Submersible	W. Coetzee - owner
D73A-04	PB11	Hout Str. 2	-28.33782	23.06687	64.0	-	Submersible	New Equipment
	PB7	Makou Dam	-28.3285	23.07132	37	12.0	Submersible	-
	PB6	ACVV	-28.33014	23.06861	75	11.0	Submersible	-
	PB9	Fish and chips	-28.33153	23.06314	30	3.4	Submersible	-
	PB8	Blou Deur/dak	-28.33095	23.06398	27	5.83 (6/2014)	Submersible	New Equipment
	PB5	Koop.	-28.32883	23.06618	35	5.13 (6/2014)	Submersible	New Equipment
D73A-06	Dam1	Reservoir	-28.32239	23.06522	100	-	Submersible	New Equipment

Table 11: Postmasburg Municipality Production Boreholes in use

Borehole Number/Site Name	Photos
SD2-GAA036/Vaalpoort	



Borehole Number/Site Name	Photos
SD2-GAA037/Vaalpoort Pump need to be replaced at time of survey.	
PB11/Hout Str. 2 New equipment.	
PB7/Makou Dam	



Borehole Number/Site Name	Photos
PB6/ACVV	
PB9/Fish and chips	
PB8/Blou Deur/dak New equipment.	



Borehole Number/Site Name	Photos
Dam1/Reservoir Newly drilled borehole and equipment.	
Koop.	



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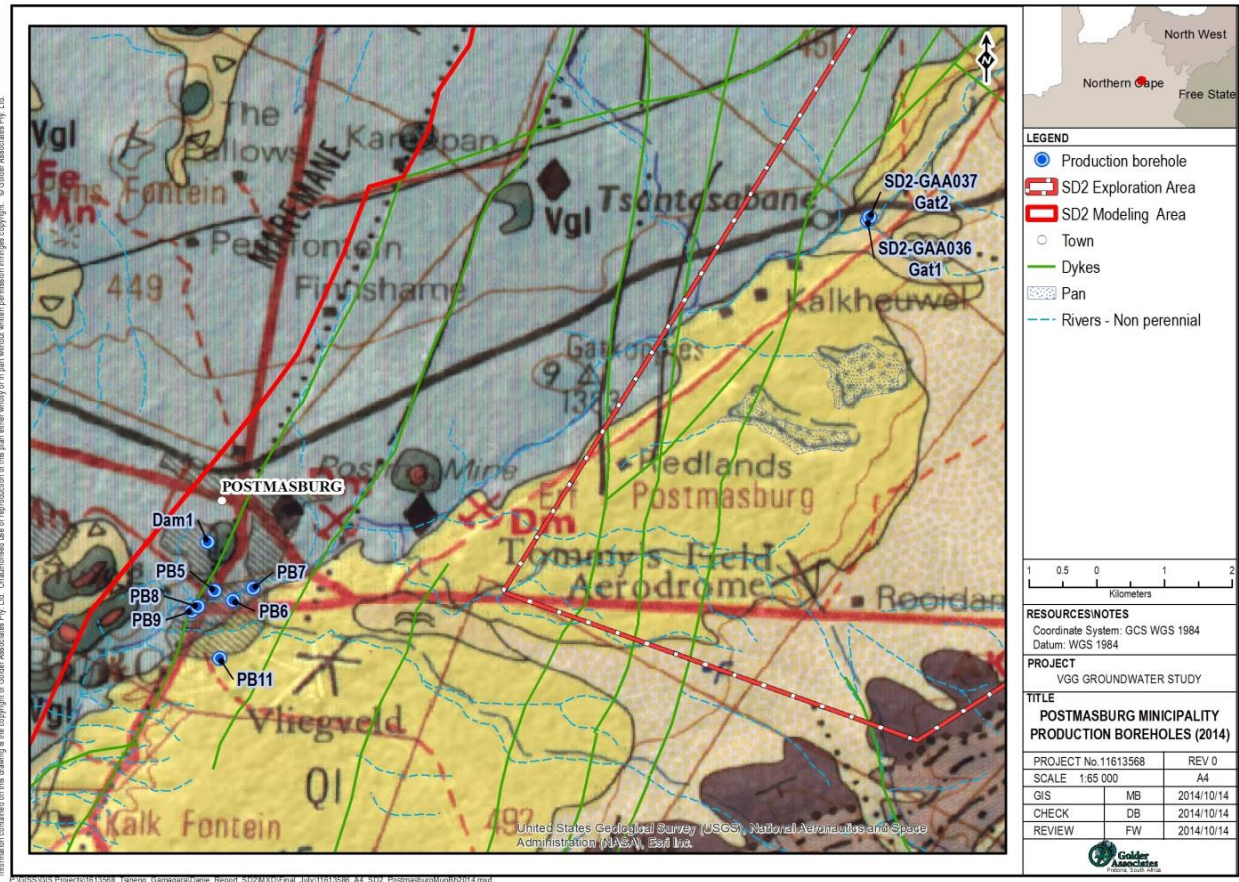


Figure 37: Postmasburg Municipality Production Boreholes (2014)

SD2 WARMS Registered Groundwater Users

11 groundwater users were located within the SD2 modelling area that is registered with the Water Authorization and Registration Management System (WARMS) and are indicated on Figure 38 and summarised in Table 12.



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Table 12: WARMS Registered Groundwater Users

Groundwater user Name	No. on Map	Latitude	Longitude	Licence number	Use	Drainage Region	WARMS Million m3/Year
AREEMENG MMOGO PRIMARY	W3	-28.303500	23.305833	25058650	AGRICULTURE: WATERING LIVESTOCK	D73A	3421
SOLANDRA INVESTMENT 506	W5	-28.316278	23.102722	25059070	MINING	D73A	2600
MF CLAASSENS	W6	-28.200000	23.133333	25002238	AGRICULTURE: IRRIGATION	D41J	24300
PEJ DUVENHAGE	W8	-28.183333	23.200000	25003237	AGRICULTURE: IRRIGATION	D41J	27250
T COETZEE	W9	-28.383333	23.216667	25003512	AGRICULTURE: IRRIGATION	D73A	98768
A DUNWOODY	W11	-28.250000	23.389247	25017525	MINING	C92A	7200
JJ COETZEE	W16	-28.200000	23.133333	25002540	AGRICULTURE: IRRIGATION	D41J	9590
CC CLAASSENS	W17	-28.183333	23.133333	25002602	AGRICULTURE: IRRIGATION	D41J	9730
LJ JANSE VAN RENSBURG	W18	-28.183333	23.133333	25004487	AGRICULTURE: IRRIGATION	D41J	6463
JH BOSHOF	W20	-28.200000	23.150000	25005048	AGRICULTURE: IRRIGATION	D41J	5450
42 BOERDERY	W21	-28.200000	23.133333	25009133	AGRICULTURE: IRRIGATION	D41J	39000
Total							1 431 450

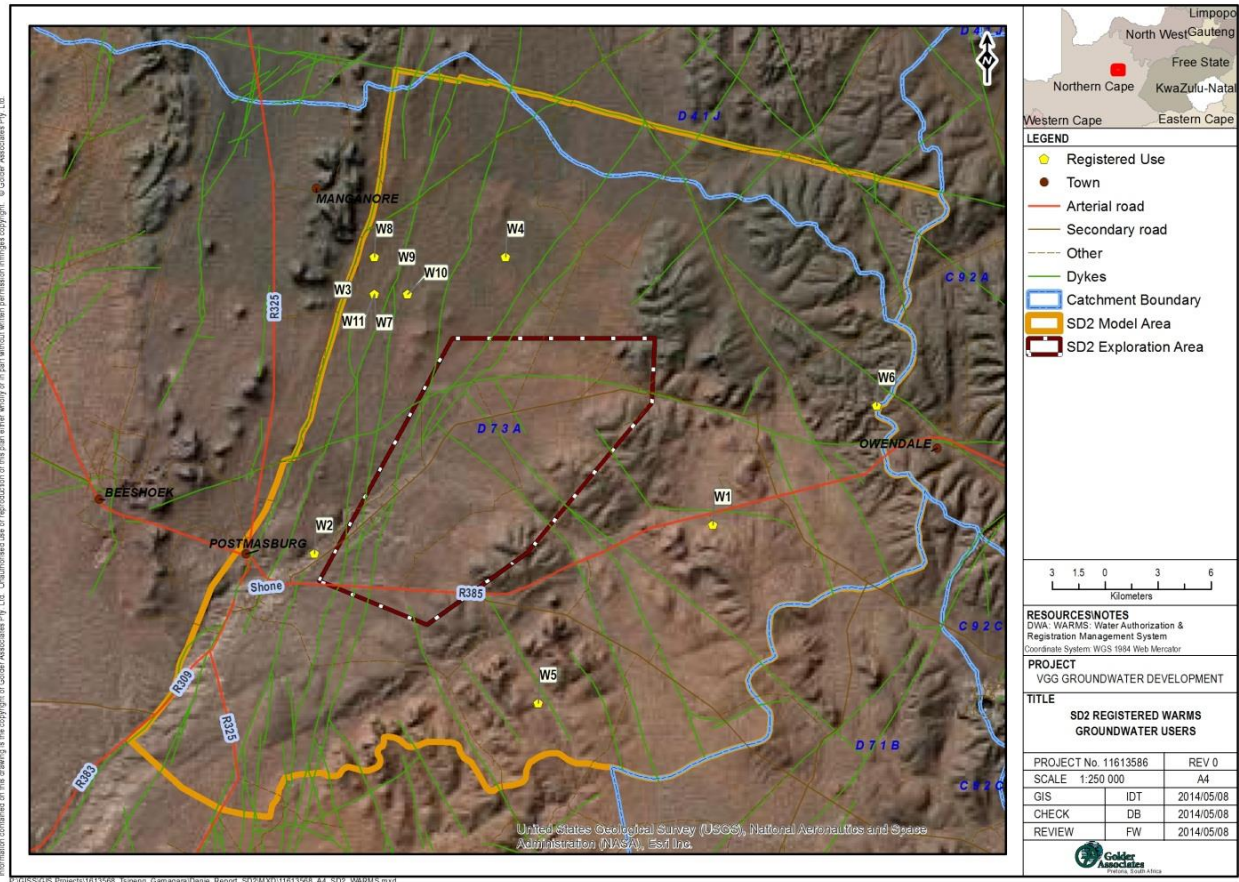


Figure 38: SD2 Registered WARMS Groundwater Users

5.1.2 Fountains

Six fountains were located from the groundwater data base which falls within the SD2 modelling area. These fountains positions are indicated on Figure 39 and are summarised in Table 13. However only fountain SD2-GAA083, falling within the designated hydrocensus area position was confirmed during the hydrocensus. Some existing fountains are non-perennial in the modelling area and may start flowing during high rainfall seasons.



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Table 13: SD2 Fountains

Fountain/Farm	Map Number	Latitude	Longitude	Altitude (mamsl)	Equipment	Estimated Flow (l/s)	Estimated Flow m ³ /Month	Estimated Flow m ³ /Year
Groenwater	GR13	-28.255580	23.326970	1451.2	-	1.01	2617.9	31415.0
Knoffelfontein	PEN6	-28.293680	23.078620	1352.2	N	12.62	32711.0	392532.5
Farm 492 ptn. Grootfontein	Grootfontein	-28.368960	23.101390	1330.1	N	0.5	1296.0	15552.0
Olyn fontein ptn. Olienfontein	OLN9	-28.349370	23.051997	1289.2	-	0.5	1296.0	15552.0
Ploegfontein	PLOEG01	-28.372470	23.036240	1269.8	N	0.5	1296.0	15552.0
Seretsesenocho ptn. Sion	SD2-GAA083	-28.170450	23.175170	1403.1	N	0.2	518.4	6220.8
Total						15.3	39 735.3	476 824.3

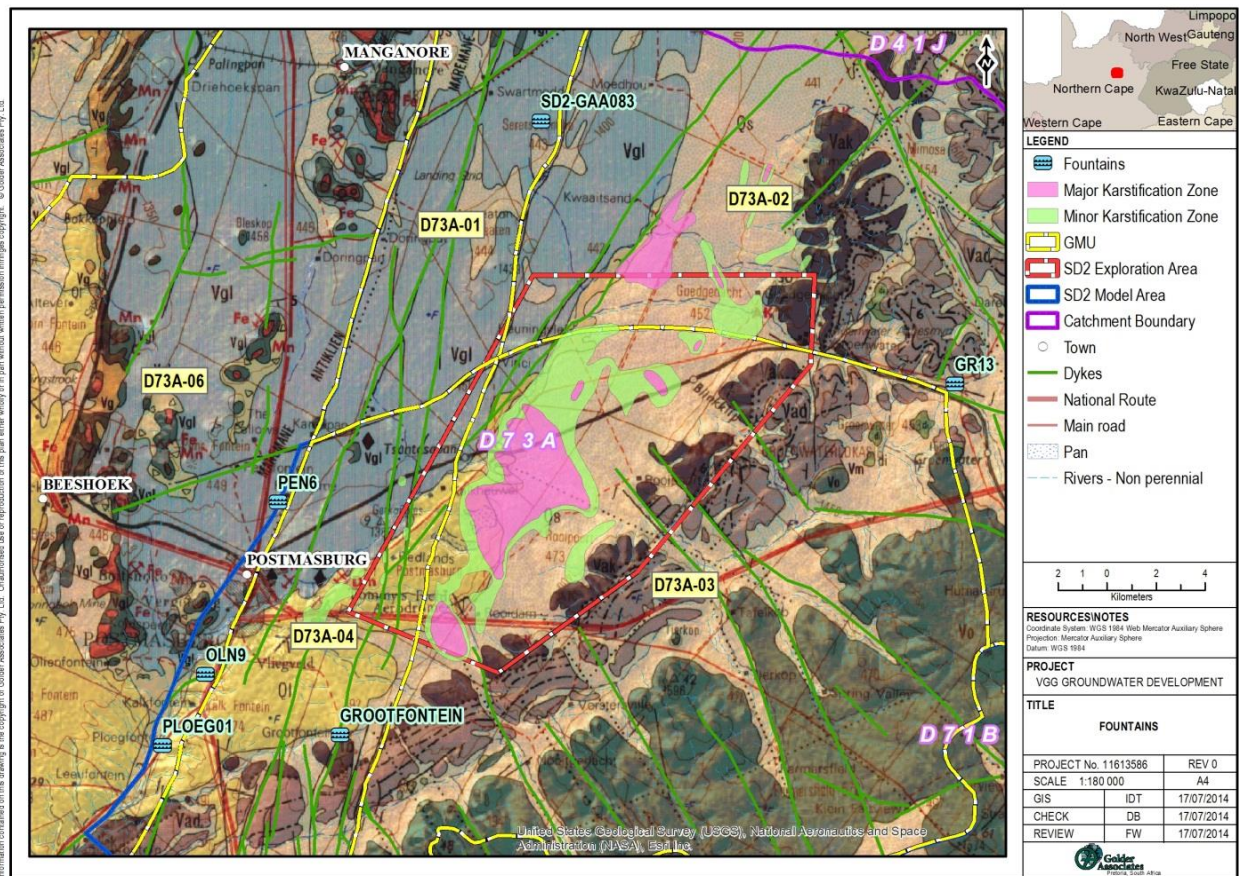


Figure 39: SD2 Fountain Positions



5.2 Groundwater Levels and Flow directions

Manual derived groundwater piezometric contours were compiled at 10 metre intervals for the SD2 study area. The contours are based on 298 water level elevation data points, sourced from the Golder in-house database, as indicated in Figure 40.

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.

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 40.

The regional groundwater flow direction for the SD2 study area is south west towards Postmasburg. 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 contours within the central parts the model domain show a low hydraulic gradient (Figure 40) due to the high aquifer transmissivity within the dolomitic compartments. The region is bounded by dykes with major steps in hydraulic heads, where water levels on the one side of a dyke are substantially lower. Piezometric levels north and northwest of the model domain show steeper gradients, indicating lower transmissivities in the BIF hard rock aquifer. The depth to the groundwater table ranges from 1 to 123 mbgl, with an (arithmetic) average depth to groundwater of 20.5 mbgl.

Groundwater piezometric contour levels ranges from 1550mamsl in the east to 1260mamsl in the south west, representing a maximum head of 290 metres for the study area.

5.3 Groundwater Quality

The groundwater quality of SD2 is discussed according to the following topics:

- Groundwater sampling;
- Groundwater chemical parameters analysed;
- Baseline Groundwater quality; and
- Groundwater classification as Piper and Expanded Durov (EDD) quality Diagrams.

5.3.1 Groundwater Sampling

Groundwater samples were collected from 37 existing boreholes during the hydrocensus and aquifer testing programme. Groundwater samples were furthermore collected from 39 exploration 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.

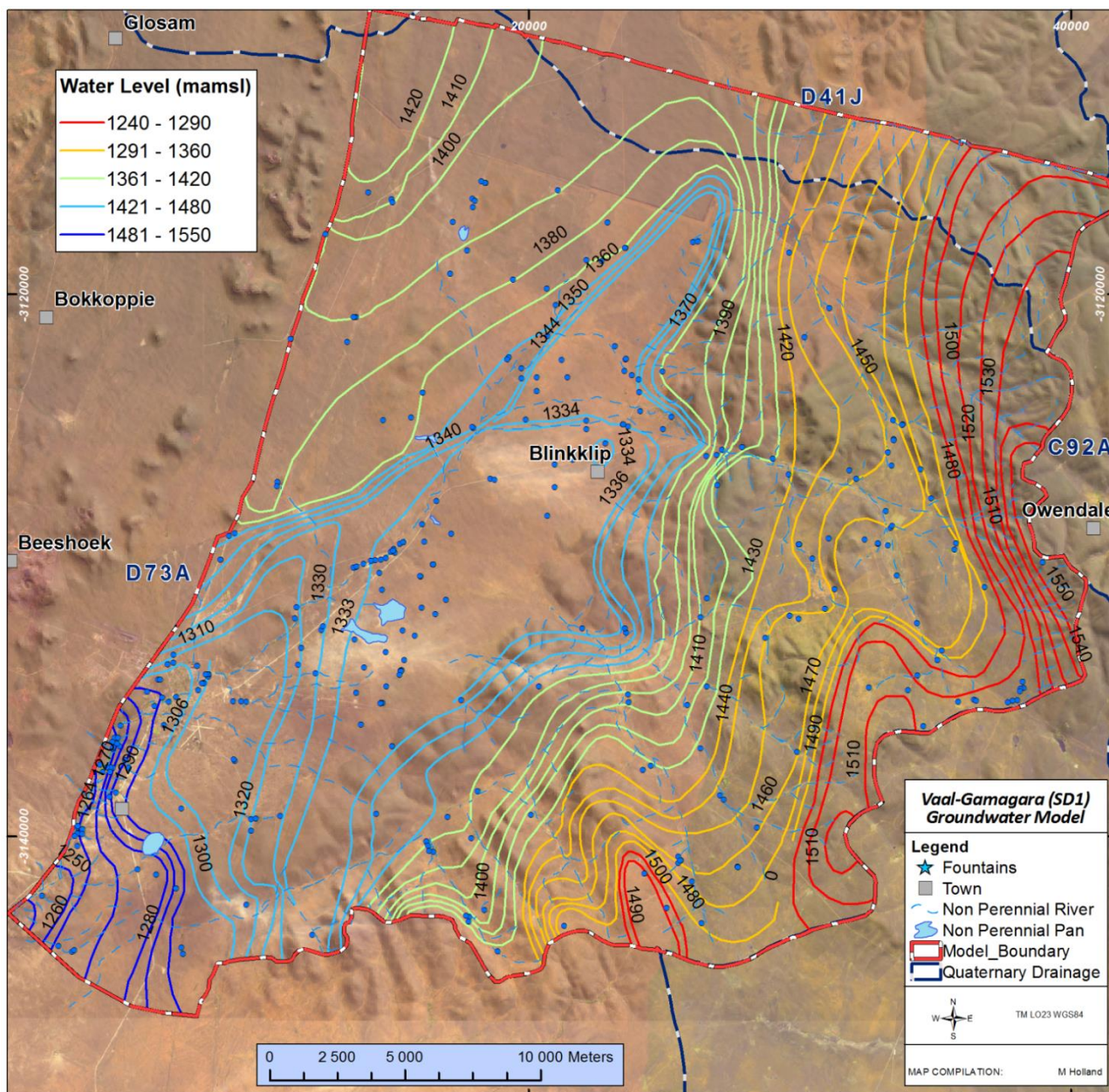


Figure 40: SD2 Groundwater Piezometric Contour Map

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 SD2 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)
	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 discussing the baseline water quality (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 SD2 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.

5.3.5 Groundwater Analytical Results

Generally 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 standards.



Table 16: SD2 Baseline Groundwater Quality

Item	Physical Parameters			Macro Determinants (Major Ions and Trace Metals)								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	39	39	39	39	39	39	39	39	39	39	39	39	39	33
10 % Percentile	7.24	43.2	308	42.5	22.6	12.1	2.27	20.3	13.4	1.93	166	0.1	0.05	0.05
Median Baseline water Quality	7.71	57.20	378	64.60	35.40	19.0	2.90	28.70	19.90	2.97	272.00	0.18	0.05	0.05
Average	7.70	58.29	414.54	65.14	37.09	22.02	3.34	39.89	22.06	4.05	258.82	0.21	0.06	0.16
90% Percentile	8.13	75.6	512	87.3	53.1	35	5.47	54.5	32.3	7.26	347	0.351	0.05	0.47
Max. Allowable Limit (SANS 241:2011)	<5 >9	<170	<1200	<300	<100	<200	<100	<300	<500	<11	-	<1.5	<0.3	<0.5

The aquifer systems at SD2 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, Mg, Na, Cl, NO_3 , Fe and Mn and are discussed accordingly below.

5.3.5.1 Electrical Conductivity

Three existing 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 154mS/m (SD2-GAA118) to 436mS/m (SD2-GAA063). These elevated EC values are probably related to the geology of the formation, contributed by higher Ca and/or Mg concentrations.

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

5.3.5.2 Total Dissolved Solids (TDS)

Three 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 and Mg concentration in the water due to more solubility of these elements in the formation.

All the new exploration boreholes except SD2-18 (1080mg/l) TDS values are below the DWAF (1998) Class 1 drinking water standard of 1000mg/l.

5.3.5.3 Calcium (Ca)

One existing boreholes borehole (SD2-GAA082; 150mg/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)

All the existing and exploration boreholes potassium concentrations are below the maximum allowable limit of the DWAF (1998) Class 1 drinking water standard of 50mg/l.

5.3.5.5 Magnesium (Mg)

Two existing boreholes (SD2-GAA081 and SD2-GAA116) 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)

One existing borehole SD2-GAA116 (274.1mg/l) and exploration borehole SD2-18 (322mg/l) chloride concentrations exceeds the maximum allowable limit of 200mg/l of the DWAF (1998) Class 1 drinking water standard.

These elevated chloride concentrations place these two boreholes in Class II and Class III respectively of the DWAF (1998) drinking water standard. Elevated chloride values are probably related to localised impacts.

5.3.5.7 Nitrate (NO₃ as N)

Ten existing boreholes and one new exploration borehole (SD2-8;10.9mg/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 11.3mg/l (SD2-GAA085) to 54.14mg/l (SD2-GAA082) and place these boreholes in Class II to Class IV 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)

All the existing and new exploration boreholes fluoride concentrations are below the maximum allowable limit of the DWAF (1998) Class 1 drinking water quality standard of 1.0mg/l.

5.3.5.9 Iron (Fe) and Manganese (Mn)

One existing boreholes (SD2-GAA140) 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 0.2mg/l and 0.5mg/l respectively.

Two new exploration borehole SD2-18 (1.02mg/l) and SD2-29(1.09 mg/l) manganese concentrations exceed the maximum allowable limit of the DWAF (1998) Class 1 standard of 0.4mg/l. These elevated iron and manganese concentrations are probably related to the geology of the SD2 area.



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Table 17: SD2 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	
SD2-GAA002	2005/08/01	7.9	61.1	384.0	244	68.9	3.19	24.2	34.3	42.6	6.4	32.6	14.4	0.132	-	-	0
SD2-GAA004	2012/04/11	7.6	46.3	326.0	211	62.1	2.84	21.8	12.5	17.2	4.2	12.6	11.6	0.12	<0.05	<0.05	0
SD2-GAA010	2005/08/01	7.8	68.8	478.0	343	77.8	2.85	47.2	13.5	30.4	5.2	13.4	-	0.1	<0.05	<0.05	0
SD2-GAA011	2005/08/01	7.7	61.6	416.0	332	74.0	1.46	42.9	8.24	14.2	1.8	20.2	-	0.24	<0.05	<0.05	0
SD2-GAA013	2014/01/27	8.3	48.8	438.0	207	42.3	3.53	39.7	21.4	35.6	5.3	24.5	8.4	0.225	0.1	-	I
SD2-GAA020	2012/04/11	7.2	9.1	60.0	27	9.9	2.42	5.25	6.95	5.8	2.5	4.58	8.2	0.108	-	-	0
SD2-GAA021	2012/04/11	7.6	36.0	272.0	125	31.4	2.5	22.3	13.5	22.2	7.6	16.4	12.3	0.1	-	-	0
SD2-GAA027	2012/04/11	8.1	97.7	680.0	340	79.5	4.95	70.7	42	106.0	15.3	50.1	15.7	0.176	-	-	II
SD2-GAA037	2012/04/11	7.7	61.2	416.0	303	76.7	2.56	43.7	17.8	93.1	3.2	19.5	10.5	0.172	-	-	0
SD2-GAA038	2004/09/21	8.1	71.4	472.0	366	74.0	3.3	62.3	17.1	29.8	3.8	33.3	12.6	0.662	-	-	I
SD2-GAA042	2004/09/21	7.9	56.9	442.0	203	52.0	2.2	35.5	25.7	35.2	15.3	18.4	15.9	0.208	-	-	II
SD2-GAA044	2012/04/11	7.8	59.2	386.0	288	65.0	2.51	36.1	20	27.6	3.3	18.2	15.2	0.164	-	-	0
SD2-GAA049	2012/04/11	7.8	55.7	392.0	269	86.0	3.69	16	19.4	27.9	2.4	19.4	18.4	0.142	-	-	0
SD2-GAA053	2012/04/12	7.6	94.5	640.0	443	109.0	1.84	59.9	27.3	51.4	4.0	54.9	17	0.161	-	-	I
SD2-GAA063	2005/08/01	7.7	436.0	454.0	335	84.4	3.63	42.1	13.9	30.1	5.0	13.8	22.1	0.1	<0.05	<0.05	III
SD2-GAA070	2013/06/03	7.6	54.6	410.0	232	76.2	2.5	31.1	11.5	30.0	0.3	51.3	-	0.291	<0.05	0.06	0
SD2-GAA074	2005/08/01	6.8	17.5	142.0	60	14.5	2.67	9.64	9.61	14.1	1.7	10.6	8.72	0.1	<0.05	<0.05	0
SD2-GAA077	2013/06/03	7.7	62.1	470.0	213	49.1	1.58	57.5	15.6	72.7	0.3	33.9	-	0.1	<0.05	<0.05	0
SD2-GAA078	2013/06/03	7.2	55.7	380.0	301	63.1	4.18	42.7	8.07	14.1	0.3	11.7	-	0.27	<0.05	0.38	I
SD2-GAA080	2013/06/03	7.9	141.0	1070.0	583	76.5	0.73	144	52.2	98.8	13.8	117	-	0.1	<0.05	0.14	II
SD2-GAA081	2013/06/03	7.7	107.0	806.0	392	93.3	1.2	85.5	22.1	80.7	17.4	70.3	-	0.23	<0.05	<0.05	II
SD2-GAA082	2013/06/03	7.7	154.0	1090.0	365	150.0	0.67	113	23.1	170.0	54.1	67.6	-	0.1	<0.05	<0.05	IV
SD2-GAA083	2013/06/03	7.8	88.8	654.0	498	95.5	1.22	74	14.6	33.3	0.3	36.3	19.6	0.127	<0.05	<0.05	I
SD2-GAA084	2013/06/03	7.9	73.8	514.0	386	74.0	1.43	67.1	11.1	19.8	8.7	14.3	-	0.14	<0.05	0.06	I
SD2-GAA085	2013/06/03	7.8	81.6	488.0	349	81.7	1.62	70.4	13.5	38.6	11.3	22.4	-	0.1	<0.05	<0.05	II
SD2-GAA086	2013/06/03	8.0	83.1	580.0	471	73.0	1.46	69.7	12.3	25.0	1.1	23.6	-	0.1	<0.05	0.06	I
SD2-GAA087	2013/06/03	7.9	64.1	470.0	347	83.9	1.3	45.6	8.34	14.9	2.4	21	-	0.19	<0.05	<0.05	0
SD2-GAA092	2005/08/01	7.4	65.7	430.0	353	88.7	2.55	40.8	10.1	20.1	4.8	12.5	21	0.118	<0.05	<0.05	I
SD2-GAA097	2013/06/04	7.3	97.6	680.0	424	93.7	1.94	71.1	35.7	67.6	12.3	44.6	25.5	0.282	<0.05	<0.05	II
SD2-GAA098	2004/09/21	6.7	32.3	242.0	126	30.5	2.02	18.9	8.9	16.2	0.9	7.5	4.18	0.17	-	-	0
SD2-GAA116	2004/09/21	8.1	186.0	1214.5	302	72.7	12.7	139.6	90.7	274.1	4.2	237.3	18.43	0.206	-	-	II
SD2-GAA134	2014/01/31	7.4	100.0	674.0	413	113.0	1.42	81	14.4	49.8	27.5	25.8	-	0.14	<0.05	<0.05	III
SD2-GAA135	2014/01/31	7.9	80.5	600.0	396	64.9	3.86	69.3	16.5	31.7	13.4	21.9	-	0.16	<0.05	<0.05	II
SD2-GAA136	2014/01/31	7.6	79.1	554.0	423	76.5	1.41	70.5	11.7	22.5	7.1	22.7	-	0.1	<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	
SD2-GAA138	2013/06/03	7.7	101.0	726.0	427	70.1	0.77	95.8	18.1	83.1	12.1	42.9	-	0.23	<0.05	<0.05	II
SD2-GAA139	2014/03/20	7.7	58.3	382.0	297	54.5	3.74	47.6	13.1	19.8	0.3	34.9	-	0.747	<0.05	<0.05	0
SD2-GAA140	2014/04/02	7.7	71.5	470.0	404	86.3	7.22	45.9	17.9	28.9	0.3	27.2	-	0.1	0.15	0.54	II
SANS241: 2011		9.7	<170	1200	-	-	-	-	200	300	11	500	-	1.5	0.3	0.5	
Class 0 Max. Allowable Limit		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		6.7	9.1	60	27.3	9.9	0.7	5.3	6.95	5.77	0.3	4.6	4.18	0.1	0.1	0.1	
Max		8.3	436.0	1214.5	583	150	12.7	144	90.7	274.11	54.1	237.3	25.5	0.8	0.2	0.5	
Average		7.7	84.3	521.7	318.9	72.3	2.8	55.7	19.8	48.51	7.6	35.4	14.72	0.2	0.1	0.1	



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Table 18: SD2 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	
SD2-9	2013/10/03	7.64	57	386	279	63	2.9	35.4	22.2	29	2.3	19.3	14.1	0.202	<0.05	<0.05	0
SD2-8	2013/10/03	7.46	60.5	452	199	50.9	3.27	41.5	21.4	54.5	10.9	19.9	8.35	0.195	<0.05	0.11	II
SD2-7	2013/10/02	7.53	57.4	416	264	67.1	2.76	34.1	20.7	26.9	2.23	19.6	14.3	0.199	<0.05	<0.05	0
SD2-6	2013/09/04	7.36	28.2	184	111	23.2	2.05	18.4	17.2	23.7	0.3	2.51	-	0.9	<0.05	<0.05	0
SD2-5	2013/09/04	7.78	44.2	308	181	43.5	2.57	26.8	17.6	29.4	2.53	23	7.63	0.194	<0.05	0.33	I
SD2-42	2014/03/27	7.2	79.2	572	409	96.3	2.27	53.1	11.3	26	7.26	21.5	-	0.251	<0.05	0.13	I
SD2-41	2014/03/27	7.94	46.1	330	189	51	4.42	22.6	27.6	32.3	3.86	23.2	-	0.163	<0.05	<0.05	0
SD2-4	2013/09/04	8.13	63.7	404	347	41.1	5.57	55.4	25.8	43.9	2.56	27.1	9.62	0.389	<0.05	0.29	I
SD2-39	2014/03/20	7.2	98.6	790	436	89.7	6.95	82.8	35	60.8	11.6	42	-	0.174	<0.05	0.21	II
SD2-38	2014/03/20	7.9	57.5	400	289	64.6	3.12	36.8	12.6	22.3	3.75	13.4	-	0.1	<0.05	<0.05	0
SD2-37	2014/02/20	7.64	52.7	364	219	59.1	3.25	26.7	28.3	37.8	2.86	25.6	-	0.1	<0.05	<0.05	0
SD2-36	2013/12/19	8.16	47.3	412	259	71.8	2.57	44.9	12.8	25.4	5.04	15.6	17.9	0.176	<0.05	-	0
SD2-35	2013/12/19	8.23	41	324	246	58.6	2.94	34.3	14.1	22.9	4.33	14.5	14.8	0.125	<0.05	-	0
SD2-34	2013/12/19	7.94	52.1	512	272	87.3	1.83	41.1	9.42	20.3	4.89	14	18.3	0.225	<0.05	-	I
SD2-33	2013/12/19	7.89	63	368	270	52	5.31	27.3	59.2	37.8	3	32.3	12.4	0.152	0.19	<0.05	I
SD2-32	2013/12/19	8.17	46.8	436	238	64.6	2.33	32.3	11.7	22.8	5.03	13.5	16.7	0.17	<0.05	-	0
SD2-31	2013/12/19	8.11	43.8	478	216	64.4	1.86	40	19	19.4	4.64	14.9	16.5	0.182	<0.05	-	0
SD2-30	2013/12/19	8.09	45.5	408	222	75	2.9	33.8	13.9	23	4.34	14	14.9	0.121	<0.05	-	0
SD2-3	2013/08/29	7.51	56.2	342	274	63	3.08	35.4	22	25.6	1.75	20.1	16.6	0.158	<0.05	<0.05	0
SD2-29	2013/11/27	6.96	43.2	350	132	42.5	4.65	28.9	14.9	53.5	0.3	26.9		0.21	0.12	1.09	III
SD2-27	2013/11/05	7.78	66.5	434	357	76.4	2.64	47.5	12.1	38.5	4.66	17.6	18.9	0.216	<0.05	<0.05	0
SD2-26	2013/11/04	7.57	58.5	372	286	66.8	2.85	36.5	15.9	26.3	2.5	15.4	0.6	0.128	<0.05	<0.05	0
SD2-25	2013/11/04	7.55	55.4	374	253	64.9	3.63	27.4	13.8	22.7	5.14	12.1	14.4	0.1	<0.05	<0.05	0
SD2-24	2013/11/04	7.63	50.3	326	226	61.6	3.31	27.2	12.6	22.7	5.09	11.3	18.2	0.123	<0.05	<0.05	0
SD2-23	2013/11/04	7.78	65.7	468	324	67.7	2.32	45.8	14.7	30.1	3.83	16.7	16.7	0.188	<0.05	<0.05	I
SD2-22	2013/11/04	7.73	46	286	213	62	2.93	22.7	12.6	19.9	3.54	14.7	12.5	0.1	<0.05	<0.05	0
SD2-21	2013/11/04	7.72	59.9	389	291	71.3	2.74	37.2	16.8	27.9	2.97	16	15.3	0.153	<0.05	<0.05	0
SD2-20	2013/10/11	7.24	67.4	446	262	54.9	4.86	38.7	50.4	50.8	1.98	59.5	6.37	0.272	<0.05	0.53	II
SD2-2	2013/08/29	7.91	37	278	144	37.8	2.61	21.5	19	28.7	2.52	25.1	20.9	0.351	0.06	<0.05	0
SD2-19	2013/10/11	7.49	75.6	482	166	75	5.47	38.8	31.5	104	20.3	28.7	4.59	0.303	<0.05	0.38	III
SD2-18	2013/10/11	7.3	141	1080	278	124	5.87	77.8	76.1	322	2.23	70.9	12.8	0.165	<0.05	1.02	III
SD2-17	2013/10/11	7.63	57.3	374	272	68.6	3.99	35.8	21.1	29.2	2.02	19.9	14.6	0.1	<0.05	<0.05	0
SD2-16	2013/10/11	7.71	58	372	284	59.2	2.81	36.3	20	26.7	2.09	16.7	14.6	0.158	<0.05	<0.05	0



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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	
SD2-15	2013/10/11	8.02	57.5	350	282	67.9	2.93	35.4	19.4	29.3	2.52	22.2	14.9	0.442	<0.05	<0.05	0
SD2-14	2013/10/09	7.69	57.3	362	276	67.3	2.85	34.2	21.3	29.8	2.57	21.4	14.5	0.189	<0.05	<0.05	0
SD2-13	2013/10/09	7.67	56.9	338	279	85.3	3.23	21.8	19	19.8	3.34	24.2	20.7	0.207	<0.05	<0.05	0
SD2-12	2013/10/03	7.65	57.2	378	274	62.8	2.88	34.9	23.5	29	2.74	20.5	14	0.215	<0.05	<0.05	0
SD2-11	2013/10/03	7.78	65.1	460	301	71.4	2.85	40.6	23	33.1	2.42	24.5	15.5	0.226	<0.05	<0.05	I
SD2-10	2013/10/03	7.74	56.9	362	274	66.8	2.84	35	19.4	28	1.93	20	14.6	0.161	<0.05	<0.05	0
SANS241: 2011	Max. Allowable Limit	9.7	<170	1200	-	-	-	-	200	300	11	500	-	1.5	0.3	0.5	
Class 0 Max. Allowable Limit		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		7.0	28.2	184.0	111.0	23.2	1.8	18.4	9.4	19.4	0.3	2.5	0.6	0.1	0.05	0.05	
Max		8.2	141	1080	436	124	6.95	82.8	76.1	322	20.3	70.9	20.9	0.9	0.19	1.09	
Average		7.7	58.3	414.5	258.8	65.1	3.34	37.09	22.02	39.9	4.0	22.06	14.0	0.2	0.06	0.16	



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5.3.5.10 Existing Point Source Pollution

From the analytical results existing point source pollution was reported in 10 of the existing boreholes and three newly drilled exploration boreholes. Point source pollution is from well-defined and specific sources e.g. animal farming and stockades. The boreholes impacted by point source pollution which exceeds the DWAF (1998) Class 1 drinking water quality standard are listed in Table 19 and indicated on Figure 41.

Table 19: SD2 Existing Point Source Pollution

Borehole No.	Farm/Locality	Chemical Determinants Exceeding DWAF drinking Water Standard Class I	Water Quality Class
SD2-GAA027	Postmasburg Municipality Land	NO3	II
SD2-GAA042	Rooipoort ptn. Rooddam	NO3	II
SD2-GAA080	Seretsesencho ptn. Sion	TDS; NO3	II
SD2-GAA081	Seretsesencho ptn. Sion	NO3	II
SD2-GAA082	Seretsesencho ptn. Sion	EC, TDS, Mg, NO3	IV
SD2-GAA085	Seretsesencho ptn. Swartmodder	NO3	II
SD2-GAA097	Farm 440 ptn. Moedhou	NO3	II
SD2-GAA134	Metseaten	NO3	III
SD2-GAA135	Metseaten	NO3	II
SD2-GAA138	Seretsesencho ptn. Sion	NO3	II
SD2-8	Postmasburg Municipality Land	NO3	II
SD2 -19	Postmasburg Municipality Land	NO3	II
SD2-39	Jen Haven	NO3	III

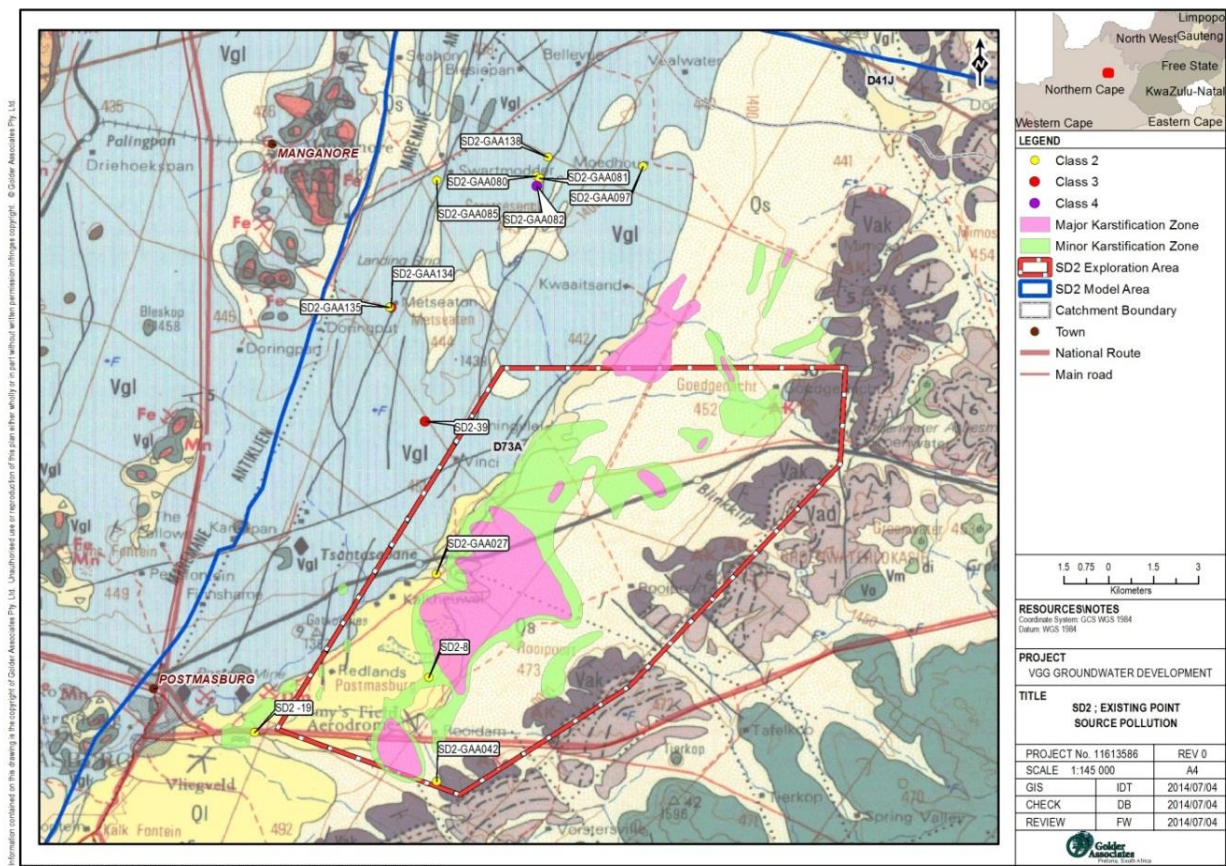


Figure 41: SD2 Existing Point Source Pollution



5.3.6 Groundwater Classification

The groundwater quality results of boreholes sampled at SD2 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 SD2 featuring as Piper expanded Durov diagrams are discussed as follows:

- Existing Boreholes;
- Exploration boreholes; and
- Well field boreholes.

5.3.6.1 Existing Boreholes

The existing boreholes groundwater quality is characterized by 76 groundwater samples analysed.

The Piper diagrams plot of the analytical results are shown (Figure 42), all the water samples except SD2-GAA116 are representative of calcium magnesium bicarbonate type of water $(Ca, Mg)(HCO_3)_2$ and are representative of unpolluted groundwater (blue sector). SD2-GAA116 has elevated EC, TDS, Mg and chloride values.

One existing fountain (SD2-GAA083) was sampled during the hydrocensus and the results plot as a calcium magnesium bicarbonate type of water $(Ca, Mg)(HCO_3)_2$.

The background groundwater quality of SD2 study area are representative as calcium magnesium bicarbonate type of water $(Ca, Mg)(HCO_3)_2$.

On the expanded Durov diagram (Figure 43) all the analytical results except SD2-GAA116 plot on the first two sectors of the diagram representing unpolluted groundwater (blue sector).

SD2-GAA116 is representative as magnesium sulphate $(Mg)SO_4$ type of water.

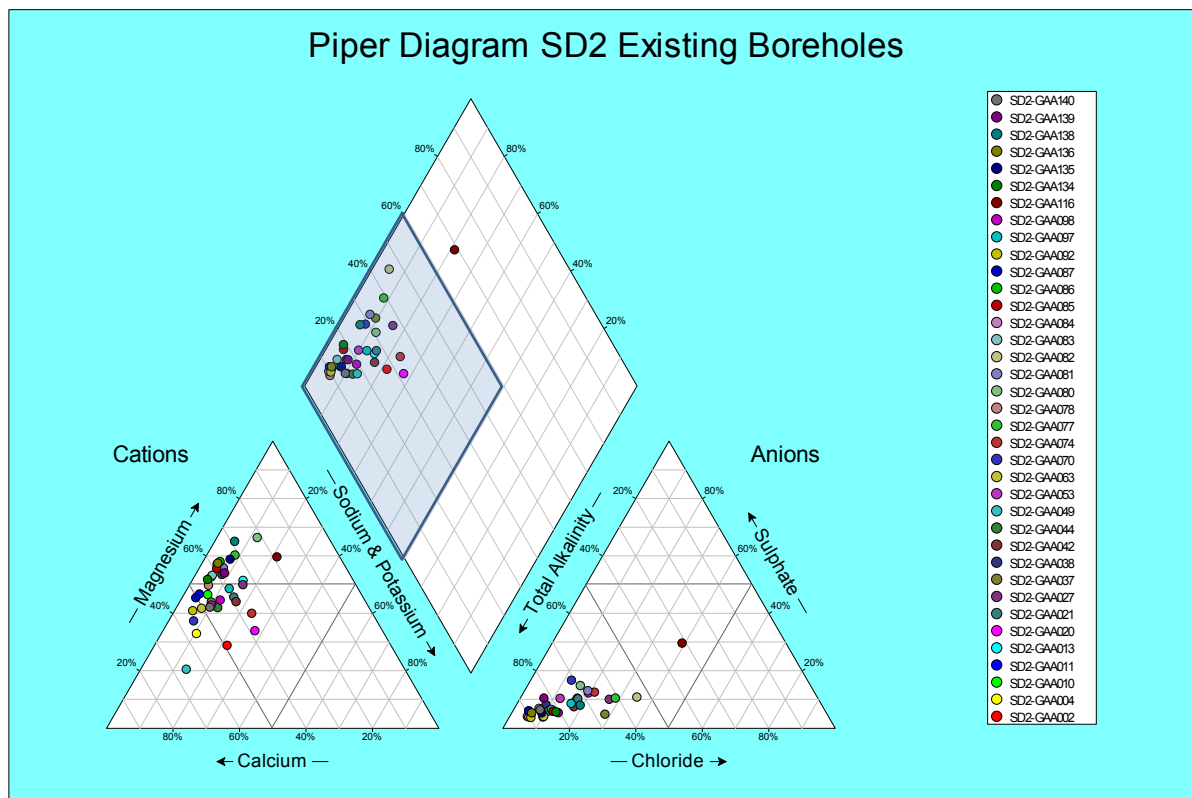


Figure 42: Piper Diagram SD2 Existing Boreholes -1

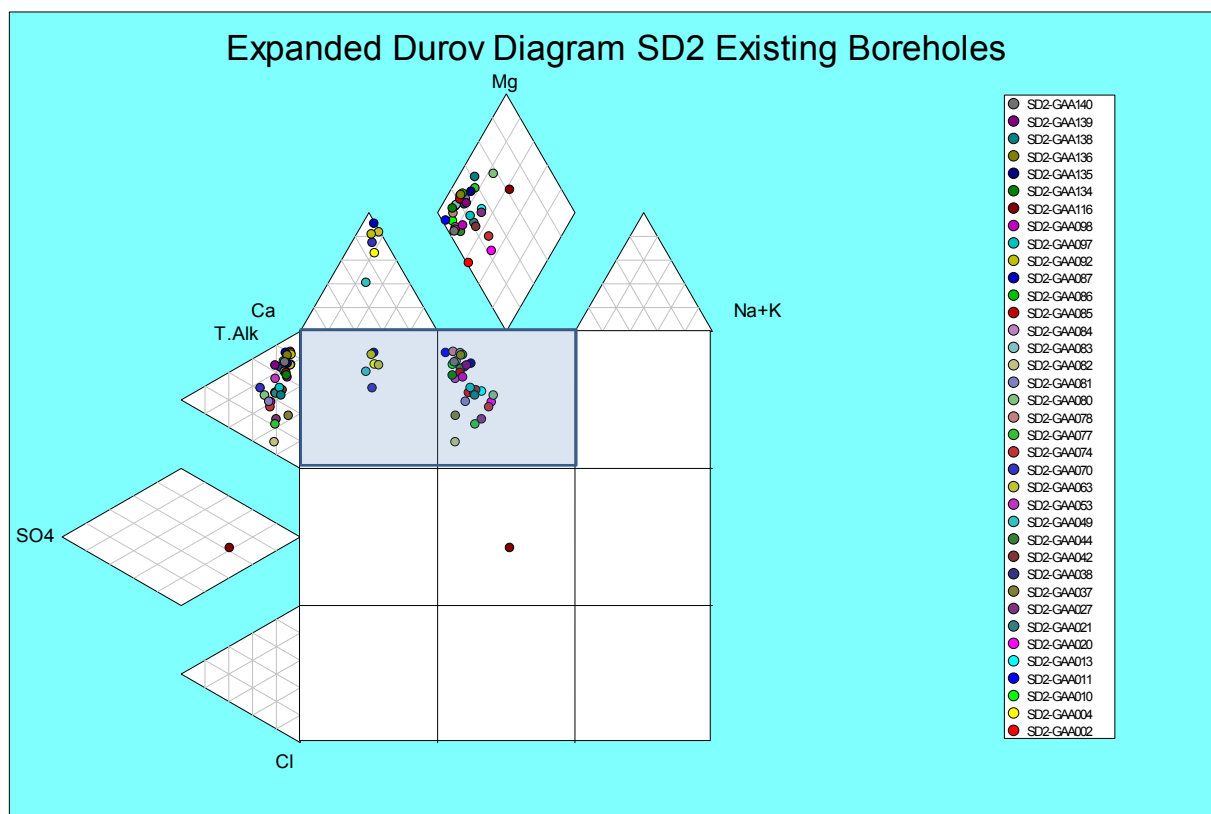


Figure 43: Expanded Durov Diagram SD2 Existing Boreholes



5.3.6.2 Exploration Boreholes

The majority of the analytical results of the exploration boreholes except SD2-18 and SD2-19, plot position on the Piper diagram (Figure 44) show a signature of calcium magnesium bicarbonate type of water ($\text{Ca, Mg}(\text{HCO}_3)_2$). 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 45) plot on the first two sectors of the diagram and represent unpolluted groundwater. SD2-19 is representative of magnesium sulphate type ($\text{Mg}(\text{SO}_4)$ type of water, and SD2-18 is representative of magnesium chloride type ($\text{Mg}(\text{Cl})$ type of water.

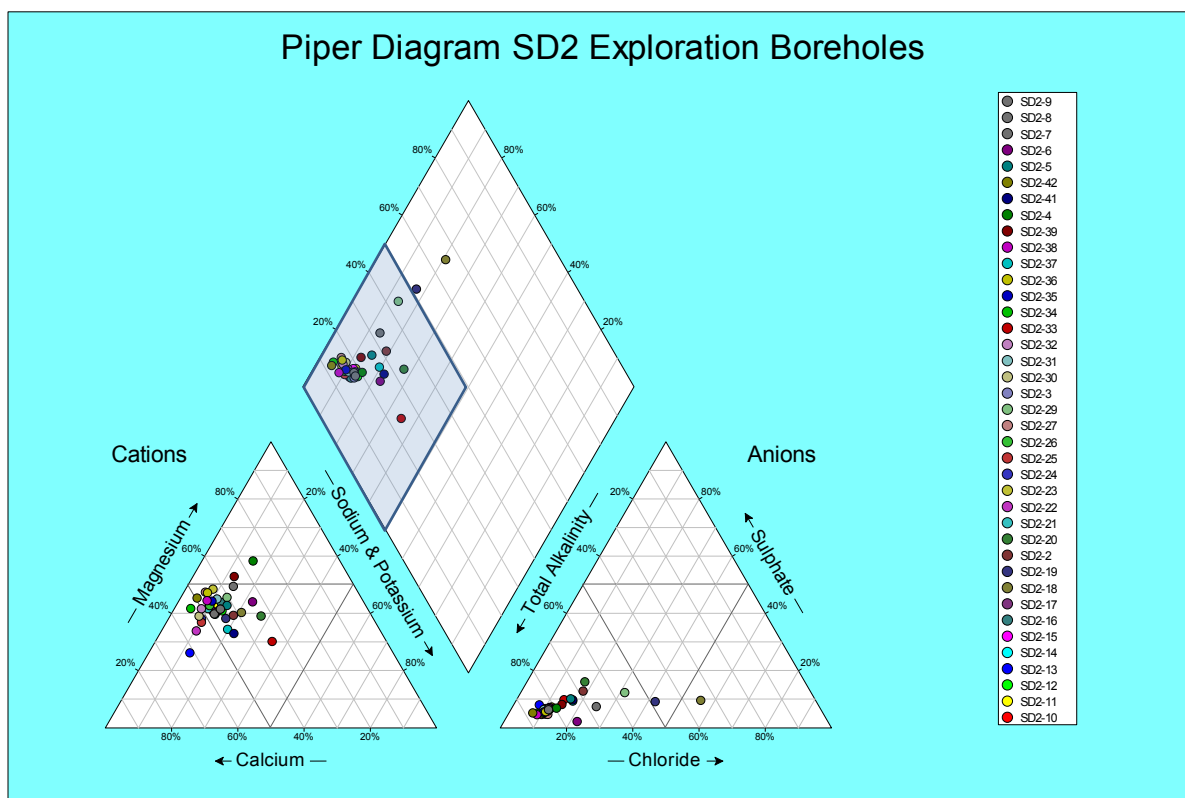


Figure 44: Piper Diagram SD2 Exploration Boreholes

5.3.6.3 Well Field Boreholes

The proposed 23 well field boreholes groundwater quality on the Piper diagram (Figure 46) show a signature of calcium magnesium bicarbonate type of water ($\text{Ca, Mg}(\text{HCO}_3)_2$). This type of water is associated with recent rainfall recharge and unpolluted groundwater.

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

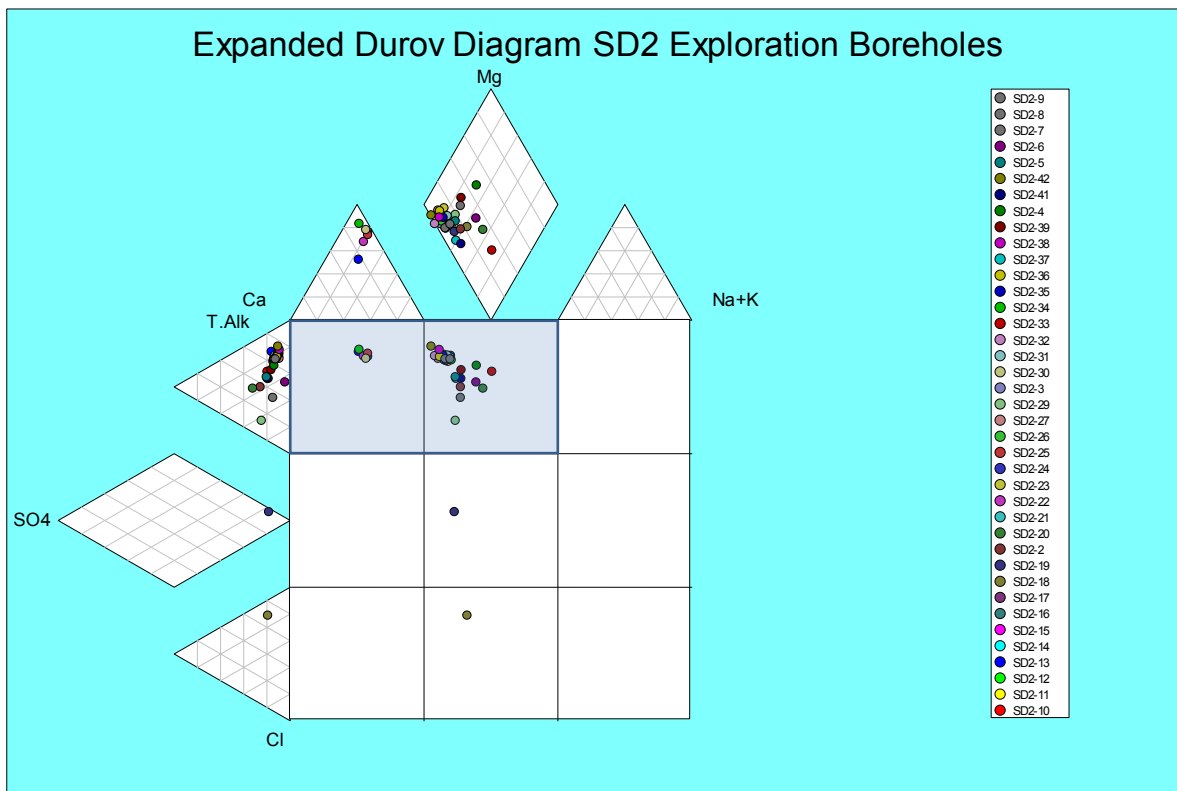


Figure 45: Expanded Durov Diagram SD2 Exploration Boreholes

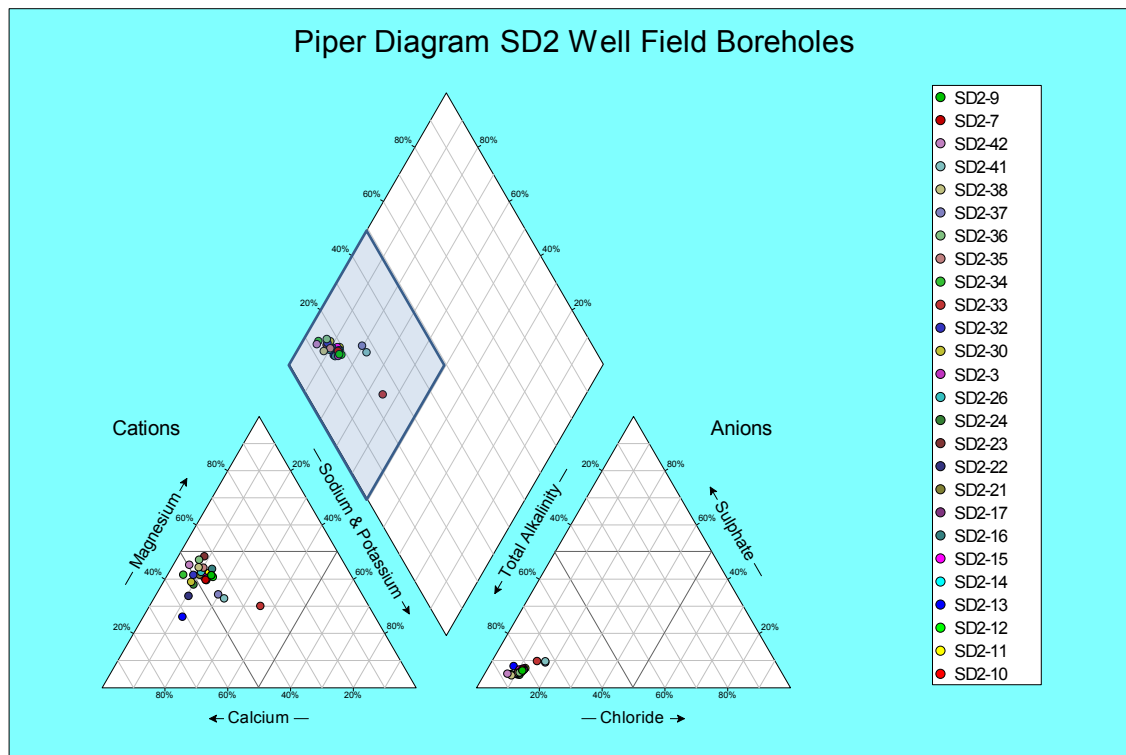


Figure 46: Piper Diagram SD2 Well Field Boreholes

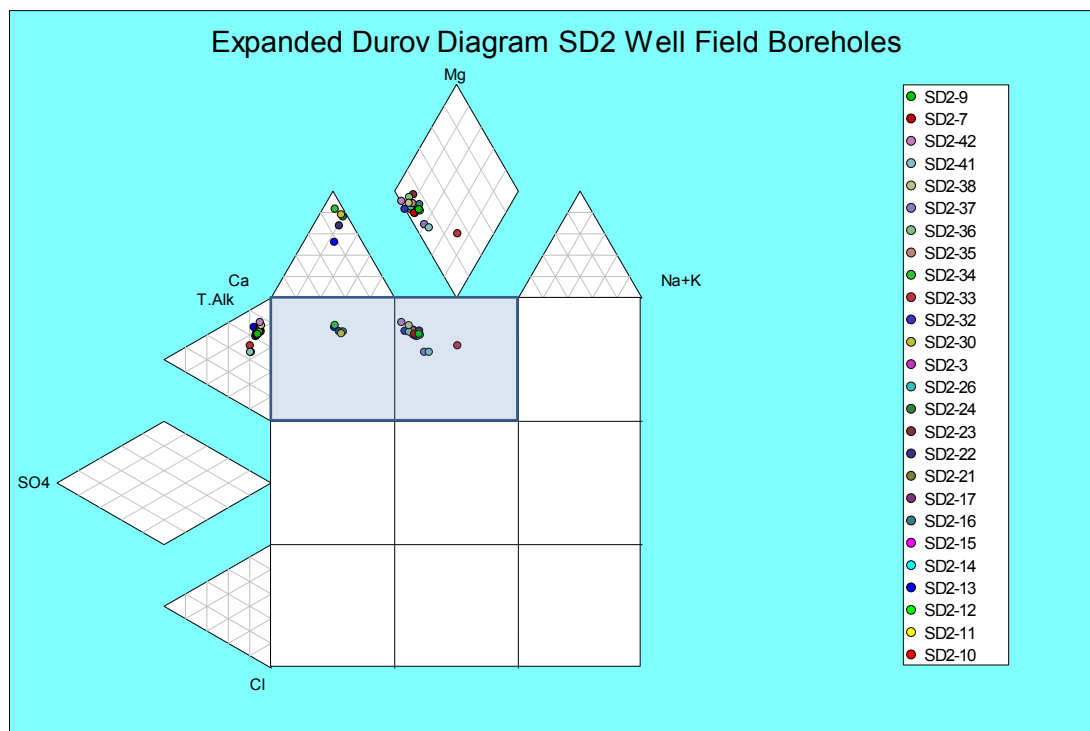


Figure 47: Expanded Durov Diagram SD2 Well Field Boreholes

5.4 Groundwater Management Units

Groundwater Management Unit (GMU) is a groundwater system that is hydraulically connected which is recognised by territory or state agencies (Richardson, 2008).

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

A total of six Groundwater Management Units (GMU's) were delineated for the entire SD2 modelling area shown in Figure 48 in order to quantify available water resources, estimate recharge volumes and calculate water balances on a sub-catchment scale.

5.5 Groundwater Monitoring

Monitoring records of groundwater quality and water levels at SD2 area are essential to establish the groundwater baseline of the study area.

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 consisting of three monitoring periods, till the end of June 2014 are listed in Table 20.

During the June 2014 baseline monitoring round, Bobby Erkland of Sedibeng Water was started off with training to manage the groundwater monitoring programme for SD1 and SD2 areas. The combined monitoring and training programme (Golder and Sedibeng Water) will be for two baseline monitoring periods, after which baseline monitoring will be conducted by Sedibeng Water.



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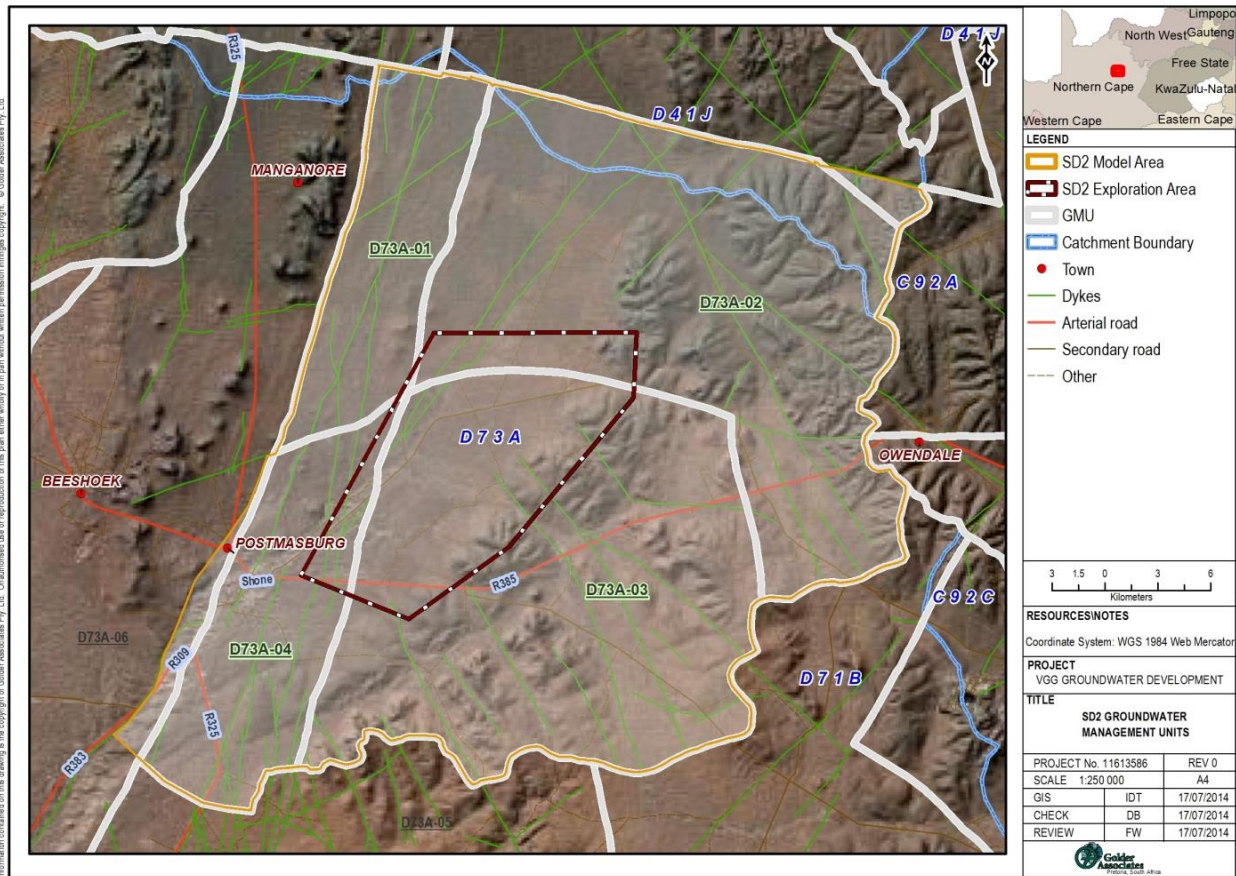


Figure 48: SD2 Groundwater Management Units

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 measure water level records where accessible;
- Continuous water level logger data at 13 selected monitoring boreholes; and
- Incorporation of DWS current and historical monitoring data.

The proposed short term groundwater monitoring programme for SD2 area will comprises of:

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



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Table 20: SD2 Quarterly Water Level Monitoring Record

Borehole No.	Depth (m)	Final Blow Yield (l/s)	Altitude (mamsl)	First SWL (mbgl)	Date Measured	Monitoring Date	Jan_2014 SWL (mbgl)	Water Level Difference +/- (m)	Monitoring Date	March_2014 SWL (mbgl)	Water Level Difference +/- (m)	Monitoring Date	June_2014 SWL (mbgl)	Water Level Difference +/- (m)
SD2-1	106	Seepage	1352.58	20.65	25/08/2013	21/01/2014	21.13	-0.48	11/03/2014	20.83	0.30	26/06/2014	21.01	-0.18
SD2-2	74	Seepage	1337.40	22.71	19/08/2013	21/01/2014	20.24	2.47	11/03/2014	19.36	0.88	26/06/2014	19.30	0.06
SD2-3	118	22	1349.67	18.28	23/08/2013	21/01/2014	18.54	-0.26	11/03/2014	18.18	0.36	26/06/2014	18.19	-0.01
SD2-4	74	Seepage	1319.30	14.23	21/08/2013	21/01/2014	13.37	0.86	11/03/2014	12.85	0.52	26/06/2014	12.90	-0.05
SD2-5	105	4	1345.97	14.47	03/09/2013	21/01/2014	14.57	-0.10	11/03/2014	14.28	0.29	26/06/2014	14.23	0.05
SD2-6	89	Seepage	1351.28	19.89	07/09/2013	21/01/2014	20.01	-0.12	11/03/2014	19.71	0.30	26/06/2014	19.67	0.04
SD2-7	52	26	1351.81	20.31	05/09/2013	21/01/2014	20.63	-0.32	11/03/2014	20.25	0.38	26/06/2014	20.29	-0.04
SD2-8	120	0.2	1351.42	20.67	09/09/2013	21/01/2014	20.27	0.40	11/03/2014	19.76	0.51	26/06/2014	19.86	-0.10
SD2-9	66	20	1349.23	17.73	12/09/2013	21/01/2014	18.04	-0.31	11/03/2014	17.64	0.40	26/06/2014	17.68	-0.04
SD2-10	60	23	1343.42	12.26	13/09/2013	21/01/2014	12.60	-0.34	11/03/2014	12.01	0.59	26/06/2014	12.26	-0.25
SD2-11	34	33	1335.51	10.38	12/09/2013	21/01/2014	10.51	-0.13	11/03/2014	9.60	0.91	26/06/2014	9.51	0.09
SD2-12	75	20	1351.19	19.86	14/09/2013	21/01/2014	20.01	-0.15	11/03/2014	19.61	0.40	26/06/2014	19.67	-0.06
SD2-13	55	16	1351.11	19.75	24/09/2013	21/01/2014	19.93	-0.18	11/03/2014	19.61	0.32	26/06/2014	19.57	0.04
SD2-14	100	14	1353.68	23.59	26/09/2013	21/01/2014	23.96	-0.37	11/03/2014	23.60	0.36	26/06/2014	23.59	0.01
SD2-15	83	20	1346.99	15.57	28/09/2013	21/01/2014	15.78	-0.21	11/03/2014	15.38	0.40	26/06/2014	15.42	-0.04
SD2-16	97	23	1350.50	18.99	20/10/2013	21/01/2014	19.40	-0.41	11/03/2014	19.00	0.40	26/06/2014	19.04	-0.04
SD2-16M	74	1.7	1350.50	18.98	02/10/2013	21/01/2014	19.14	-0.16	11/03/2014	18.71	0.43	26/06/2014	18.75	-0.04
SD2-17	59	8	1337.80	12.77	30/09/2013	21/01/2014	12.96	-0.19	11/03/2014	12.25	0.71	26/06/2014	12.07	0.18
SD2-18	73	0.2	1343.31	11.78	30/09/2013	21/01/2014	11.97	-0.19	11/03/2014	11.35	0.62	26/06/2014	11.65	-0.30
SD2-19	61	Seepage	1322.14	17.45	02/10/2013	21/01/2014	17.68	-0.23	11/03/2014	17.11	0.57	26/06/2014	17.34	-0.23
SD2-20	61	0.2	1319.82	12.78	05/10/2013	21/01/2014	13.04	-0.26	11/03/2014	12.54	0.50	26/06/2014	12.45	0.09
SD2-21	94	20	1350.54	19.18	17/10/2013	21/01/2014	19.36	-0.18	11/03/2014	18.96	0.40	26/06/2014	19.01	-0.05



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Borehole No.	Depth (m)	Final Blow Yield (l/s)	Altitude (mamsl)	First SWL (mbgl)	Date Measured	Monitoring Date	Jan_2014 SWL (mbgl)	Water Level Difference +/- (m)	Monitoring Date	March_2014 SWL (mbgl)	Water Level Difference +/- (m)	Monitoring Date	June_2014 SWL (mbgl)	Water Level Difference +/- (m)
SD2-22	73	4.3	1386.39	45.01	19/10/2013	21/01/2014	45.21	-0.20	11/03/2014	44.96	0.25	26/06/2014	44.92	0.04
SD2-23	73	20	1352.62	21.16	21/10/2013	21/01/2014	21.34	-0.18	11/03/2014	20.95	0.39	26/06/2014	20.99	-0.04
SD2-24	119	15.5	1379.54	47.35	27/10/2013	19/01/2014	47.61	-0.26	11/03/2014	47.48	0.13	26/06/2014	47.34	0.14
SD2-25	66	0.7	1382.89	42.00	25/10/2013	19/01/2014	41.61	0.39	11/03/2014	41.31	0.30	26/06/2014	41.23	0.08
SD2-26	75	40	1354.13	22.65	26/10/2013	21/01/2014	22.73	-0.08	11/03/2014	22.34	0.39	26/06/2014	22.38	-0.04
SD2-27	61	13.5	1382.78	16.84	28/10/2013	21/01/201	No		11/03/2014	No access	-	26/06/2014	-	-
SD2-28	85	Seepage	1389.02	49.70	10/11/2013	19/01/2014	49.97	-0.27	11/03/2014	-	-	26/06/2014	-	-
SD2-29	73	0.2	1399.30	47.52	14/11/2013	18/01/2014	47.76	-0.24	11/03/2014	44.86	2.90	26/06/2014	46.06	-1.20
SD2-30	98	30	1384.47	52.25	15/11/2013	19/01/2014	52.27	-0.02	11/03/2014	-	-	26/06/2014	51.83	0.44
SD2-31	85	4.1	1366.46	10.71	15/11/2013	27/01/2014	10.73	-0.02	11/03/2014	10.55	0.18	26/06/2014	10.31	0.24
SD2-32	90	11	1372.67	31.28	21/11/2013	27/01/2014	30.98	0.30	11/03/2014	30.77	0.21	26/06/2014	30.66	0.11
SD2-33	104	1.5	1400.93	59.27	05/12/2013	19/01/2014	59.43	-0.16	11/03/2014	58.97	0.46	26/06/2014	58.96	0.01
SD2-34	34	26	1367.47	11.94	28/11/2013	27/01/2014	11.81	0.13	11/03/2014	11.64	0.17	26/06/2014	11.39	0.25
SD2-35	100	22	1382.17	49.91	04/12/2013	19/01/2014	50.07	-0.16	11/03/2014	49.79	0.28	26/06/2014	50.22	-0.43
SD2-36	97	20	1365.06	23.43	02/12/2013	15/01/2014	33.33	-9.90	11/03/2014	33.05	0.28	26/06/2014	32.97	0.08
SD2-37	85	4	1394.02	-	07/02/2014	-	-	-	11/03/2014	59.26	-	26/06/2014	59.09	0.17
SD2-38	89	10.8	1381.44	-	25/02/2014	-	-	-	11/03/2014	37.60	-	26/06/2014	37.51	0.09
SD2-39	70	1.1	1386.70	-	22/02/2014	-	-	-	11/03/2014	15.66	-	26/06/2014	16.36	-0.70
SD2-40	60	Seepage	1392.31	-	22/02/2014	-	-	-	11/03/2014	52.49	-	26/06/2014	52.10	0.39
SD2-41	72	13	1394.32	-	28/02/2014	-	-	-	11/03/2014	50.54	-	26/06/2014	50.52	0.02
SD2-42	39	17	1375.76	-	25/02/2014	-	-	-	11/03/2014	4.71	-	26/06/2014	5.10	-0.39
SD2-43	121	Seepage	1382.20	-	05/03/2014	-	-	-	11/03/2014	-	-	26/06/2014	38.46	



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Borehole No.	Depth (m)	Final Blow Yield (l/s)	Altitude (mamsl)	First SWL (mbgl)	Date Measured	Monitoring Date	Jan_2014 SWL (mbgl)	Water Level Difference +/- (m)	Monitoring Date	March_2014 SWL (mbgl)	Water Level Difference +/- (m)	Monitoring Date	June_2014 SWL (mbgl)	Water Level Difference +/- (m)
SD2-44	60	Seepage	1397.80	-	01/03/2014	-	-	-	11/03/2014	-	-	26/06/2014	28.23	
SD2-45	130	0.1	1395.54	-	06/03/2014	-	-	-	11/03/2014	51.68	-	26/06/2014	51.63	0.05
SD2-46	125	Seepage	1382.77	-	07/03/2014	-	-	-	11/03/2014	38.90	-	26/06/2014	38.86	0.04



5.5.1 Continuous Water Level Monitoring

Thirteen electronic data loggers (3x Golder's and 10 x Sedibeng Water data loggers) are currently installed in monitoring boreholes (Figure 49) representative of different GMU, dolomitic compartments and aquifer zones and are listed in Table 21.



Figure 49: SD2-11 Installed Water Level Logger

These data loggers accurately record (within a 0.05% of depth range) continuous water level data at set intervals of 4 hours and are used to accurately monitor seasonal and long term water level fluctuations.

Differences between hand measured and logger water levels are due to barometric pressure fluctuations and water levels in low yielding boreholes which haven't reached static status at time of measurement. These fluctuations can be compensated for by installing barologgers, one barologger per 30km radius to compensate for barometric pressure shifts or real time water level logger at implementation of phase II. Data loggers are quarterly down loaded during baseline monitoring periods.

The positions of the water level data loggers are indicated on Figure 50 and water level monitoring graphs of the different monitoring boreholes are listed as Figure 51 to Figure 62.

Compared to the previous measurements the latest water levels recorded show a seasonal increase of 0.33m at monitoring boreholes SD2-5 (GMU: D73A-03) and a decrease of 0.59 to 1m at monitoring boreholes SD2-11 and SD2-20 of 1 respectively (GMU: D73A-04).



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Table 21: SD2 Installed Water Level Loggers

GMU	Borehole No.	Water Level (mbgl)	Date installed	First Date Downloaded	Water Level (mbgl)	Water Level Diff (m)	Second Date Downloaded	Water Level (mbgl)	Water Level Diff (m)
D73A-01	SD2-39	15.66	12/03/2014	-	-	-	No access	16.36	-
D73A-02	SD2-31	10.55	12/03/2014	-	-	-	26/06/2014	10.31	-
	SD2-25	41.31	12/03/2014	-	-	-	26/06/2014	41.23	-
	SD2-33	58.97	12/03/2014	-	-	-	26/06/2014	58.96	-
D73A-03	SD2-5	14.38	18/10/2013	21/01/2014	14.57	-0.19	26/06/2014	14.23	-0.34
	SD2-10	12.01	12/03/2014	-	-	-	26/06/2014	12.26	-
	SD2-18	11.35	12/03/2014	-	-	-	26/06/2014	11.65	-
	SD2-16M	18.71	12/03/2014	-	-	-	26/06/2014	18.75	-
	SD2-24	47.48	12/03/2014	-	-	-	26/06/2014	47.34	-
D73A-04	SD2-11	10.4	18/10/2013	21/01/2014	10.51	-0.11	26/06/2014	9.51	1.0
	SD2-20	12.73	18/10/2013	21/01/2014	13.04	-0.31	26/06/2014	12.45	0.59
	SD2-4	12.85	12/03/2014	-	-	-	26/06/2014	12.9	-
	SD2-2	19.36	12/03/2014	-	-	-	26/06/2014	19.4	-



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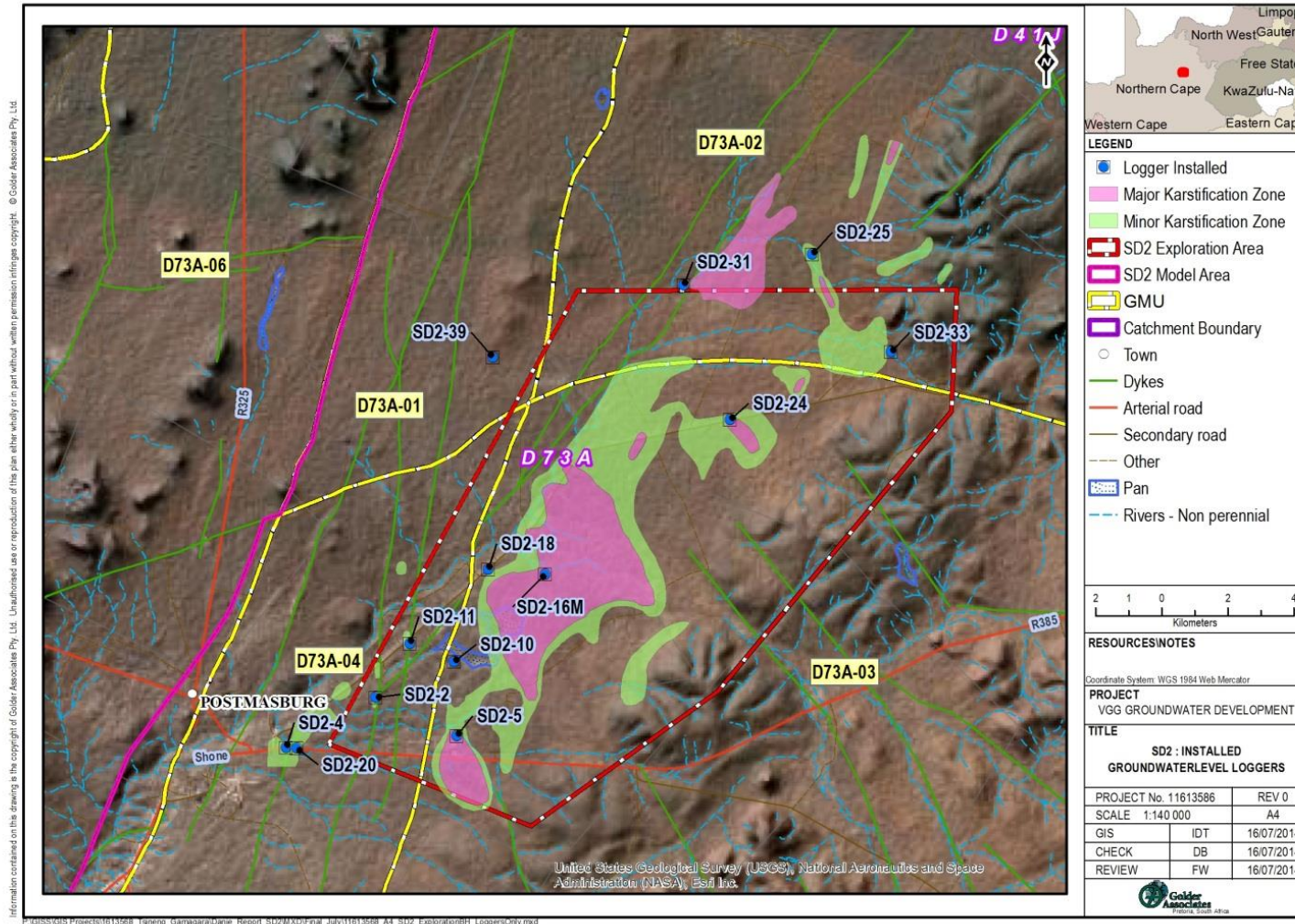


Figure 50: Positions of Installed Groundwater WL Loggers



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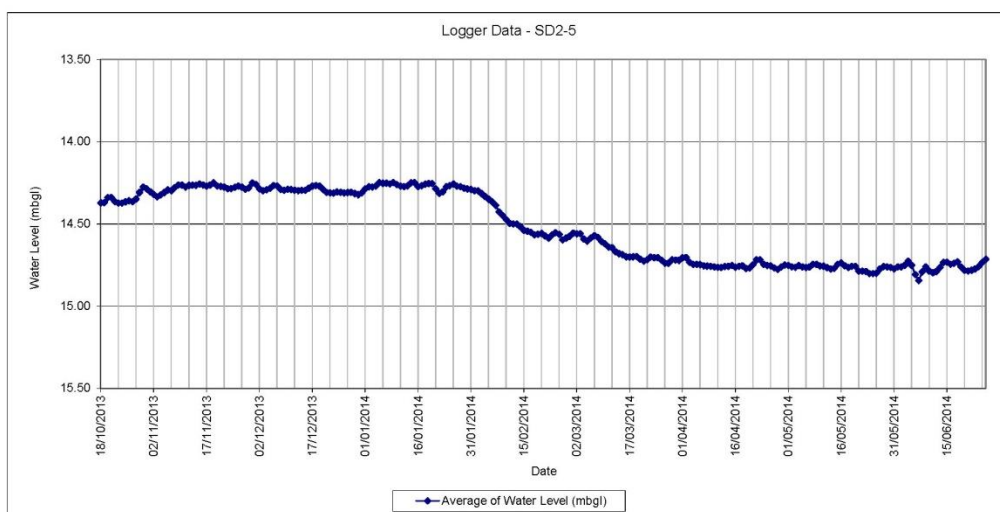


Figure 51: SD2-5 Water Level Logger Data

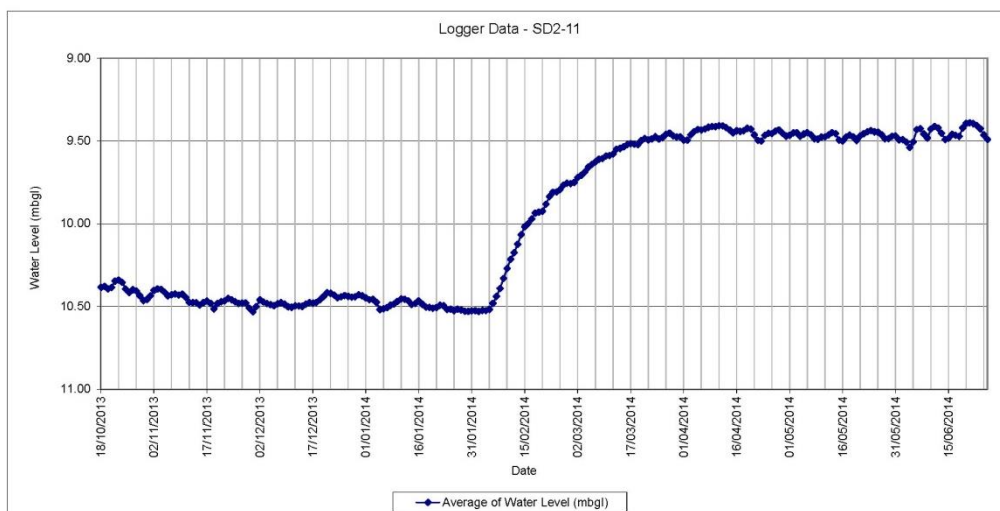


Figure 52: SD2-11 Water Level Logger Data

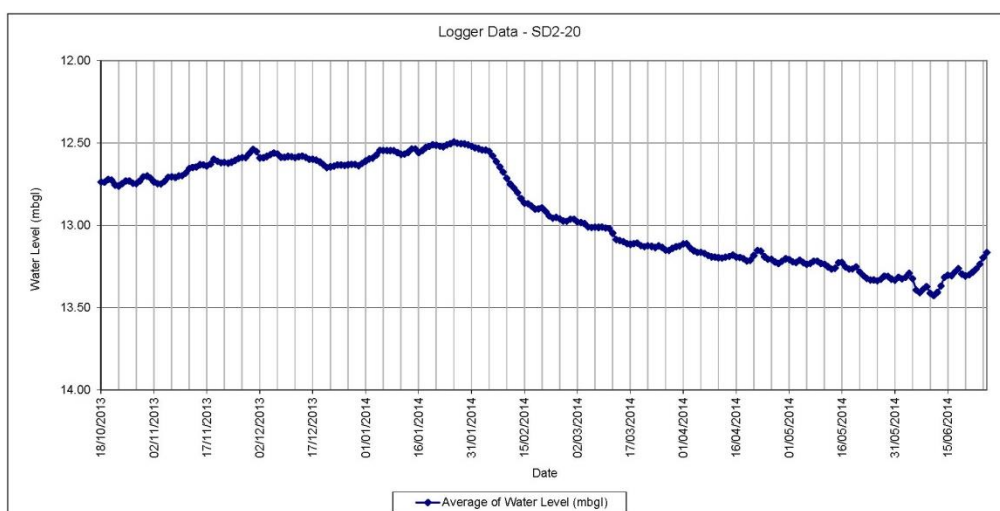


Figure 53: SD2-20 Water Level Logger Data



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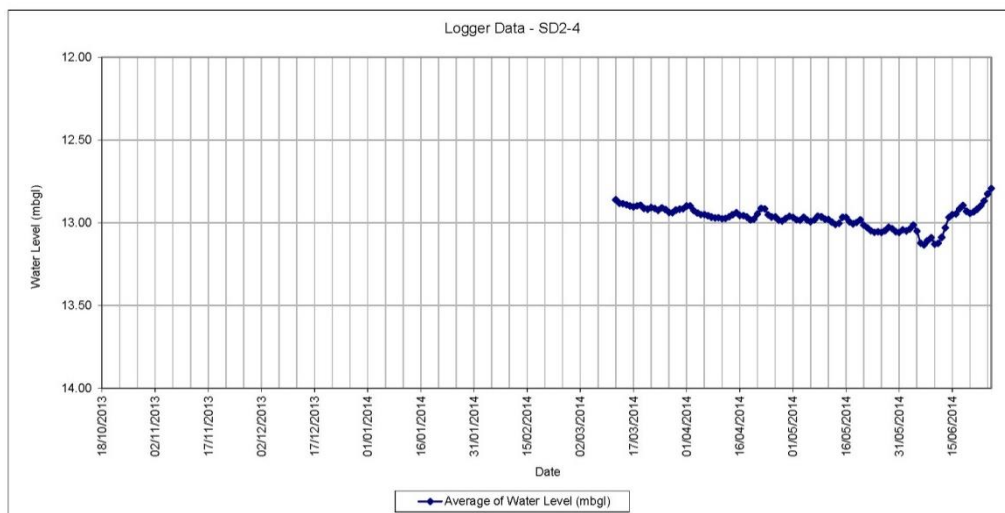


Figure 54: SD2-4 Water Level Logger Data

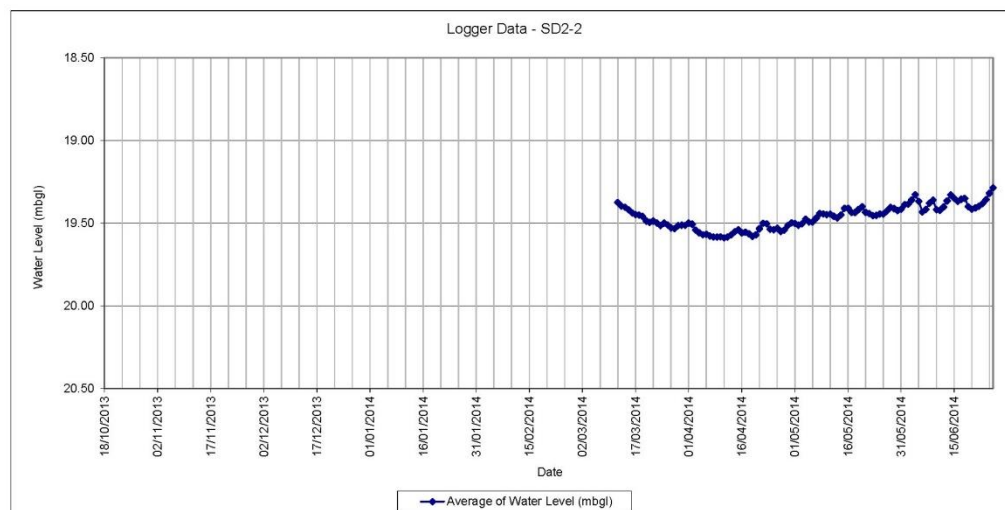


Figure 55: SD2-2 Water Level Logger Data

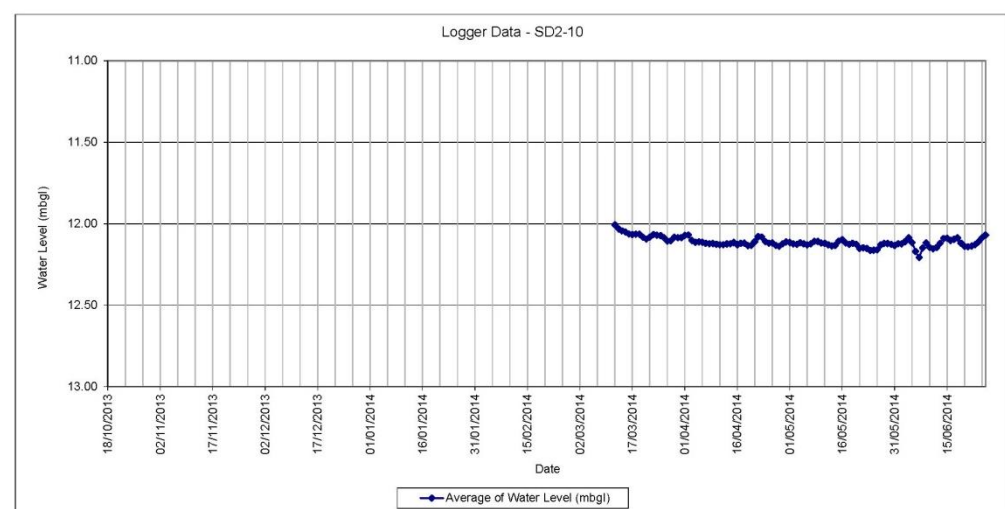


Figure 56: SD2-10 Water Level Logger Data



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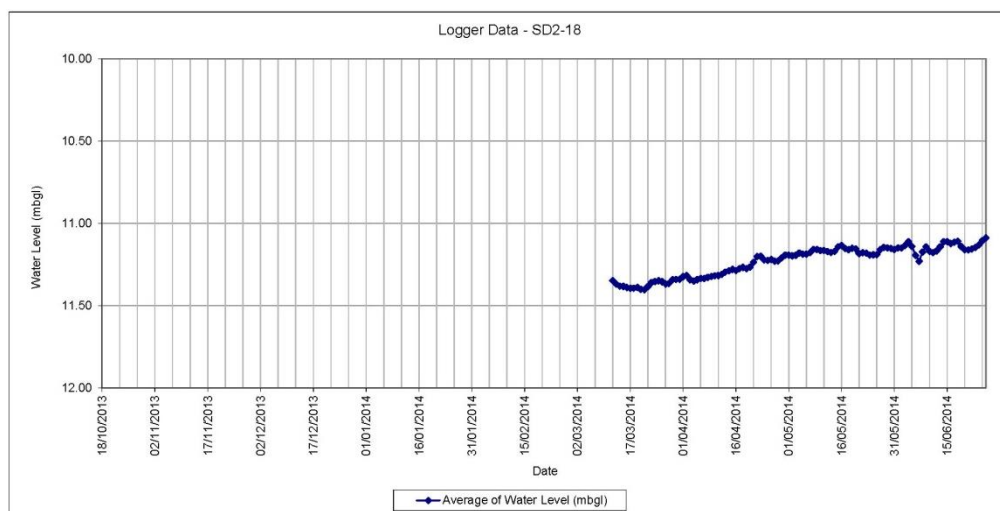


Figure 57: SD2-18 Water Level Logger Data

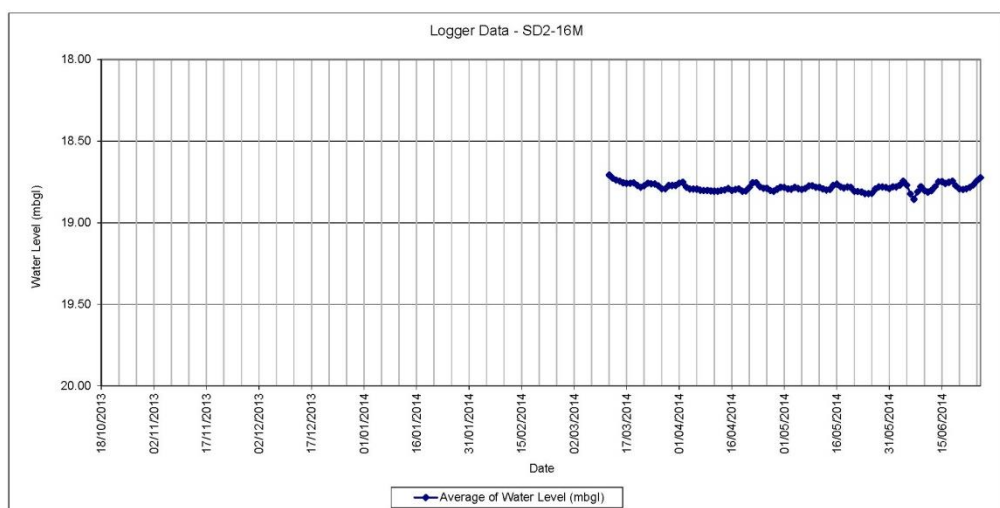


Figure 58: SD2-16M Water Level Logger Data

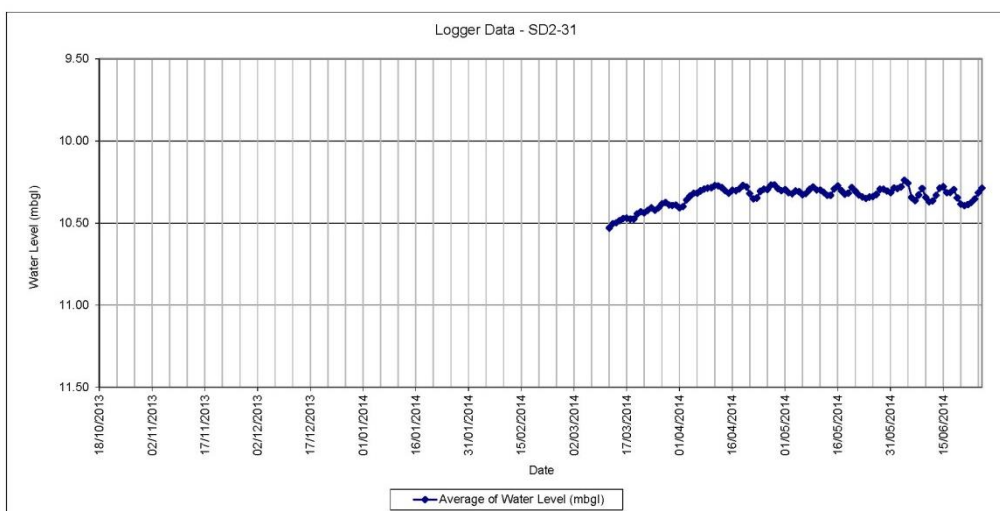


Figure 59: SD2-31 Water Level Logger Data



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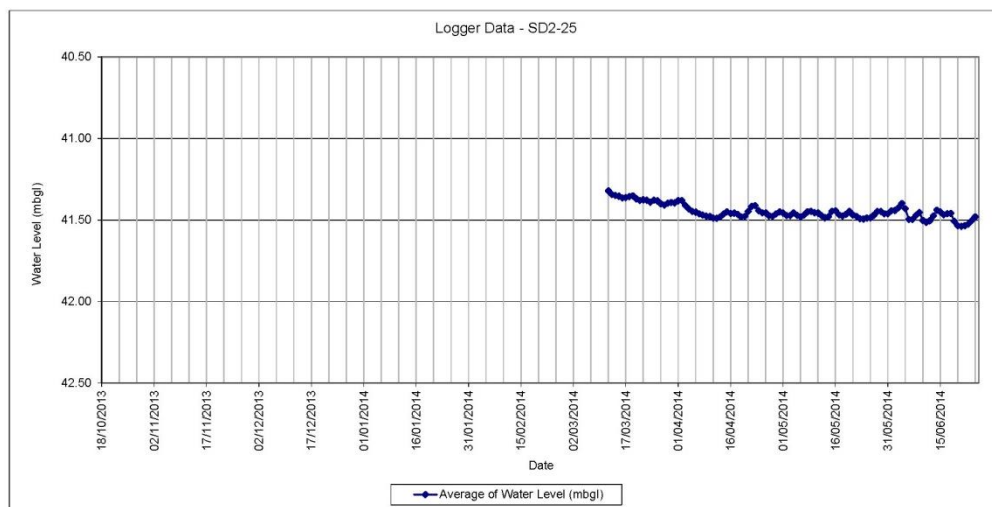


Figure 60: SD2-25 Water Level Logger Data

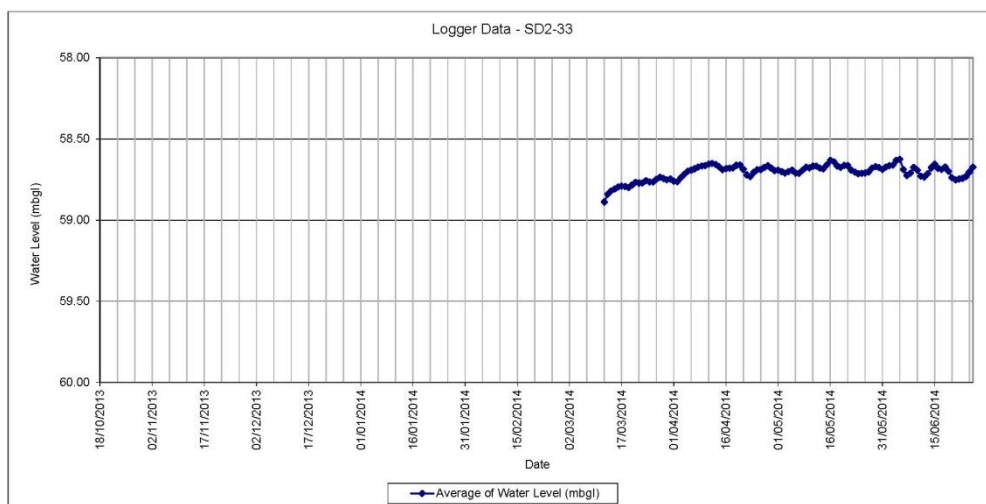


Figure 61: SD2-33 Water Level Logger Data

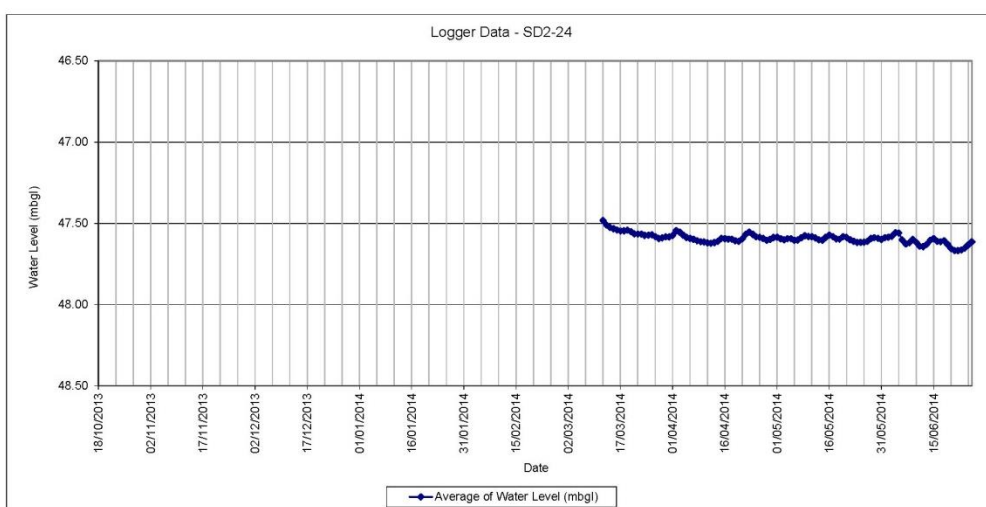


Figure 62: SD2-24 Water Level Logger Data



5.5.2 DWS Historical and Current Groundwater Monitoring

The positions of boreholes monitored by DWS historically and current are listed in Table 22 and are indicated on Figure 63.

Table 22: Historical and Current Groundwater Monitoring

GMU	BH Number	Start WL Date	Starting WL (mbgl)	Last WL Date	WL (mbgl)	Min	Max	Mean	WL Difference	Comment
D73A-02	SD2-GAA120	22/03/2000	16.93	19/02/2014	19.81	16.85	21.89	19.46	2.88	Current
	SD2-GAA121	07/05/2002	17.98	19/02/2014	19.74	17.98	21.30	19.50	1.76	Current
	GR9	03/11/1994	6.63	14/06/2013	6.52	4.00	11.24	7.10	-0.11	Current
	G47250	23/02/2000	14.59	19/02/2014	16.18	14.59	20.56	16.39	1.59	Current
D73A-03	D7N0571	18/10/1994	8.01	09/10/2007	16.27	8.01	16.27	24.28	8.26	Historical
	GAT3	11/11/2008	13.2	30/05/2011	14.59	12.22	14.62	12.87	1.39	Current
	GR1	24/04/2004	3.1	20/02/2014	2.64	2.40	5.92	3.73	-0.46	Current
	GR3	03/11/1994	14.04	14/06/2013	26.32	14.04	29.11	23.37	12.28	Current
	GR4	03/11/1994	23.85	14/06/2013	23.98	23.85	28.13	25.89	0.13	Current
D73A-04	PB12	11/11/2008	19.52	04/03/2014	24.13	19.52	26.73	23.37	4.61	Current
	G00103NC	26/04/2004	60.3	17/02/2014	50.93	40.55	62.25	53.21	-9.37	Current
	G00109NC	28/09/2004	11.7	19/02/2014	8.42	0.59	12.92	6.89	-3.28	Current
	G00110NC	08/06/2004	16.21	19/02/2014	8.35	6.88	16.21	10.70	-7.86	Current
	D7N0530	24/02/2000	1	09/12/2013	8.09	1.00	9.64	5.33	7.09	Current
	SF09	27/09/1994	23.74	08/02/2012	31.98	23.74	31.98	29.60	8.24	Current
	SF10	13/08/2008	34.78	08/02/2012	34.19	34.19	34.92	34.64	-0.59	Current
	G45956	18/09/2012	5.52	12/02/2014	2.85	2.85	6.14	4.49	-2.67	Current
	G45989	23/11/1999	8.75	17/02/2014	6.34	5.67	9.64	7.92	-2.41	Current
	G45990	23/11/1999	8.3	18/02/2014	5.57	4.28	8.78	6.88	-2.73	Current
	G45994	13/12/1999	4.27	22/07/2004	2.71	0.55	4.58	3.81	-1.56	Historical
	G45996	30/01/2000	3.08	22/07/2004	3.21	3.08	3.21	3.14	0.13	Historical
	G47254	24/02/2000	2.23	15/06/2011	1.82	1.82	5.94	3.92	-0.41	Current
	KAL03	31/03/2010	18.05	22/05/2012	18.64	11.15	18.64	16.86	0.59	Current
	KMF04	18/03/2008	18.12	08/02/2012	17.94	8.83	12.00	10.23	-0.18	Current
	KMF05	18/03/2008	23.03	24/08/2012	22.89	22.72	23.47	23.08	-0.14	Current
	KMF06	18/03/2008	23.27	08/02/2012	22.95	22.95	23.90	23.32	-0.32	Current
D73A-06	G45997	24/02/2000	6.39	09/12/2013	8.58	2.24	8.58	5.93	2.19	Current



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GMU	BH Number	Start WL Date	Starting WL (mbgl)	Last WL Date	WL (mbgl)	Min	Max	Mean	WL Difference	Comment
	G45998	24/02/2000	9.81	22/07/2004	10.09	9.81	10.09	9.94	0.28	Historical
	G00111NC	01/01/2008	58.65	23/06/2004	55.12	55.12	58.65	56.88	-3.53	Current
	KAL04	13/08/2008	1.95	20/08/2012	1.82	0.68	2.16	1.44	-0.13	Current
	KAL05	13/08/2008	12.1	20/08/2012	9.18	8.83	13.75	10.88	-2.92	Current
	KO01	18/09/2008	17.95	22/05/2012	10.94	5.82	18.63	13.91	-7.01	Current
	OF1	13/08/2008	3.62	08/02/2012	6.4	2.90	11.00	6.88	2.78	Current
	OF2	13/08/2008	16.35	08/02/2012	11.23	9.86	17.80	14.57	-5.12	Current
	OF3	13/08/2008	16.11	13/06/2011	14.48	9.14	16.60	14.92	-1.63	Current
	OF5	13/08/2008	14.3	24/08/2012	6.64	6.43	14.84	10.63	-7.66	Current
	OF6	13/08/2008	14.6	08/02/2012	8.64	8.14	15.20	12.53	-5.96	Current
	OF7	13/08/2008	14.37	07/03/2011	7.18	7.18	14.85	12.73	-7.19	Current
	G00101NC	22/04/2004	6.8	22/05/2013	7.25	2.26	7.84	6.29	0.45	Current
	G00102NC	18/10/2008	59.02	30/05/2011	75.48	49.28	75.47	62.58	16.46	Historical
	SF04	13/08/2008	10.06	19/06/2013	6.74	4.85	10.06	7.31	-3.32	Current
	SF05	27/09/1994	6.37	19/06/2013	5.08	4.40	10.80	7.66	-1.29	Current
	SF06	13/08/2008	9.31	19/06/2013	5.94	0.81	9.31	6.61	-3.37	Current
	SF07	13/08/2008	8.39	08/02/2012	2.55	2.55	8.39	6.26	-5.84	Current



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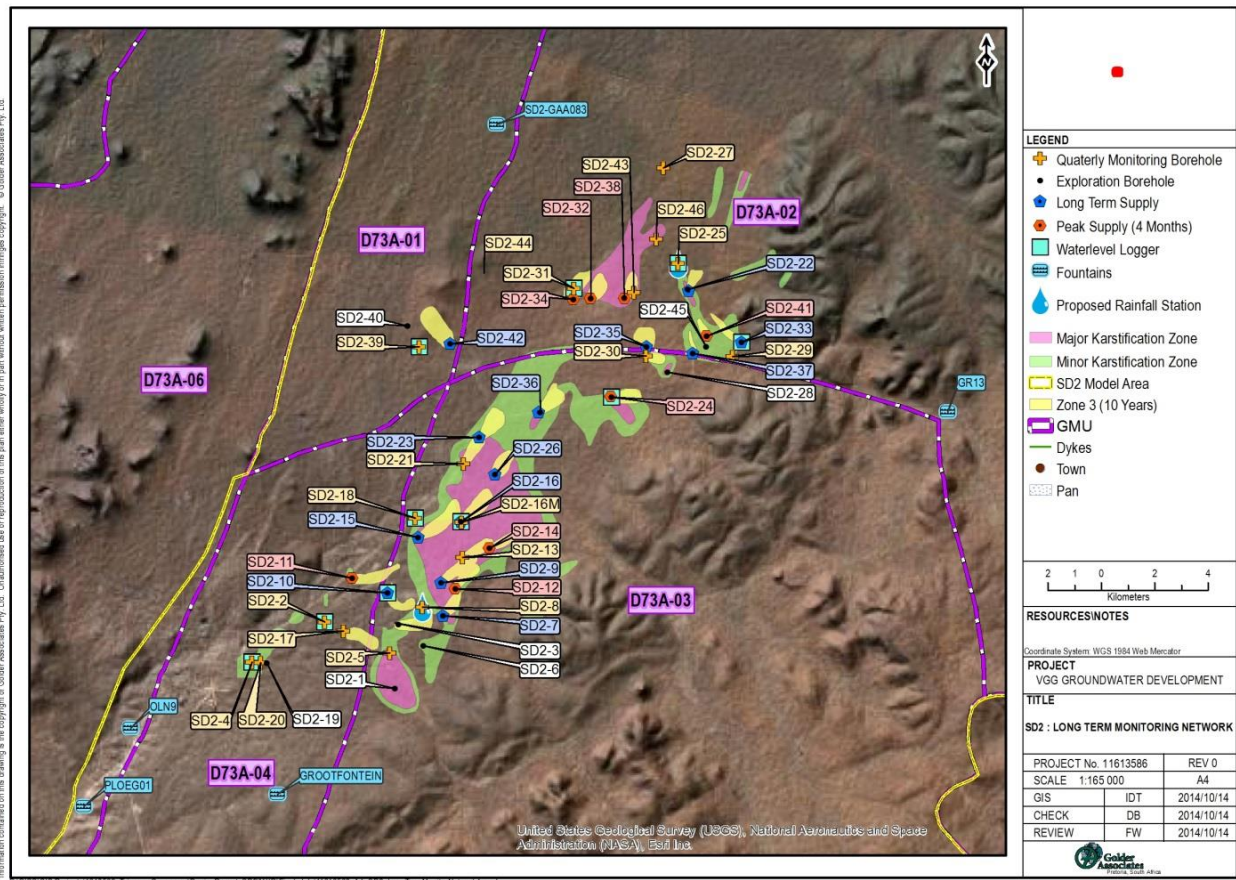


Figure 63: DWS Historical and Current Groundwater Monitoring SD2 - Area

Historical water level monitoring records of monitoring boreholes Gat3/SD2-GAA050 and G00102NC/Dam1 (examples), displaying seasonal water level fluctuations are shown in Figure 64 and Figure 65. The DWS water levels graphs are listed in the appendix Volume II of this report.

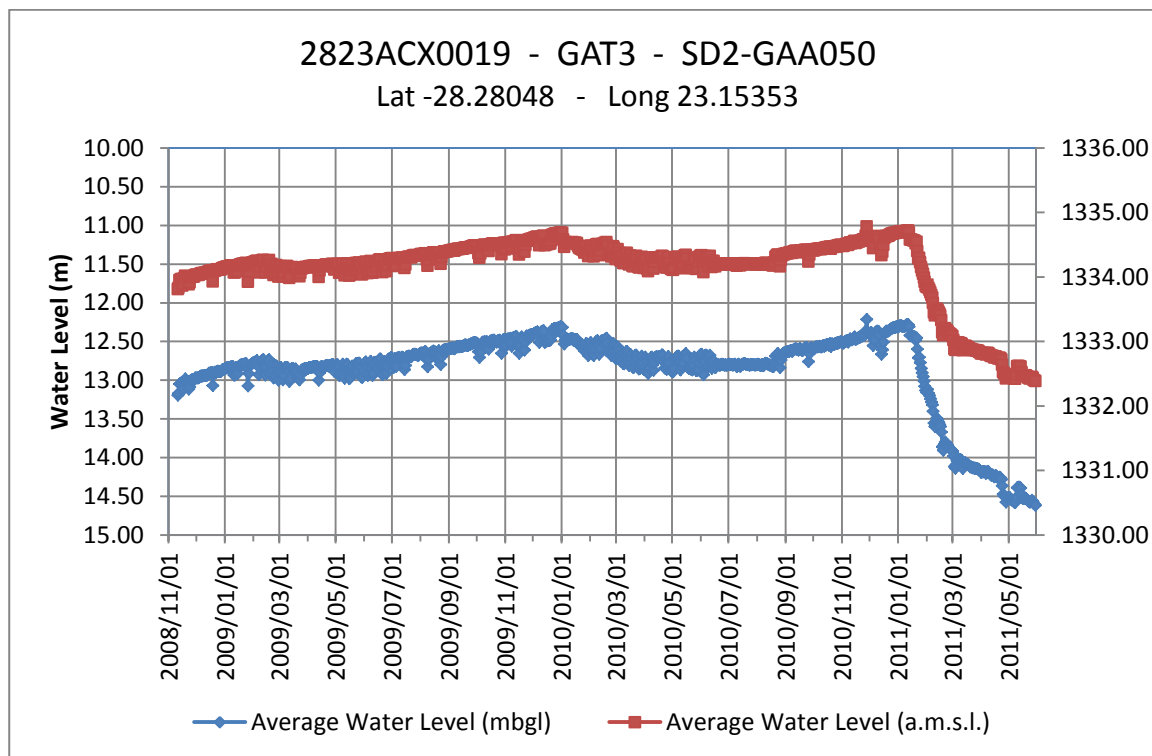


Figure 64: DWS Water Level Record of Gat3/SD2-GAA050 – Postmasburg Municipality Production Borehole

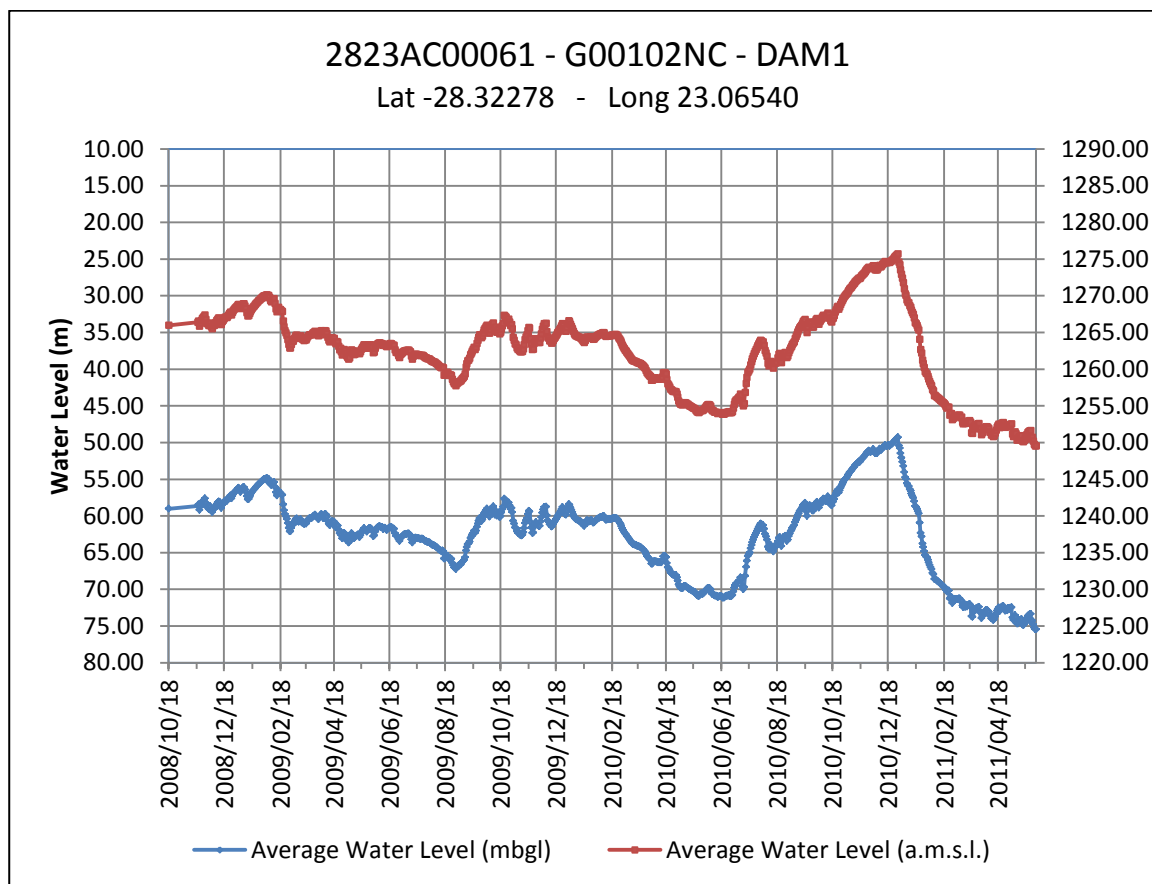


Figure 65: DWS Water Level Record of G00102NC/Dam1 – Postmasburg Municipality Production Borehole

5.5.3 Proposed Groundwater Monitoring Network

The proposed monitoring network for SD2 well field area is indicated on Figure 66 and entails an initial baseline monitoring period of up to three years and long term monitoring program at implementation of well fields. The monitoring programme will be the responsibility of Sedibeng Water.

The groundwater monitoring programme for SD2 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 (Table 23) boreholes must be equipped with real time water level loggers and incorporated with DWS 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;
- 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 north and south (Figure 66), to understand and simulate aquifer responses to abstraction and recharge at higher confidence.

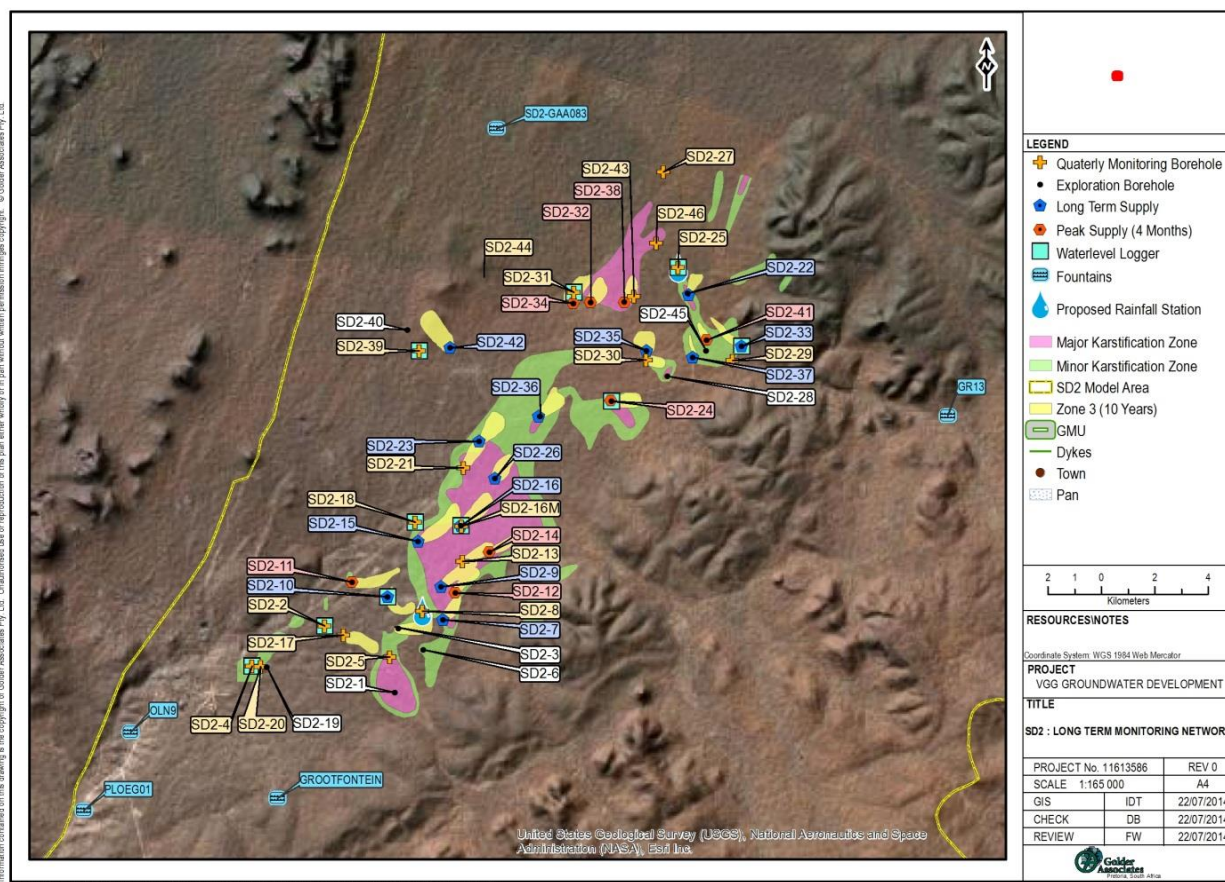


Figure 66: Long Term Monitoring Network



Table 23: Designated Monitoring Boreholes

GMU	Borehole Number	Status	Comment
D73A-01	SD2-39	Monitoring	Level logger currently installed
D73A-02	SD2-25	Monitoring	Level logger currently installed
	SD2-27	Production	-
	SD2-29	Monitoring	-
	SD2-31	Production	Level logger currently installed
	SD2-43	Monitoring	-
	SD2-44	Monitoring	-
	SD2-46	Monitoring	-
D73A-03	SD2-5	Monitoring	-
	SD2-8	Monitoring	-
	SD2-13	Production	-
	SD2-16M	Monitoring	Level logger currently installed
	SD2-21	Production	-
	SD2-18	Monitoring	Level logger currently installed
	SD2-30	Production	-
D73A-04	SD2-2	Monitoring	Level logger currently installed
	SD2-4	Monitoring	Level logger currently installed
	SD2-17	Production	-
	SD2-20	Monitoring	-

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 methods works well for areas underlain by dolomite and BIF formations.

The published hydrogeological maps (DWA 1996) indicate the average recharge for the study area as 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.

SD2 modelling area was delineated into 8 recharge zones based on related chloride values (Figure 67) and geology. These recharge estimate zones were delineated using chloride values from higher yielding boreholes and boreholes considered uncontaminated (lower chloride values). 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.



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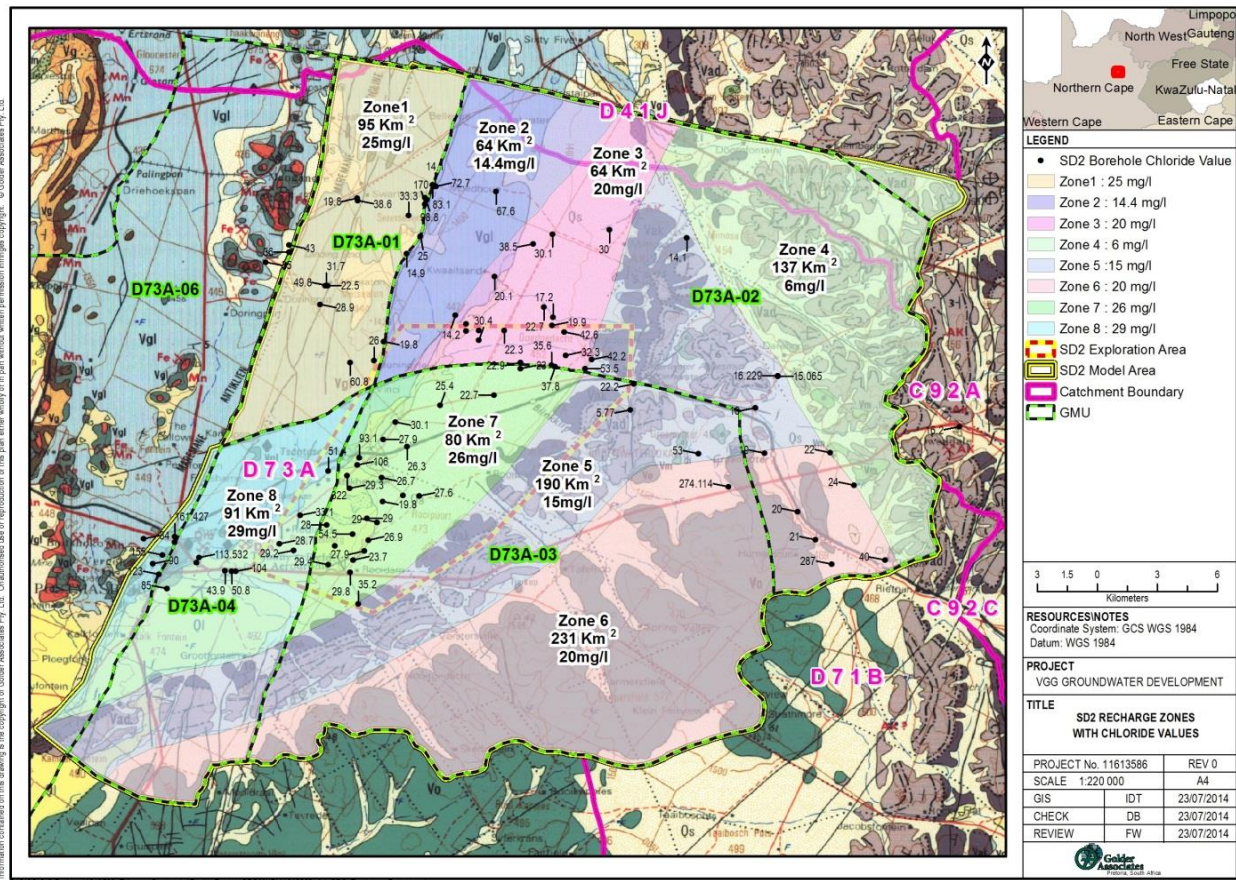


Figure 67: SD2 Recharge Zones - Cl Values

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 = $0.05e^{(0.01 \times \text{Rainfall})}$)

The mean and median annual recharge for the SD2 modelling area recharge zones is presented in Table 24.

The exploitable groundwater resource (median recharge) for the SD2, D73A catchment for all GMU's as presented in Table 24 amounts 9.0 million m³/a.



Table 24: Summarised Recharges Estimates for SD2 Recharge Zones 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	25	2.4	95	7.8	5.3	0.7	0.5	D73A	D73A-01
2	14.4	4.2	64	13.8	9.4	0.9	0.6	D73A	D73A-02
3	20	3	64	9.8	6.7	0.6	0.4	D73A	D73A-02
4	6	10	137	32.8	22.3	4.5	3.1	D73A	D73A-02
5	15	4	190	13.1	8.9	2.5	1.7	D73A	D73A-02
									D73A-03
									D73A-04
6	20	3	231	9.8	6.7	2.3	1.5	D73A	D73A-02
									D73A-03
									D73A-04
7	26	4	80	13.1	8.9	1.0	0.7	D73A	D73A-03
									D73A-04
8	29	2.1	91	6.9	4.7	0.6	0.4	D73A	D73A-04
Total			952	-	-	13.2	9.0	8	-

5.7 Hydrogeological Conceptualizing

The hydrogeological conceptualizing for SD2 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 used as basis for the numerical groundwater model.

Because of the extent of the investigation area the hydrogeology is conceptualise and represented as five hydrogeological sections, the positions of sections are indicated on Figure 68:

- Cross Section A – B;
- Cross Section C – D;
- Cross Section E – F;
- Cross Section G – H and
- Cross Section I – J.



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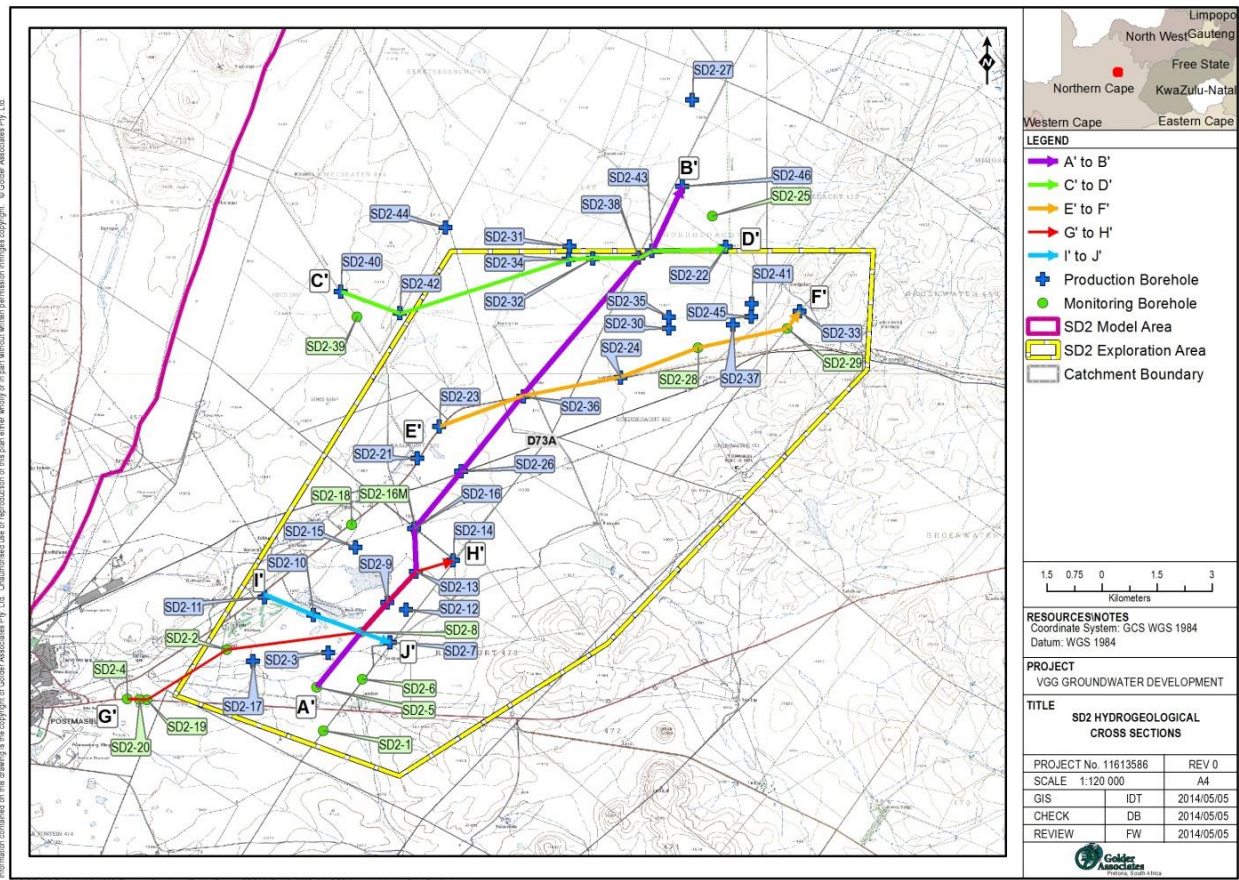


Figure 68: Position of Hydrogeological Cross Sections

5.7.1 Hydrogeological Cross Section A – B

A hydrological cross section was done in a south-west – north-east direction to illustrate the geological and hydrogeological information associated with the main dolomite karst zone and the water level step of 10m between two major dolomite compartments (Figure 69).

The cross-section shows the presence of a calcrete layer at surface of approximately 20 to 30m thickness with a low permeability. Gravel deposits comprising out of BIF fragments, jasper and chert are represented below the calcrete horizon, underlain by dolomite with major karstification. Semi conciliated BIF is present to the northeast at surface also underlain of the dolomite, though less karstification zones.

These karstification zones which developed in the dolomite and along dolerite dyke contacts are highly permeable with blow yields intersected as high as 40l/s (SD2-26).

The groundwater flow direction is largely towards Postmasburg in the southwest, with transmissivity values ranging from 38 to 1013 (SD2-36).



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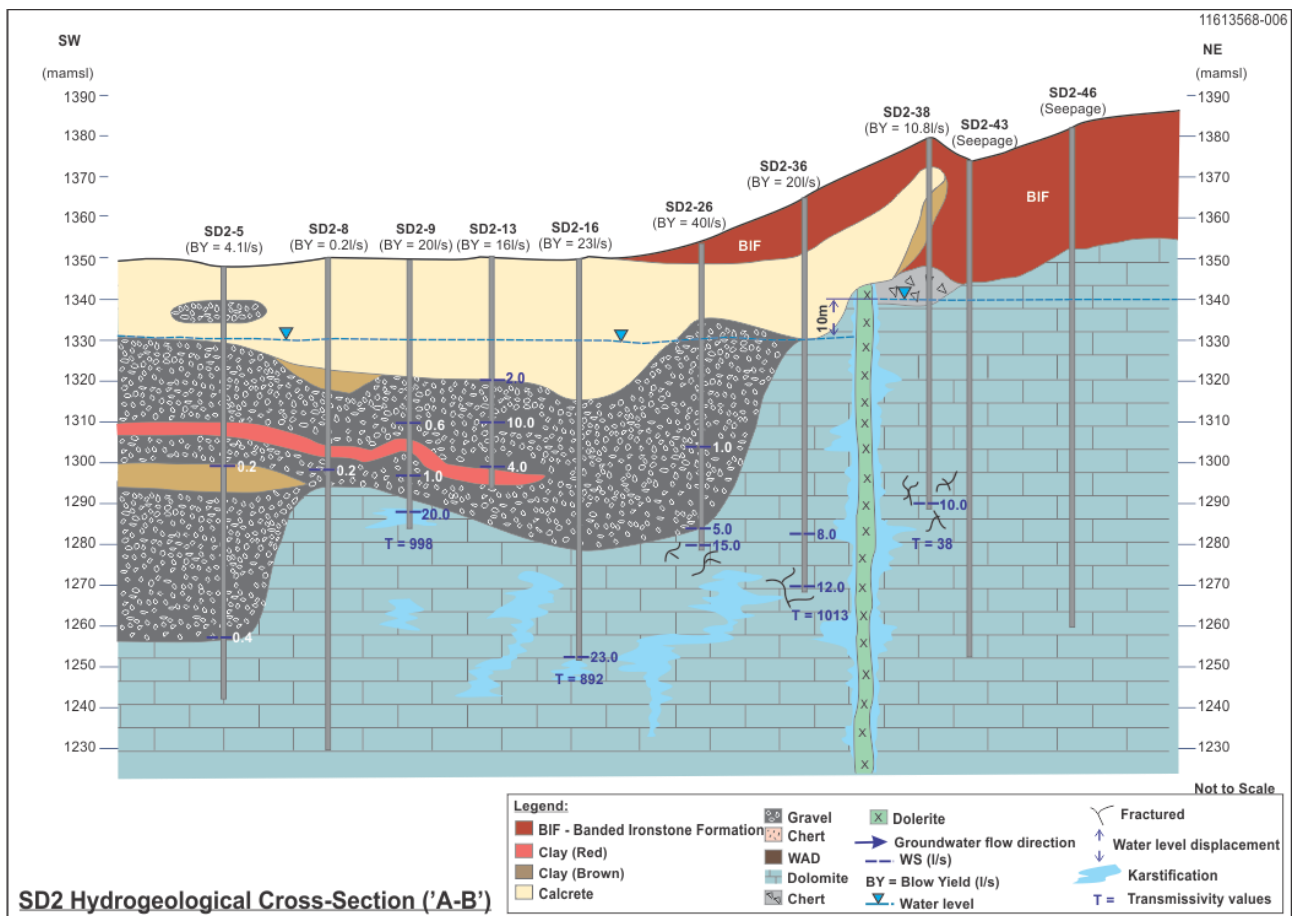


Figure 69: Hydrogeological Cross Section A - B

5.7.2 Hydrogeological Cross Section C – D

A hydrogeological cross section was done from west to east direction to illustrate the geological and hydrogeological information obtained from the exploration drilling and is illustrated in Figure 70. The water level displacements of 14m and 13m respectively between different dolomitic compartments by dolerite dykes are shown in Figure 70.

The cross-section shows the presence of chert rich dolomite at surface in the west and BIF formation at the surface in the east, dipping 5 to 6 degrees southeast. The BIF is underlain by dolomite with major karstification.

These karstification zones which developed in the dolomite and along dolerite dyke contact are highly permeable with blow yield intersected ranging from 4.3 to 26l/s.

The groundwater flow direction largely towards Postmasburg in the southwest, with transmissivity values ranging from 36 to 842 (SD2-34).

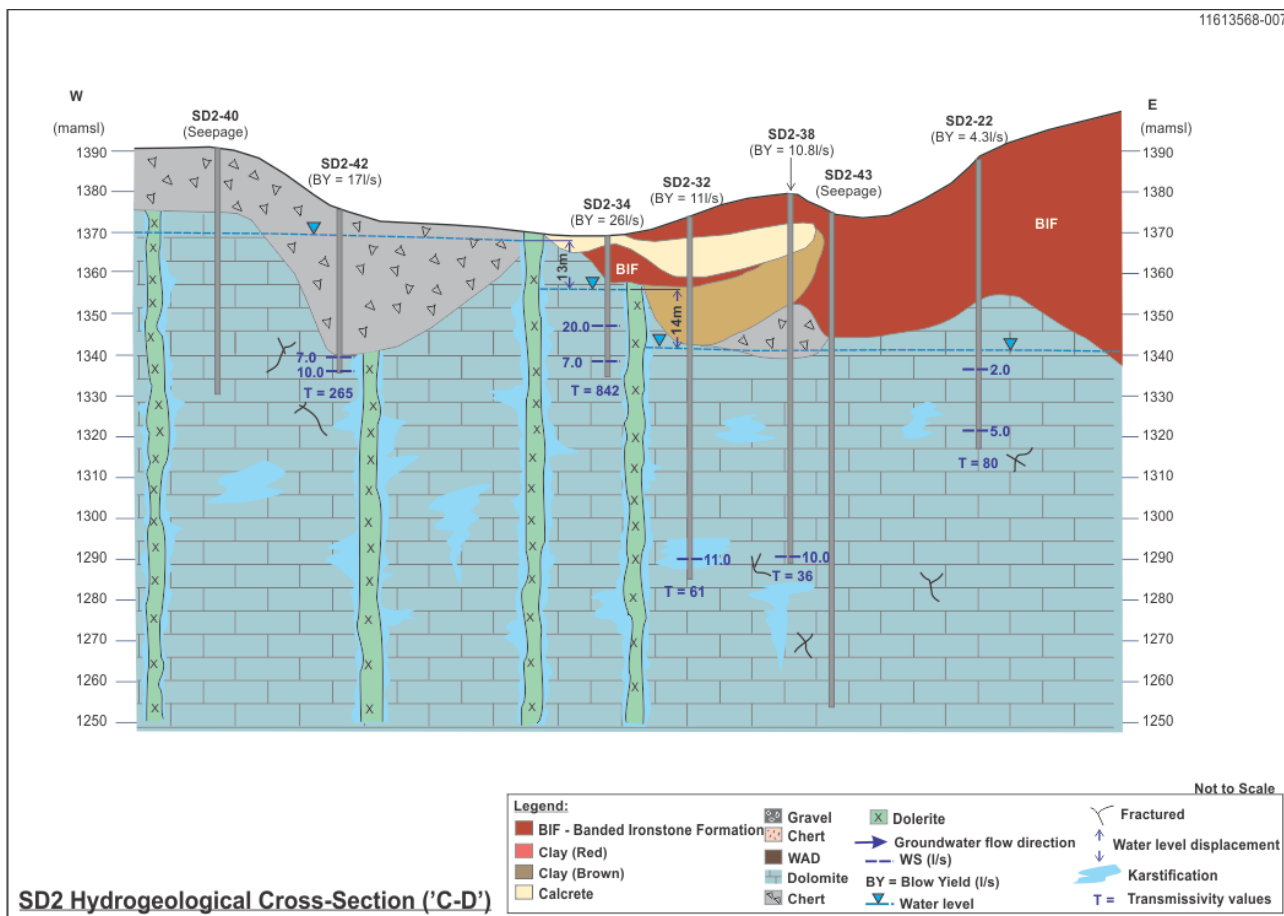


Figure 70: Hydrogeological Cross Section C - D

5.7.3 Hydrogeological Cross Section E – F

Hydrological cross section E'-F' was done from west to east to illustrate the geological and hydrogeological conditions in this region as illustrated in Figure 71. The water level displacements of 10m between different dolomitic compartments by dolerite dykes are shown in Figure 71.

The cross-section shows the occurrence of semi conciliated BIF formation at the surface, underlain by dolomite with major karstification zones.

These karstification zones which developed in the dolomite and along dolerite dyke contact are highly permeable with blow yield intersected ranging from 0.2 to 20l/s.

The groundwater flow direction largely towards Postmasburg in the southwest, with transmissivity values ranging from 119 to 1338 (SD2-23).

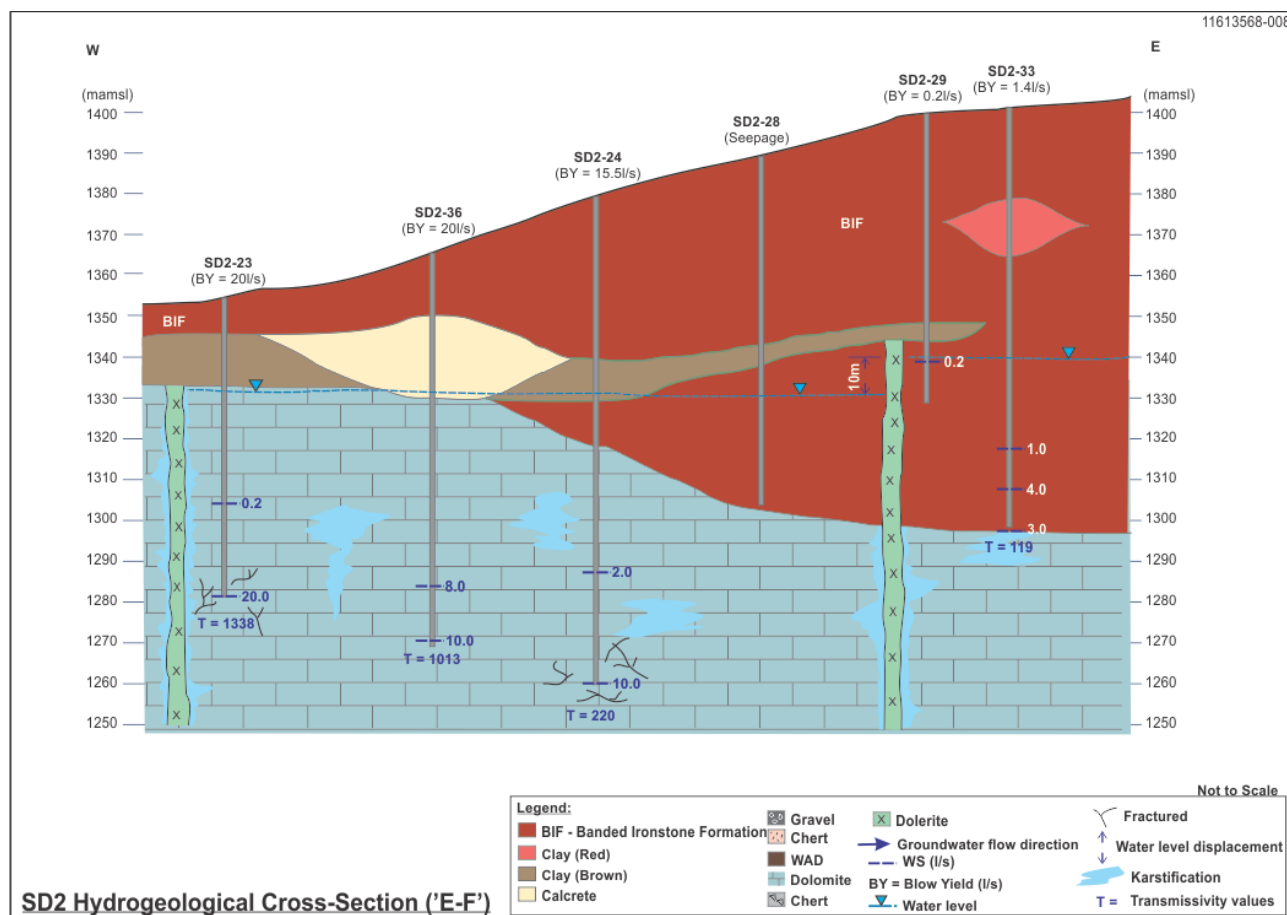


Figure 71: Hydrogeological Cross Section E - F

5.7.4 Hydrogeological Cross Section G – H

Hydrological cross section G-H was done in a southwest – northeast direction to illustrate the geological and hydrogeological information associated with the main karstification zone and the displacement of the water table between the two proposed well field dolomitic compartments (Figure 72). The water level displacements of 14m and 12m respectively between different dolomitic compartments by dolerite dykes are shown in Figure 72.

The cross-section shows the presence of a calcrete layer at surface of approximately 25m thickness with a low permeability. Clay and gravel deposits comprising out of BIF fragments, jasper and chert are represented below the calcrete horizon, underlain by dolomite with major karstification.

These karstification zones which developed in the dolomite and along dolerite dyke contacts are highly permeable with blow yields intersected as high as 20 l/s (SD2-9).

The groundwater flow direction is mainly towards Postmasburg in the southwest, with transmissivity values ranging from 472 to 965 (SD2-9).

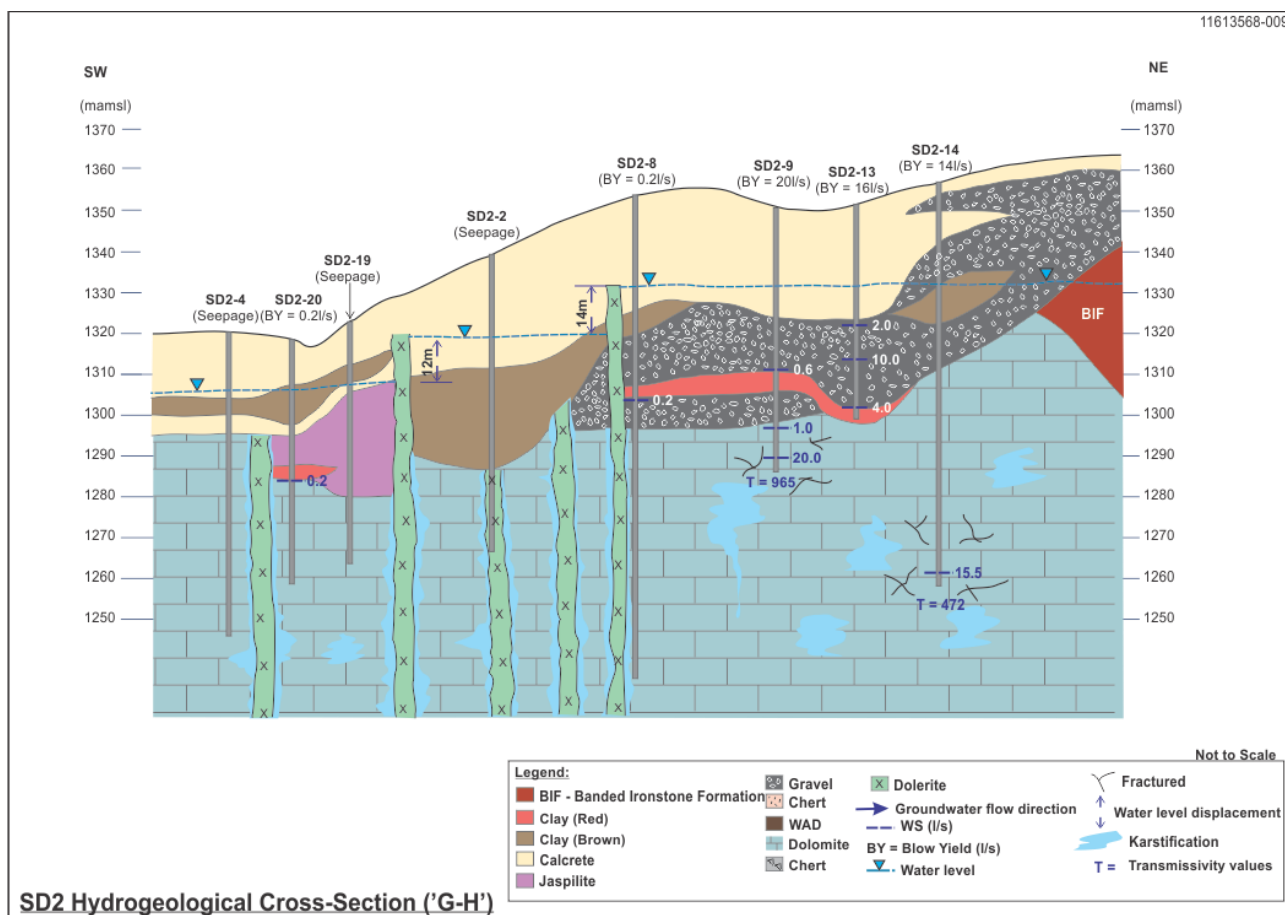


Figure 72: Hydrogeological Cross Section G – H

5.7.5 Hydrogeological Cross Section I – J

Hydrological cross section I-J was done from west to east to illustrate the geological and hydrogeological conditions encountered in this region. Water level displacements of 14m and 12m respectively between different dolomitic compartments by dolerite dykes are shown in Figure 73.

The cross-section shows the occurrence of a calcrete layer at surface of approximately 25m thickness with a low permeability. Clay and gravel deposits comprising out of BIF fragments, jasper and chert are present below the calcrete horizon, underlain by dolomite with major karstification. Semi conciliated BIF is present at surface in the east, dipping 5 to 6 degrees east.

These karstification zones which developed in the dolomite and along dolerite dyke contacts are highly permeable with blow yields intersected as high as 33l/s (SD2-11).

The groundwater flow direction largely towards Postmasburg in the southwest, with transmissivity values ranging from 500 to 3788 (SD2-10).



5.7.6 Hydrogeological Cross Section I – J

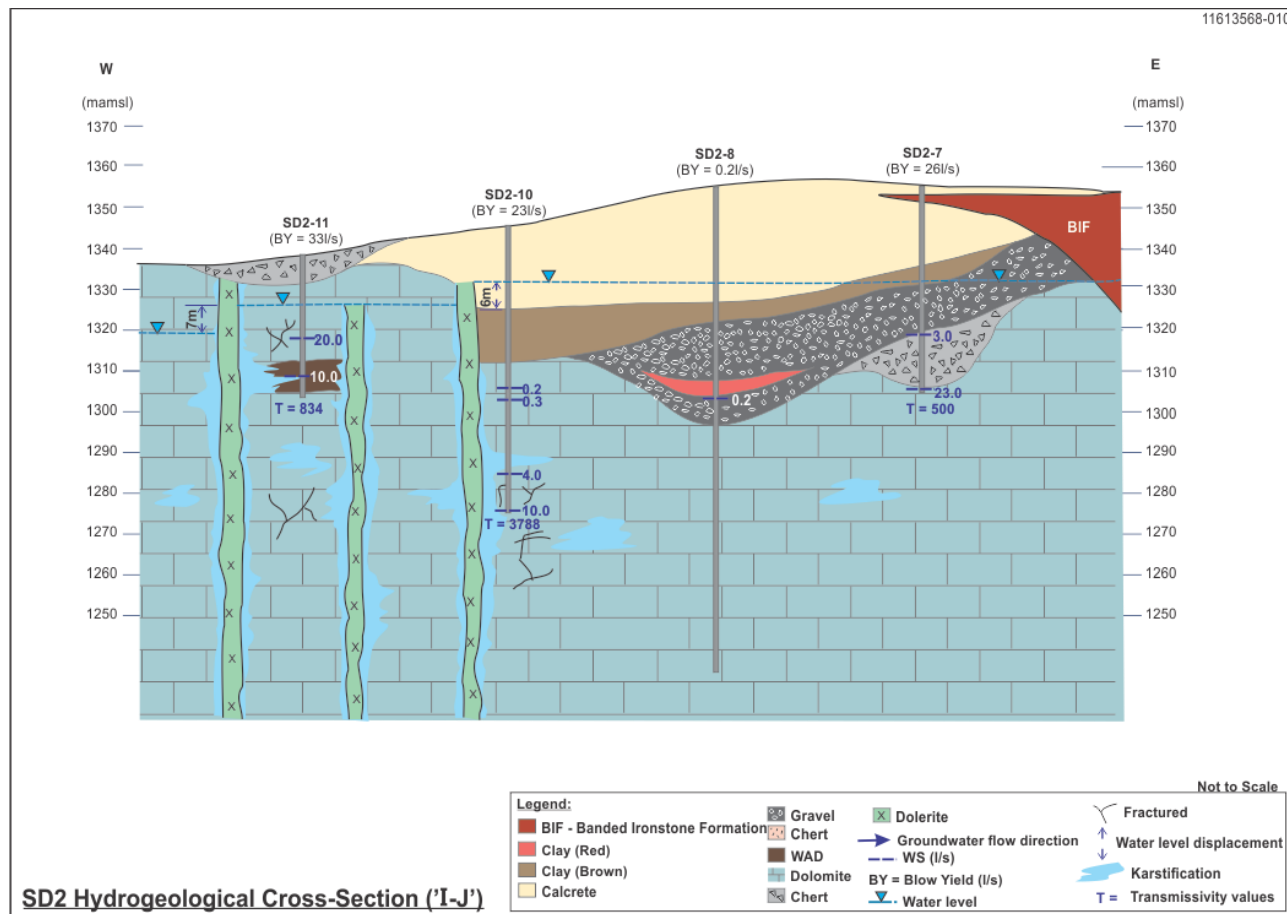


Figure 73: Hydrogeological Cross Section I - J

5.7.7 SD2 Aquifer Zones

From the available drilling and test pumping data of SD2, 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)	Median T (m ² /d)	Average T (m ² /d)
Exploration Boreholes						
Upper Kalahari Calcrete and Gravel	2	-	-	570.0 to 892.0	838.0	731.0
Fractured and Weathered semi consolidated BIF	2	-	-	119 to 1500.0	810.0	810.0
Karstification in Dolomite	29	1.58 X 10 ⁻⁶ to 7.38 X 10 ⁻⁴	0.00023	265.0 to 8530.0	838.0	1817.0

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 SD2 – D73A (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	3234	18.57	-7.07	-0.56	-6.39	-5.10	-1.53	3.57	C
GRDM Present Day	3234	33.91	-1.82	-0.56	0	-32.08	-9.62	22.46	A

Using the GRDM (Present day scenario for 2008) as a representative value for total inflow (recharge) and net base flow, there is a groundwater balance of 22.46 million m³/a available for use in the D73A 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 SD2 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 SD2 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 (2009).

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 upper quaternary catchment (D73A) 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 along:

- The northern boundary, representing shallow inflows along the non-perennial drainage system towards quaternary catchment D41J; and
- The south-western edge of the model domain, representing potential groundwater outflow towards downstream aquifer systems (Figure 74).

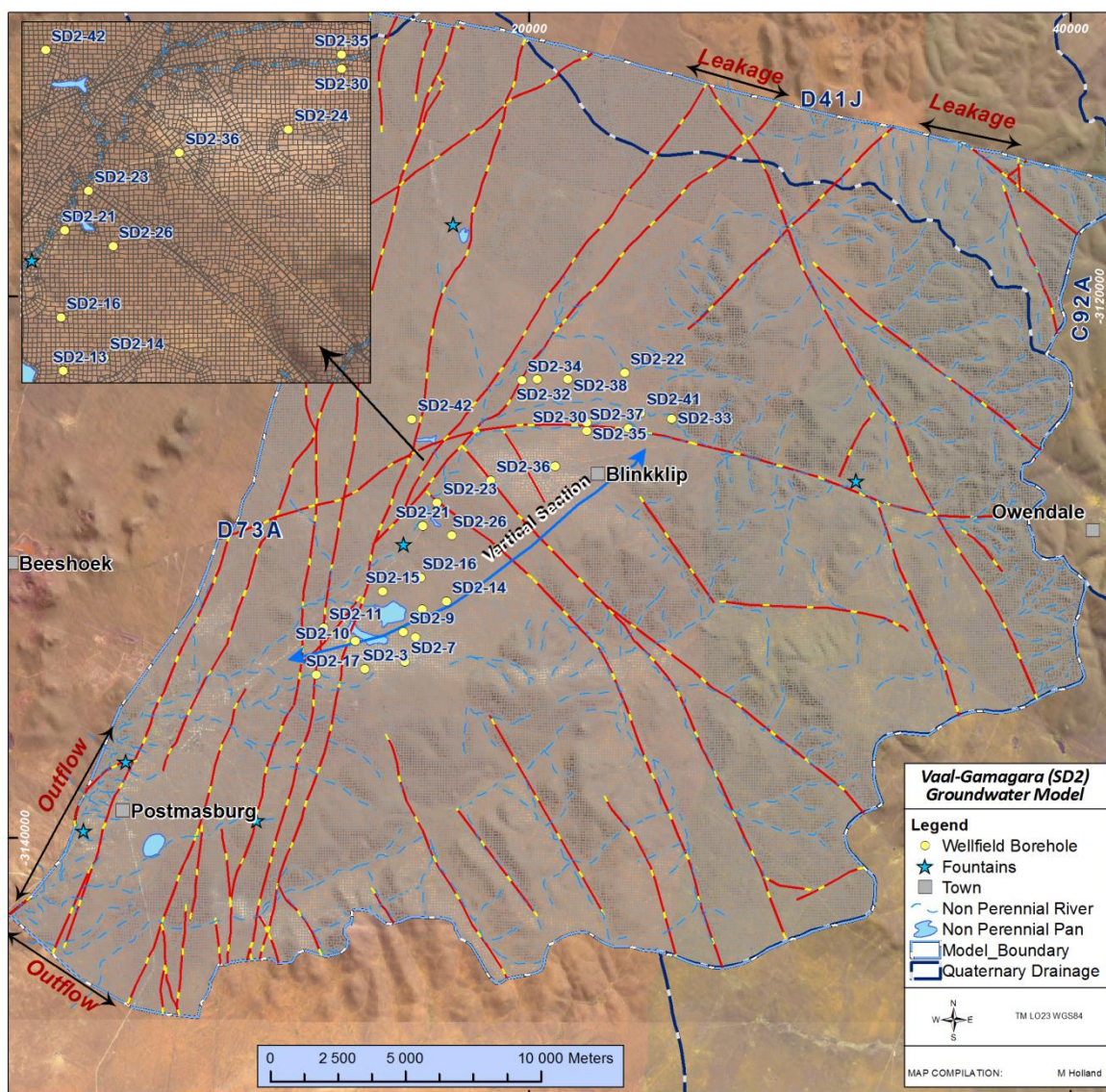


Figure 74: SD2 Finite-Element mesh and Model Domain (also showing cross-section reference)

The total model domain covers an area of 951 km². The horizontal element size (side length) varies from a minimum of 30 to 50 m (average) along surface drainages and mapped dykes and faults (as provided by Golder Associates), to a maximum side length of 200 m further away from the area of interest or steep gradients. The chosen model discretisation allows a sufficiently accurate representation of discrete physical features (dykes, fault zones and drainages) in a regional groundwater flow model, employed to ensure a justifiable water balance and natural upstream boundaries of the flow system for the area of interest.

6.1.2 Groundwater Model Layers

The finite-element model was conceptually 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. However, to increase the numerical accuracy of the unsaturated flow calculations, various model layers have been further sub-divided (Table 27). The numerical model is therefore spatially discretised into 127 684 nodes on 9 node layers, which make up 8 element layers with 145 056 elements (triangles and quadrangles) per layer, to account for the various hydrogeological units underlying the proposed well fields.

The SRTM elevation data were lowered by 2.4m to fit ortho-heights obtained from local trig beacon and compared to gravity survey data and surveyed boreholes elevations.



The thickness of the Kalahari Group layer (split into four model layers) was based on the isopach's interpolated by the client. The Banded Ironstone Formation and Ventersdorp lava's, where present in the model domain, were represented as two model layers with an inferred thickness ranging from 15 to 170m. The dolomitic units are discretised into 4 model layers, representing both the highly karstified dolomites as well as the deeper dolomitic bedrock. The bottom elevation of the active groundwater flow system was set at approximately 120 m below the current groundwater level, resulting in a model thickness ranging from 145 to 335 m. The layer arrangement is summarised in Table 27 and shown in a cross-section in Figure 74. The vertical section was chosen across the main well field area (Figure 75) and shows the detailed vertical representation and discretisation of the conceptual model.

Table 27: Layer Arrangement for the SD2 Groundwater Model

Conceptual Model Layer	Element layers	Map Colour	Aquifer feature	Data used for interpolation
I, top	I, top		Surface elevation	SRTM 90 m Digital Elevation Model (DEM)
I, bottom	1-4		Kalahari Group	Divide Layer 1 into 4 (Equal proportion) - Kalahari Group Isopach
II, bottom	1-2		Banded Ironstone Formation/Ventersdorp Lava	Thickness ~ 15 to 170 m
III, bottom	5-6		Weathered- and Karst Aquifer	Fixed offset from Layer 2
IV, bottom	7-8		Karst Aquifer	120 m below initial water level

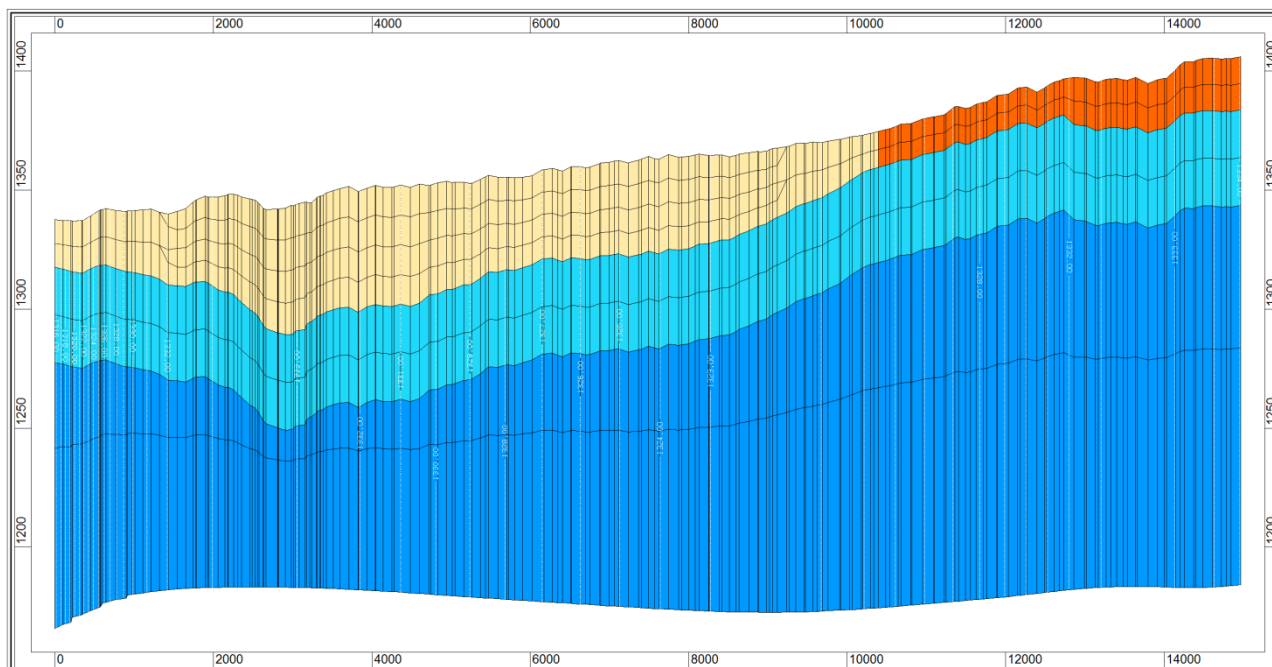


Figure 75: SD2 Vertical Grid Layout Example



6.1.3 Sources and Sinks

6.1.3.1 Groundwater Recharge

The spatial distribution of the recharge rates adapted from the conceptual model is shown in Figure 76. Groundwater enters the model domain 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. The median annual recharge values range between 1 and 20 mm per year for the SD2 groundwater system (Figure 76).

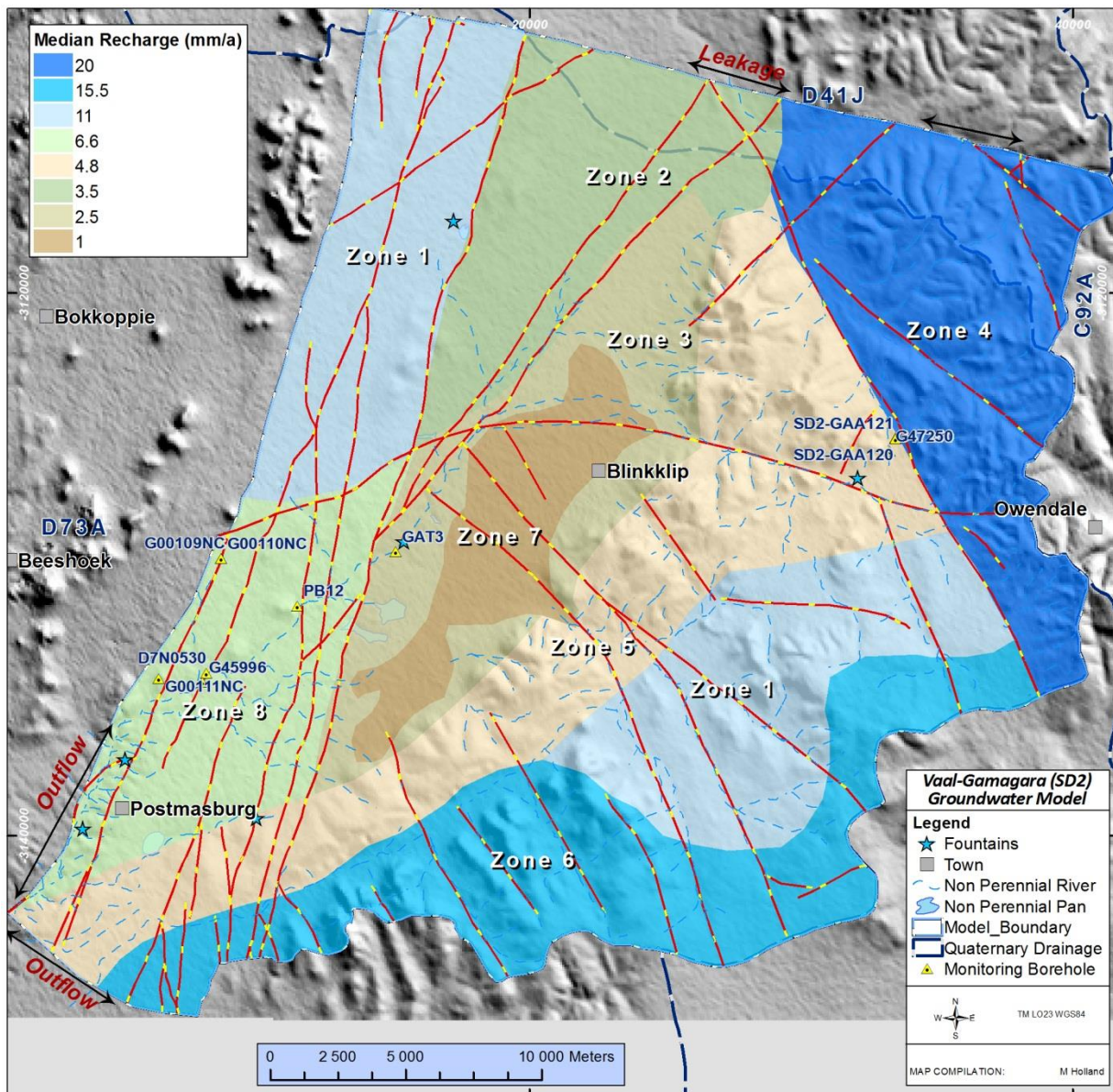


Figure 76: Recharge Rates (and zones) Assigned in the SD2 Groundwater Model

Generally groundwater level monitoring data show a good relationship between the Cumulative Rainfall Departures (CRD) from the mean rainfall and observed water level fluctuations in the dolomitic aquifer, indicating dynamic recharge (Figure 77). The Postmasburg rainfall station data was used as the input for the variable monthly recharge calculations for the transient model runs and calibrated against the existing groundwater monitoring boreholes shown in Figure 76.



The eight steady state recharge zones were combined into three variable recharge areas for the transient model runs. The median recharge rates over a 17 year period from (March 1997 to March 2014) for the delineated zones are given in Table 28.

The available groundwater monitoring data are limited and not all boreholes have complete records of water levels over time or represent in some cases water levels during pumping conditions and not static (rest) water levels. The longest record of water level measurements extends back to November 1999.

Table 28: Median Recharge Rates for the Variable Recharge Areas

Variable Recharge	Km ²	Median Recharge (17 year) (mm/a)	Combined Zones
Area 1	242.7	14	Zone 4 and 6
Area 2	350.97	9	Zone 1 and 8
Area 3	357.58	3.5	Zone 2,3, 5 and 7

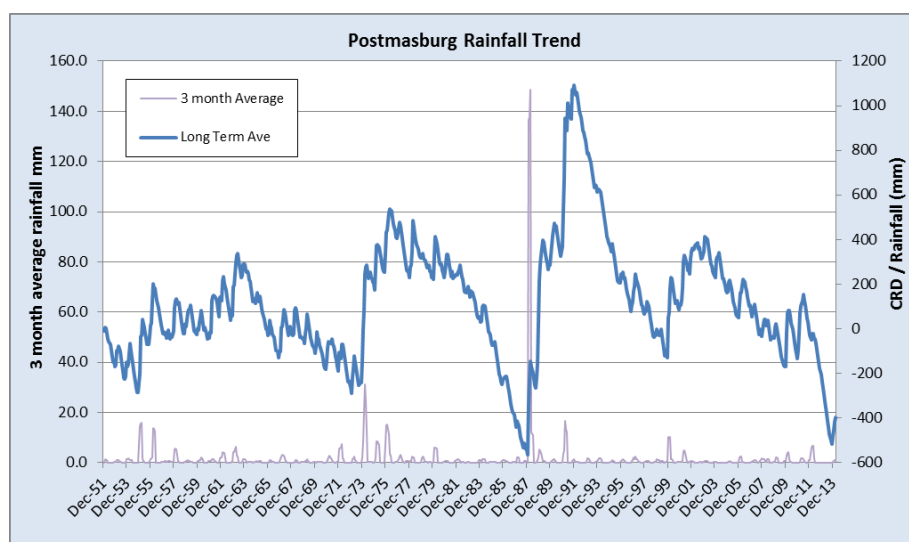


Figure 77: Groundwater Level versus the Cumulative Rainfall Departure

6.1.3.2 Groundwater Abstraction

Both steady state and transient borehole abstractions from the model domain were simulated using a well (flux) 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 nodes above the well node and the inflows for each node (or across each model layer) automatically calculated by the software. The monthly abstraction rates applied to the steady state model amount to a total groundwater withdrawal of 124 441 m³/month.

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 seasonal 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 $1\text{E-}7$ m/s was assumed. Known springs (Figure 74) within the SD2 area were incorporated as free seepage boundaries at the specific node of the spring location.

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 298 boreholes were used as targets for the manual calibration. 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 biased therefore the steady state calibration towards a reasonable fit of the most recent water levels respectively abstraction and recharge conditions.

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 (Table 29) to represent the observed flow system.

Table 29: Average Transmissivity and Hydraulic Conductivity Values for the SD2 Region

Stat.	T-Value (m^2/d)	Hydraulic Conductivity	
		(m/d)	(m/s)
Arithmetic mean	1568	10.5	$1.2\text{E-}4$
Median	834	5.6	$6.4\text{E-}5$
Geometric mean	276	4.4	$2.1\text{E-}05$

The spatial distribution of the calibrated conductivity values for layer 5 is shown in Figure 78 and a cross-section along the well field is shown in Figure 79. The values for all model layers summarised in Table 30.

Table 30: Calibrated Hydraulic Conductivity Ranges for SD2 Groundwater Model

Layer	Aquifer	Hydraulic conductivity [m/s]	
		Min	max
I-IX	Dyke (Barriers to Flow)	$1\text{E-}9$	$1\text{E-}7$
I-IV	Kalahari	$8\text{E-}7$	$4\text{E-}6$
I-VI	Weathered- and Karst Aquifers	$1\text{E-}6$	$3.6\text{E-}4$
	BIF and Lava	$5\text{E-}8$	$5\text{E-}6$
VII-IX	Deep Karst Aquifer	$5\text{E-}7$	$6\text{E-}5$



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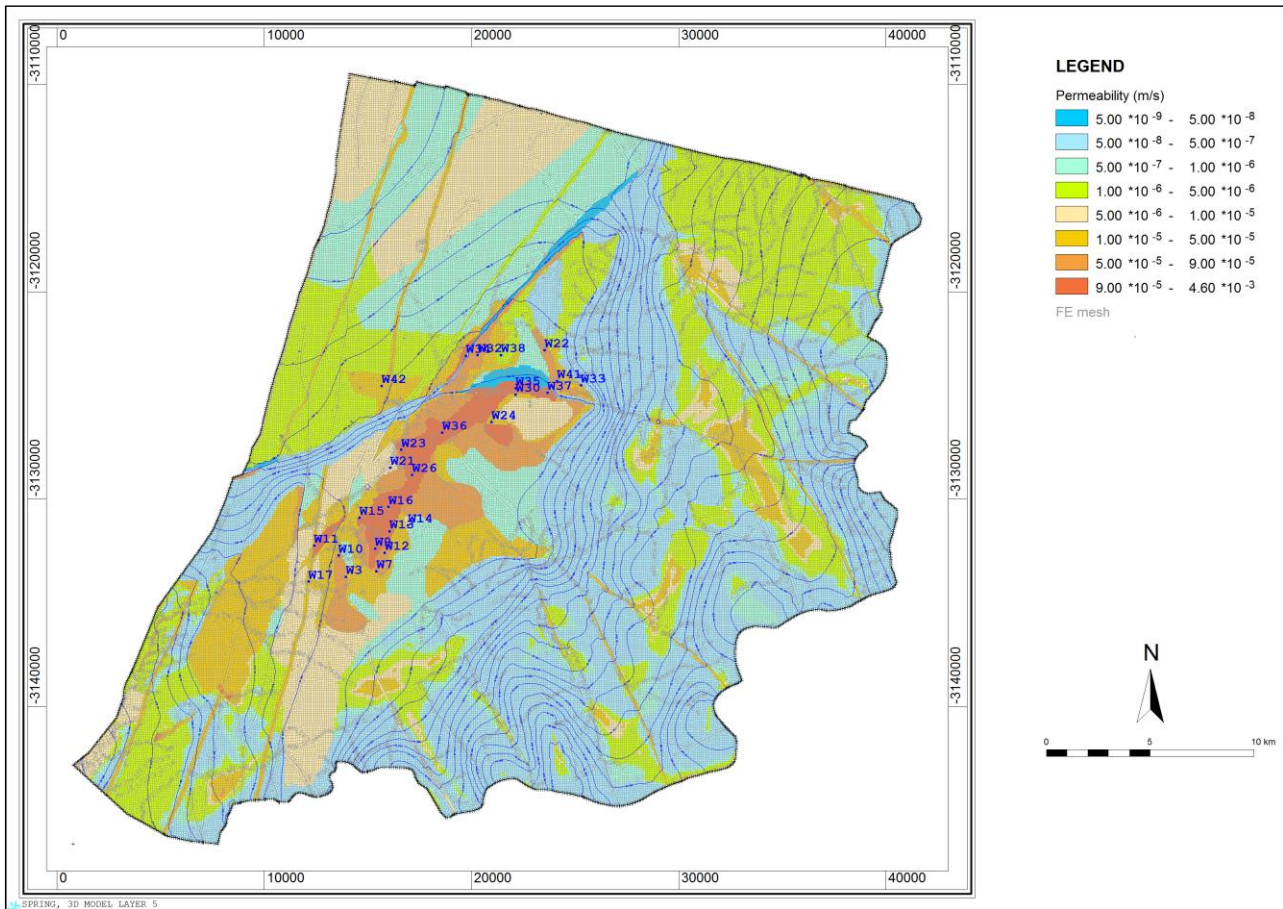


Figure 78: Lateral Distribution of Permeability's (layer 5) and Simulated Steady State Heads (10 m contour interval)

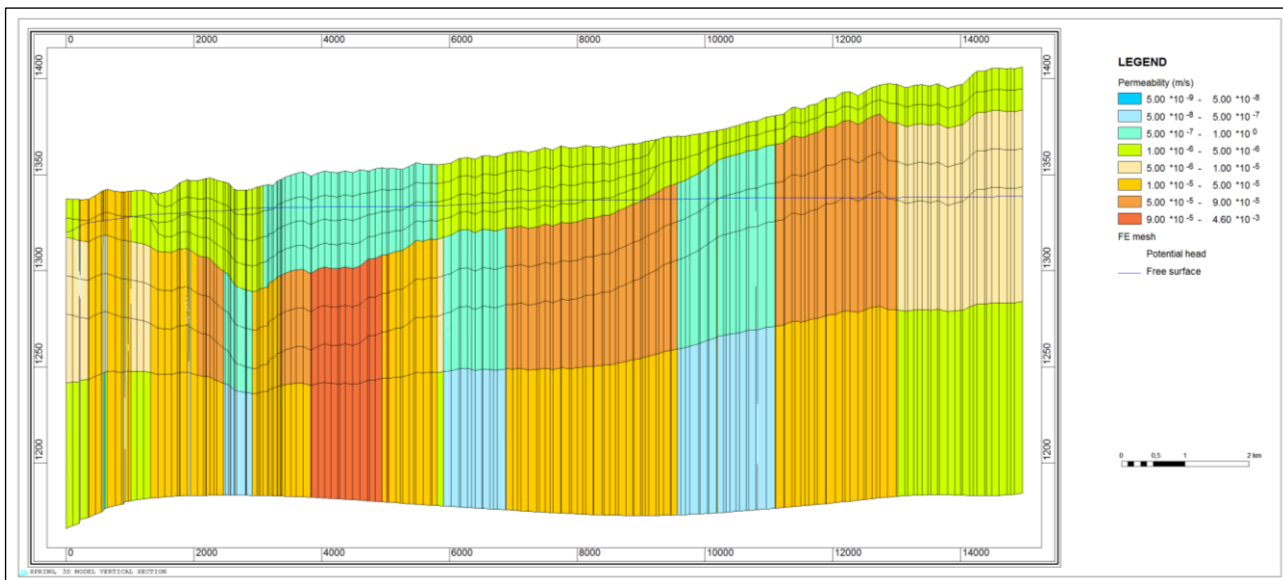


Figure 79: Vertical Distribution of Permeability's and Simulated Steady State Heads (potentiometric surface)

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 also 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 1999 to 2014 and entailed 183 stress periods (months) with variable monthly recharge rates.
- The second component entails stress periods assigned for the predictive model runs considering various aquifer management scenarios for the period 2013 to 2031 (205 stress periods or months).

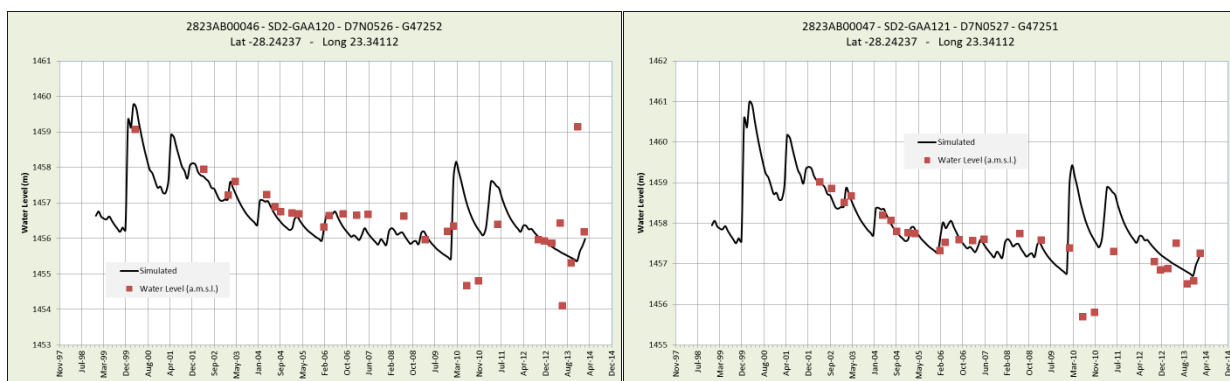
The model was further optimised by calibrating the simulated heads to observed pumping test drawdown data for selected SD2 production boreholes. The pumping tests ranged from 24 to 72 hours and the transient model comprised of 73 one-hour time steps. A summary of the calibration targets is shown in Table 31. The pumping tests however, do not represent the entire the model domain and the refined model calibration was therefore limited to the SD2 well field region only.

Table 31: T Boreholes (with pumping test data) used as Transient Calibration Targets

BH ID	Model Node	L/S	m ³ /hour	Time (Minutes)
SD2-09	1692	20	72	4320
SD2-11	1694	30	108	2880
SD2-12	1695	20	72	4320
SD2-14	1697	15	54	1440
SD2-15	1698	20	72	4320
SD2-16	1699	20	72	4320
SD2-21	1705	13	46.8	4320
SD2-34	1718	30	108	4320
SD2-35	1719	30	108	4320
SD2-38	1722	13	46.8	3360
SD2-42	1726	20	72	4320

For the transient calibration the available long term water level monitoring and 10 (SD2) 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 80 shows a comparison of simulated vs. observed heads for a number of representative boreholes. Unfortunately good quality records of water level measurements were limited with a number of probably inaccurate and/or incomplete records.



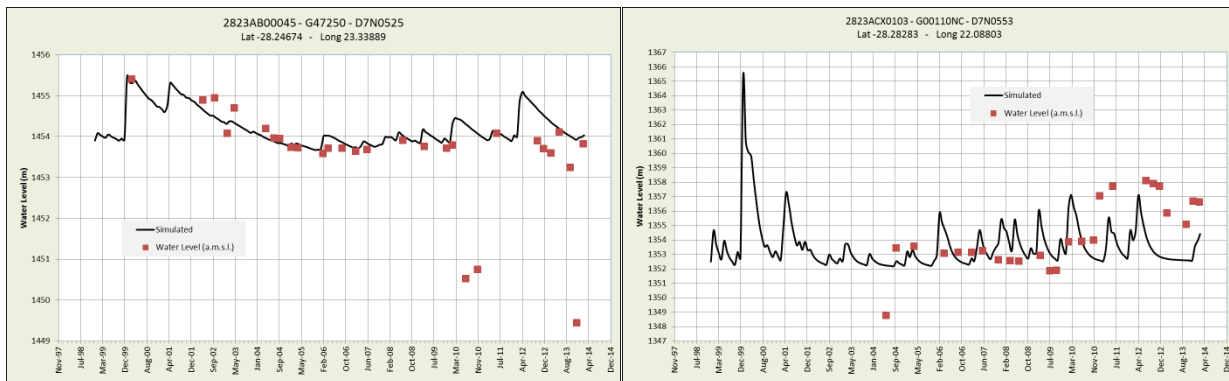


Figure 80: Transient Simulated versus Observed Groundwater Levels

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.

The transient calibration of pumping test datasets refines and verifies the steady-state calibration by matching transient hydraulic-head trends which reflect the stresses of pumping from the production boreholes (Figure 81). The transient model calibration was used to optimize the spatial variability of storage coefficients.

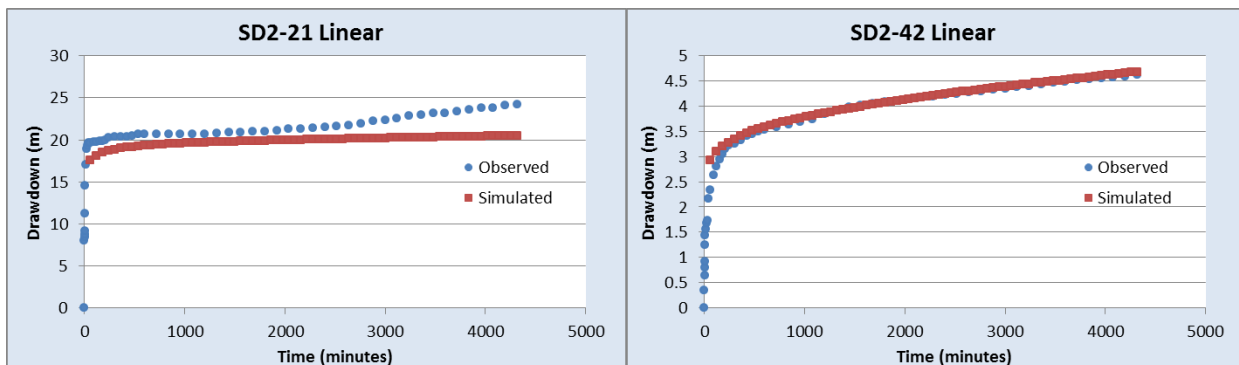


Figure 81: Transient Model Calibration using Drawdown from initial Static Water Level

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 32. The steady-state water balance (Table 32) 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 or is abstracted, and that only around 14 % of the inflow (recharge) reports to the head dependent outflow boundaries, i.e. towards downstream catchments. Total (steady-state) groundwater abstractions consume in comparison (for the steady-state scenario) around 18 % of the total recharge for the area. The detailed water balances for the 4 delineated Groundwater Management Units (GMU) is shown in Table 33. It is important to note that the water balance exclude the GMU immediately east of Postmasburg (D73A-06).



Table 32: SD2 Regional Steady State Water Balance

Inflow	m³/month	m³/annum
Recharge	683 202	8 198 424
Outflow	m³/month	m³/annum
Shallow seepages to pans and spring discharge	-150 742	-1 808 899
Boreholes Abstraction	-124 442	-1 493 303
Contribution to Drainages and potential evapotranspiration	-309 523	-3 714 278
South-western Outflow	-78 825	-945 894
Leakage across Northern Boundary	-19 670	-236 045
Total Outflow	-683 202	-8 198 420

Table 33: Steady-state water balance for each of the 4 delineated GMUs (in m³/month)

Inflow	D73A-01	D73A-02	D73A-03	D73A-04
Recharge	81 191	329 045	243 456	24 293
Inflow from D73A-01		51 581		13 049
Inflow from D73A-02			85 255	
Inflow from D73A-03				120 554
Total Inflow	81 191	380 626	328 711	157 896
Outflow				
Shallow seepages to pans and spring discharge	-7 391	-107 919	-22 099	-12 618
Boreholes Abstraction	-5 788	-28 166	-75 003	-7 908
Contribution to Drainages and potential evapotranspiration	-3 381	-139 616	-111 055	-53 421
Leakage across Northern Boundary		-19 670		
Internal Outflow to D73A-02	-51 581			
Internal Outflow to D73A-03		-85 255		
Internal Outflow to D73A-04	-13 049		-120 554	
Internal Outflow to D73A-06				-83 950
Total Outflow	-81 191	-380 626	-328 711	-157 896

6.3.2 Applied Rainfall Variability (2014 to 2031)

The calibrated transient model was subsequently used to simulate the impact of proposed abstractions from the SD2 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 1997 to 2014, which is regarded to be a conservative approach, was used to simulate the recharge in the predictive scenario.

6.3.3 Applied Abstraction Scenarios (2014to 2031)

The forward simulations of the proposed SD2 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 – 26 production boreholes;
 - Upper limit of abstraction with a combined yield of 729 270 m³/month (8.75 million m³/annum).
- Scenario 2 – 21 production boreholes of which 4 is regarded as short-term;
 - Optimised long term abstractions with a combined yield of 462 528 m³/month (5.5 million m³/annum) with a peak yield (during 4 months a year) of 538 740 m³/month (6.5 million m³/annum).



- Scenario 3 – 21 production boreholes of which 8 is regarded as peak supply;
 - Optimised long- and short term abstractions with a combined yield of 307,476 m³/month (3.7 million m³/annum) for the SD2 production boreholes with a peak yield (during 4 months a year) of 458 148 m³/month (5.5 million m³/annum).

The various abstraction scenarios are detailed in (Table 34), while the position of the SD2 well fields and associated (upper limit Scenario 1) abstraction rates are shown spatially in Figure 82.

Table 34: SD2 Abstraction Rates for the Forward Scenario's 1, 2 and 3 (in m³/month)

BH no.	Scenario 1	Scenario 2	Scenario 3
SD2-3	21 900	0	0
SD2-7	39 420	26 280	26 280
SD2-9	39 420	39 420	26 280
SD2-10	39 420	31 536	26 280
SD2-11	32 850	26 280*	21 900*
SD2-12	39 420	26 280	26 280*
SD2-13	21 900	0	0
SD2-14	26 280	18 396*	18 396*
SD2-15	39 420	26 280	26 280
SD2-16	39 420	26 280	26 280
SD2-17	10 950	0	0
SD2-21	13 140	0	0
SD2-22	13 140	13 140	13 140
SD2-23	39 420	31 536	26 280
SD2-24	13 140	13 140*	13 140*
SD2-26	39 420	31 536	31 536
SD2-30	10 950	0	0
SD2-32	13 140	13 140	13 140*
SD2-33	13 140	13 140	13 140
SD2-34	52 560	39 420	26 280*
SD2-35	39 420	39 420	26 280
SD2-36	39 420	39 420	26 280
SD2-37	39 420	39 420	26 280
SD2-38	26 280	18 396*	18 396*
SD2-41	13 140	13 140	13 140*
SD2-42	13 140	13 140	13 140
Total	729 270	538 740	458 148

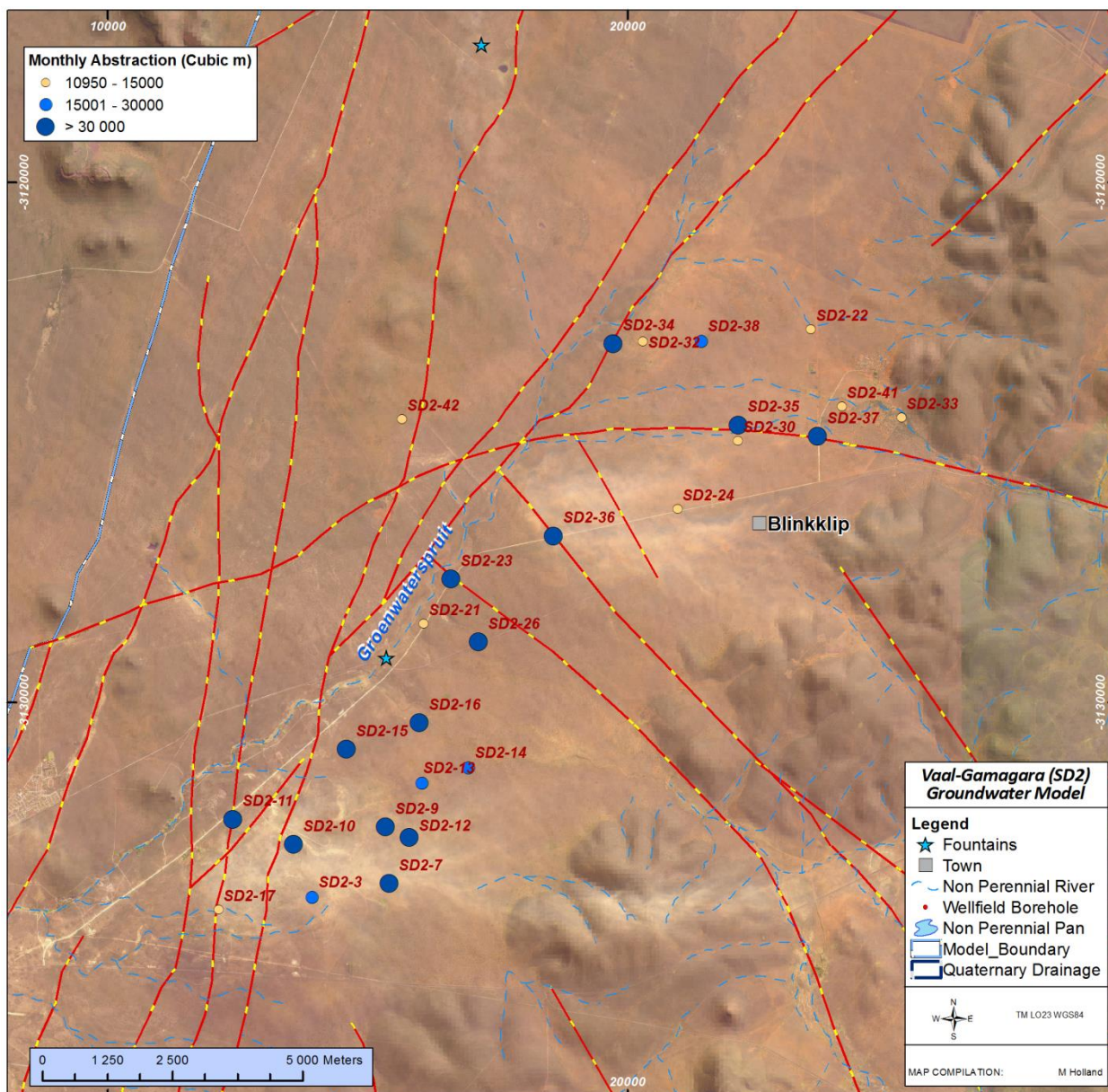


Figure 82: Locality of SD2 Well Fields (Scenario 1)

6.3.4 SD2 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 25 x 18 km (considering a 2 m cut-off value), due to the distribution of the well fields as shown in Figure 83. 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.

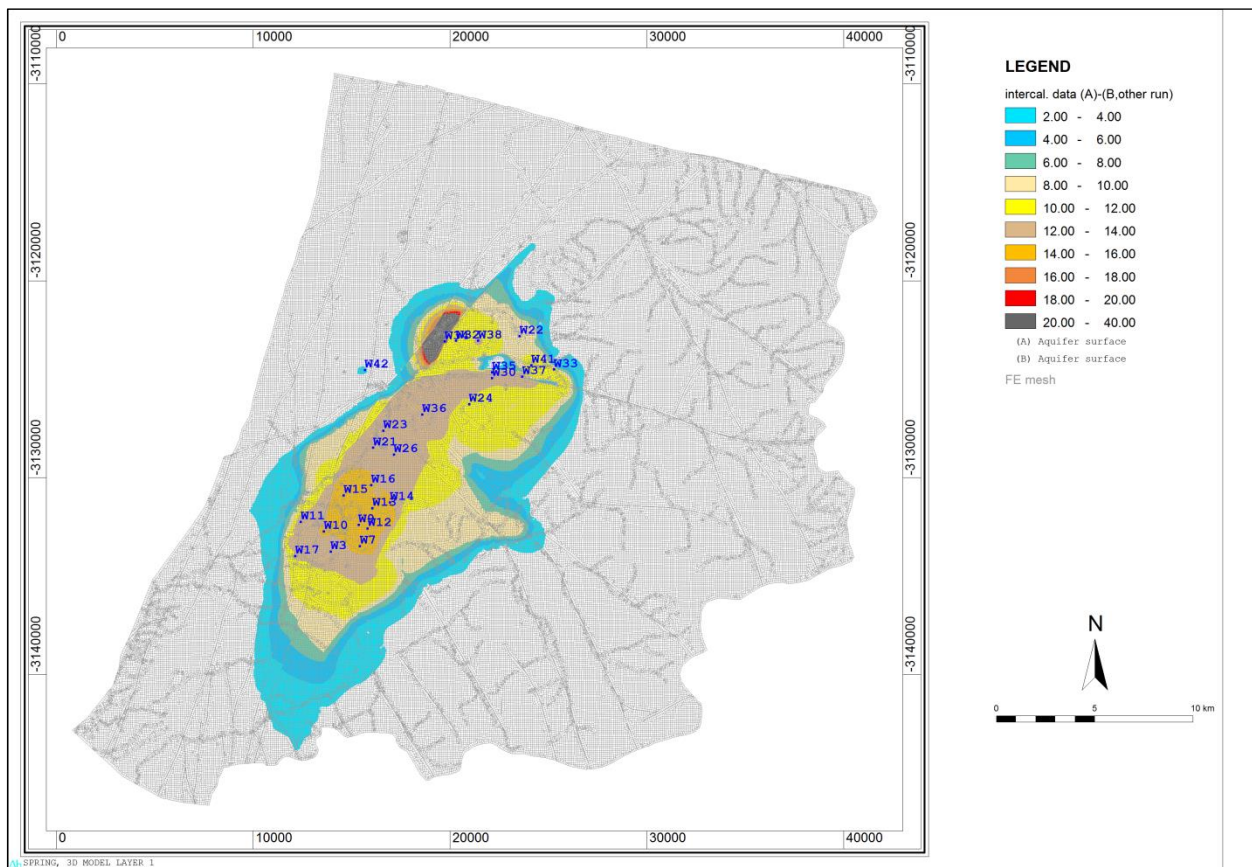


Figure 83: Scenario 1-Cone of Dewatering (m)

6.3.5 SD2 Well Field Scenario 2

The drawdown cone in the optimised Scenario (2) is smaller in extent and depth (Figure 84). The cone of dewatering is expectedly more pronounced within the central part where numerous production boreholes are within close proximity to each other (i.e. SD2-7, SD2- 9, SD2- 10, SD2-14 and SD2-16).

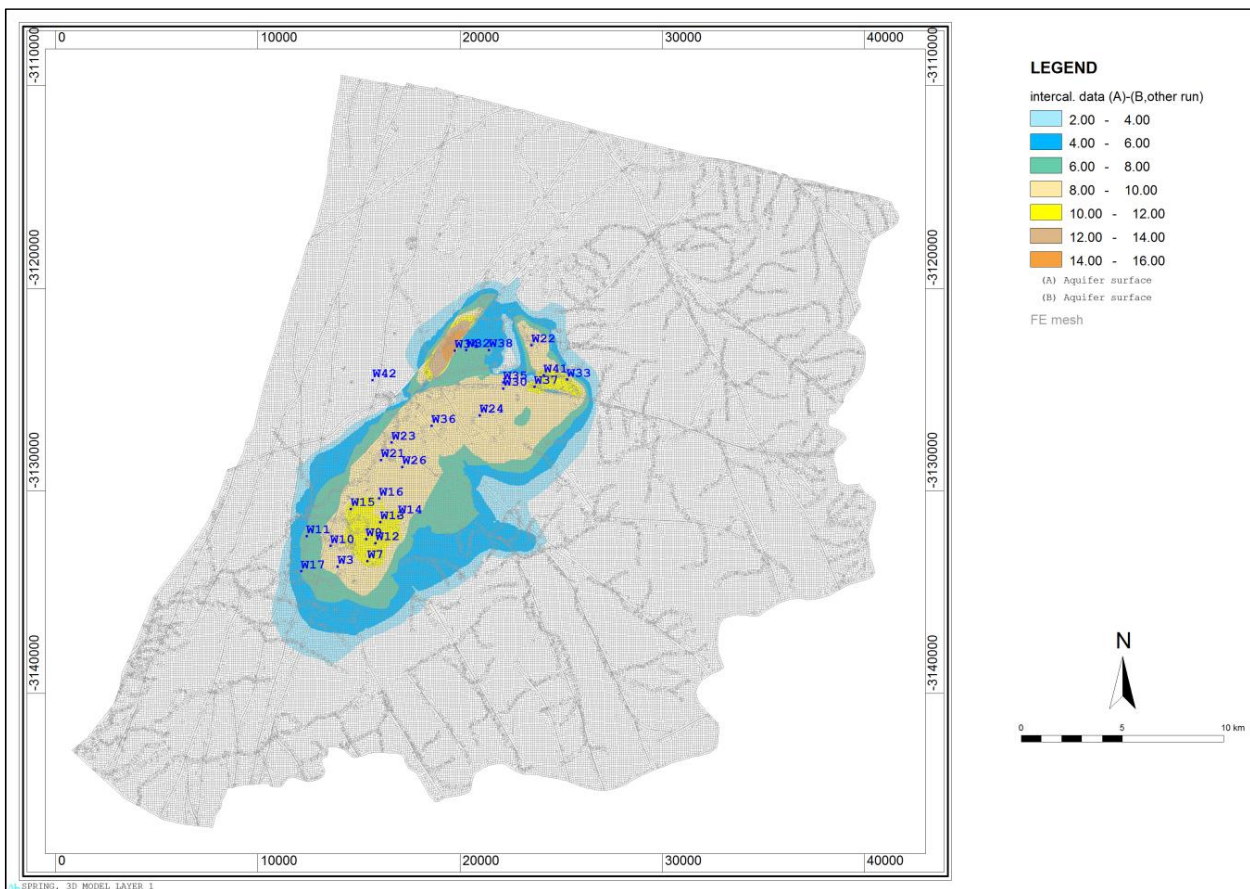


Figure 84: Scenario 2 - Cone of Dewatering (m)

6.3.6 SD2 Well Field Scenario 3

The final dewatering cone of Scenario (3) (Figure 85) extends approximately 19 x 10 km (considering a 2 m cut-off value) with drawdown ranging predominately between 6 and 8 m.

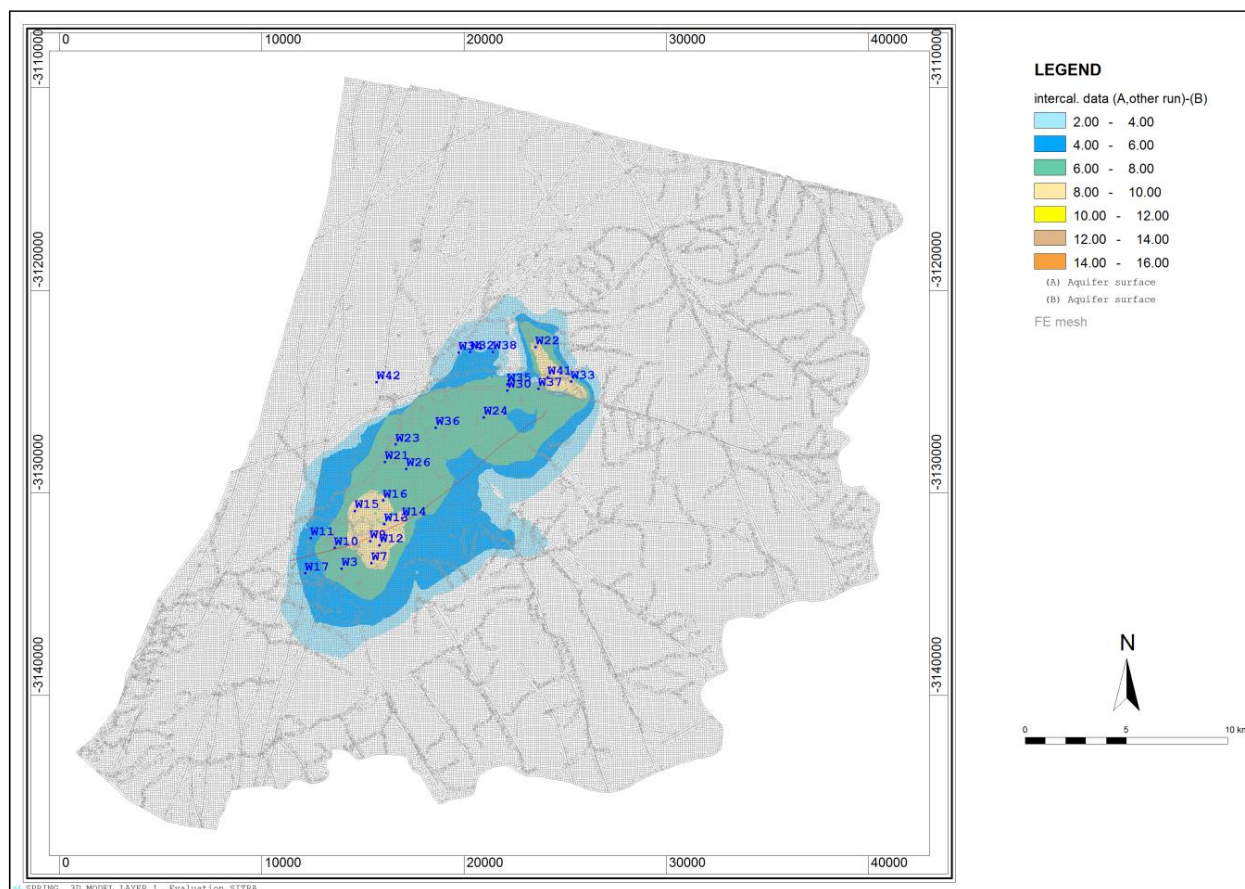


Figure 85: Scenario 3 - Cone of Dewatering (m).

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 3 is shown in Table 35.

Table 35: Simulated Water Balance (Transient State – 2031 – Scenario 3)

Regional Water Balance	Scenario 3	Base Case	Diff. From Base Case
Inflow	m³/month	m³/month	m³/month
Recharge	1 603 282	1 603 282	
Outflow	m³/month	m³/month	m³/month
Shallow seepages to pans and spring discharge	-153 200	-175 388	-22 187
Boreholes Abstraction	-582 590	-124 442	458 148
Contribution to Drainages and potential evapotranspiration	-332 891	-342 063	-9 173
Outflow Boundaries	-109 949	-110 019	-70
Sub-Total Outflow	-1 178 630	-751 912	
Change In Storage	-424 653	-851 370	-426 718
Total Outflow	-1 603 282	-1 603 282	

6.3.6.2 Change in Storage

The abstractions from the SD2 well fields results in a change of storage together with a small reduction in groundwater contributions to drainages and pans and a minimal reduction in flows across the outflow



boundaries (to downstream catchments). If the outflows (abstractions) 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 86, while the net change in storage for the base case (no well field abstractions) compared to Scenario 3 is shown Figure 87. The total abstraction from the model domain amounts to approximately 53 % of the average recharge of 870 885 m³/month (10.45 million m³/annum) for the simulation period (Delta H; 2014).

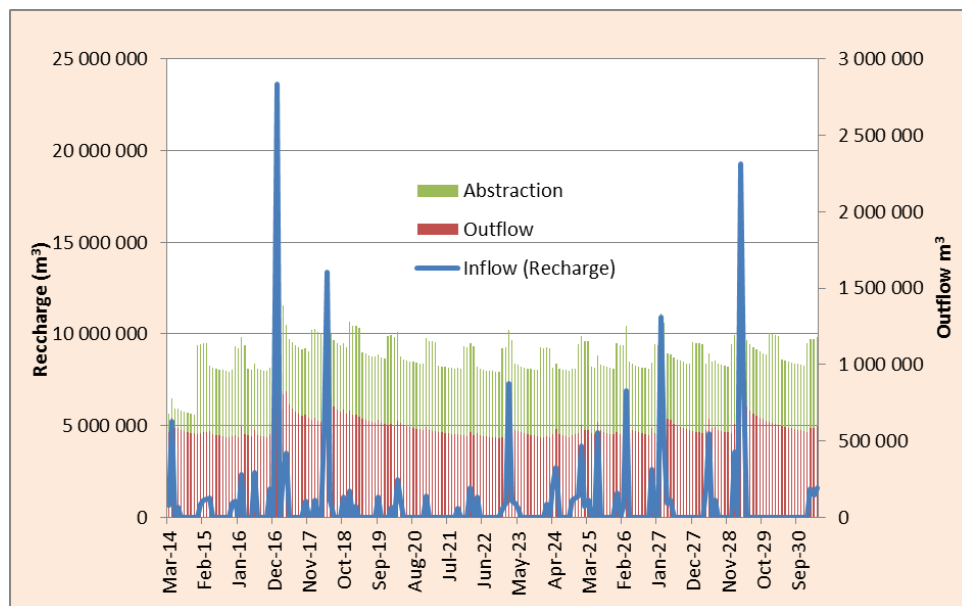


Figure 86: Simulated In- and Outflows for the Modelled Scenario 3

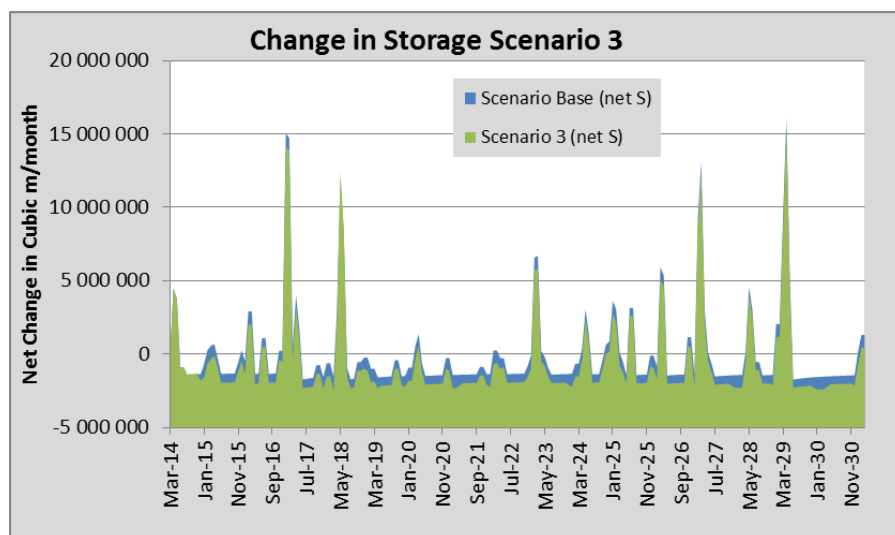


Figure 87: Net change in Storage for Scenario 3 compared to the Base Case

6.3.6.3 Impact on Outflow Boundary

The SD2 well fields (Scenario 3) will have almost no influence on the groundwater outflow (boundaries) based on the resulting predictions. The total cumulative loss of outflows (for the simulation period 30 years) compared to the base case is 3 173 m³.



6.3.6.4 Impact on drainages (groundwater baseflow) and seepages (pans and springs)

Conceptually (and based on the simulated water balances), groundwater pumped from the well field initially comes from storage in the vicinity of the well fields, but after sufficient time has elapsed, the cone of depression will eventually reach a new dynamic equilibrium. However, in order to maintain this equilibrium, groundwater abstractions must be balanced by increased recharge (increase in the amount of water entering the system by e.g. reduction in evapotranspiration losses (or artificial recharge,) or reduced discharge (reducing the amount of water leaving the system). The total cumulative reduction in groundwater flow towards surface water drainages and springs and pans (Figure 88) due to the proposed well field abstraction (for the simulation period of 17 years) compared to the base case is approximately 889 180 m³ and 2 673 945 m³ respectively.

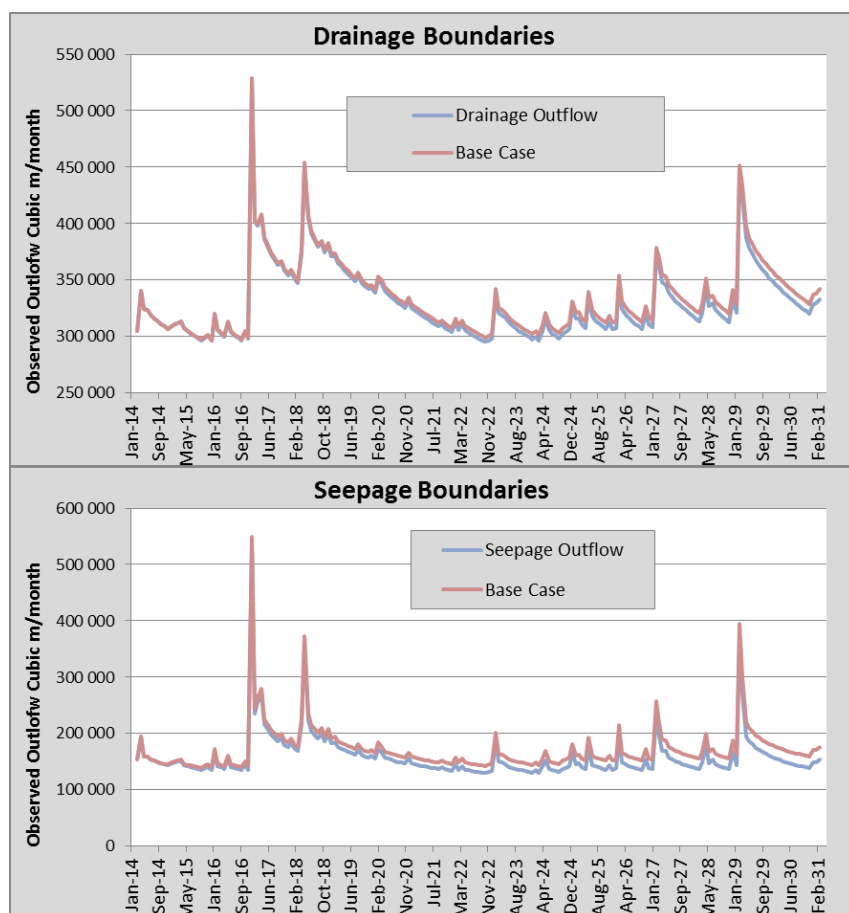


Figure 88: Cumulative change in Storage for Scenario 3 compared to the Base Case

6.3.7 Reserve Determination

The groundwater component of the Reserve is the part of the groundwater resource that sustains basic human needs (BHN) and in some instances contributes to EWR. To be able to quantify the groundwater component of the Reserve, the volume of groundwater needed for BHN and contributing to EWR needs to be quantified. The EWRs of the Resource in question must consider the following:

- Groundwater contribution to baseflow in rivers.
- Groundwater contribution to wetlands.
- Groundwater contribution to springs and other Groundwater Dependant Ecosystems.

The groundwater component of the Reserve is defined by the following relationship:



$$Reserve(\%) = \frac{EWR_{gw} + BHN_{gw}}{Re} \times 100$$

Where:

Re = recharge + (inflow – outflow)

BHN_{gw} = basic human needs derived from groundwater (not regarded in this case)

EWR_{gw} = groundwater contribution to EWR

The potential impact on the Reserve (considered in this case as the ecological component only) is shown in Table 36 and is based on the recharge and baseflow from the model simulation. The ecological Reserve range is from 8 to 57 %. It is evident that the development of the SD2 well field has an insignificant impact on the low flows contributing to the Reserve.

Table 36: Groundwater Reserve Summary for the four Delineated GMUs

GMU	Area Km ²	Recharge* (million m ³ /a)	Baseflow (million m ³ /a)	Low Flow (Pre-Well field) (million m ³ /a)	Reserve	Low Flow (Post-Well field) (million m ³ /a)	Reserve
D73A-01	96	0.51	0.05	0.04	8%	0.04	8%
D73A-02	351	4.56	1.86	1.67	37%	1.66	36%
D73A-03	363	3.43	1.48	1.33	39%	1.32	39%
D73A-04	121	0.92	0.58	0.52	57%	0.52	56%

* - Total Inflow [Recharge – (Inflow – Outflow)]

6.3.8 Impact on Water Levels

6.3.8.1 Well Field Boreholes

The simulated impacts of the groundwater abstraction from the SD2 well field on the regional groundwater levels are shown as contour maps of water table drawdown by comparing the water levels simulated for the last stress period of the base case (no well field abstractions) (in 2031) simulation against the lowered water levels due to abstraction from the SD2 well field (in 2031).

No drawdown values below 2 meters are visualised to account for the inaccuracy in the model calibration, which is however 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. 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 25 x 18 km (considering a 2 m cut-off value), due to the distribution of the well fields as shown in Figure 89. 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.

The drawdown cone in the optimised Scenario (2) is smaller in extent and depth (Figure 84). The cone of dewatering is expectedly more pronounced within the central part where numerous production boreholes are within close proximity to each other (i.e. SD2-7, SD2- 9, SD2- 10, SD2-14 and SD2-16). The final dewatering cone of Scenario (3) (Figure 89) extends approximately 19 x 10 km (considering a 2 m cut-off value) with drawdown ranging predominately between 6 and 8 m.

The simulated drawdown behaviour for each well field borehole (Scenario 3) is shown in Appendix B, while a summary of the drawdown for each scenario is given Table 37. The simulated drawdown behaviour for the proposed long term monitoring (designated) boreholes (Scenario 3) is shown in Appendix B. The predicted drawdown on the existing boreholes (as a result of the SD2 well field dewatering cone) identified during the hydrocensus is shown in Appendix C.



Table 37: Summary of Simulated Drawdown at the end of the Predictive Period (March 2031) for the Three Simulated Scenarios

BH no.	Scenario 1 Drawdown (m)	Scenario 2 Drawdown (m)	Scenario 3 Drawdown (m)
SD2-3	13.5	7.4	5.8
SD2-7	15.3	10.8	8.8
SD2-9	14.5	10.0	7.7
SD2-10	14.7	10.3	8.1
SD2-11	12.6	6.8	5.3
SD2-12	15.7	11.0	8.9
SD2-13	14.3	9.3	7.3
SD2-14	15.0	13.5	11.5
SD2-15	15.6	9.6	7.7
SD2-16	13.9	9.9	8.0
SD2-17	11.9	5.0	3.7
SD2-21	16.5	8.4	6.6
SD2-22	9.3	8.8	7.6
SD2-23	13.1	9.1	7.0
SD2-24	11.3	9.0	6.8
SD2-26	13.3	9.1	7.2
SD2-30	12.3	8.9	6.4
SD2-32	11.4	6.0	3.8
SD2-33	11.4	11.3	9.5
SD2-34	20.4	14.8	3.1
SD2-35	12.5	9.0	6.4
SD2-36	12.5	8.8	6.6
SD2-37	12.6	9.7	6.8
SD2-38	20.3	16.8	14.7
SD2-41	9.9	9.6	8.0
SD2-42	5.5	2.1	2.0
Average	13.4	9.4	7.1



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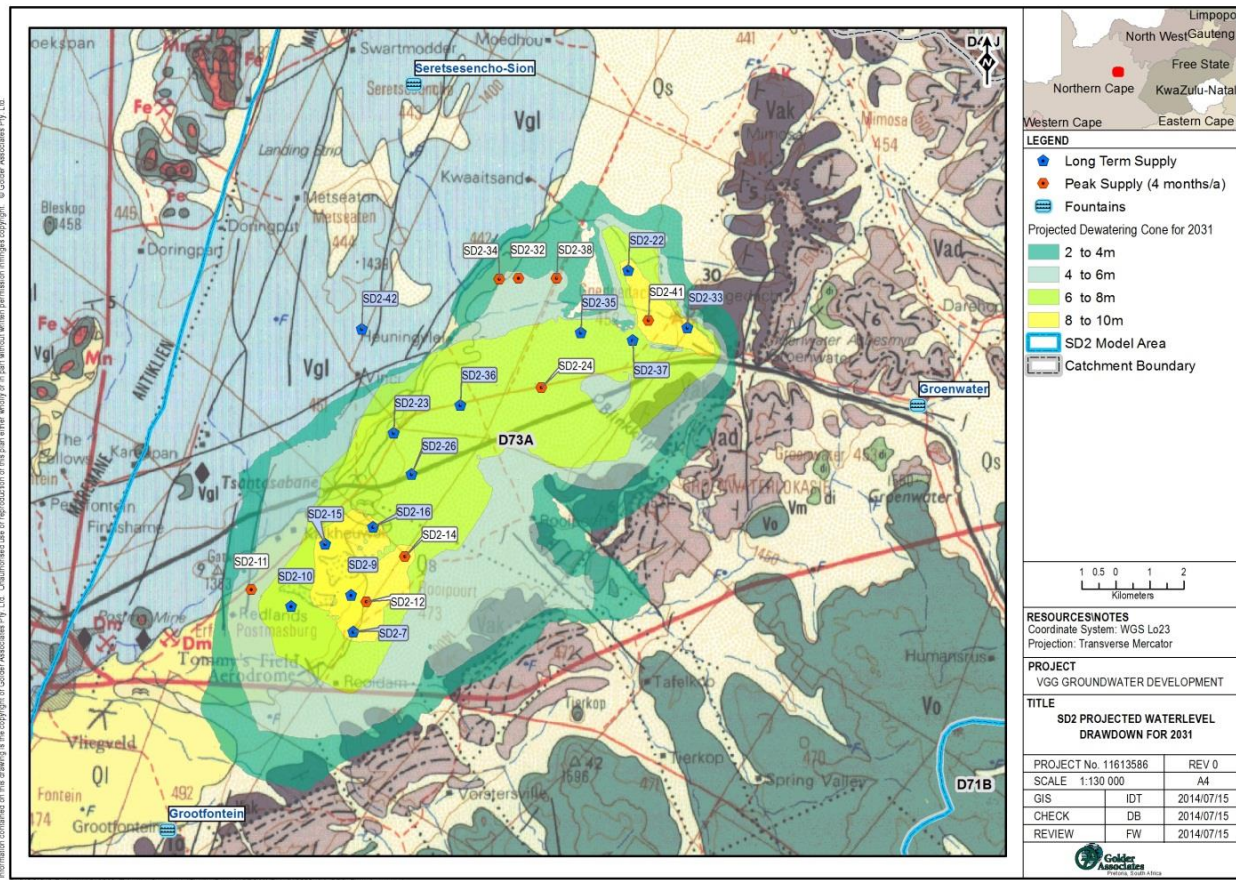


Figure 89: SD2 Projected Water Level Draw Down – 2031

6.3.8.2 Designated monitoring boreholes

The designated monitoring boreholes (19) are indicated on Figure 90 and are summarised in Table 38. The designated monitoring boreholes simulated drawdown behaviour graphs are shown in Appendix B of volume I.

The simulated behaviour of monitoring boreholes SD2-02 and SD2-04, which are located relatively close to each other in the same groundwater management units, are indicated in Figure 91 and Figure 92. At monitoring borehole SD2-02 the long term simulated impact on the water level is 1.6m, whereas at SD2-04 there is no impact on the water level. These different simulated reactions between boreholes in GMU are because of formations being compartmentalised by dolerite dykes.



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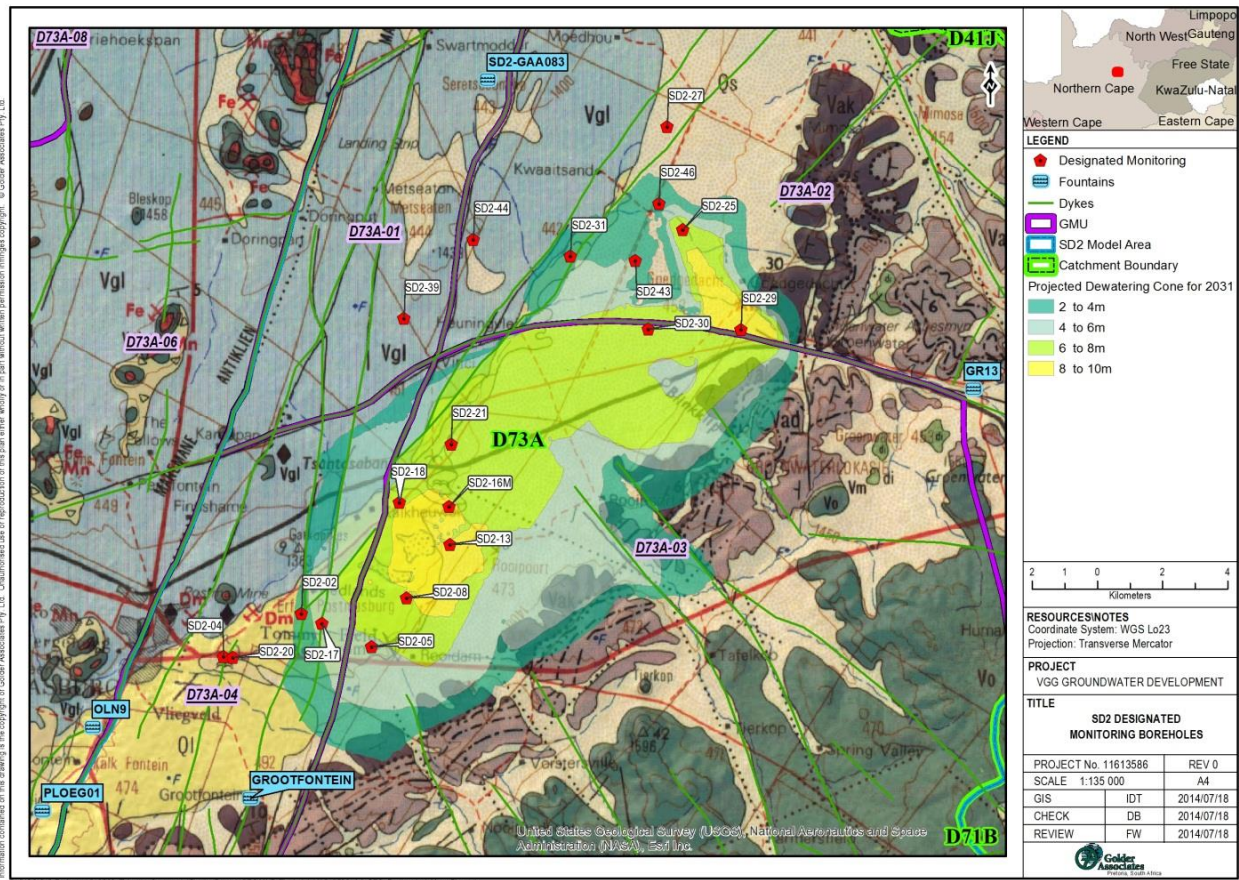


Figure 90: SD2 Designated Monitoring Boreholes

Table 38: SD2 Designated Monitoring Boreholes

GMU	Borehole Number	Predicted Water Level DD 2031 (mbgl)	Latest Water Level 2014 (mbgl)	Comment
D73A-01	SD2-39	1.2	16.36	-
D73A-02	SD2-25	6.5	41.23	-
	SD2-27	-0.7	16.84	Long term WL not impacted
	SD2-29	7.5	46.06	-
	SD2-31	2.7	10.31	-
	SD2-43	3.0	38.46	-
	SD2-44	0.0	28.23	-
	SD2-46	2.6	38.06	-
D73A-03	SD2-05	4.4	14.23	-
	SD2-08	6.7	19.86	-
	SD2-13	7.3	19.57	-
	SD2-16M	7.3	18.75	-



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GMU	Borehole Number	Predicted Water Level DD 2031 (mbgl)	Latest Water Level 2014 (mbgl)	Comment
	SD2-21	6.6	19.01	-
	SD2-18	6.9	11.65	-
	SD2-30	6.4	51.83	-
D73A-04	SD2-02	1.6	19.3	-
	SD2-04	-0.5	12.9	Long term WL not impacted
	SD2-17	3.7	12.07	-
	SD2-20	-0.4	12.45	Long term WL not impacted

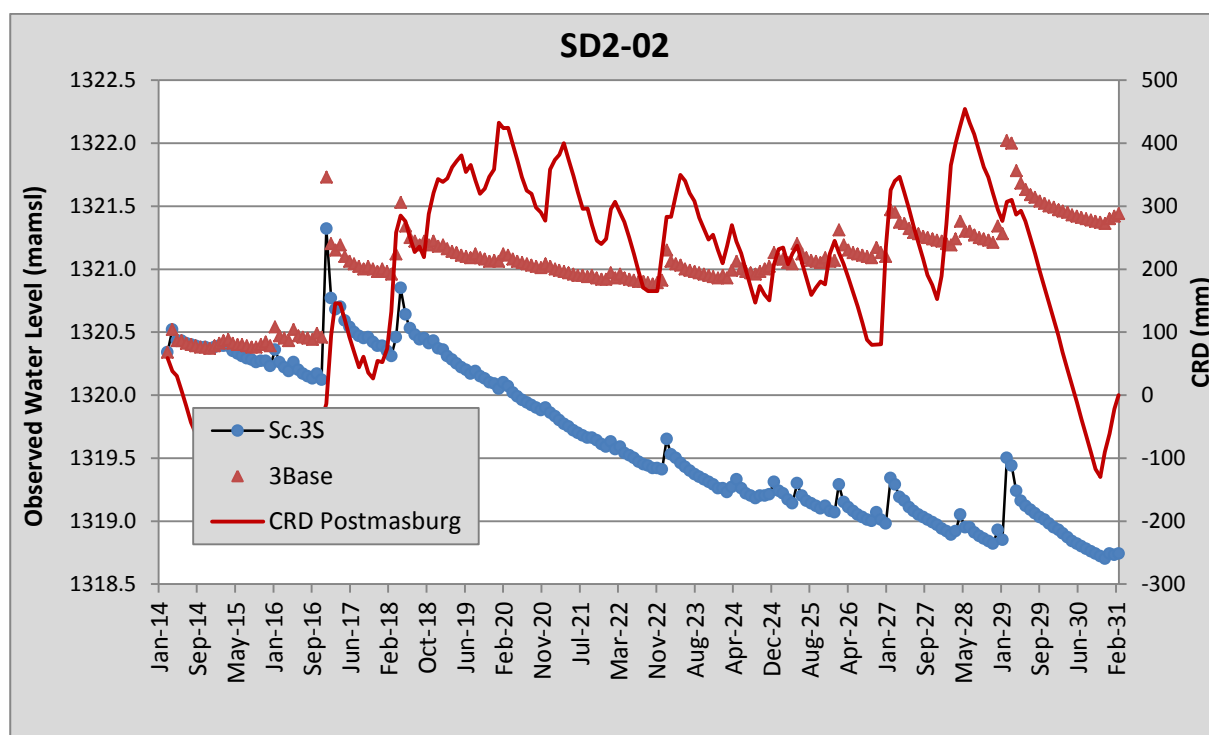


Figure 91: Simulated Drawdown Behaviour of SD2-02

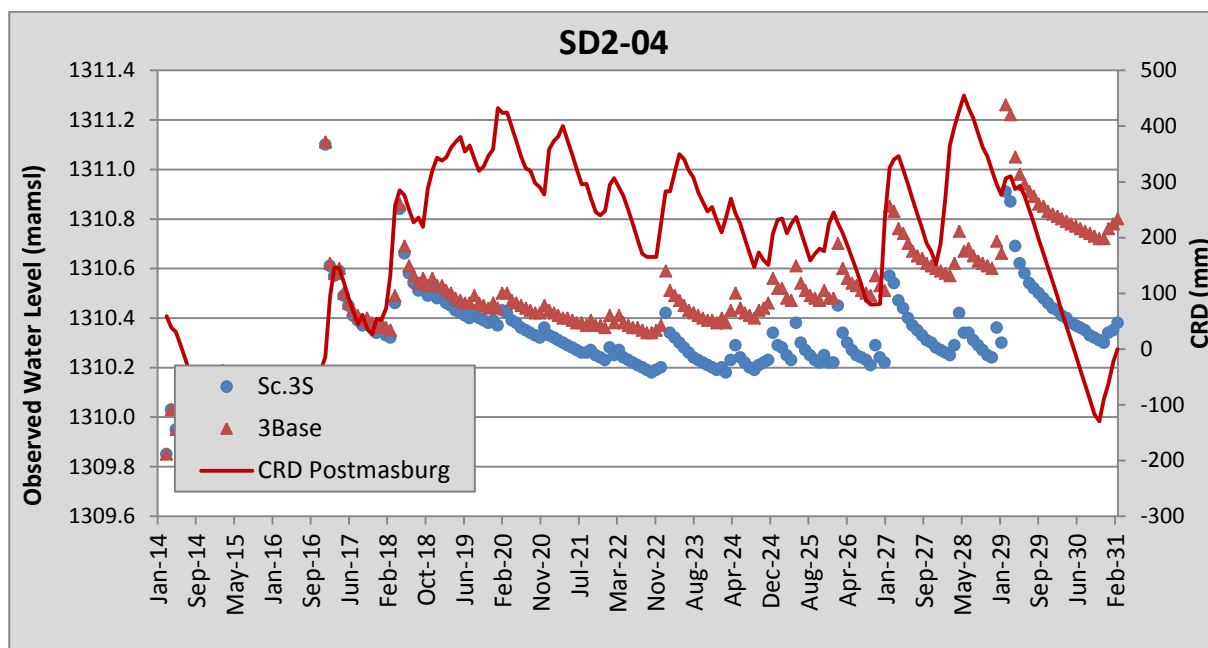


Figure 92: Simulated Drawdown Behaviour of SD2-04

6.3.8.3 Well Field Protection Zone

The approach followed for delineating zones is documented in more detail in the SD2 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 SD2 well-field scenario 3 comprising of 21 boreholes, as shown in Figure 93. The protection zones of each well were captured separately, but combined for protection zones 3 and 4 to account for their general overlap in the different well fields. The main protection areas are expectedly elongated towards the upstream catchment areas of the well fields.

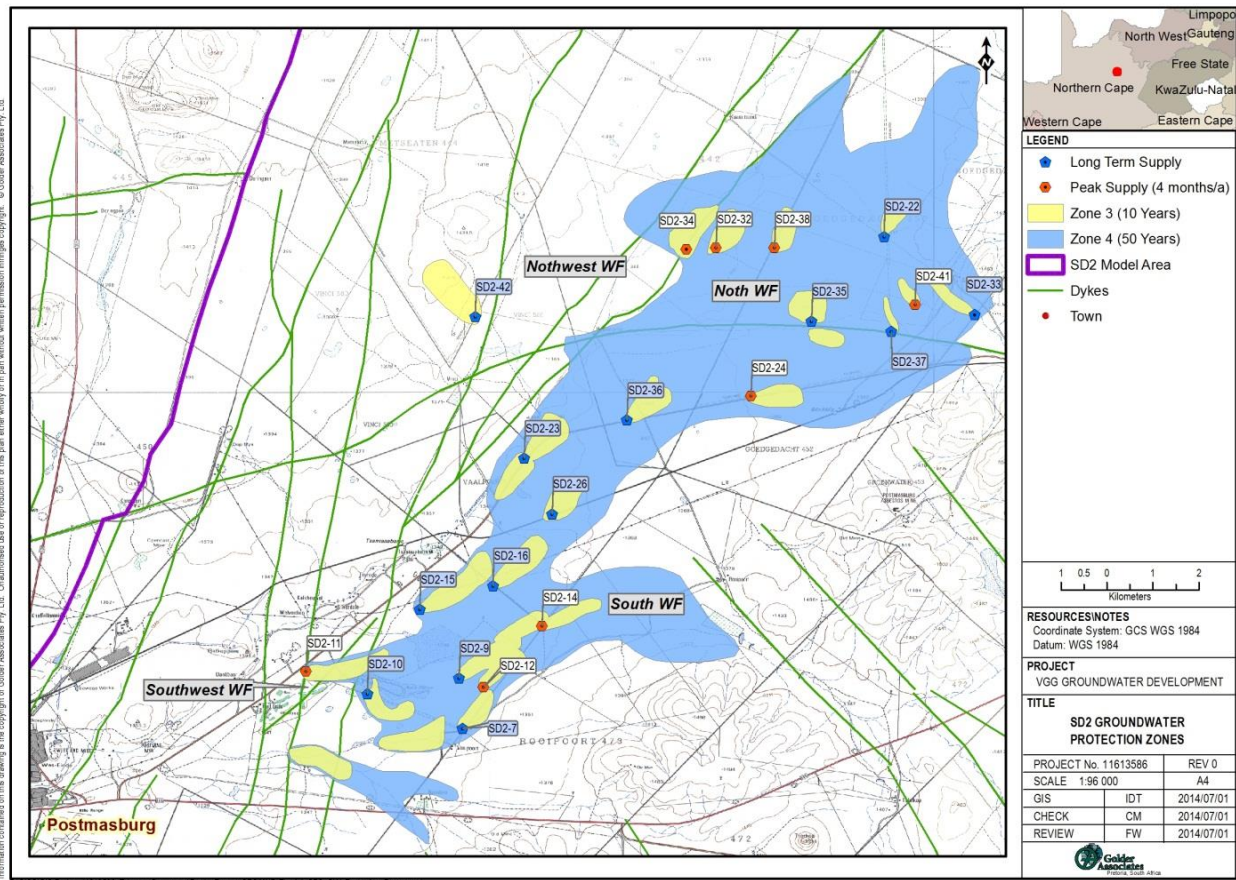


Figure 93: SD2- Groundwater Protection Zones

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 SD2 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 3 (21 production boreholes), were optimised through three groundwater model simulations (scenario 1, 2 and 3) to fall within the recommended critical drawdown level of 6 m for dolomitic aquifer, as determined during the pumping test analysis.

The existing ground water users whose boreholes (58) will be impacted by the projected 2031 dewatering cone are indicated on Figure 94. Long term predicted water level draw down (2031) simulations for these boreholes are summarised in Table 39 and the graphs are listed in Appendix C of this document.

The simulated drawdowns for the existing boreholes range between 1.3m (SD2-GAA001) to 7.2m (SD2-GAA056) with an average drawdown of 5.2m

From the available borehole information and predicted 2031 water level drawdowns existing borehole SD2-GAA28 will probably dry up. This shallow borehole with a depth of 12m (not verified) are currently not in use, and has an available drawdown of 5.65m.

The existing fountains reported in the SD2 modelling area fall outside the projected 2031 dewatering cone as indicated on Figure 94 and will not be impacted by the proposed well field.

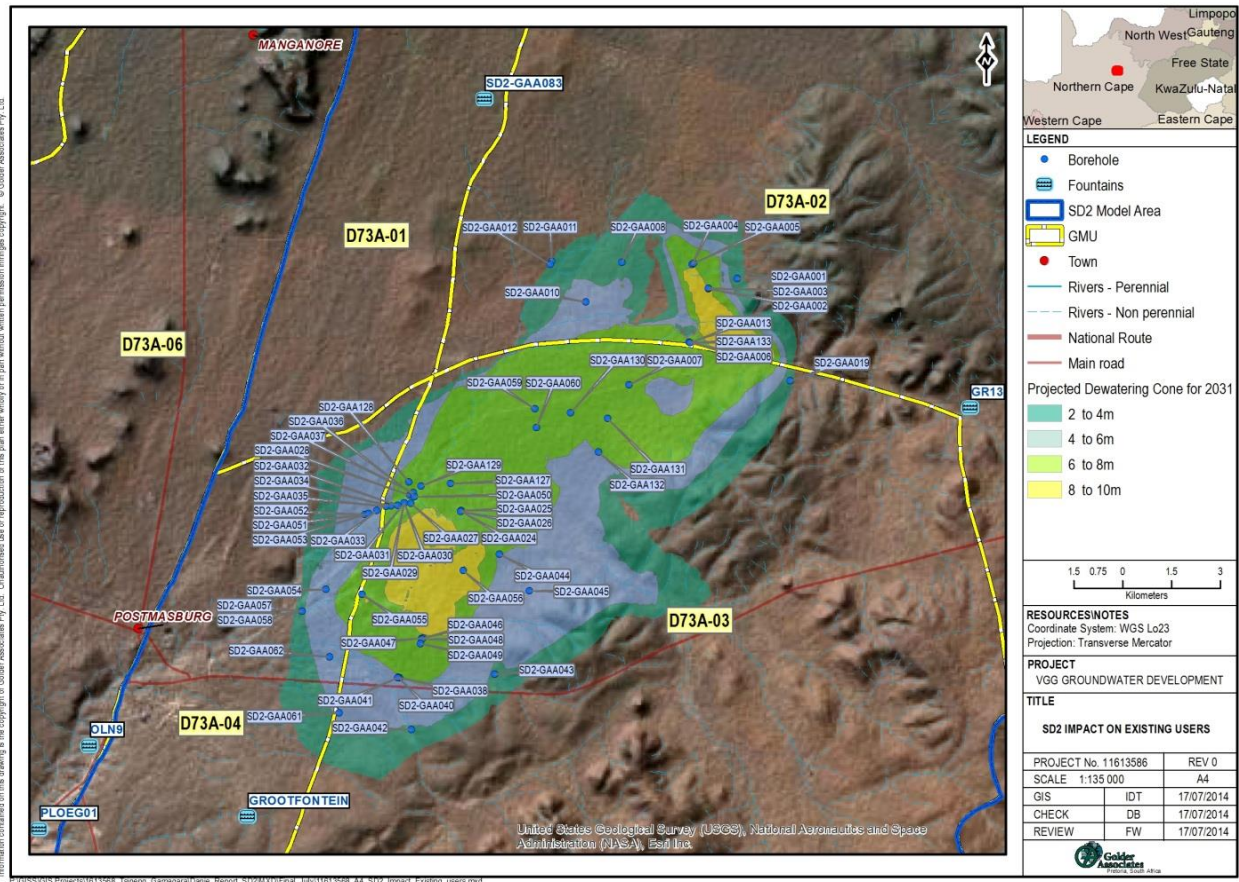


Figure 94: Simulated Impact on Existing Groundwater Users



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Table 39: 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 DD-2030 (mbgl)	Depth-WL-DD(2030) (m)
SD2-GAA001	S WILLEMSE	GOEDGEDACHT PTN. JEN-HAVEN	113	M	N	36.52	-	1.3	75.18
SD2-GAA002	S WILLEMSE	GOEDGEDACHT PTN. JEN-HAVEN	86	S	N	41.74	-	7.0	37.26
SD2-GAA003	S WILLEMSE	GOEDGEDACHT PTN. JEN-HAVEN	-	N	N	46.64	-	6.5	-
SD2-GAA004	S WILLEMSE	GOEDGEDACHT PTN. JEN-HAVEN	88.55	N	Y	45.34	-	6.5	36.71
SD2-GAA005	S WILLEMSE	GOEDGEDACHT PTN. JEN-HAVEN	80	N	N	44.5	-	6.8	28.7
SD2-GAA006	S WILLEMSE	GOEDGEDACHT PTN. JEN-HAVEN	-	W	N	48.2	-	6.9	-
SD2-GAA007	S WILLEMSE	GOEDGEDACHT PTN. JEN-HAVEN	-	W	N	53.73	-	5.6	-
SD2-GAA008	C OLIVIER	FARM 442 PTN. GELUK	60.96	W	N	-	-	2.7	58.26
SD2-GAA010	RANDELL JARVIS	FARM 442 PTN. ELLENDALE	79.24	W	Y	32	-	3.3	43.94
SD2-GAA011	RANDELL JARVIS	FARM 442 PTN. ELLENDALE	69	W	Y	14.51	-	1.9	52.59
SD2-GAA012	RANDELL JARVIS	FARM 442 PTN. ELLENDALE	-	N	N	9.42	-	1.7	-
SD2-GAA013	J.A CLOETE	GOEDGEDACHT PTN. JEN-HAVEN	88.2-	N	Y	49.05	-	6.5	32.65
SD2-GAA019	JAMES KOLOJE	GROENWATER	-	N	N	54.22	-	2.3	-
SD2-GAA024	ROUX VAN DER MERWE	VAALPOORT	-	S	N	19.89	-	6.9	-
SD2-GAA025	ROUX VAN DER MERWE	VAALPOORT	-	S	N	20.04	-	6.9	-
SD2-GAA026	ROUX VAN DER MERWE	VAALPOORT	-	W	N	-	-	6.9	-
SD2-GAA027	NOENOE FOURIE	POSTMASBURG	-	S	N	-	-	6.8	-



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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 DD-2030 (mbgl)	Depth-WL-DD(2030) (m)
SD2-GAA028	NOENOE FOURIE	POSTMASBURG	12	N	N	6.35	-	6.6	-0.95
SD2-GAA029	BERTIE MULLER	POSTMASBURG PTN. KLEIN SION	100	M	N	-	-	6.7	-
SD2-GAA030	PIET LE ROUX	POSTMASBURG PTN. DIE NAWEEK	36	S	N	8.11	-	6.7	21.19
SD2-GAA031	PIET LE ROUX	POSTMASBURG PTN. DIE NAWEEK	176	N	N	-	-	6.7	-
SD2-GAA032	BERTIE MULLER	POSTMASBURG PTN. KLEIN SION	50	S	N	8.67	-	1.6	39.73
SD2-GAA033	JOHAN GREEFF	POSTMASBURG PTN. DIE GREWE	30	S	N	7.63	-	4.4	17.97
SD2-GAA034	JOHAN GREEFF	POSTMASBURG PTN. DIE GREWE	-	S	N	4.2	-	5.4	-
SD2-GAA035	JOHAN GREEFF	POSTMASBURG PTN. DIE GREWE	-	W	N	6.11	-	4.8	-
SD2-GAA036	POSTMASBURG MUNICIPALITY	VAALPOORT (GATKOPPIES1)	50	S	N	9	-	6.7	34.3
SD2-GAA037	Municipality use - W COETZEE	VAALPOORT	-	N	N	9.69	-	6.7	-
SD2-GAA038	Auther Olivier	VINCI	-	W	N	-	-	4.6	-
SD2-GAA040	BENNIE BREDENKAMP	ROOIPOORT PTN. ROOIDAM	51.81	W	N	19.54	-	4.5	27.77
SD2-GAA041	BENNIE BREDENKAMP	ROOIPOORT PTN. ROOIDAM	36.57	W	N	16.12	-	4.5	15.95
SD2-GAA042	BENNIE BREDENKAMP	ROOIPOORT PTN. ROOIDAM	51.81	Q	N	28.43	-	2.8	20.58
SD2-GAA043	BENNIE BREDENKAMP	ROOIPOORT PTN. ROOIDAM	71.62	W	N	48.47	-	3.1	20.05
SD2-GAA044	ROUX VAN DER MERWE	ROOIPOORT PTN. VAALPOORT	-	M	N	-	-	5.4	-
SD2-GAA045	ROUX VAN DER MERWE	ROOIPOORT PTN. VAALPOORT	-	W	N	-	-	4.0	-



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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 DD-2030 (mbgl)	Depth-WL-DD(2030) (m)
SD2-GAA046	ANDREIS CORDIER	ROOIPOORT PTN. VAALPOORT	30.48	S	N	21.35	-	6.7	2.43
SD2-GAA047	MNR SAAYMAN	ROOIPOORT PTN. VAALPOORT	51.8	N	N	19.96	-	6.8	25.04
SD2-GAA048	ANDRIES CORDIER	ROOIPOORT PTN. VAALPOORT	-	W	N	24.69	-	6.7	-
SD2-GAA049	ANDRIES CORDIER	ROOIPOORT PTN. VAALPOORT	-	W	N	23.74	-	6.5	-
SD2-GAA050	Municipality Borehole	POSTMASBURG	30	N	N	-	-	6.8	-
SD2-GAA051	MARIANNA MATHEE	POSTMASBURG PTN. GATKOPPIES	-	N	N	0.32	-	4.4	-
SD2-GAA052	MARIANNA MATHEE	POSTMASBURG PTN. GATKOPPIES	-	N	N	5.32	-	4.3	-
SD2-GAA053	MARIANNA MATHEE	POSTMASBURG PTN. GATKOPPIES	-	S	N	5.96	-	4.4	-
SD2-GAA054	MUNICIPALITY BOREHOLE - NOOI DE BRUIN	POSTMASBURG	30	S	N	16.17	5.56	4.3	9.53
SD2-GAA055	MUNICIPALITY BOREHOLE - HANS VAN WYK	POSTMASBURG	-	W	N	-	-	6.6	-
SD2-GAA056	MUNICIPALITY BOREHOLE - VYTJIE NEELS	POSTMASBURG	-	W	N	21.33	-	7.2	-
SD2-GAA057	PIETER STAFFORD	POSTMASBURG PTN. REDLANDS	-	S	N	11.59	-	1.6	-
SD2-GAA058	PIETER STAFFORD	POSTMASBURG PTN. REDLANDS	-	M	N	-	-	1.7	-
SD2-GAA059	ATTIE BRITS	FARM 442 PORTION 5 KLEIN GOEDGEDACHT	-	N	N	33.36	-	6.3	-
SD2-GAA060	ATTIE BRITS	FARM 445 PORTION 5 KLEIN	83	M	N	-	-	6.3	-



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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 DD-2030 (mbgl)	Depth-WL-DD(2030) (m)
		GODEGEDACHT							
SD2-GAA061	BOOI PIETERSE	POSTMASBURG	-	W	N	-	-	3.1	-
SD2-GAA062	TOWNSON	POSTMASBURG	-	W	N	15.89	-	3.8	-
SD2-GAA127	LOEKIE VAN DER MERWE	VAALPOORT	-	S	N		-	6.8	-
SD2-GAA128	LOEKIE VAN DER MERWE	VAALPOORT	-	S	N	10.33	-	6.3	-
SD2-GAA129	LOEKIE VAN DER MERWE	VAALPOORT	-	S	N		-	6.7	-
SD2-GAA130	L VAN DER MERWE	GOEDGEDACHT	-	W	N	46.04	-	6.0	-
SD2-GAA131	L VAN DER MERWE	GOEDGEDACHT	-	S	N	41.73	-	5.6	-
SD2-GAA132	L VAN DER MERWE	GOEDGEDACHT	-	N	N	25.14	-	5.3	-
SD2-GAA133	JEN HAVEN	FARM 442 PTN. HEUNINGVLEI	116	W	N	15.89	-	6.5	93.61
Minimum								1.3	
Maximum								7.2	
Average								5.2	



7.0 SD2 WELL FIELD ABSTRACION RATES

7.1 SD2 Well fields

Subsequent to the simulated groundwater impacts (Scenario 3), the recommended abstraction rates for SD2 proposed well field are listed in Table 40 and indicated on Figure 95. From the 28 boreholes drilled and constructed as potential production boreholes, 21 (75%) are utilised as well field boreholes:

- 13 Boreholes can be implemented for long term (continuous) use at an combined monthly abstraction rate of 307 476m³/month; and
- 8 Boreholes can be implemented for peak supply (4 months/a) use at a combined abstraction rate of 150 627m³/month.

The well field borehole management recommendations are listed in Table 41 and Appendix A of Volume I of the report.

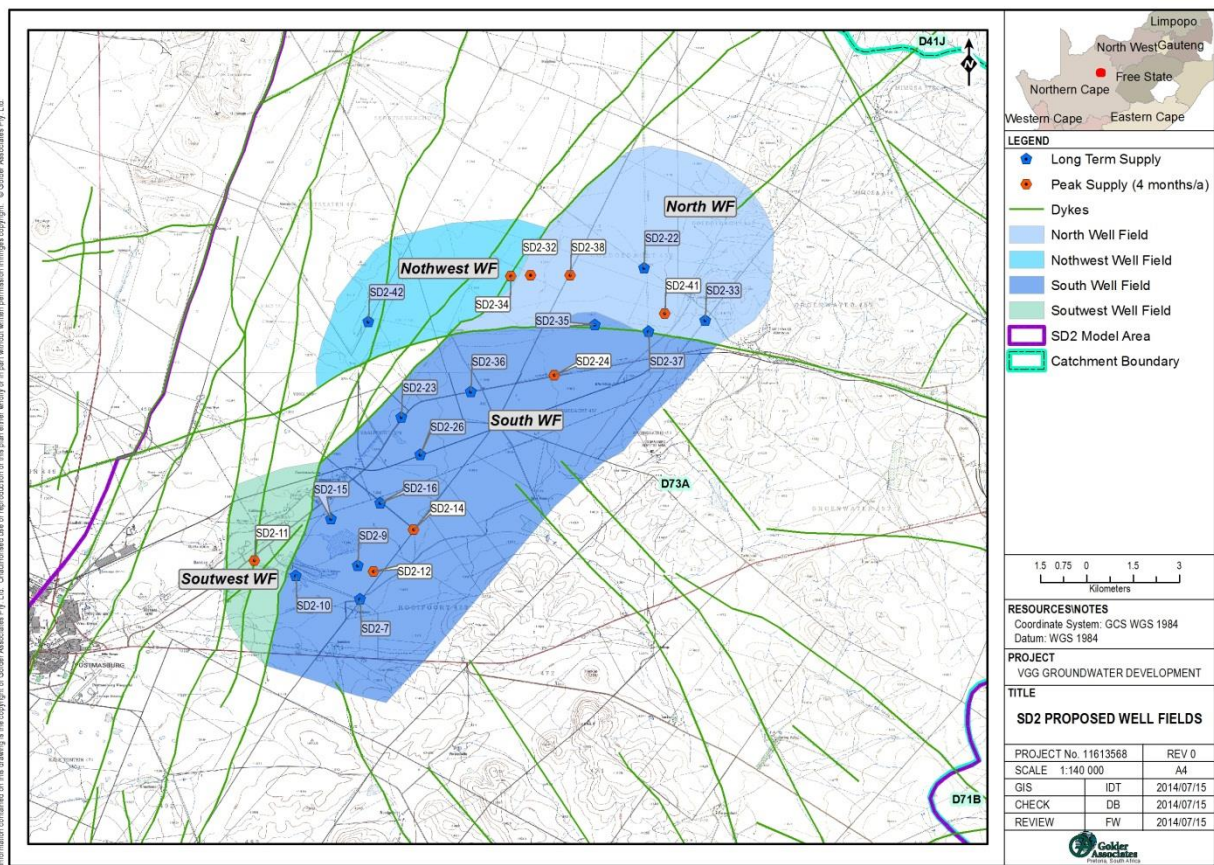


Figure 95: SD2 Proposed Well Fields



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Table 40: SD2 Recommended Well Field Abstraction Rates

Well field	Borehole No.	Latitude	Longitude	Depth (m)	Diam. (mm)	WL (mamsl)	WL (mbgl)	Discharge (l/s)	T (m ² /d)	Pumping Hours Per day	Daily Abstraction m ³ /day	Monthly Abstraction m ³ /month	Long Term m ³ /month	Peak Supply m ³ /month	Water Quality Class
South	SD2-7	-28.3161	23.1572	52.4	203	1332.75	20.63	10	500	24	1296	39420	26280	-	0
South	SD2-9	-28.3063	23.15652	66.3	165	1332.74	18.19	10	965	24	1296	39420	26280	-	0
South	SD2-10	-28.3093	23.1385	70.5	165	1332.85	12.60	10	3788	24	1296	39420	26280	-	0
South	SD2-12	-28.3081	23.1612	74.06	165	1332.49	20.23	10	4120	24	1296	39420	-	26280	0
South	SD2-14	-28.296	23.17275	100	165	1332.91	23.96	7	472	24	864	26280	-	18396	0
South	SD2-15	-28.2928	23.14875	80.44	165	1332.82	16.4	10	12360	24	1296	39420	26280	-	0
South	SD2-16	-28.2882	23.1631	97	165	1332.7	19.40	10	892	24	1296	39420	26280	-	0
South	SD2-23	-28.2632	23.16925	73	203	1332.88	21.34	10	1338	24	1296	39420	26280	-	I
South	SD2-24	-28.2511	23.21368	119	165	1333.45	47.61	10	220	12	432	13140	-	13140	0
South	SD2-26	-28.2741	23.1747	75	203	1333.1	22.73	12	1500	24	1296	39420	31536	-	0
South	SD2-35	-28.2364	23.22553	100.48	203	1333.87	50.12	10	1342	24	1296	39420	26280	-	0
South	SD2-36	-28.2557	23.1894	97.5	203	1333.08	33.92	10	1013	24	1296	39420	26280	-	0
South-West	SD2-11	-28.305	23.12651	34	203	1326.66	10.47	10	834	20	1080	32850	-	21900	I
North	SD2-22	-28.2198	23.23976	73	165	1342.96	45.20	5	203	24	432	13140	13140	-	0
North	SD2-32	-28.222	23.20683	90	203	1343.12	31.63	5	61	24	432	13140	-	13140	0
North	SD2-33	-28.2351	23.25756	101.96	165	1343.1	59.43	5	119	24	432	13140	13140	-	I
North	SD2-37	-28.2383	23.24114	83.86	165	1336.55	59.9	10	2528	24	1296	39420	26280	-	0
North	SD2-38	-28.222	23.21828	88.75	165	1343.49	38.08	7	33	24	864	26280	-	18396	0
North	SD2-41	-28.2332	23.24583	72	203	1343.28	51.54	5	-	24	432	13140	-	13140	0
North-West	SD2-34	-28.2223	23.20101	34	203	1357.23	11.68	10	872	24	1728	52560	-	26280	I



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North-West	SD2-42	-28.2355	23.15964	39	165	1370.55	5.95	5	269	24	432	13140	13140	-	I
Total											15062.4	458148	307476	150672	
		Long Term m3/Month										307476			
		Peak Supply m3/Month										150672			
		Long Term m3/annum										3 689 712			
		Peak Supply m3/annum										1 808 064			
		Long + Peak Supply m3/annum										5 497 776			



7.2 SD2 Well Field Management Recommendations

The management recommendations of SD2 well field supply boreholes are summarised in Table 41 and listed in Appendix A of Volume I of the report.

SD2-41 was not tested and need to be pump tested before management recommendations are finalized. Blow yield was measured at 13l/s and recommended yield is a conservative 40% of blow yield at 5l/s for 24hours.

Table 41: SD2 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 (hrs/day)	Pump Intake (mbgl)	Dynamic Water level (mbgl)	Critical Water level (mbgl)
South	SD2-7	52.4	20.63	500	0.05	0	10	24	48	24	36
South	SD2-9	66.3	18.19	965	0.05	0	10	24	48	19.5	30
South	SD2-10	70.5	12.60	3788	0.05	0	10	24	48	19	36
South	SD2-12	74.06	20.23	4120	0.05	0	10	24	48	23	34
South	SD2-14	100	23.96	472	0.05	0	7	24	54	29	42
South	SD2-15	80.44	16.4	12360	0.05	0	10	24	48	18	30
South	SD2-16	97	19.40	892	0.05	0	10	24	54	22.5	36
South	SD2-23	73	21.34	1338	0.05	I	10	24	54	26	40
South	SD2-24	119	47.61	220	0.05	0	10	12	72	54	60
South	SD2-26	75	22.73	1500	0.05	0	12	24	54	31	42
South	SD2-35	100.48	50.12	1342	0.05	0	10	24	72	50.5	60
South	SD2-36	97.5	33.92	1013	0.05	0	10	24	60	35	42
South-West	SD2-11	34	10.47	834	0.05	I	10	20	30	12	21
North	SD2-22	73	45.20	203	0.05	0	5	24	66	49	60
North	SD2-32	90	31.63	61	0.05	0	5	24	72	52	60
North	SD2-33	101.96	59.43	119	0.05	I	5	24	80	66.6	72
North	SD2-37	83.86	59.9	2528	0.05	0	10	24	80	60	70
North	SD2-38	88.75	38.08	33	0.05	0	7	24	72	51	65
North	SD2-41	72	51.54	-	0.05	0	5	24	70	60	66
North-West	SD2-34	34	11.68	872	0.05	I	10	24	28	13	22
North-West	SD2-42	39	5.95	269	0.05	I	5	24	30	6.36	20



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 SD2 area:

- The Vaal Gamagara Water Supply study area (SD2) 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;
- Twenty eight high yielding boreholes were drilled with a combined air-lift yield of 503 l/s. Exploration drilling in SD2 area was completed on 8 March 2014;
- Pump Borehole test pumping in the SD2 area was completed by 15 March 2014, with twenty six higher yielding exploration boreholes subjected to 24 to 72 hour CDT's. The combined pumping yield of these tests was 456l/s;
- The following major aquifer systems were confirmed in the SD2 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.
- Major karstification zones in the dolomite are the main aquifer system in SD2 area, with borehole blow yields ranging up to 40.0l/s (SD2-26);
- Water level depths of the exploration boreholes range from 5.21m to 59.86m with an average of 27.9m;
- The baseline water quality of the new exploration boreholes is based on macro chemistry analysis of 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 and Trace Metals)								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	39	39	39	39	39	39	39	39	39	39	39	39	39	33
10 % Percentile	7.24	43.2	308	42.5	22.6	12.1	2.27	20.3	13.4	1.93	166	0.1	0.05	0.05
Median Baseline water Quality	7.71	57.20	378	64.60	35.40	19.0	2.90	28.70	19.90	2.97	272.00	0.18	0.05	0.05
Average	7.70	58.29	414.54	65.14	37.09	22.02	3.34	39.89	22.06	4.05	258.82	0.21	0.06	0.16
90% Percentile	8.13	75.6	512	87.3	53.1	35	5.47	54.5	32.3	7.26	347	0.351	0.05	0.47
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 quality representative for SD2 study area are calcium magnesium bicarbonate type of water (Ca, Mg)(HCO₃)₂;
- Borehole management recommendations for the identified well fields, scenario 3 (21 production boreholes) amounts to an average annual abstraction rate of **4 292 400m³/a**;
- The 3D numerical groundwater flow model was conducted to predict the impact of the proposed SD2 well field on the regional groundwater flow, aquifer recharge and discharge. The predictive simulation for scenario 3 (21 boreholes) with a combined peak abstraction of 5 497 776m³/a reveals an extended cone of depression with a 2m to 14.7m drawdown of the aquifer in the SD2 area;
- The individual borehole pumping rates for scenario 3 (21 production boreholes), were optimised to limit water level drawdowns on the regional dolomite aquifer to within 4 to 6 m, to limit the risk of sinkhole occurrences as a result of lowering the water level depth. Simulated dynamic water level drawdowns for the production boreholes range from 2 (SD2-42, dolomite) to 14.7m (SD2-38, BIF) with an average drawdown of 7m for the SD2 well field region. The cone of dewatering is in some areas clearly limited by the presence of dykes, which compartmentalise the aquifer system;
- The assumption is made that the dolerite dykes are 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 SD2 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); 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 using the GRDM methodology. Using the GRDM (Present day scenario for 2008) as a representative value for total inflow (recharge) and net base flow, there is a groundwater balance of 22.46 million m³/a available for use in the D73A quaternary catchment.

9.0 RECOMMENDATIONS

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

- A WULA to implement the 21 production boreholes to abstract **3 689 712m³/a** on a continuous basis over the long term and an additional **1 808 064m³/a** for a four months annual peak supply (**5 497 776m³/a combined**) to augment water supply to the VGWS. This represents an average annual abstraction of **4 292 400m³/a**.
- The recommended well field abstractions for SD2 are listed in table below:

Well Field	Number of BH's	Yield l/s	Long Term m ³ /m	Long Term m ³ /a	Peak Supply m ³ /m	Peak Supply m ³ /a	Long + Peak Supply Term m ³ /a
South	12	119	241776	2901312	57816	693792	3595104
South-West	1	10	0	0	21900	262800	262800
North	6	37	52560	630720	44676	536112	1166832
North-West	2	15	13140	157680	26280	315360	473040
Total	21	181	307 476	3 689 712	150 672	1 808 064	5 497 776



- All 21 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 SD2 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 SD2 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 north and south).
 - 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 DWS 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; and
- Regional water level monitoring by DWS needs to be implemented in the modelling area and downstream below the modelling outflow boundary.

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APPENDIX A

Well Field Management Recommendations

MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823ACX0060 Number: SD2-7 Site type: Borehole

Distr./Farm No.: Site Name/Descr.: POSTMASBURG WELLFIELD

Latitude [°]:	28.316072	Alt. No. 1:		Diam. [mm]:	203	Water lev. [m]:	20.63
Longitude [°]:	23.157200	Alt. No. 2:		Depth [m]:	52.40	WL status:	Static
Altitude [m]:	1353.88	Rep. inst.: GOLD		Col. ht. [m]:	0.50	Date WL meas.:	20140121

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.:	SD2-7	Date sampled:	20130913	Depth sampl. [m]:	46.80	Comment:	
Main Parameters:		Calculated Parameters:		Bacteriol. Parameters:			
pH:	7.53	Na:	20.7	Cl:	26.9	Langel.:	0.13
EC: [mS/m]	57.4	K:	2.76	NO3 as N:	2.23	Aggr-Ind:	12.18
TDS:	416	Si:	14.3	SO4:	19.6	Ion-bal:	3.70
T. Alk.:	264	Al:	< 0.05	F:	0.199	CaCO3:	307.67
Ca:	67.1	Fe:	< 0.05			SPC:	
Mg:	34.1	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
37.00	42.00	3.00	Notch (V- or U-notch)		
50.00	52.00	23.00	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	32.00	254	Steel		Plain casing			
32.00	44.00	254	Steel		Perforated or slotted			
0.00	34.00	203	Steel		Plain casing			
34.00	52.00	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	20130911	60	46.80	6.22	0.89					
STEP TEST STEP 2	20130911	60	46.80	16.10	2.80					
STEP TEST STEP 3	20130911	60	46.80	25.26	6.12					
STEP TEST STEP 4	20130911	60	46.80	30.22	15.79	100	10			
CONSTANT	20130911	2880	46.80	30.04	8.42	100	10	500	0.05	

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	24	10.00	CLASS 0	24.00	36.00

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



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823ACX0062 Number: SD2-9 Site type: Borehole

Distr./Farm No.: Site Name/Descr.: POSTMASBURG WELLFIELD

Latitude [°]:	28.306271	Alt. No. 1:		Diam. [mm]:	165	Water lev. [m]:	18.19
Longitude [°]:	23.156516	Alt. No. 2:		Depth [m]:	66.44	WL status:	Static
Altitude [m]:	1351.26	Rep. inst.:	GOLD	Col. ht. [m]:	0.49	Date WL meas.:	20140228

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.:	SD2-9	Date sampled:	20130916	Depth sampl. [m]:	58.80	Comment:	
Main Parameters:		Calculated Parameters:		Bacteriol. Parameters:			
pH:	7.64	Na:	22.2	Cl:	29	Langel.:	0.23
EC: [mS/m]	57	K:	2.9	NO3 as N:	2.3	Aggr-Ind:	12.28
TDS:	386	Si:	14.1	SO4:	19.3	Ion-bal:	0.86
T. Alk.:	279	Al:	< 0.05	F:	0.202	CaCO3:	302.79
Ca:	63	Fe:	< 0.05			SPC:	
Mg:	35.4	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 j Value exceeds minimum allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
39.00	40.00	0.60	Notch (V- or U-notch)		
53.00	54.00	1.00	Notch (V- or U-notch)		
61.00	61.50	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	305	Steel		Plain casing			
0.00	29.00	254	Steel		Plain casing			
0.00	36.00	203	Steel		Plain casing			
36.00	54.00	203	Steel		Perforated or slotted			
0.00	34.00	165	Steel		Plain casing			
34.00	64.00	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	20130915	60	58.80	5.23	0.30				
STEP TEST STEP 2	20130915	60	58.80	10.33	0.49				
STEP TEST STEP 3	20130915	60	58.80	15.23	0.07				
STEP TEST STEP 4	20130915	60	58.80	20.64	0.98	100	10		
CONSTANT (1)	20130915	1440	58.80	20.10	0.52	100	90		
CONSTANT (2)	20140228	4320	53.15	20.08	0.28	100	3	965	0.05

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	24	10.00	CLASS 0	19.5	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: 2823ACX0063 Number: SD2-10 Site type: Borehole

Distr./Farm No.: Site Name/Descr.: POSTMASBURG WELLFIELD

Latitude [°]:	28.309325	Alt. No. 1:		Diam. [mm]:	165	Water lev. [m]:	12.60
Longitude [°]:	23.138496	Alt. No. 2:		Depth [m]:	70.50	WL status:	Static
Altitude [m]:	1345.85	Rep. inst.:	GOLD	Col. ht. [m]:	0.40	Date WL meas.:	20140121

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.:	SD2-10	Date sampled:	20131013	Depth sampl. [m]:	58.50	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.74	Na:	19.4	Cl:	28	Langel.:	0.35	E.Coli:
EC: [mS/m]	56.9	K:	2.84	NO3 as N:	1.93	Aggr-Ind:	12.40	Faec. co:
TDS:	362	Si:	14.6	SO4:	20	Ion-bal:	2.12	Total Co:
T. Alk.:	274	Al:	< 0.05	F:	0.161	CaCO3:	310.62	SPC:
Ca:	66.8	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 minimim allowable limit				
Mg:	35	Mn:	0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
39.00	39.50	0.20	Notch (V- or U-notch)		
43.00	43.50	0.30	Notch (V- or U-notch)		
58.00	58.50	6.00	Notch (V- or U-notch)		
62.00	62.50	4.00	Notch (V- or U-notch)		
67.00	70.00	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	34.00	254	Steel		Plain casing			
0.00	30.00	203	Steel		Plain casing			
30.00	60.00	203	Steel		Perforated or slotted			
0.00	34.00	165	Steel		Plain casing			
34.00	70.00	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	20131011	60	58.50	4.04	1.20						
STEP TEST STEP 2	20131011	60	58.50	10.01	6.91						
STEP TEST STEP 3	20131011	60	58.50	15.21	10.09						
STEP TEST STEP 4	20131011	60	58.50	20.31	17.59	0.10	99	3			
CONSTANT	20131012	1440	58.50	15.09	9.82		100	40	3788	0.05	

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	24	10.00	CLASS 0	19.00	36.00

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



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823ACX0064 Number: SD2-11 Site type: Borehole

Distr./Farm No.: Site Name/Descr.: POSTMASBURG WELLFIELD

Latitude [°]:	28.304981	Alt. No. 1:		Diam. [mm]:	203	Water lev. [m]:	10.47
Longitude [°]:	23.126510	Alt. No. 2:		Depth [m]:	34.00	WL status:	Static
Altitude [m]:	1337.65	Rep. inst.:	GOLD	Col. ht. [m]:	0.48	Date WL meas.:	20140121

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.:	SD2-11	Date sampled:	20130912	Depth sampl. [m]:	28.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters.		
pH:	7.78	Na:	23	Cl:	33.1	Langel.:	0.45	E.Coli:
EC: [mS/m]	65.1	K:	2.85	NO3 as N:	2.42	Aggr-Ind:	12.51	Faec. co:
TDS:	460	Si:	15.5	SO4:	24.5	Ion-bal:	2.10	Total Co:
T. Alk.:	301	Al:	< 0.05	F:	0.226	CaCO3:	345.13	SPC:
Ca:	71.4	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:	40.6	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
22.00	22.50	20.00	Notch (V- or U-notch)		
27.00	28.00	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	18.00	254	Steel		Plain casing			
0.00	15.00	203	Steel		Plain casing			
15.00	33.00	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	20130920	60	28.80	8.55	0.11					
STEP TEST STEP 2	20130920	60	28.80	16.49	0.28					
STEP TEST STEP 3	20130920	60	28.80	24.20	0.85					
STEP TEST STEP 4	20130920	60	28.80	30.40	1.33	100	60			
CONSTANT	20130921	2880	28.80	30.10	1.68	100	1440	834	0.05	

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	20	1.00	CLASS 1	12.00	21.00

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



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823ACX0065 Number: SD2-12 Site type: Borehole

Distr./Farm No.: Site Name/Descr.: POSTMASBURG WELLFIELD

Latitude [°]:	28.308063	Alt. No. 1:		Diam. [mm]:	165	Water lev. [m]:	20.23
Longitude [°]:	23.161201	Alt. No. 2:		Depth [m]:	74.06	WL status:	Static
Altitude [m]:	1353.00	Rep. inst.:	GOLD	Col. ht. [m]:	0.50	Date WL meas.:	20140222

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.:	SD2-12	Date sampled:	20130919	Depth sampl. [m]:	70.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.65	Na:	23.5	Cl:	29	Langel.:	0.23	E.Coli:
EC: [mS/m]	57.2	K:	2.88	NO3 as N:	2.74	Aggr-Ind:	12.28	Faec. co:
TDS:	378	Si:	14	SO4:	20.5	Ion-bal:	1.20	Total Co:
T. Alk.:	274	Al:	< 0.05	F:	0.215	CaCO3:	300.23	SPC:
Ca:	62.8	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:	34.9	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
31.00	31.50	0.00010	Notch (V- or U-notch)		SEEPAGE
41.00	41.50	1.30	Notch (V- or U-notch)		
72.00	72.50	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	305	Steel		Plain casing			
0.00	30.00	254	Steel		Plain casing			
0.00	26.00	203	Steel		Plain casing			
26.00	62.00	203	Steel		Perforated or slotted			
0.00	39.00	165	Steel		Plain casing			
39.00	75.00	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	20130917	60	70.80	5.50	0.30					
STEP TEST STEP 2	20130917	60	70.80	10.54	1.23					
STEP TEST STEP 3	20130917	60	70.80	15.22	2.02					
STEP TEST STEP 4	20130917	60	70.80	21.18	5.02	100	60			
CONSTANT (1)	20130918	1440	70.80	20.10	4.63	100	300			
CONSTANT (2)	20140222	4320	70.00	20.12	4.80	100	1	4120	0.05	

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	24	10.00	CLASS 0	23.00	34.00

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



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823ACX0067 Number: SD2-14 Site type: Borehole

Distr./Farm No.: Site Name/Descr.: POSTMASBURG WELLFIELD

Latitude [°]:	28.296017	Alt. No. 1:		Diam. [mm]:	165	Water lev. [m]:	23.96
Longitude [°]:	23.172748	Alt. No. 2:		Depth [m]:	100.00	WL status:	Static
Altitude [m]:	1357.17	Rep. inst.:	GOLD	Col. ht. [m]:	0.30	Date WL meas.:	20140121

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.: SD2-14		Date sampled: 20131016		Depth sampl. [m]: 88.50		Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.69	Na:	21.3	Cl:	29.8	Langel.:	0.31	E.Coli:
EC: [mS/m]	57.3	K:	2.85	NO3 as N:	2.57	Aggr-Ind:	12.36	Faec. co:
TDS:	362	Si:	14.5	SO4:	21.4	Ion-bal:	1.21	Total Co:
T. Alk.:	276	Al:	< 0.05	F:	0.189	CaCO3:	308.58	SPC:
Ca:	67.3	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 minimim allowable limit				
Mg:	34.2	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
98.00	98.50	13.50	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	3.00	305	Steel		Plain casing			
0.00	20.00	254	Steel		Plain casing			
0.00	57.00	203	Steel		Plain casing			
0.00	88.00	165	Steel		Plain casing			
88.00	100.00	165	Steel		Perforated or slotted			
57.00	70.00	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	20131013	60	88.50	4.03	0.89					
STEP TEST STEP 2	20131013	60	88.50	8.18	3.51					
STEP TEST STEP 3	20131013	60	88.50	14.25	10.39					
STEP TEST STEP 4	20131013	60	88.50	20.40	22.30	100	40			
CONSTANT (1)	20131014	600	88.50	15.02	11.05	100	60			
CONSTANT (2)	20131015	1440	88.50	15.20	12.16	100	90	472	0.05	

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	7.00	CLASS 0	29.00	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: 2823ACX0068 Number: SD2-15 Site type: Borehole

Distr./Farm No.: Site Name/Descr.: POSTMASBURG WELLFIELD

Latitude [°]:	28.292804	Alt. No. 1:		Diam. [mm]:	165	Water lev. [m]:	15.90
Longitude [°]:	23.148754	Alt. No. 2:		Depth [m]:	80.44	WL status:	Static
Altitude [m]:	1349.10	Rep. inst.:	GOLD	Col. ht. [m]:	0.50	Date WL meas.:	20140305

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.:	SD2-15	Date sampled:	20131021	Depth sampl. [m]:	76.80	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	8.02	Na:	19.4	Cl:	29.3	Langel.:	0.65	E.Coli:
EC: [mS/m]	57.5	K:	2.93	NO3 as N:	2.52	Aggr-Ind:	12.70	Faec. co:
TDS:	350	Si:	14.9	SO4:	22.2	Ion-bal:	0.61	Total Co:
T. Alk.:	282	Al:	< 0.05	F:	0.442	CaCO3:	315.01	SPC:
Ca:	67.9	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 minimim allowable limit				
Mg:	35.4	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
79.00	83.00	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	3.00	305	Steel		Plain casing			
0.00	24.00	254	Steel		Plain casing			
0.00	29.00	203	Steel		Plain casing			
29.00	47.00	203	Steel		Perforated or slotted			
0.00	64.00	165	Steel		Plain casing			
64.00	82.00	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	20131019	60	76.80	5.14	0.42					
STEP TEST STEP 2	20131019	60	76.80	10.12	1.27					
STEP TEST STEP 3	20131019	60	76.80	15.13	2.19					
STEP TEST STEP 4	20131019	60	76.80	20.00	3.23	100	5			
CONSTANT (1)	20131020	1440	76.80	20.05	3.36	100	30			
CONSTANT (2)	20140305	4320	76.80	20.08	3.58	100	720	12360	0.05	

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	24	10.00	CLASS 0	18.00	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: 2823ACX0074 Number: SD2-16 Site type: Borehole

Distr./Farm No.: Site Name/Descr.: POSTMASBURG WELLFIELD

Latitude [°]:	28.288158	Alt. No. 1:		Diam. [mm]:	165	Water lev. [m]:	19.40
Longitude [°]:	23.163097	Alt. No. 2:		Depth [m]:	97.00	WL status:	Static
Altitude [m]:	1352.45	Rep. inst.:	GOLD	Col. ht. [m]:	0.35	Date WL meas.:	20140121

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.: SD2-16		Date sampled: 20131130		Depth sampl. [m]: 88.50		Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.71	Na:	20	Cl:	26.7	Langel.:	0.28	E.Coli:
EC: [mS/m]	58	K:	2.81	NO3 as N:	2.09	Aggr-Ind:	12.33	Faec. co:
TDS:	372	Si:	14.6	SO4:	16.7	Ion-bal:	-0.41	Total Co:
T. Alk.:	284	Al:	< 0.05	F:	0.158	CaCO3:	297.01	SPC:
Ca:	59.2	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:	36.3	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
97.00	97.50	30.00	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	32.00	305	Steel		Plain casing			
0.00	48.00	254	Steel		Plain casing			
0.00	76.00	203	Steel		Plain casing			
0.00	73.00	165	Steel		Plain casing			
73.00	97.00	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	20131027	60	88.50	5.47	0.35					
STEP TEST STEP 2	20131027	60	88.50	11.40	1.05					
STEP TEST STEP 3	20131027	60	88.50	16.12	1.86					
STEP TEST STEP 4	20131027	60	88.50	20.18	3.25	100	2			
CONSTANT	20131028	4320	88.50	20.04	5.84	100	3	892	0.05	

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	10.00	CLASS 0	23.50	36.00

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



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823AAX0001 Number: SD2-22 Site type: Borehole

Distr./Farm No.: 452 Site Name/Descr.: GOEDGEDACHT WELLFIELD

Latitude [°]:	28.219793	Alt. No. 1:		Diam. [mm]:	165	Water lev. [m]:	45.20
Longitude [°]:	23.239764	Alt. No. 2:		Depth [m]:	73.00	WL status:	Static
Altitude [m]:	1388.80	Rep. inst.:	GOLD	Col. ht. [m]:	0.59	Date WL meas.:	20140121

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.:	SD2-22	Date sampled:	20131025	Depth sampl. [m]:	70.50	Comment:		
Main Parameters:			Calculated Parameters:			Bacteriol. Parameters:		
pH:	7.73	Na:	12.6	Cl:	19.9	Langel.:	0.23	E.Coli:
EC: [mS/m]	46	K:	2.93	NO3 as N:	3.54	Aggr-Ind:	12.25	Faec. co:
TDS:	286	Si:	12.5	SO4:	14.7	Ion-bal:	1.81	Total Co:
T. Alk.:	213	Al:	< 0.05	F:	< 0.1	CaCO3:	248.06	SPC:
Ca:	62	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:	22.7	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
53.00	53.50	2.00	Notch (V- or U-notch)		
68.00	73.00	5.00	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	6.00	305	Steel		Plain casing			
0.00	34.00	254	Steel		Plain casing			
0.00	33.00	203	Steel		Plain casing			
33.00	57.00	203	Steel		Perforated or slotted			
0.00	31.00	165	Steel		Plain casing			
31.00	73.00	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	20131023	60	70.50	5.13	1.06					
STEP TEST STEP 2	20131023	60	70.50	11.04	4.24					
STEP TEST STEP 3	20131023	60	70.50	15.52	7.80					
STEP TEST STEP 4	20131023	20	70.50	20.02	27.54	100	150			
PUMP INLET	20131023	4	70.50	18.85	24.69					
CONSTANT	20131024	2880	70.50	13.07	9.32	100	1200	203	0.05	

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	24	5.00	CLASS 0	49.00	60.00

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: 2823ACX0080 Number: SD2-23 Site type: Borehole

Distr./Farm No.: 579 Site Name/Descr.: VAALPOORT WELLFIELD

Latitude [°]:	28.263208	Alt. No. 1:		Diam. [mm]:	200	Water lev. [m]:	21.34
Longitude [°]:	23.169254	Alt. No. 2:		Depth [m]:	71.05	WL status:	Static
Altitude [m]:	1354.70	Rep. inst.: GOLD		Col. ht. [m]:	0.45	Date WL meas.:	20140121

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.: SD2-23		Date sampled: 20131102		Depth sampl. [m]: 58.50		Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.78	Na:	14.7	Cl:	30.1	Langel.:	0.45	E.Coli:
EC: [mS/m]	65.7	K:	2.32	NO3 as N:	3.83	Aggr-Ind:	12.52	Faec. co:
TDS:	468	Si:	16.7	SO4:	16.7	Ion-bal:	-0.73	Total Co:
T. Alk.:	324	Al:	< 0.05	F:	0.188	CaCO3:	357.29	SPC:
Ca:	67.7	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:	45.8	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
50.00	50.50	0.20	Notch (V- or U-notch)		
72.00	72.50	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	6.00	305	Steel		Plain casing			
0.00	28.00	254	Steel		Plain casing			
0.00	61.00	203	Steel		Plain casing			
61.00	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] %	T [m²/d]	Storage	Comment
STEP TEST STEP 1	20131101	60	58.50	5.50	1.37				
STEP TEST STEP 2	20131101	60	58.50	10.01	2.99				
STEP TEST STEP 3	20131101	60	58.50	15.40	6.79				
STEP TEST STEP 4	20131101	60	58.50	20.06	12.22	100	7		
CONSTANT	20131101	1440	58.50	15.01	6.70	100	3	1338	0.05

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	10.00	CLASS 1	26.00	40.00

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



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823ACX0081 Number: SD2-24 Site type: Borehole

Distr./Farm No.: 452 Site Name/Descr.: GOEDGEDACHT WELLFIELD

Latitude [°]:	28.251060	Alt. No. 1:		Diam. [mm]:	165	Water lev. [m]:	47.61
Longitude [°]:	23.213680	Alt. No. 2:		Depth [m]:	119.00	WL status:	Static
Altitude [m]:	1381.50	Rep. inst.:	GOLD	Col. ht. [m]:	0.40	Date WL meas.:	20140119

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.:	SD2-24	Date sampled:	20131116	Depth sampl. [m]:	94.50	Comment:		
Main Parameters:				Calculated Parameters:			Bacteriol. Parameters:	
pH:	7.63	Na:	12.6	Cl:	22.7	Langel.:	0.14	E.Coli:
EC: [mS/m]	50.3	K:	3.31	NO3 as N:	5.09	Aggr-Ind:	12.17	Faec. co:
TDS:	326	Si:	18.2	SO4:	11.3	Ion-bal:	1.52	Total Co:
T. Alk.:	226	Al:	0.1	F:	0.123	CaCO3:	265.57	SPC:
Ca:	61.6	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:	27.2	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
94.00	94.50	2.00	Notch (V- or U-notch)		
119.00	95.50	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	5.00	305	Steel		Plain casing			
0.00	28.00	254	Steel		Plain casing			
0.00	64.00	203	Steel		Plain casing			
0.00	89.00	165	Steel		Plain casing			
89.00	119.00	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	20131114	60	94.50	5.11	0.90				
STEP TEST STEP 2	20131114	60	94.50	10.02	3.42				
STEP TEST STEP 3	20131114	60	94.50	15.02	7.69				
STEP TEST STEP 4	20131114	60	94.50	20.24	12.10	0.16 99	240		
CONSTANT	20131114	2880	94.50	15.02	8.56	0.22 97	2880	220	0.05

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	12	10.00	CLASS 0	54.00	60.00

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



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823ACX0082 Number: SD2-26 Site type: Borehole

Distr./Farm No.: 579 Site Name/Descr.: VAALPOORT WELLFIELD

Latitude [°]:	28.274140	Alt. No. 1:		Diam. [mm]:	200	Water lev. [m]:	22.73
Longitude [°]:	23.174700	Alt. No. 2:		Depth [m]:	71.64	WL status:	Static
Altitude [m]:	1356.30	Rep. inst.: GOLD		Col. ht. [m]:	0.50	Date WL meas.:	20140121

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.:	SD2-26	Date sampled:	20131110	Depth sampl. [m]:	64.50	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters.		
pH:	7.57	Na:	15.9	Cl:	26.3	Langel.:	0.21	E.Coli:
EC: [mS/m]	58.5	K:	2.85	NO3 as N:	2.50769	Aggr-Ind:	12.25	Faec. co:
TDS:	372	Si:		SO4:	15.4	Ion-bal:	0.94	Total Co:
T. Alk.:	286	Al:	< 0.05	F:	0.128	CaCO3:	316.79	SPC:
Ca:	66.8	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:	36.5	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
50.00	50.50	1.00	Notch (V- or U-notch)		
68.00	68.50	5.00	Notch (V- or U-notch)		
72.00	72.50	15.00	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	20.00	254	Steel		Plain casing			
0.00	45.00	203	Steel		Plain casing			
45.00	75.00	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	20131107	60	64.50	5.37	1.39				
STEP TEST STEP 2	20131107	60	64.50	10.55	4.37				
STEP TEST STEP 3	20131107	60	64.50	17.40	9.50				
STEP TEST STEP 4	20131107	60	64.50	25.04	16.68	100	10		
CONSTANT	20131107	4320	64.50	20.07	13.56	100	720	1500	0.05

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	12.00	CLASS 0	31.00	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: 2823AAX0007 Number: SD2-32 Site type: Borehole

Distr./Farm No.: 442 Site Name/Descr.: FARM 442 WELLFIELD

Latitude [°]:	28.222000	Alt. No. 1:		Diam. [mm]:	200	Water lev. [m]:	31.81
Longitude [°]:	23.206830	Alt. No. 2:		Depth [m]:	90.40	WL status:	Static
Altitude [m]:	1374.80	Rep. inst.:	GOLD	Col. ht. [m]:	0.25	Date WL meas.:	20131130

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: Observation
Consumer: Non-urban
Application:

WATER CHEMISTRY:

Sample No.:	SD2-32	Date sampled:	20131202	Depth sampl. [m]:	82.50	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	8.17	Na:	11.7	Cl:	22.8	Langel.:	0.72	E.Coli:
EC: [mS/m]	46.8	K:	2.33	NO3 as N:	5.03	Aggr-Ind:	12.75	Faec. co:
TDS:	436	Si:	16.7	SO4:	13.5	Ion-bal:	3.17	Total Co:
T. Alk.:	238	Al:		F:	0.17	CaCO3:	294.03	SPC:
Ca:	64.6	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:	32.3	Mn:						

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
80.00	80.50	11.00	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	35.00	254	Steel		Plain casing			
0.00	72.00	203	Steel		Plain casing			
72.00	90.00	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	20131130	60	82.50	5.22	8.12					
STEP TEST STEP 2	20131130	60	82.50	8.13	26.10					
STEP TEST STEP 3	20131130	15	82.50	12.26	50.68	100	80			
PUMP INLET	20131130	3	82.50	10.74	50.69					
CONSTANT	20131201	1440	82.50	8.08	32.79	100	180	61	0.05	

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	24	5.00	CLASS 0	52.00	60.00

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



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823ABX0002 Number: SD2-33 Site type: Borehole

Distr./Farm No.: 452 Site Name/Descr.: GOEDVERDACHT WELLFIELD

Latitude [°]:	28.235060	Alt. No. 1:		Diam. [mm]:	165	Water lev. [m]:	59.43
Longitude [°]:	23.257560	Alt. No. 2:		Depth [m]:	101.96	WL status:	Static
Altitude [m]:	1402.96	Rep. inst.:	GOLD	Col. ht. [m]:	0.43	Date WL meas.:	20140119

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: Observation
Consumer: Non-urban
Application:

WATER CHEMISTRY:

Sample No.: SD2-33		Date sampled: 20131204		Depth sampl. [m]: 0		Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	8.2	Na:	64.5	Cl:	42.2	Langel.:	0.43	E.Coli:
EC: [mS/m]	52.8	K:	5.6	NO3 as N:	2.45	Aggr-Ind:	12.47	Faec. co:
TDS:	394	Si:	11	SO4:	38.4	Ion-bal:	1.91	Total Co:
T. Alk.:	220	Al:		F:	0.261	CaCO3:	194.31	SPC:
Ca:	33.7	Fe:	0.13 †	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:	26.8	Mn:						

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
84.00	84.50	1.00	Notch (V- or U-notch)		
90.00	90.50	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	22.00	305	Steel		Plain casing			
22.00	36.00	254	Steel		Plain casing			
0.00	42.00	216	Steel		Plain casing			
42.00	90.00	216	Steel		Perforated or slotted			
0.00	44.00	165	Steel		Plain casing			
44.00	102.00	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	20140114	60	94.50	5.06	3.51					
STEP TEST STEP 2	20140114	60	94.50	10.06	11.00					
STEP TEST STEP 3	20140114	60	94.50	15.06	19.24					
STEP TEST STEP 4	20140114	50	94.50	19.01	34.31	0.15	100	240		
PUMP INLET	20140114	5	94.50	13.12	35.04					
CONSTANT	20140114	2880	94.50	9.00	12.89	100	840	119	0.05	

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	80.00	Electric motor	24	5.00	CLASS 1	66.60	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: 2823AAX0008 Number: SD2-34 Site type: Borehole

Distr./Farm No.: 442 Site Name/Descr.: FARM 442 WELLFIELD

Latitude [°]:	28.222290	Alt. No. 1:		Diam. [mm]:	216	Water lev. [m]:	11.68
Longitude [°]:	23.201010	Alt. No. 2:		Depth [m]:	34.46	WL status:	Static
Altitude [m]:	1369.54	Rep. inst.:	GOLD	Col. ht. [m]:	0.50	Date WL meas.:	20140228

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: Observation
Consumer: Non-urban
Application:

WATER CHEMISTRY:

Sample No.:	SD2-34	Date sampled:	20131204	Depth sampl. [m]:	28.50	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters.		
pH:	7.94	Na:	9.42	Cl:	20.3	Langel.:	0.66	E.Coli:
EC: [mS/m]	52.1	K:	1.83	NO3 as N:	4.89	Aggr-Ind:	12.71	Faec. co:
TDS:	512 †	Si:	18.3	SO4:	14	Ion-bal:	10.29 ‡	Total Co:
T. Alk.:	272	Al:		F:	0.225	CaCO3:	386.86	SPC:
Ca:	87.3	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:	41.1	Mn:						

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
23.00	23.50	20.00	Notch (V- or U-notch)		
29.00	29.50	7.00	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	254	Steel		Plain casing			
0.00	20.00	216	Steel		Plain casing			
20.00	32.00	216	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	20131202	60	28.50	5.53	0.12				
STEP TEST STEP 2	20131202	60	28.50	10.04	0.28				
STEP TEST STEP 3	20131202	60	28.50	20.02	0.92				
STEP TEST STEP 4	20131202	60	28.50	30.10	1.99	100	110		
CONSTANT (1)	20131203	1440	28.50	20.06	1.40	0.04	97	1440	
CONSTANT (2)	20140228	4320	28.84	30.04	2.77	100	1560	872	0.05

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	28.00	Electric motor	24	10.00	CLASS 1	13.00	22.00

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



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823AAX0009 Number: SD2-35 Site type: Borehole

Distr./Farm No.: 452 Site Name/Descr.: GOEDVERDACHT WELLFIELD

Latitude [°]:	28.236380	Alt. No. 1:		Diam. [mm]:	216	Water lev. [m]:	50.12
Longitude [°]:	23.225530	Alt. No. 2:		Depth [m]:	98.85	WL status:	Static
Altitude [m]:	1384.40	Rep. inst.:	GOLD	Col. ht. [m]:	0.45	Date WL meas.:	20140223

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: Observation
Consumer: Non-urban
Application:

WATER CHEMISTRY:

Sample No.:	SD2-35	Date sampled:	20131204	Depth sampl. [m]:	82.50	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	8.23	Na:	14.1	Cl:	22.9	Langel.:	0.75	E.Coli:
EC: [mS/m]	41	K:	2.94	NO3 as N:	4.33	Aggr-Ind:	12.79	Faec. co:
TDS:	324	Si:	14.8	SO4:	14.5	Ion-bal:	1.99	Total Co:
T. Alk.:	246	Al:		F:	0.125	CaCO3:	287.28	SPC:
Ca:	58.6	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:	34.3	Mn:						

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
68.00	68.50	0.80	Notch (V- or U-notch)		
73.00	73.50	21.20	Notch (V- or U-notch)		
86.00	86.50	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	22.00	305	Steel		Plain casing			
0.00	40.00	254	Steel		Plain casing			
40.00	46.00	254	Steel		Perforated or slotted			
0.00	58.00	216	Steel		Plain casing			
58.00	82.00	216	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	20131209	60	82.50	6.02	0.07					
STEP TEST STEP 2	20131209	60	82.50	10.06	0.12					
STEP TEST STEP 3	20131209	30	82.50	15.00	0.16	100	2			
STEP TEST STEP 1	20131209	60	82.50	15.06	0.21					
STEP TEST STEP 2	20131209	60	82.50	20.06	0.26					
STEP TEST STEP 3	20131209	60	82.50	30.05	0.30	100	2			
CONSTANT (1)	20131210	1440	82.50	25.03	0.28	100	15			
CONSTANT (2)	20140223	4320	70.84	30.05	0.43	100	1200	1342	0.05	

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	24	10.00	CLASS 0	50.50	60.00

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



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823ACX0089 Number: SD2-36 Site type: Borehole

Distr./Farm No.: 442 Site Name/Descr.: FARM 442 WELLFIELD

Latitude [°]:	28.255740	Alt. No. 1:		Diam. [mm]:	165	Water lev. [m]:	33.92
Longitude [°]:	23.189400	Alt. No. 2:		Depth [m]:	97.50	WL status:	Static
Altitude [m]:	1367.00	Rep. inst.:	GOLD	Col. ht. [m]:	0.59	Date WL meas.:	20140115

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: Observation
Consumer: Non-urban
Application:

WATER CHEMISTRY:

Sample No.: SD2-36		Date sampled: 20131202		Depth sampl. [m]: 88.50		Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	8.16	Na:	12.8	Cl:	25.4	Langel.:	0.78	E.Coli:
EC: [mS/m]	47.3	K:	2.57	NO3 as N:	5.04	Aggr-Ind:	12.83	Faec. co:
TDS:	412	Si:	17.9	SO4:	15.6	Ion-bal:	9.03 †	Total Co:
T. Alk.:	259	Al:		F:	0.176	CaCO3:	363.81	SPC:
Ca:	71.8	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:	44.9	Mn:						

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
83.00	83.50	8.00	Notch (V- or U-notch)		
95.00	95.50	12.00	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	35.00	254	Steel		Plain casing			
0.00	66.00	216	Steel		Plain casing			
0.00	78.00	165	Steel		Plain casing			
78.00	97.00	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	20131205	60	88.50	5.24	0.26				
STEP TEST STEP 2	20131205	60	88.50	10.68	0.92				
STEP TEST STEP 3	20131205	60	88.50	15.08	1.68				
STEP STEP STEP 4	20131205	60	88.50	20.09	2.29	100	80		
CONSTANT	20131206	1440	88.50	15.02	1.54	100	480		

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	24	10.00	CLASS 0	35.00	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: 2823AAX0032 Number: SD2-37 Site type: Borehole

Distr./Farm No.: 452 Site Name/Descr.: GOEDGEDACHT WELLFIELD

Latitude [°]:	28.238330	Alt. No. 1:		Diam. [mm]:	165	Water lev. [m]:	59.90
Longitude [°]:	23.241140	Alt. No. 2:		Depth [m]:	83.86	WL status:	Static
Altitude [m]:	1394.02	Rep. inst.:	GOLD	Col. ht. [m]:	0.50	Date WL meas.:	20140220

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.:	SD2-37	Date sampled:	20140223	Depth sampl. [m]:	76.50	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.64	Na:	28.3	Cl:	37.8	Langel.:	0.12	E.Coli:
EC: [mS/m]	52.7	K:	3.25	NO3 as N:	2.86	Aggr-Ind:	12.15	Faec. co:
TDS:	364	Si:		SO4:	25.6	Ion-bal:	2.14	Total Co:
T. Alk.:	219	Al:	< 0.05	F:	< 0.1	CaCO3:	257.27	SPC:
Ca:	59.1	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:	26.7	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
71.00	71.50	1.00	Notch (V- or U-notch)		
83.00	83.50	3.00	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	25.00	254	Steel		Plain casing			
0.00	63.00	203	Steel		Plain casing			
63.00	81.00	203	Steel		Perforated or slotted			
0.00	67.00	165	Steel		Plain casing			
67.00	85.00	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	20140220	60	76.50	5.03	0.12					
STEP TEST STEP 2	20140220	60	76.50	10.04	0.29					
STEP TEST STEP 3	20140220	60	76.50	15.10	0.51					
STEP TEST STEP 4	20140220	60	76.50	20.46	0.76	100	10			
CONSTANT	20140221	2880	76.50	20.17	0.77	100	10	2528	0.05	

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	80.00	Electric motor	24	10.00	CLASS 0	60.00	70.00

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



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: Site Identifier: 2823AAX0034 Number: SD2-38 Site type: Borehole

Distr./Farm No.: 452 Site Name/Descr.: GOEDGEDACHT WELLFIELD

Latitude [°]:	28.221980	Alt. No. 1:		Diam. [mm]:	165	Water lev. [m]:	38.08
Longitude [°]:	23.218280	Alt. No. 2:		Depth [m]:	88.75	WL status:	Static
Altitude [m]:	1381.44	Rep. inst.:	GOLD	Col. ht. [m]:	0.42	Date WL meas.:	20140305

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:

WATER CHEMISTRY:

Sample No.:	SD2-38	Date sampled:	20140308	Depth sampl. [m]:	81.04	Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters.		
pH:	7.9	Na:	12.6	Cl:	22.3	Langel.:	0.53	E.Coli:
EC: [mS/m]	79 †	K:	3.12	NO3 as N:	3.75	Aggr-Ind:	12.57	Faec. co:
TDS:	400	Si:		SO4:	13.4	Ion-bal:	-0.60	Total Co:
T. Alk.:	289	Al:	< 0.05	F:	< 0.1	CaCO3:	312.54	SPC:
Ca:	64.6	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:	36.8	Mn:	< 0.05					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
88.00	88.50	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	3.00	381	Steel		Plain casing			
0.00	20.00	305	Steel		Plain casing			
0.00	47.00	254	Steel		Plain casing			
0.00	60.00	203	Steel		Plain casing			
60.00	78.00	203	Steel		Perforated or slotted			
0.00	71.00	165	Steel		Plain casing			
71.00	89.00	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	20140305	60	81.04	6.00	0.33					
STEP TEST STEP 2	20140305	60	81.04	10.55	3.71					
STEP TEST STEP 3	20140305	60	81.04	15.54	11.10					
STEP TEST STEP 4	20140305	50	81.04	20.33	42.54	100	10			
PUMP INLET	20140305	10	81.04	18.77	42.54					
CONSTANT	20140306	3360	81.04	15.01	27.43	100	20	33	0.05	

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	24	7.00	CLASS 0	51.00	65.00

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



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MANAGEMENT RECOMMENDATIONS

BASIC SITE INFORMATION: *Site Identifier:* 2823AAX0037 *Number:* SD2-41 *Site type:* Borehole

Distr./Farm No.: 452 *Site Name/Descr.:* GOEDGEDACHT WELLFIELD

<i>Latitude [°]:</i> 28.233160	<i>Alt. No. 1:</i>	<i>Diam. [mm]:</i> 203	<i>Water lev. [m]:</i> 50.54
<i>Longitude [°]:</i> 23.245830	<i>Alt. No. 2:</i>	<i>Depth [m]:</i> 72.00	<i>WL status:</i> Static
<i>Altitude [m]:</i> 1394.32	<i>Rep. inst.:</i> GOLD	<i>Col. ht. [m]:</i> 0.50	<i>Date WL meas.:</i> 20140227

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.: SD2-41		Date sampled: 20140228		Depth sampl. [m]: 0		Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters:		
pH:	7.94	Na:	27.6	Cl:	32.3	Langel.:	0.31	E.Coli:
EC: [mS/m]	46.1	K:	4.42	NO3 as N:	3.86	Aggr-Ind:	12.32	Faec. co:
TDS:	330	Si:		SO4:	23.2	Ion-bal:	2.32	Total Co:
T. Alk.:	189	Al:	< 0.05	F:	0.163	CaCO3:	220.20	SPC:
Ca:	51	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:	22.6	Mn:	< 0.05					

AQUIFER INFORMATION:

<i>Depth to Top [m]</i>	<i>Depth to Bot. [m]</i>	<i>Yield[l/s]</i>	<i>Method meas.</i>	<i>Aquifer type</i>	<i>Comment</i>
63.00	63.50	2.00	Notch (V- or U-notch)		
67.00	67.50	11.00	Notch (V- or U-notch)		

CASING DETAILS:

<i>Depth to Top [m]</i>	<i>to Bot. [m]</i>	<i>Diam. [mm]</i>	<i>Material</i>	<i>Thickn. [mm]</i>	<i>Type of openings</i>	<i>Openings [mm]:</i>	<i>Hor. Dist.</i>	<i>Vert. Dist.</i>
						<i>Length Width</i>		
0.00	4.00	381	Steel		Plain casing			
0.00	28.00	305	Steel		Plain casing			
0.00	54.00	254	Steel		Plain casing			
0.00	54.00	203	Steel		Plain casing			
54.00	72.00	203	Steel		Perforated or slotted			

RECOMMENDATIONS:

<i>Prior.</i>	<i>Rec. equipm.</i>	<i>Depth to intk. [m]</i>	<i>Type of power</i>	<i>Duty cyc. [hrs]</i>	<i>Disch. rate [l/s]</i>	<i>Water quality</i>	<i>Dyn. water level [m]</i>	<i>Crit. water level [m]</i>
1	Mono-type pump	70.00	Electric motor	24	5.00	CLASS 0	60.00	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: 2823AAX0038 Number: SD2-42 Site type: Borehole

Distr./Farm No.: 444 Site Name/Descr.: METSEATEN WELLFIELD

Latitude [°]:	28.235490	Alt. No. 1:		Diam. [mm]:	165	Water lev. [m]:	5.95
Longitude [°]:	23.159640	Alt. No. 2:		Depth [m]:	39.00	WL status:	Static
Altitude [m]:	1375.80	Rep. inst.: GOLD		Col. ht. [m]:	0.50	Date WL meas.:	20140312

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.: SD2-42		Date sampled: 20140313		Depth sampl. [m]: 33.34		Comment:		
Main Parameters:				Calculated Parameters:		Bacteriol. Parameters.		
pH:	7.2	Na:	11.3	Cl:	26	Langel.:	0.11	E.Coli:
EC: [mS/m]	79.2 †	K:	2.27	NO3 as N:	7.26	Aggr-Ind:	12.19	Faec. co:
TDS:	572 †	Si:		SO4:	21.5	Ion-bal:	-0.86	Total Co:
T. Alk.:	409	Al:	< 0.05	F:	0.251	CaCO3:	458.67	SPC:
Ca:	96.3	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:	53.1	Mn:	0.13 †					

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
13.00	13.50	0.00	Notch (V- or U-notch)		
20.00	20.50	0.00	Notch (V- or U-notch)		
26.00	26.50	0.00	Notch (V- or U-notch)		
28.00	28.50	0.00	Notch (V- or U-notch)		
29.00	29.50	0.00	Notch (V- or U-notch)		
37.00	37.50	10.00	Notch (V- or U-notch)		
39.00	39.50	12.00	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	9.00	165	Steel		Plain casing			
9.00	39.00	165	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	20140312	60	33.34	6.03	0.51					
STEP TEST STEP 2	20140312	60	33.34	10.02	1.09					
STEP TEST STEP 3	20140312	60	33.34	15.52	2.23					
STEP TEST STEP 4	20140312	60	33.34	20.58	3.35	100	60			
CONSTANT	20140313	4320	33.34	20.04	4.62	100	360	269	0.05	

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	24.00	Electric motor	24	5.00	CLASS 1	6.36	20.00

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



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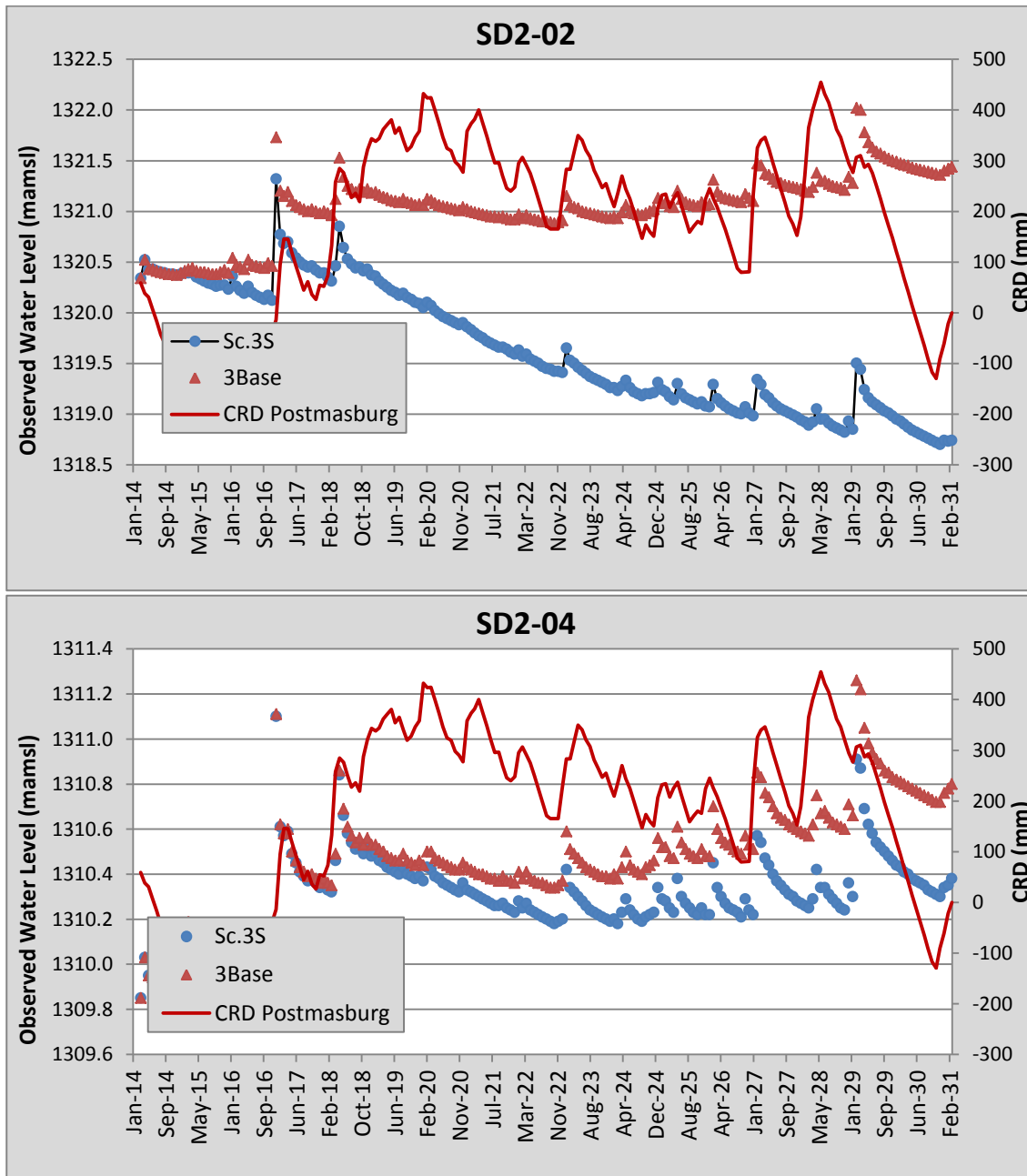
APPENDIX B

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



APPENDIX B

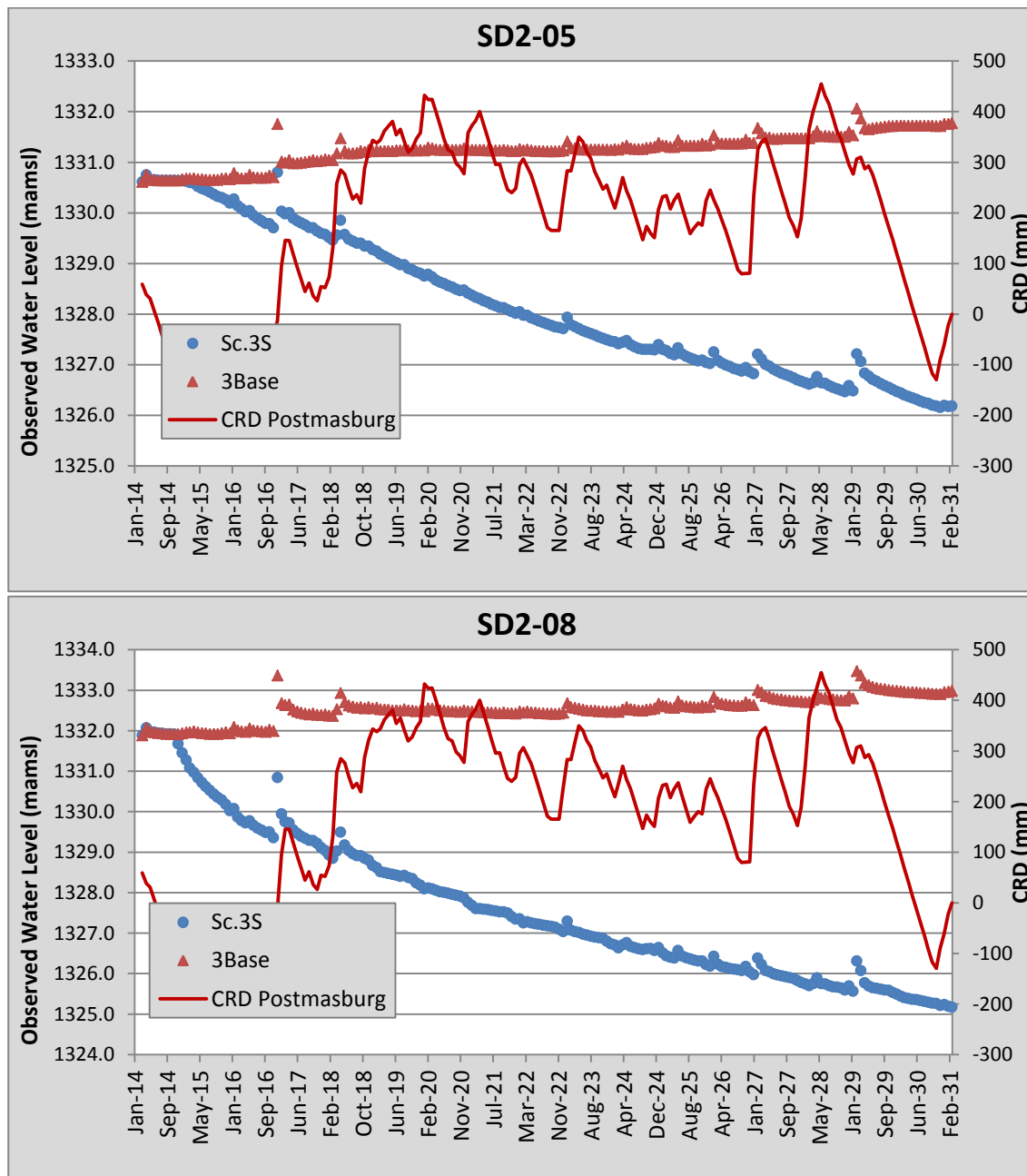
VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I





APPENDIX B

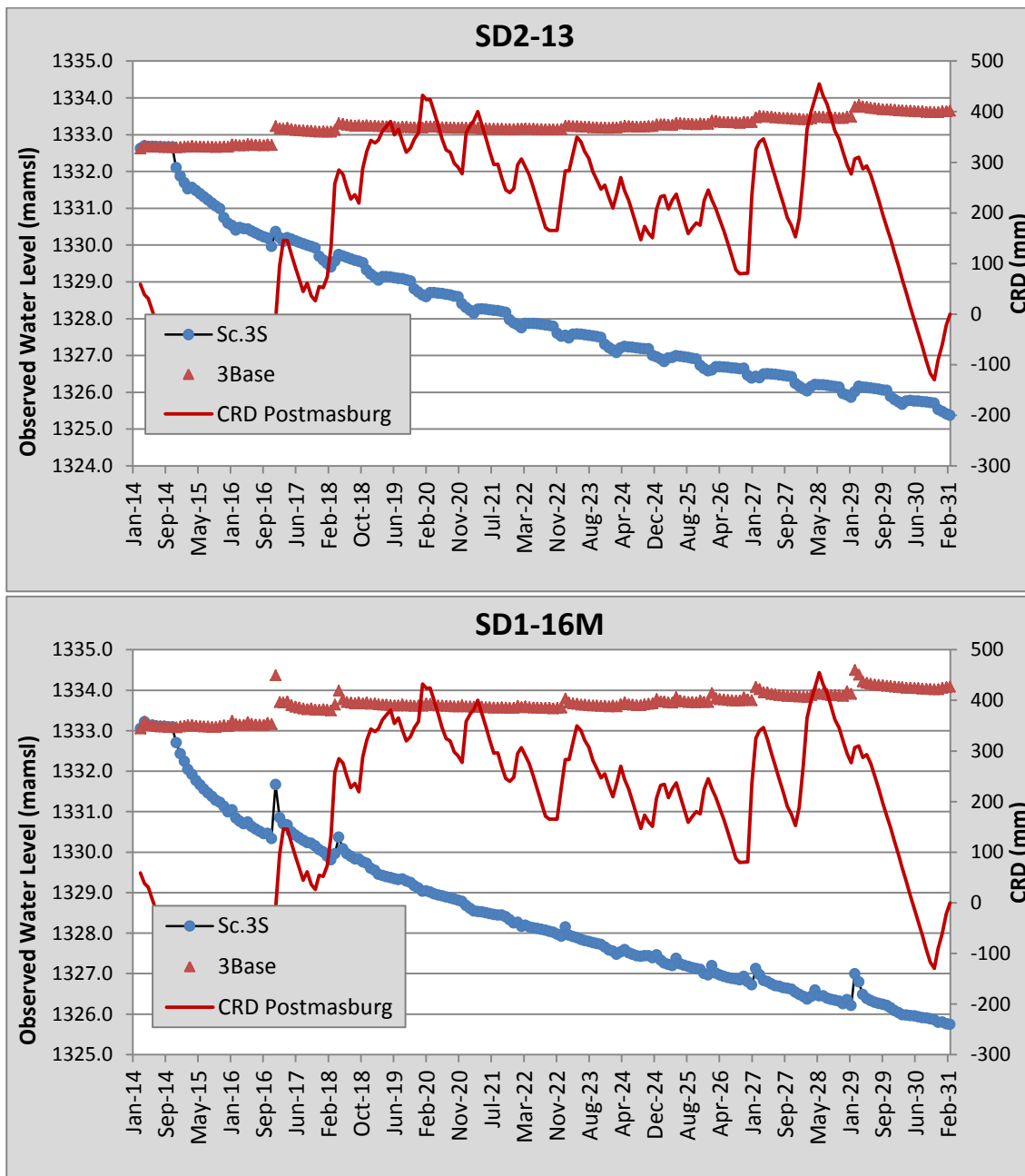
VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I





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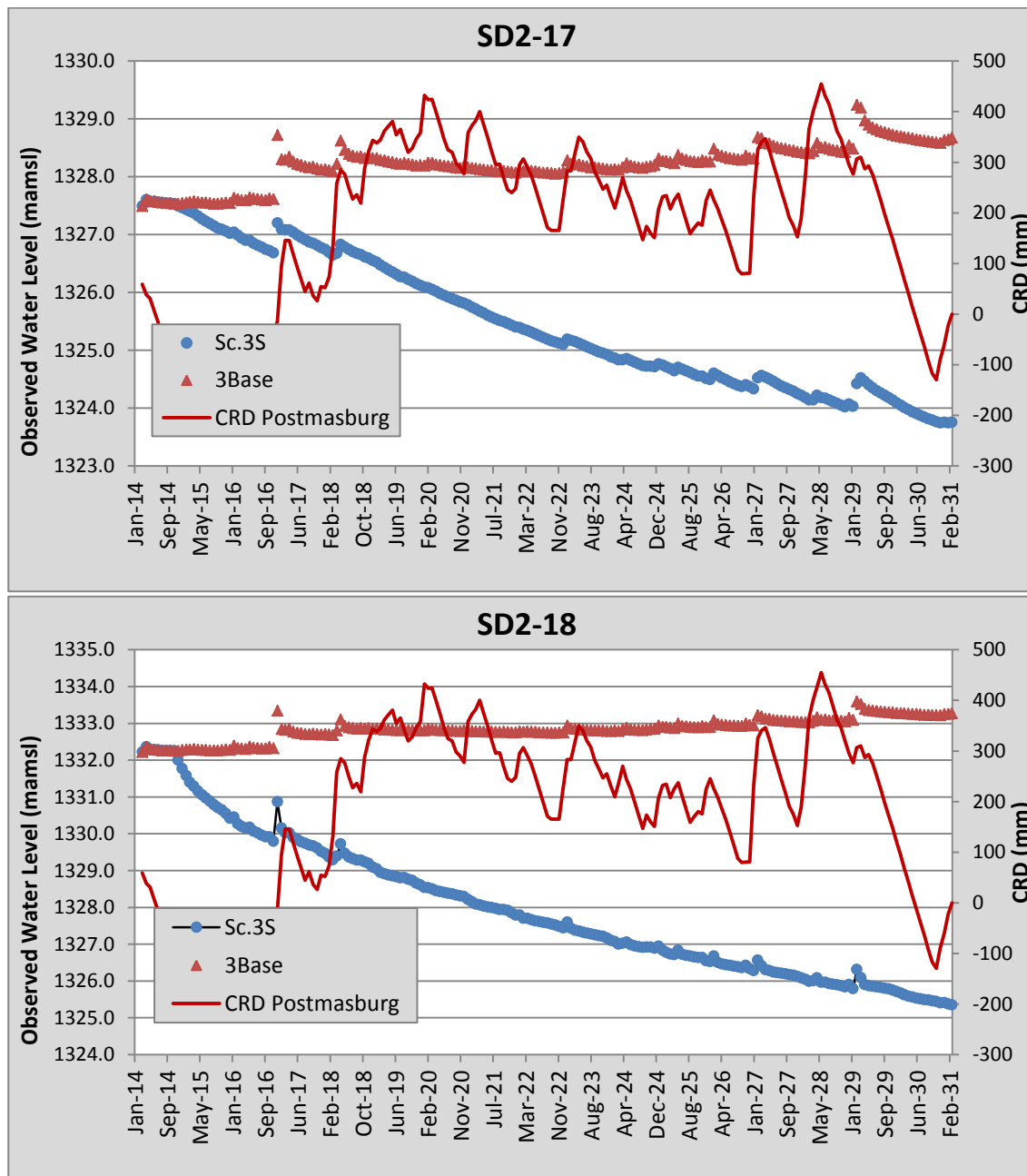
VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I





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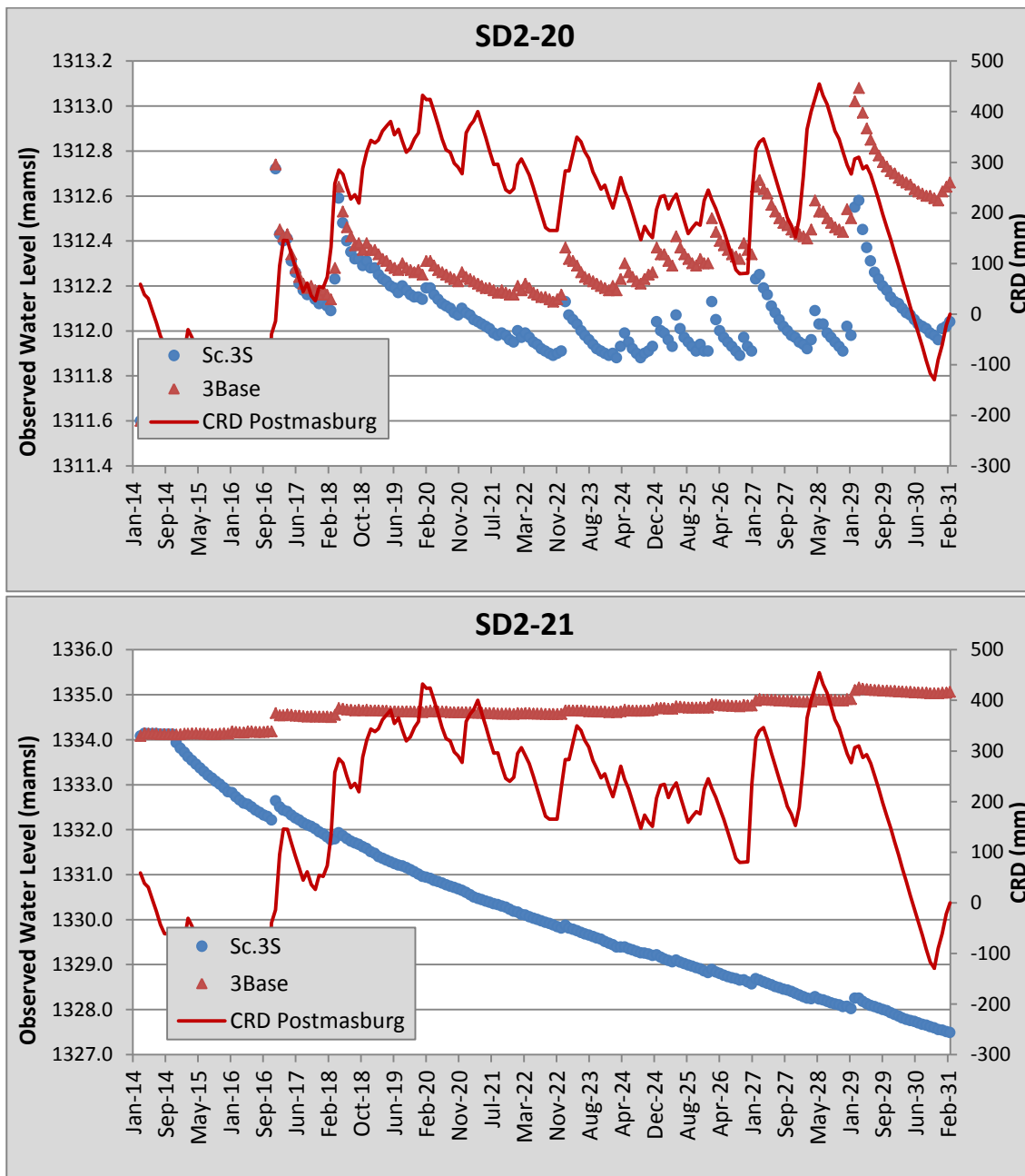
VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I





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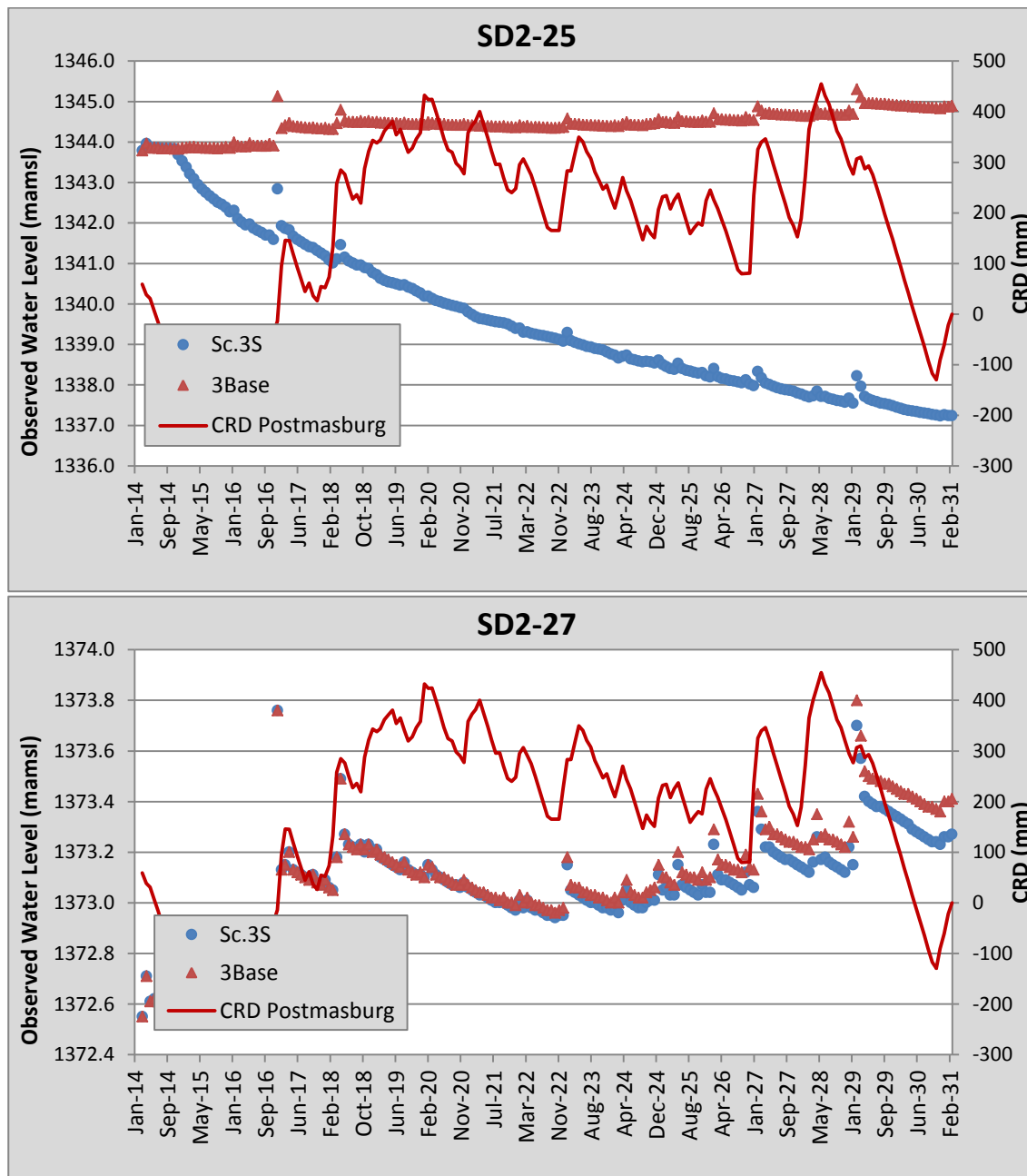
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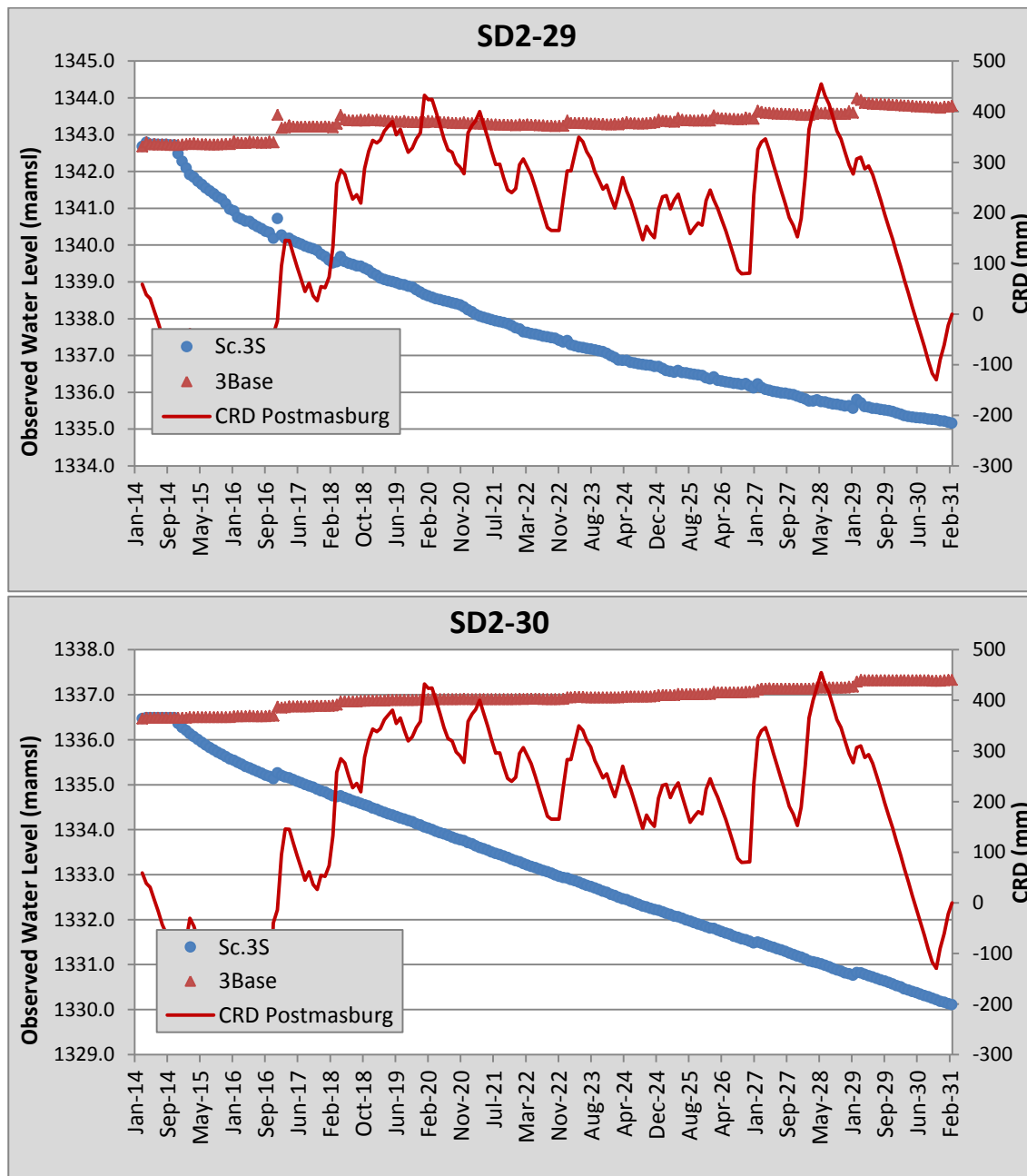
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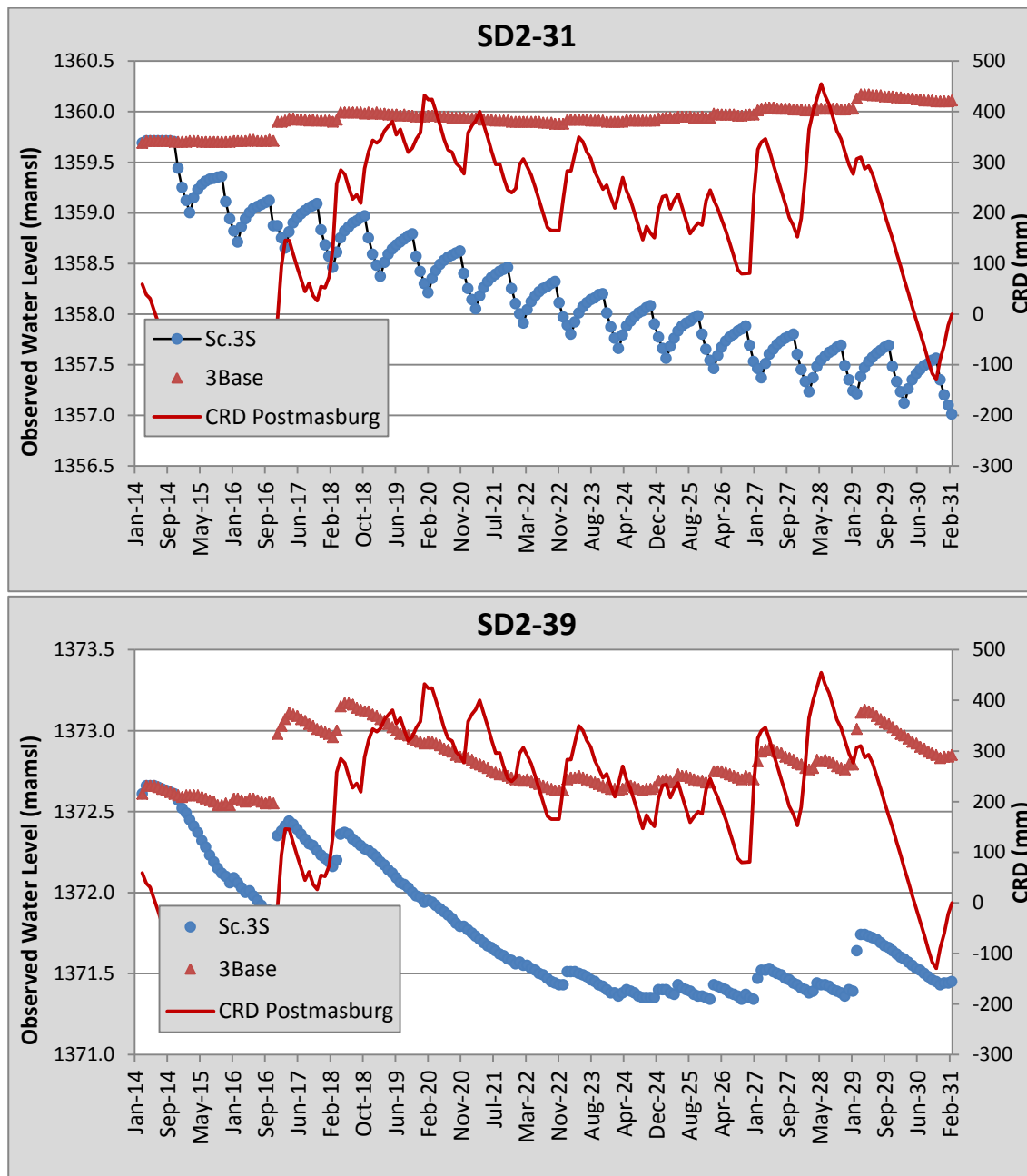
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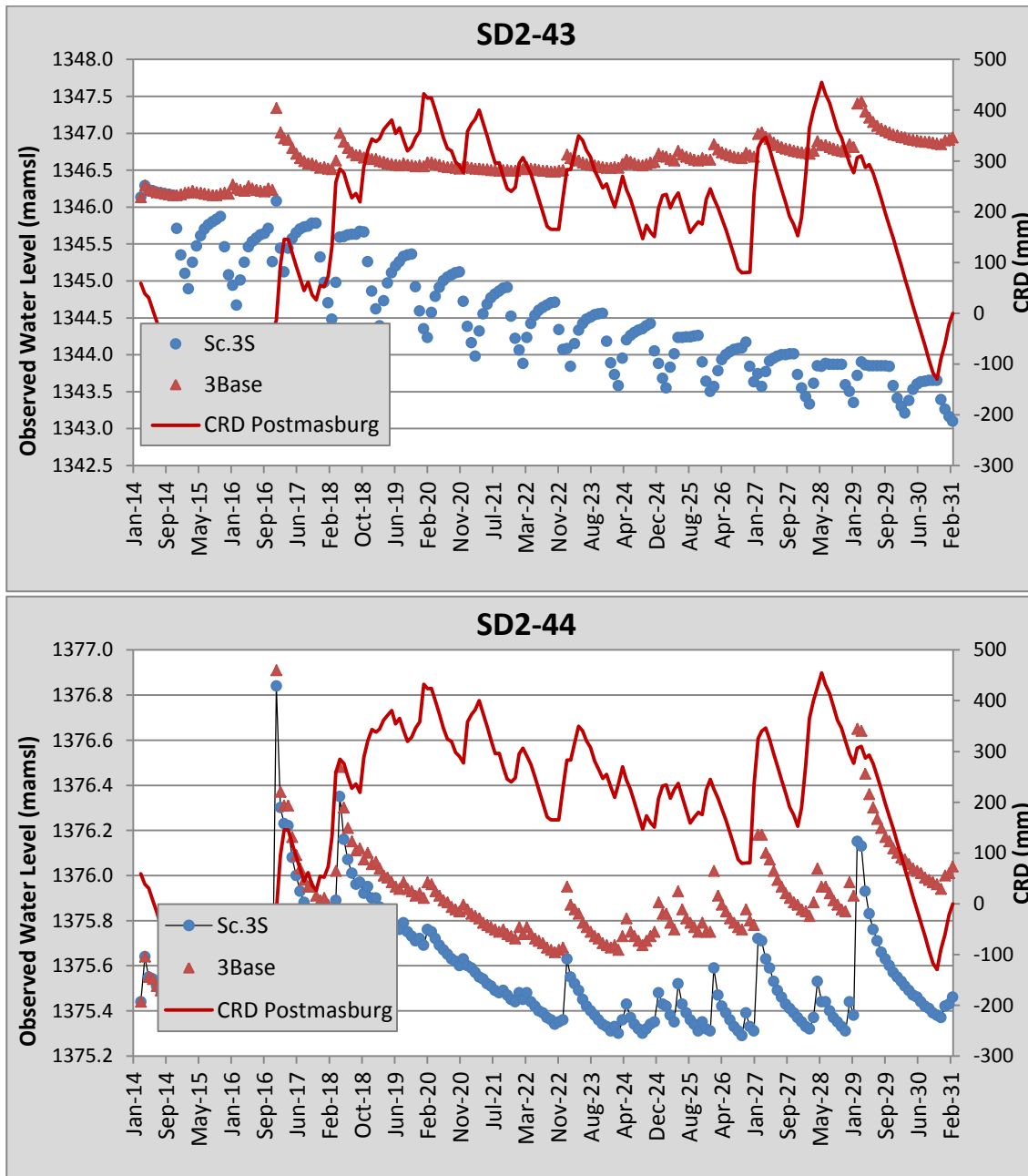
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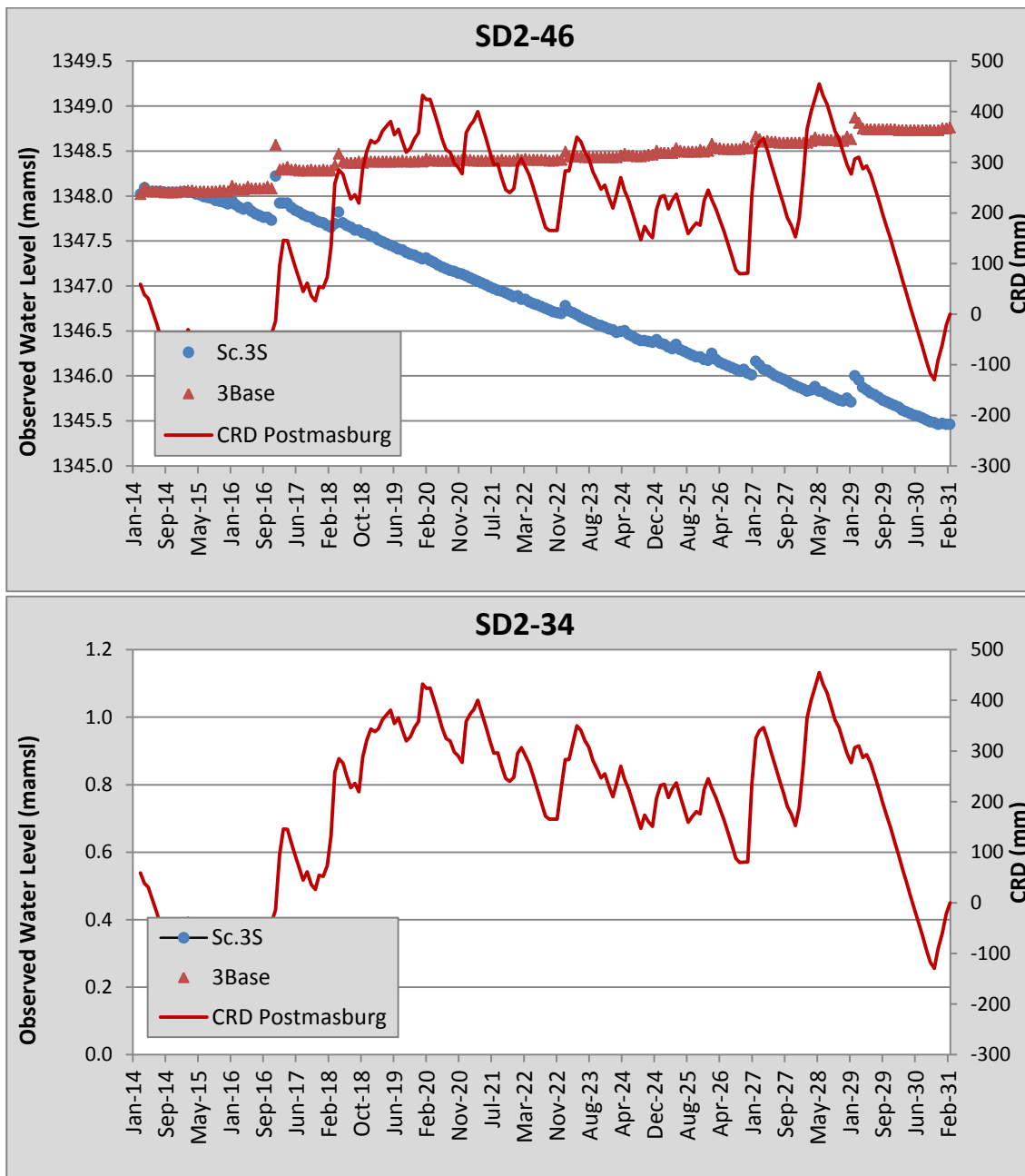
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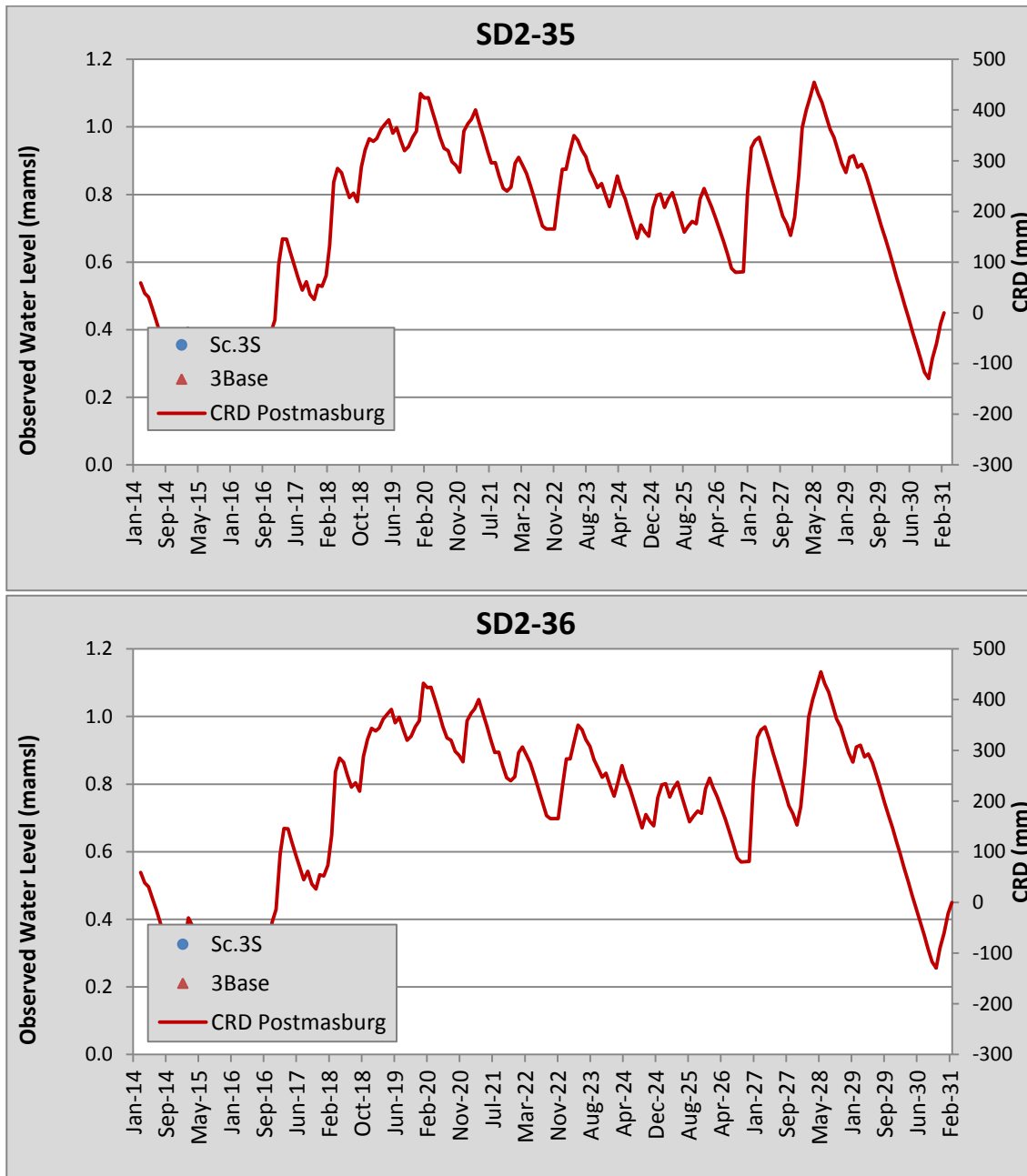
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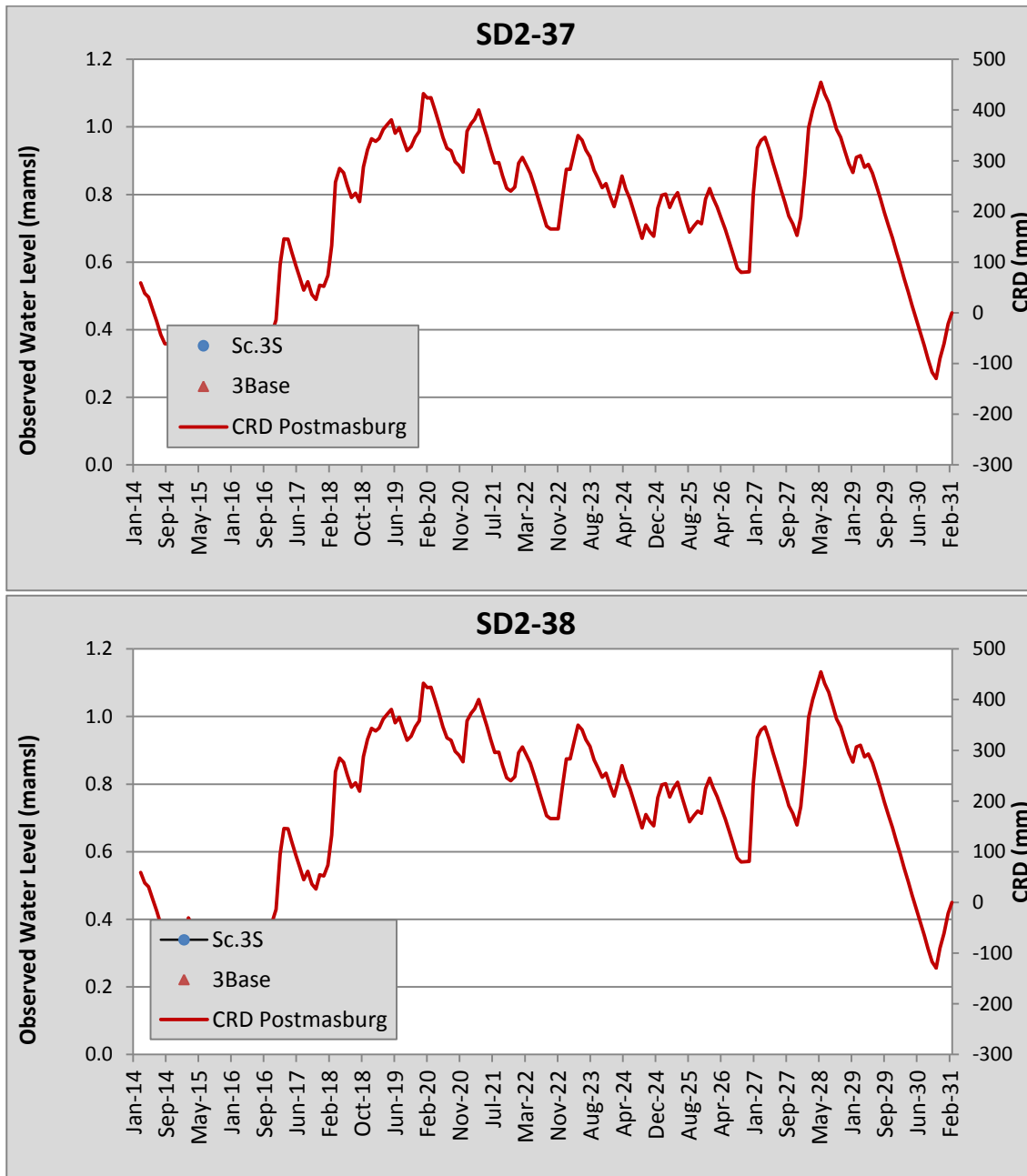
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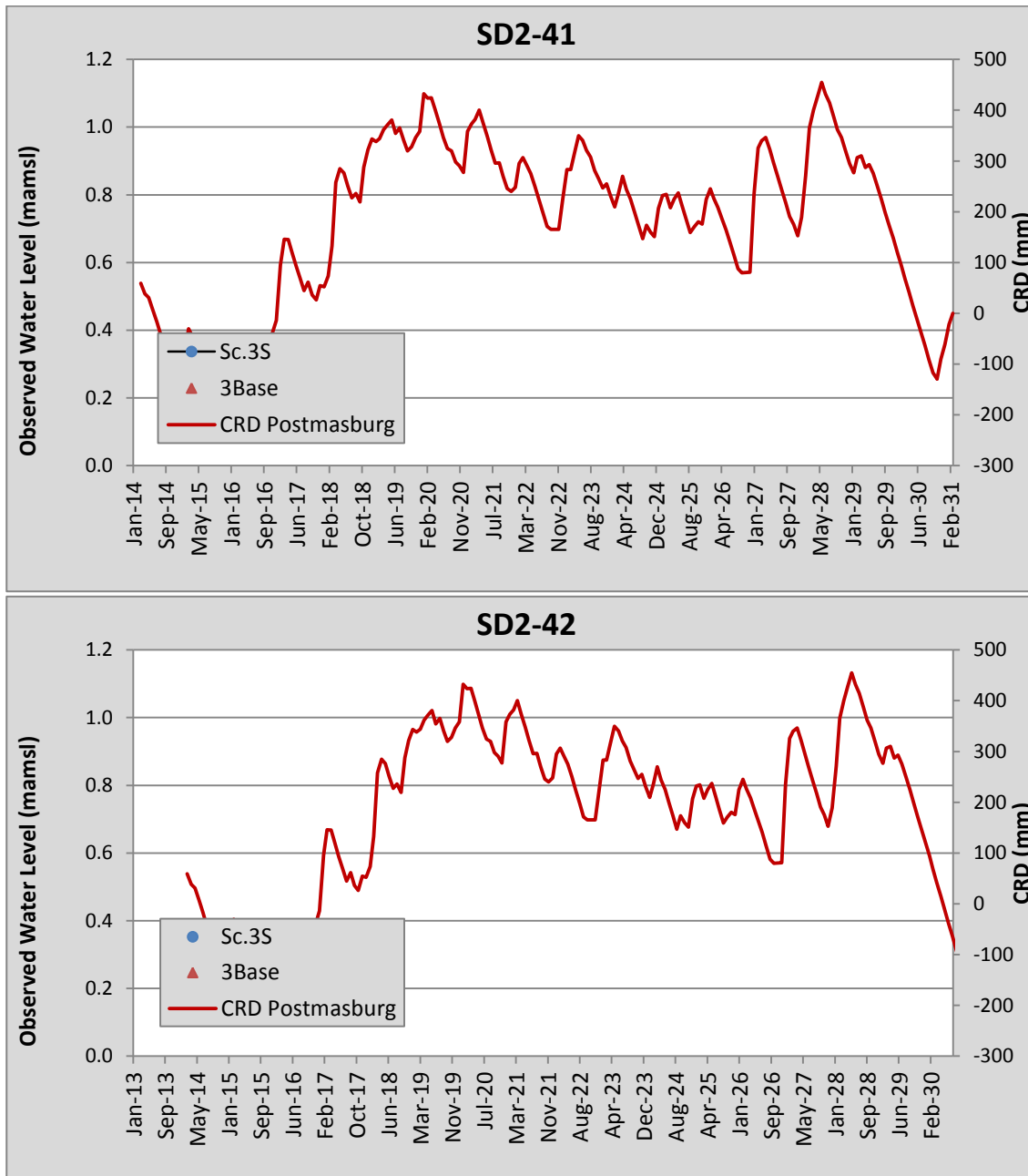
VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I





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VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I





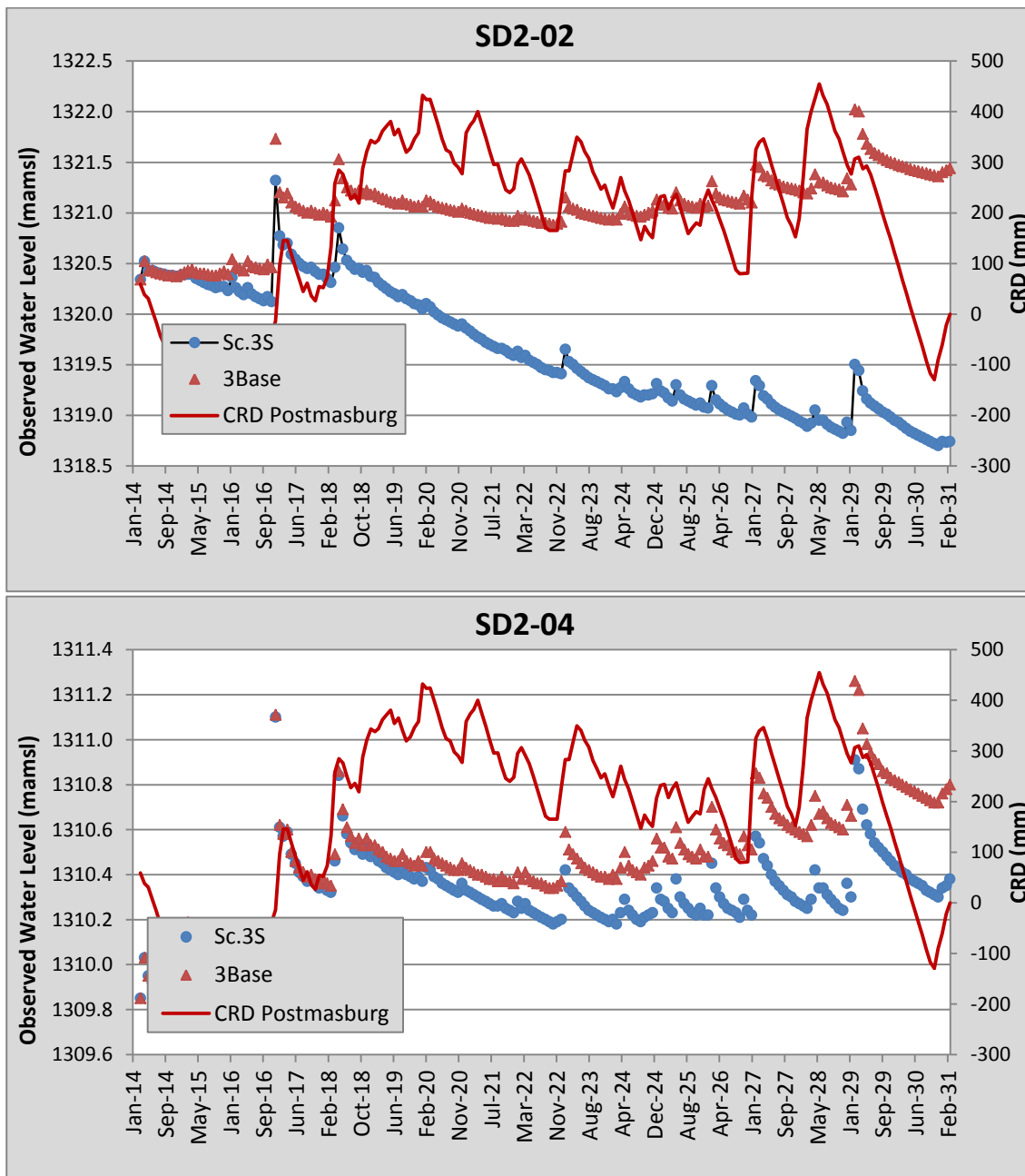
APPENDIX C

Long-Term Water Level Drawdown Simulations for Existing Boreholes



APPENDIX B

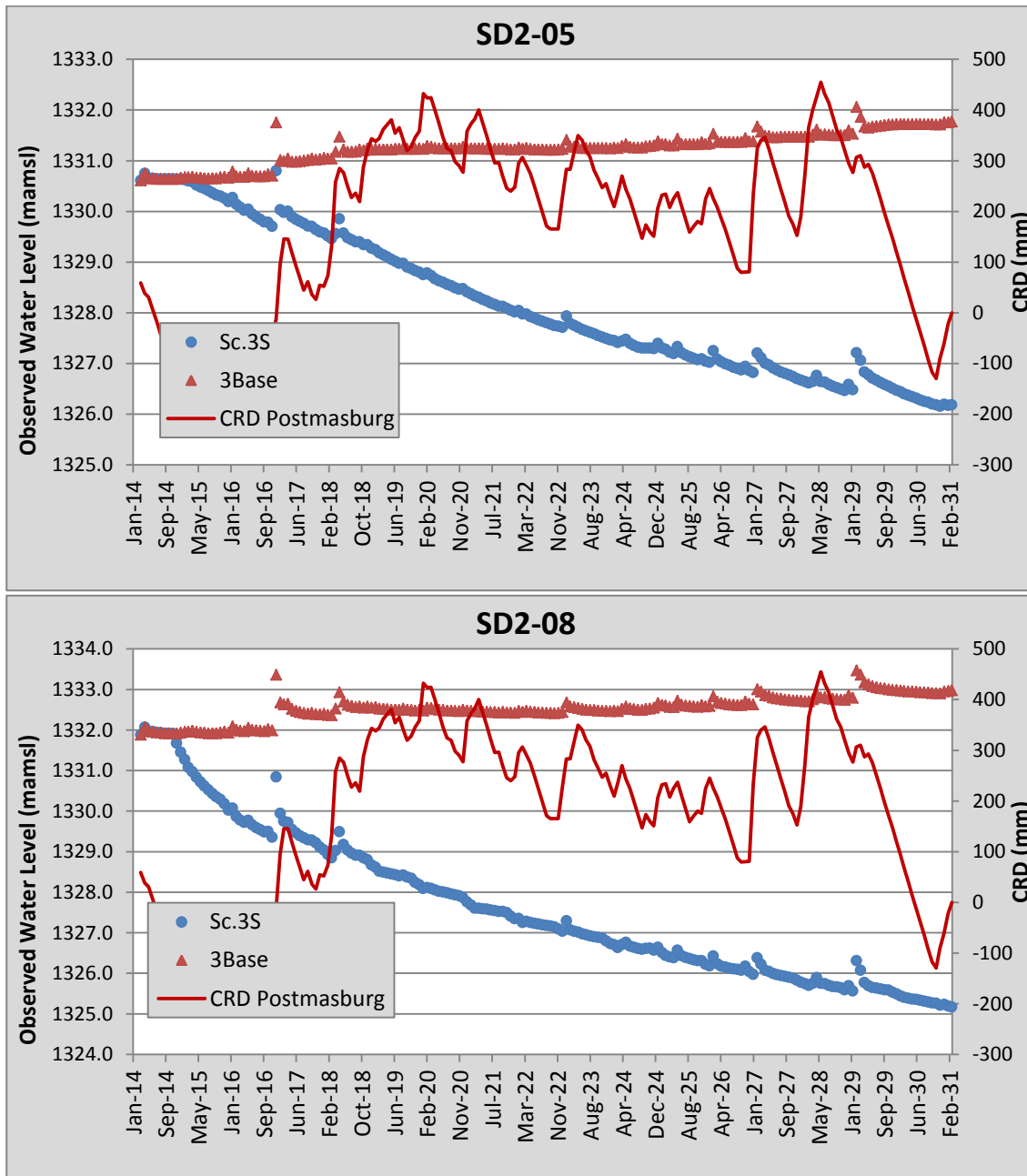
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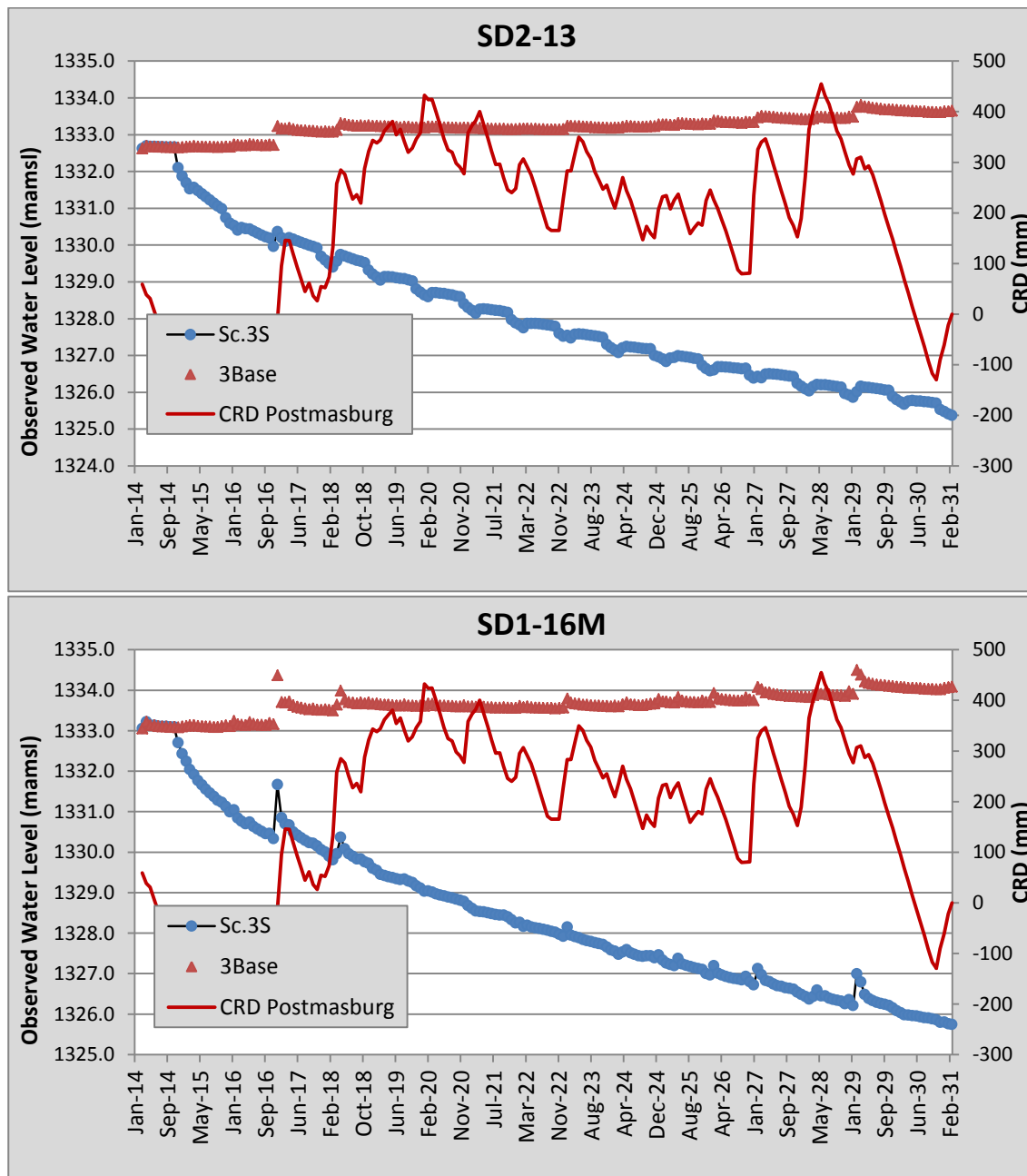
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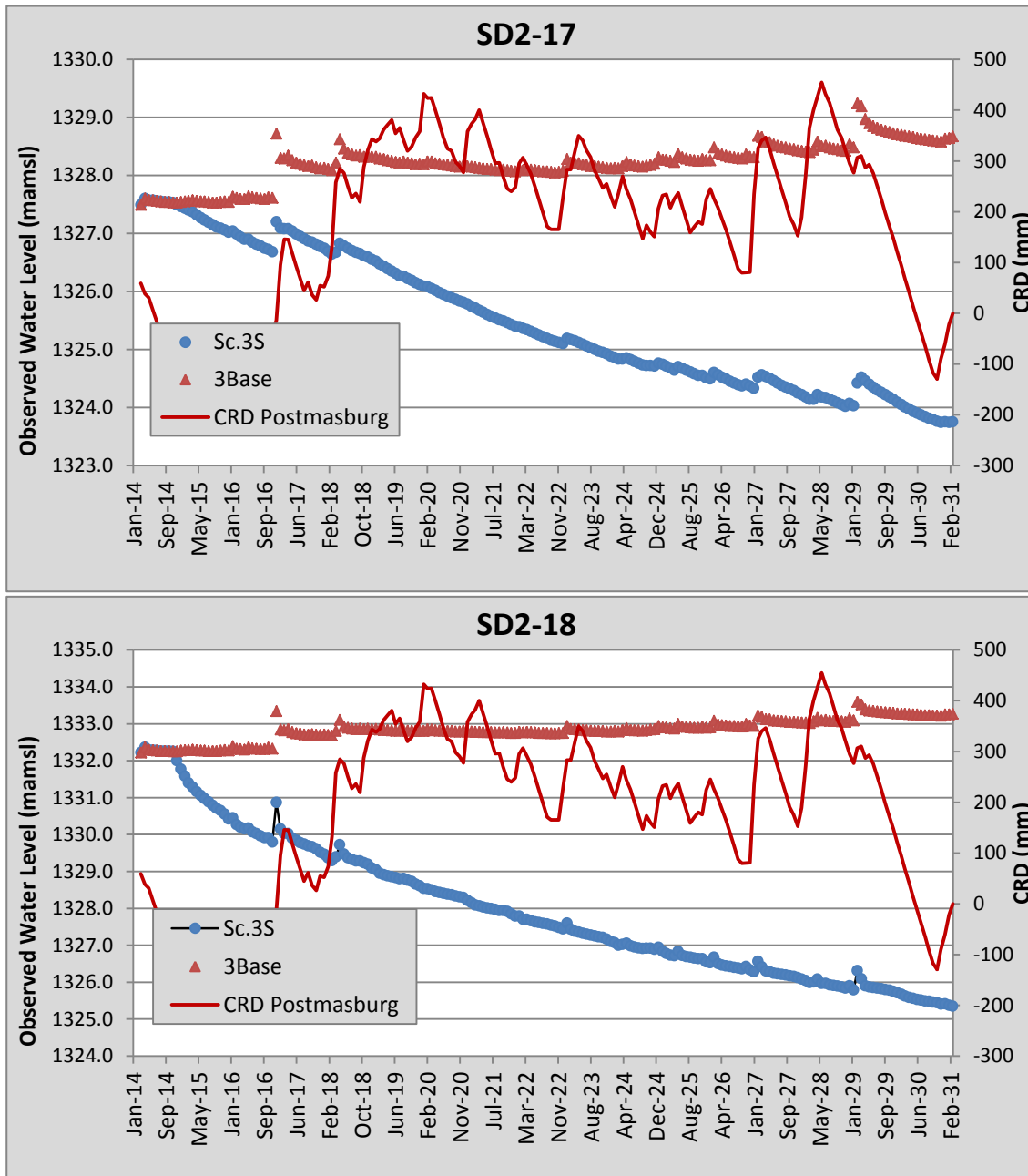
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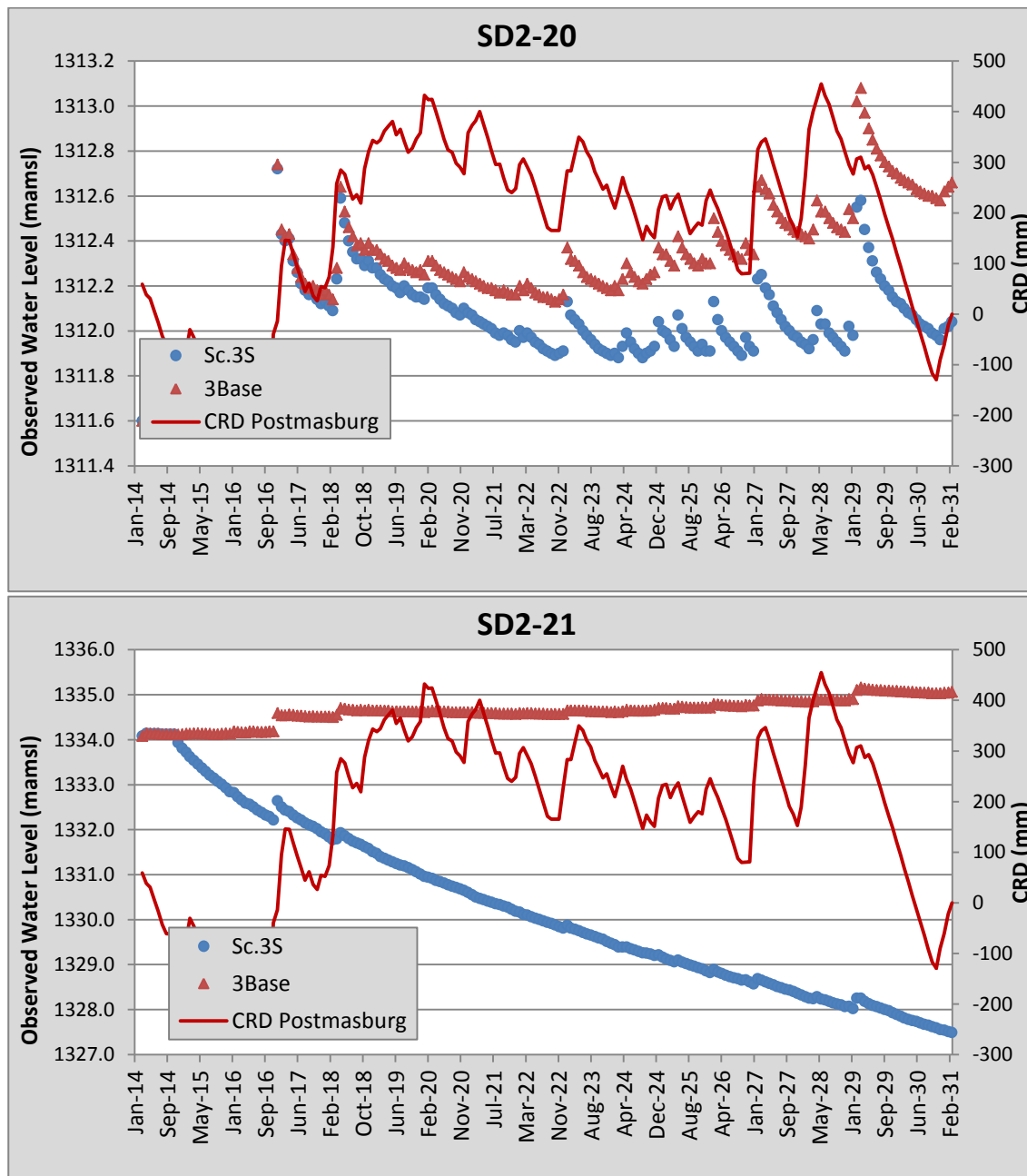
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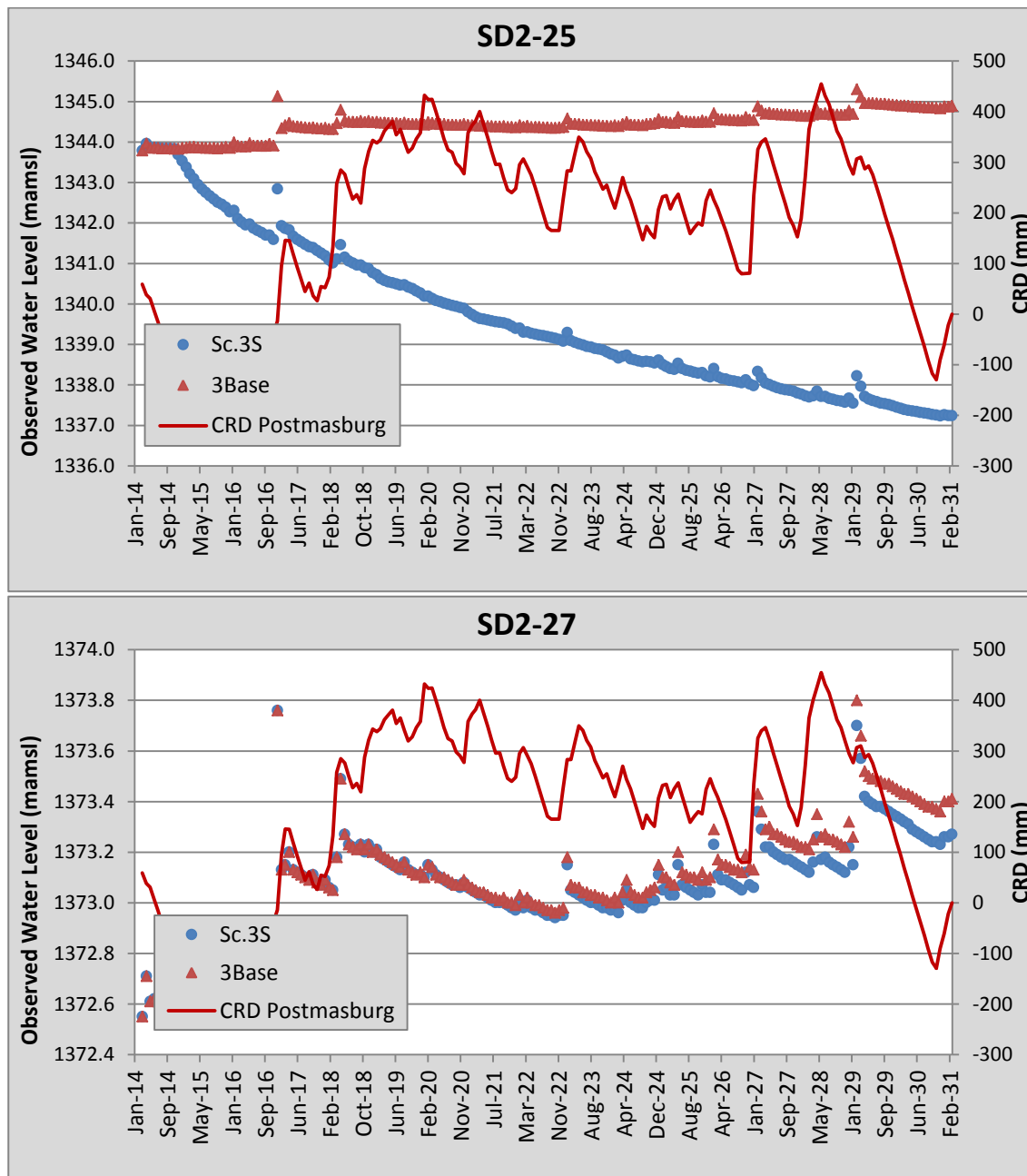
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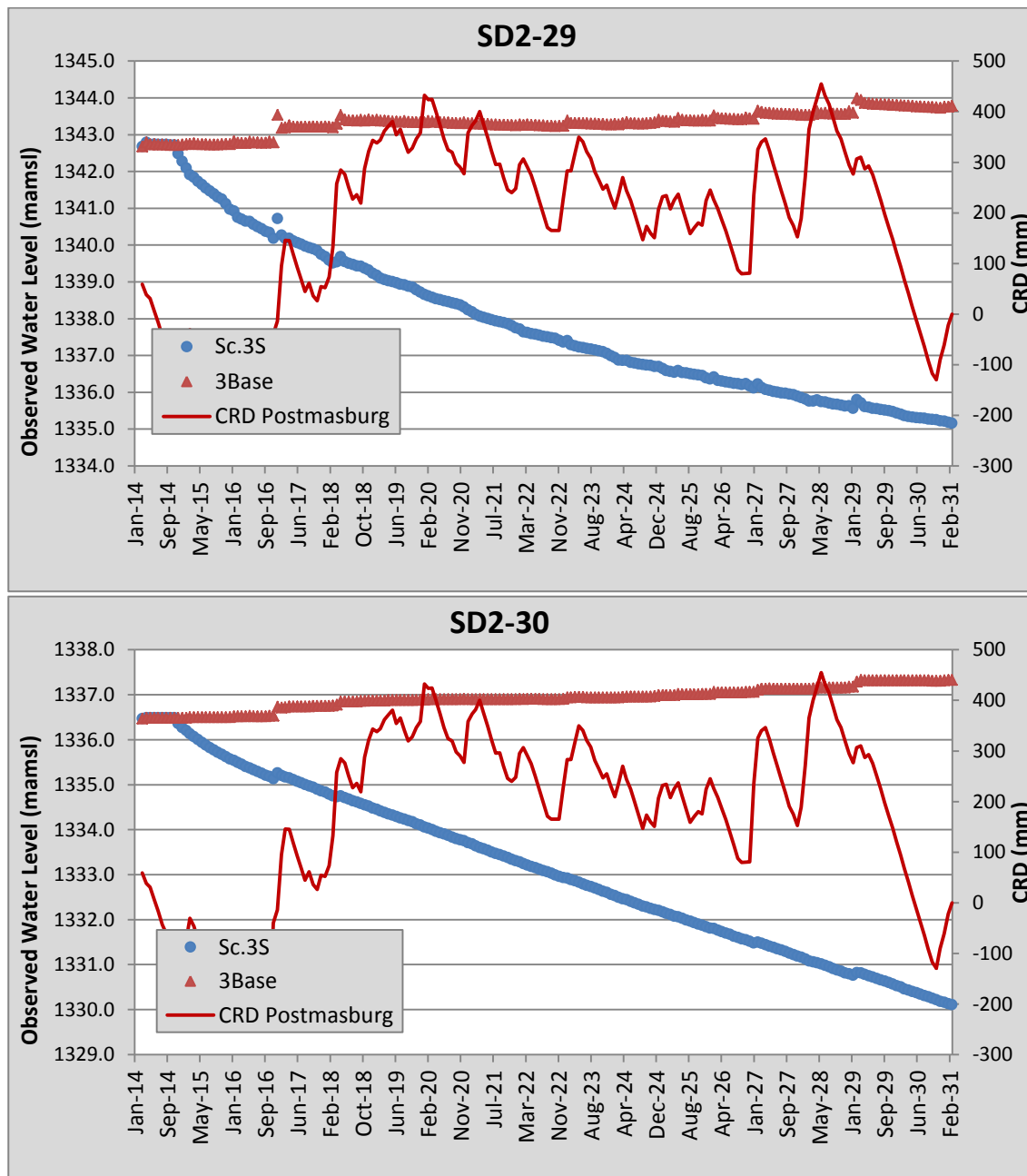
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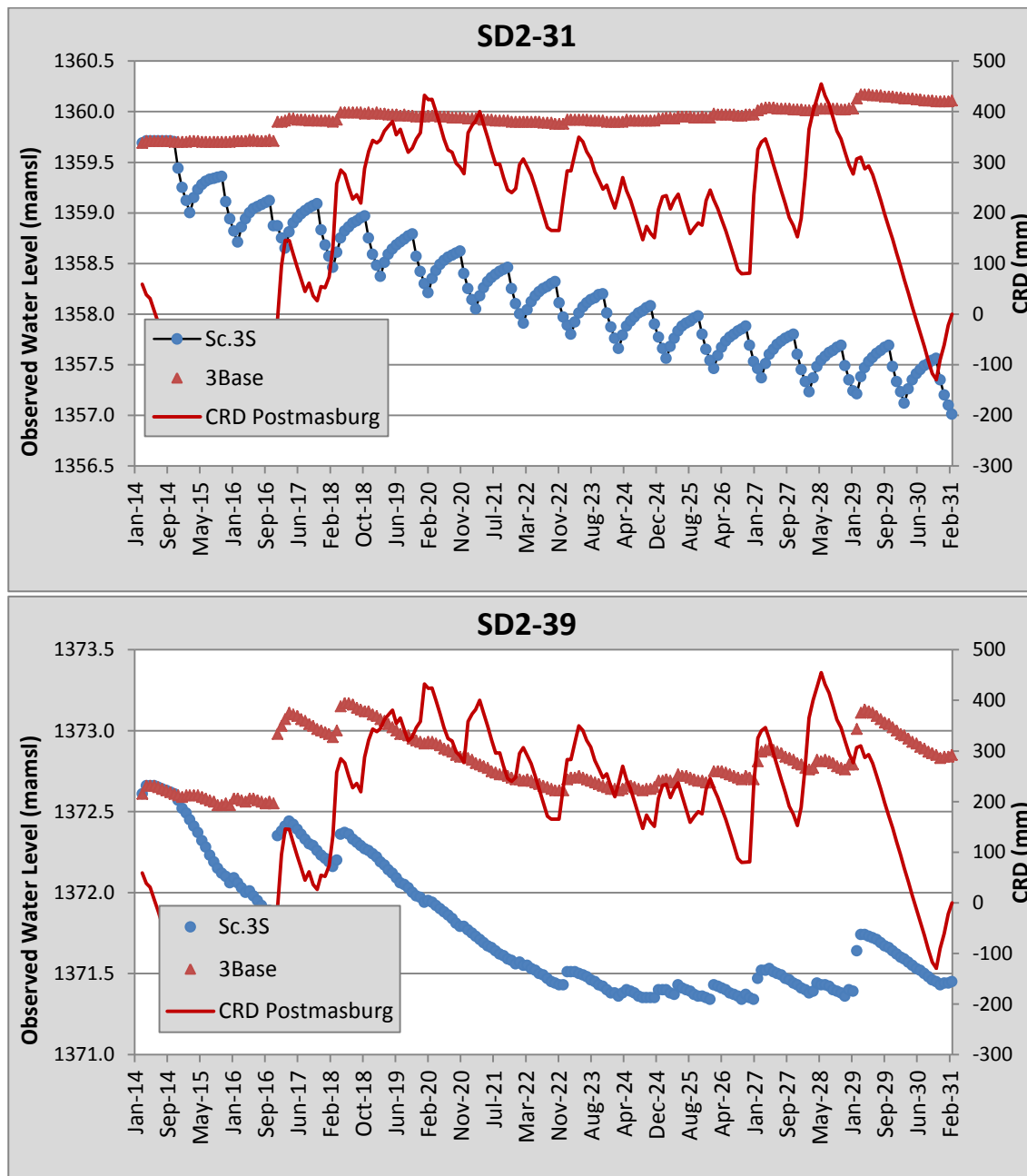
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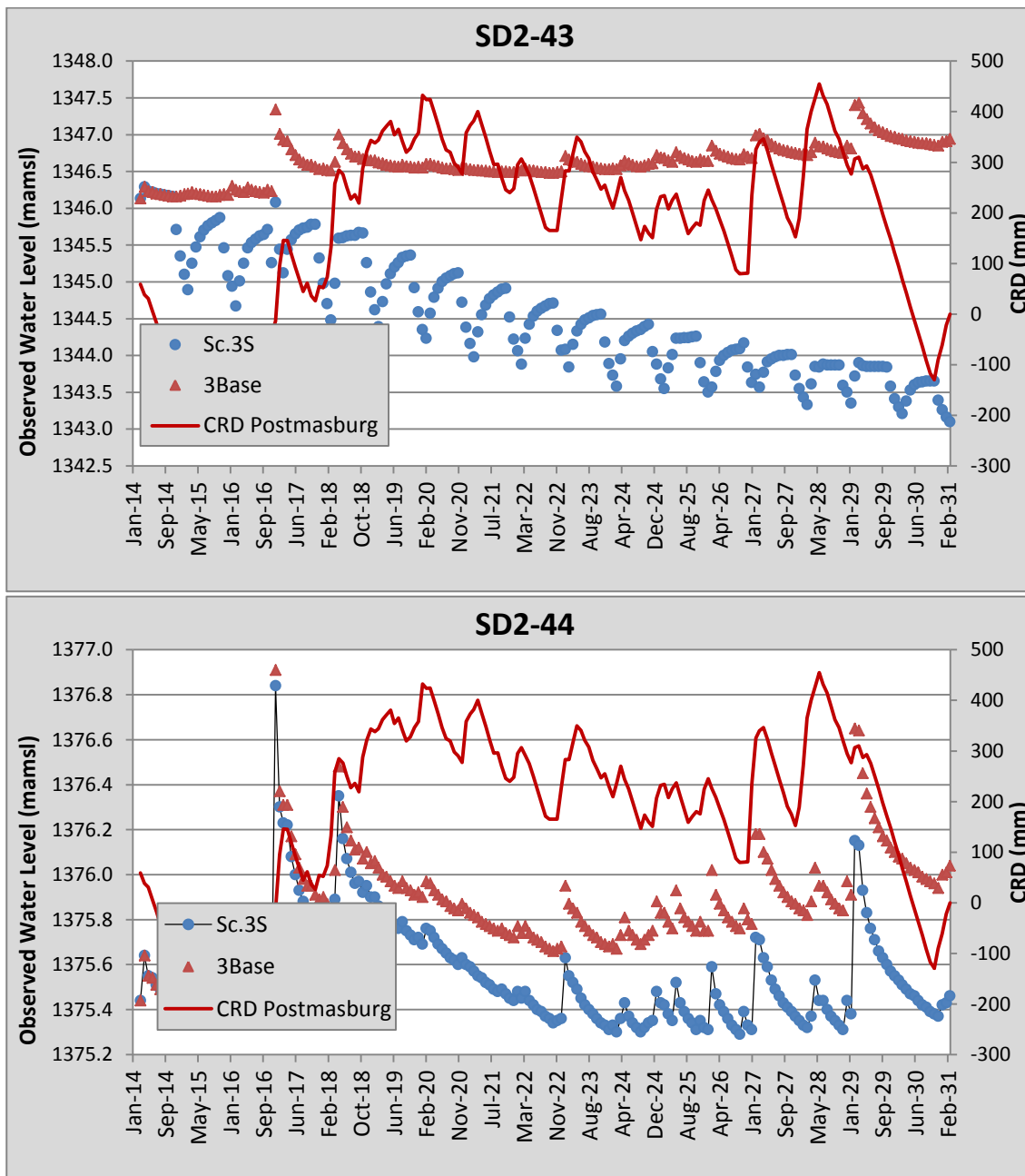
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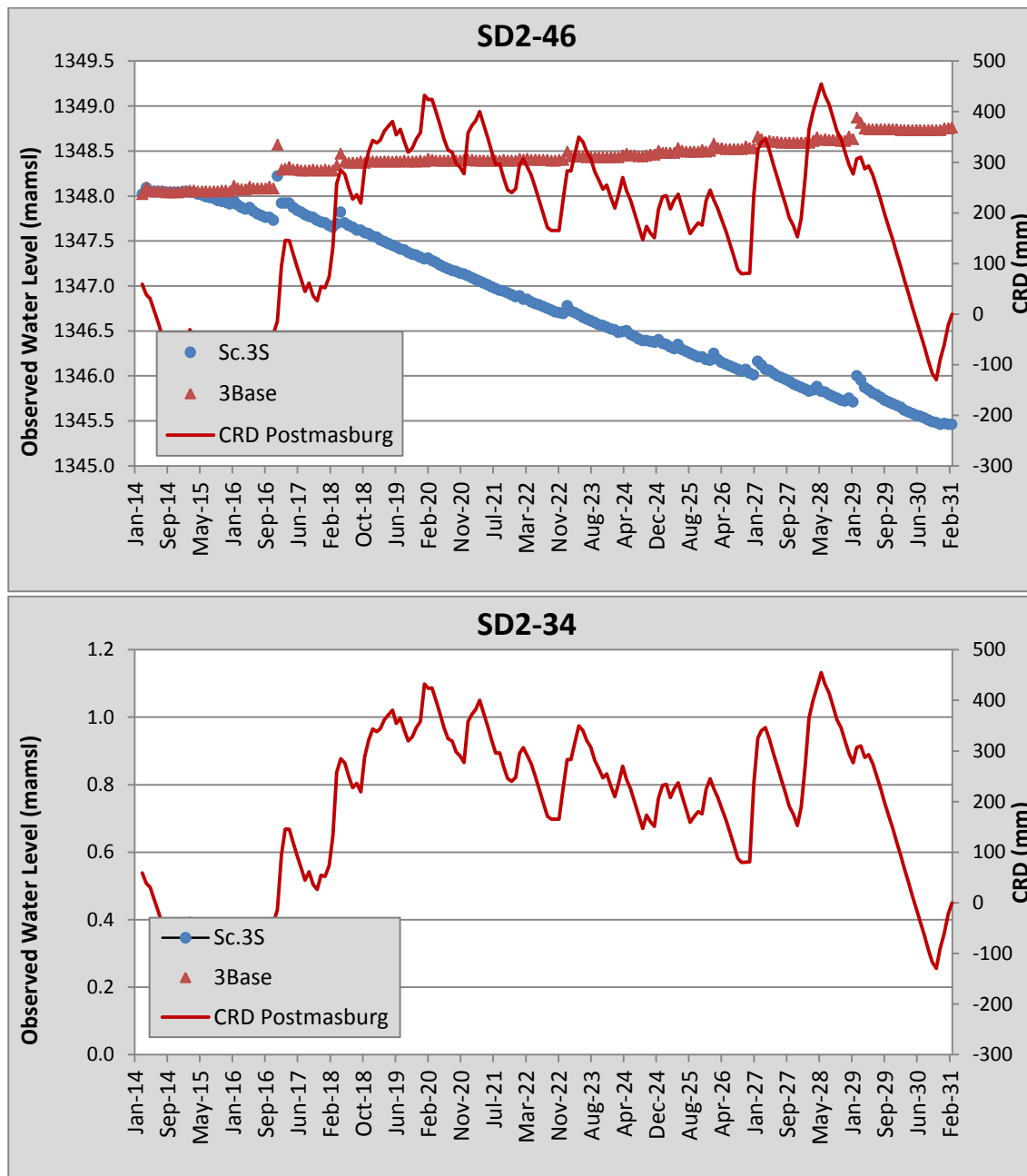
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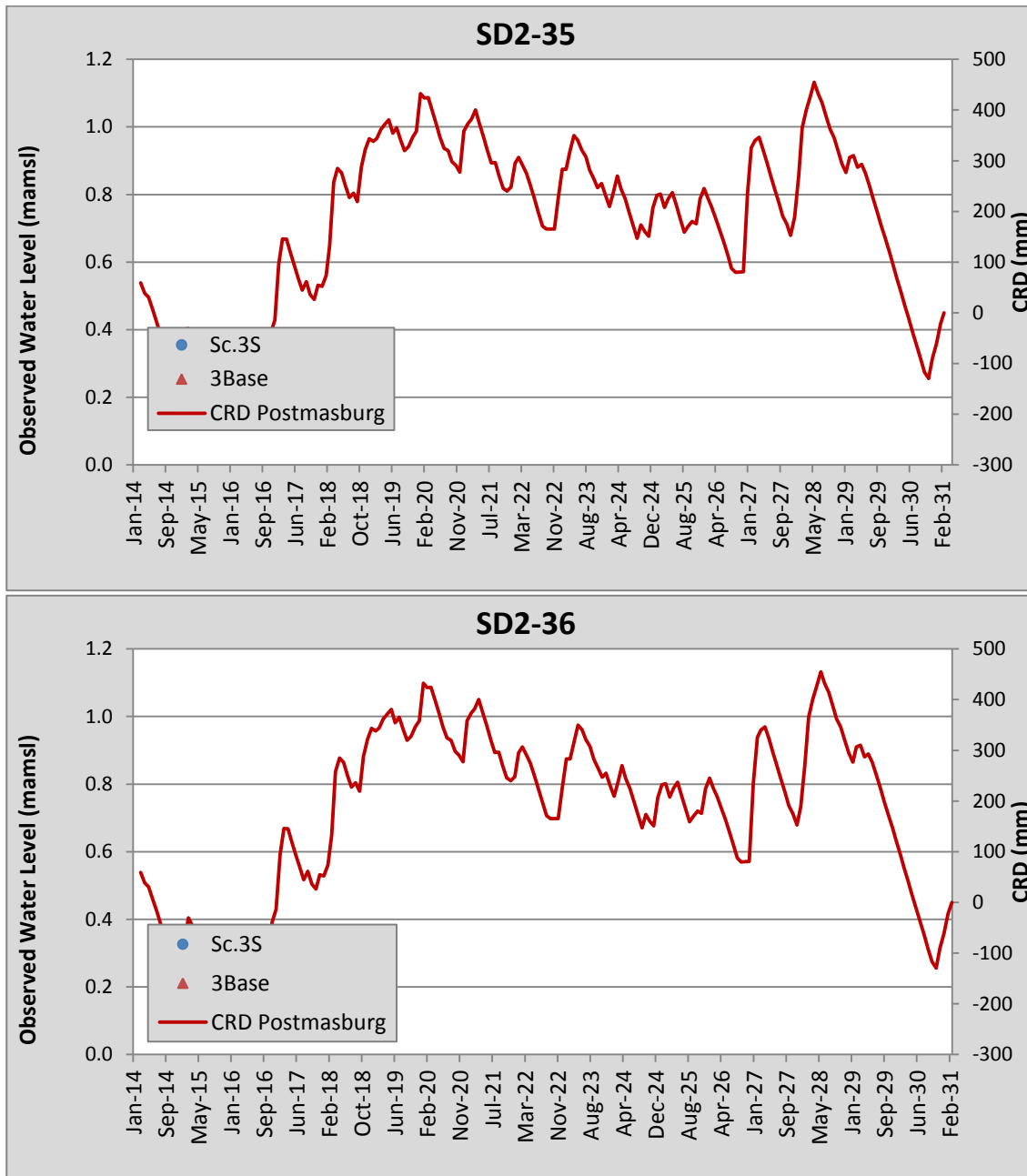
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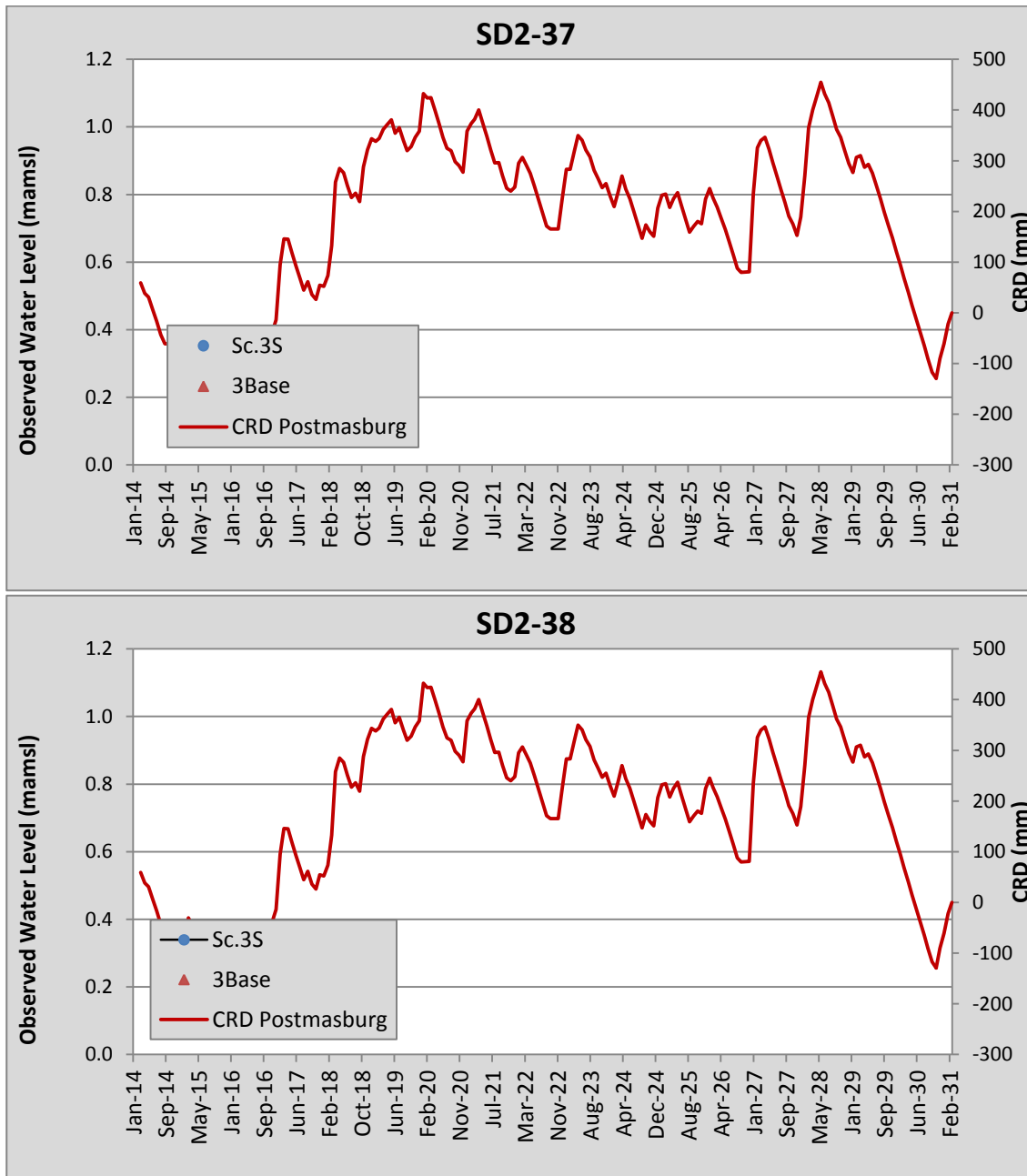
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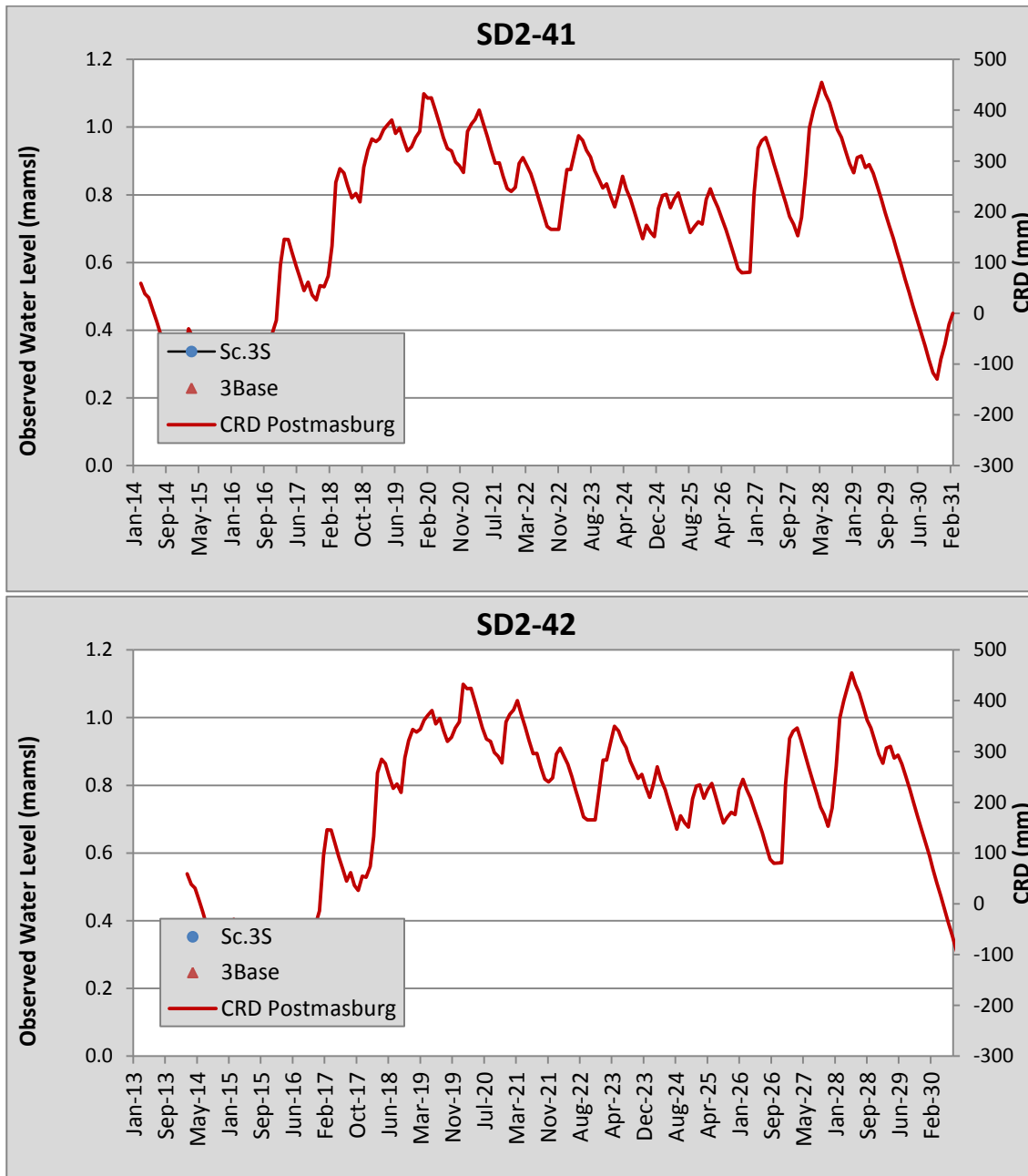
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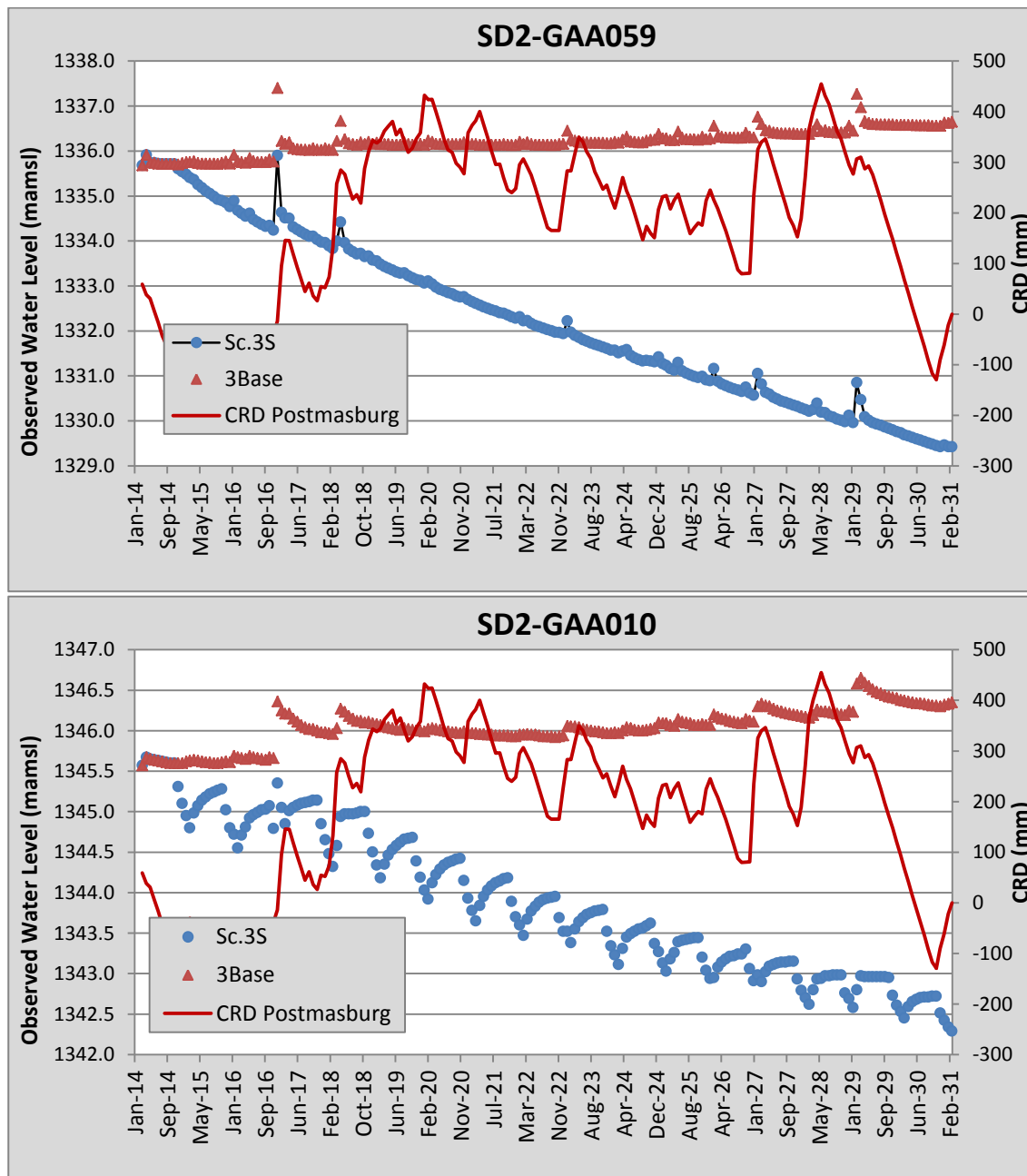
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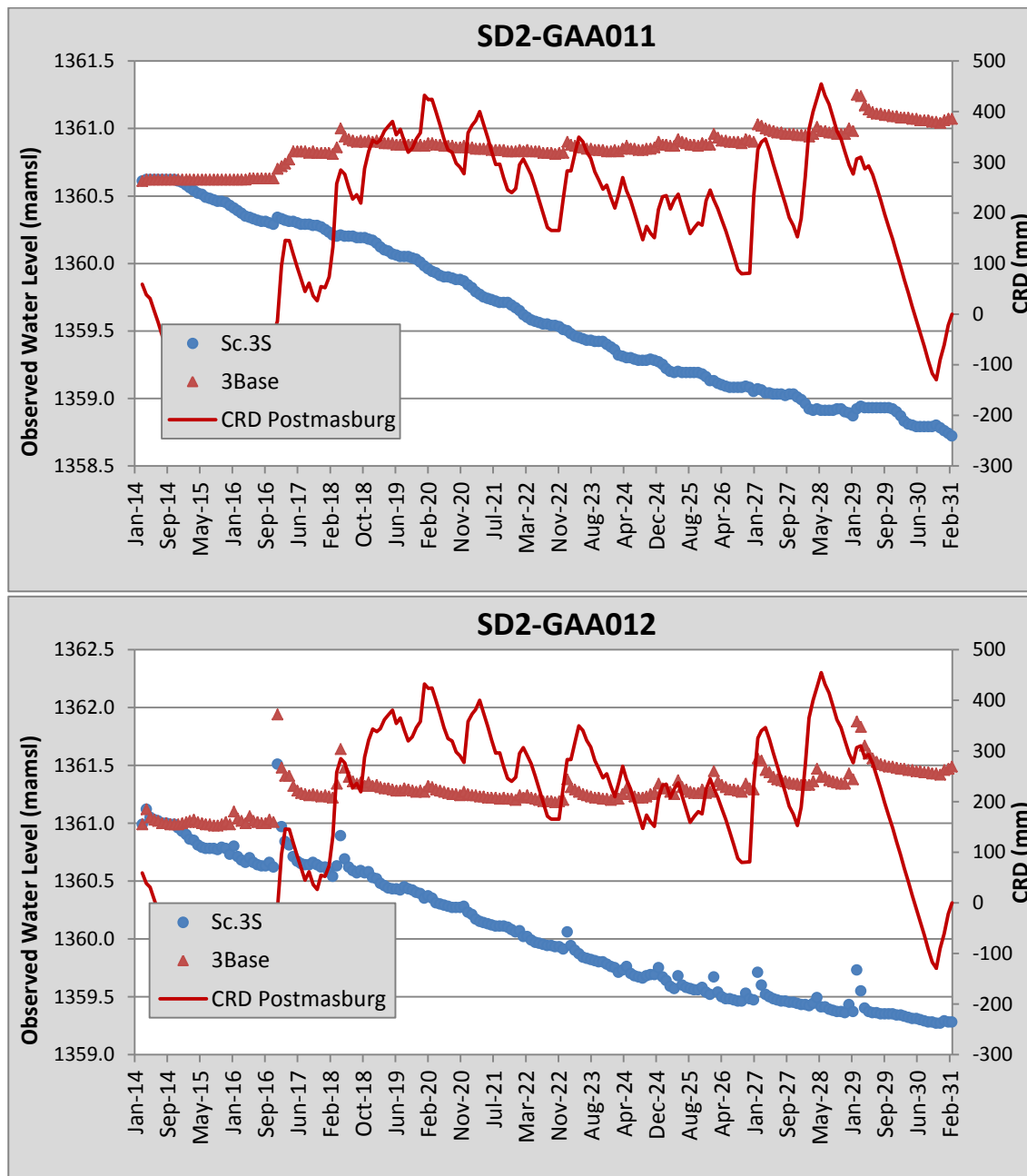
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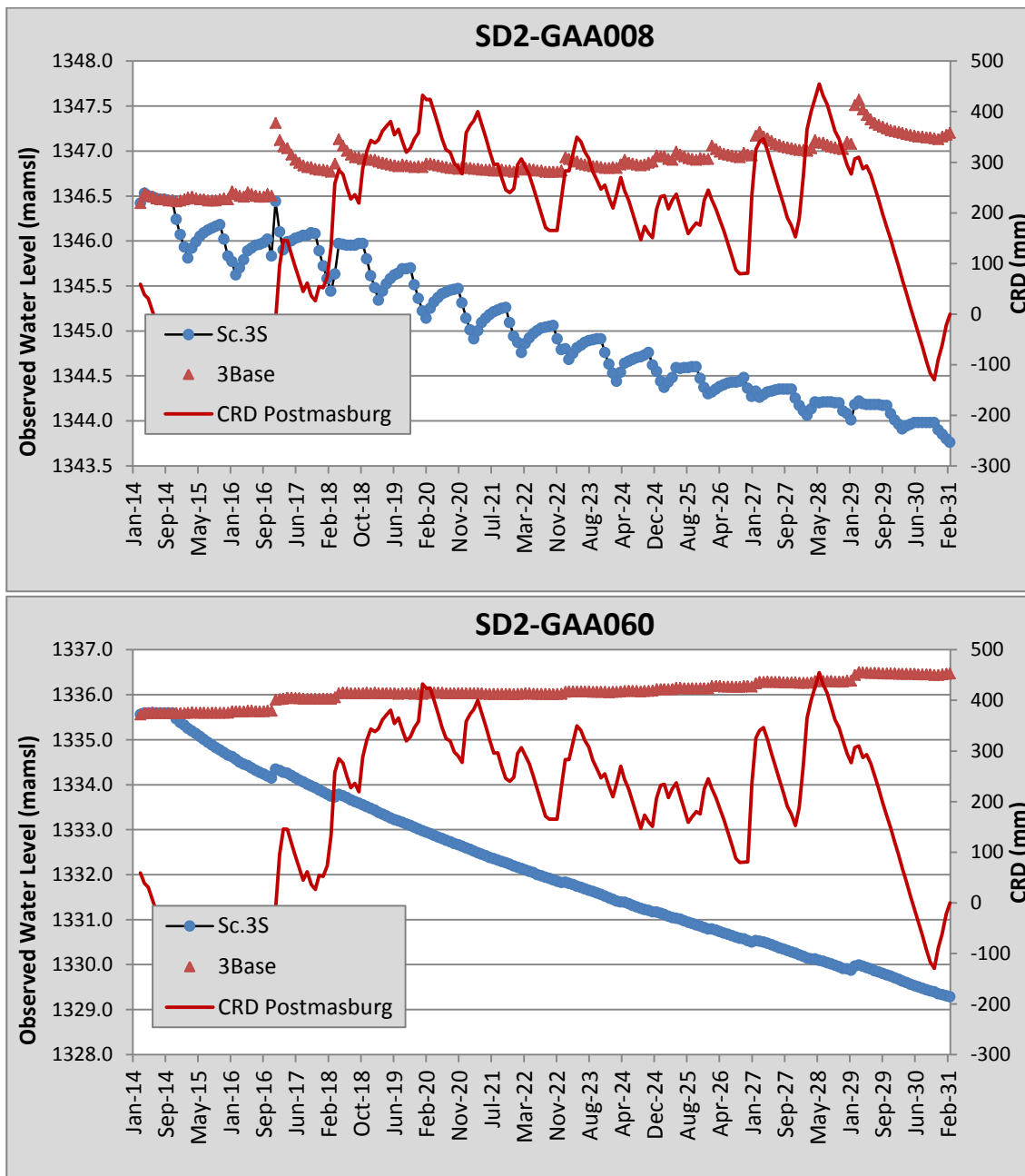
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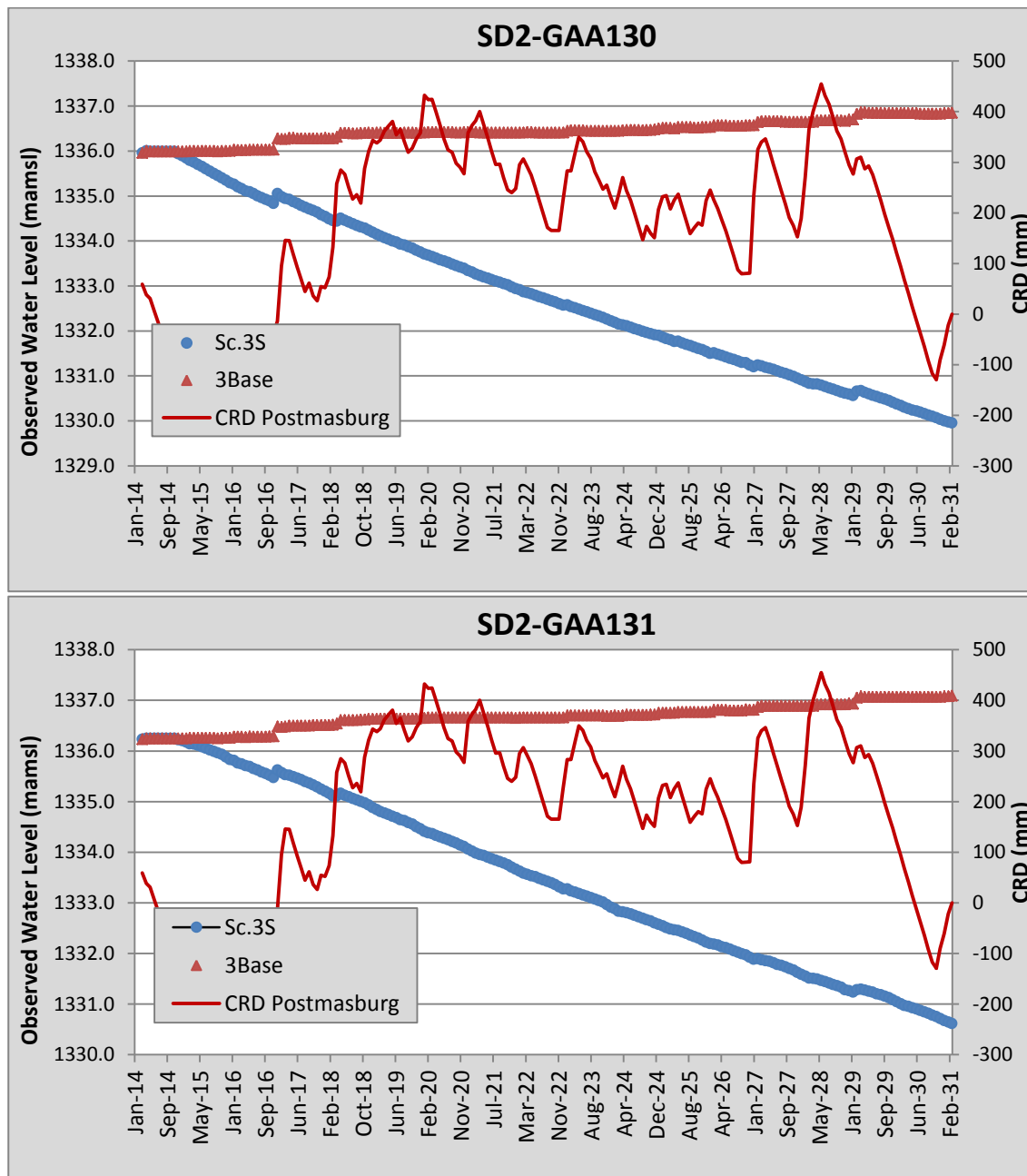
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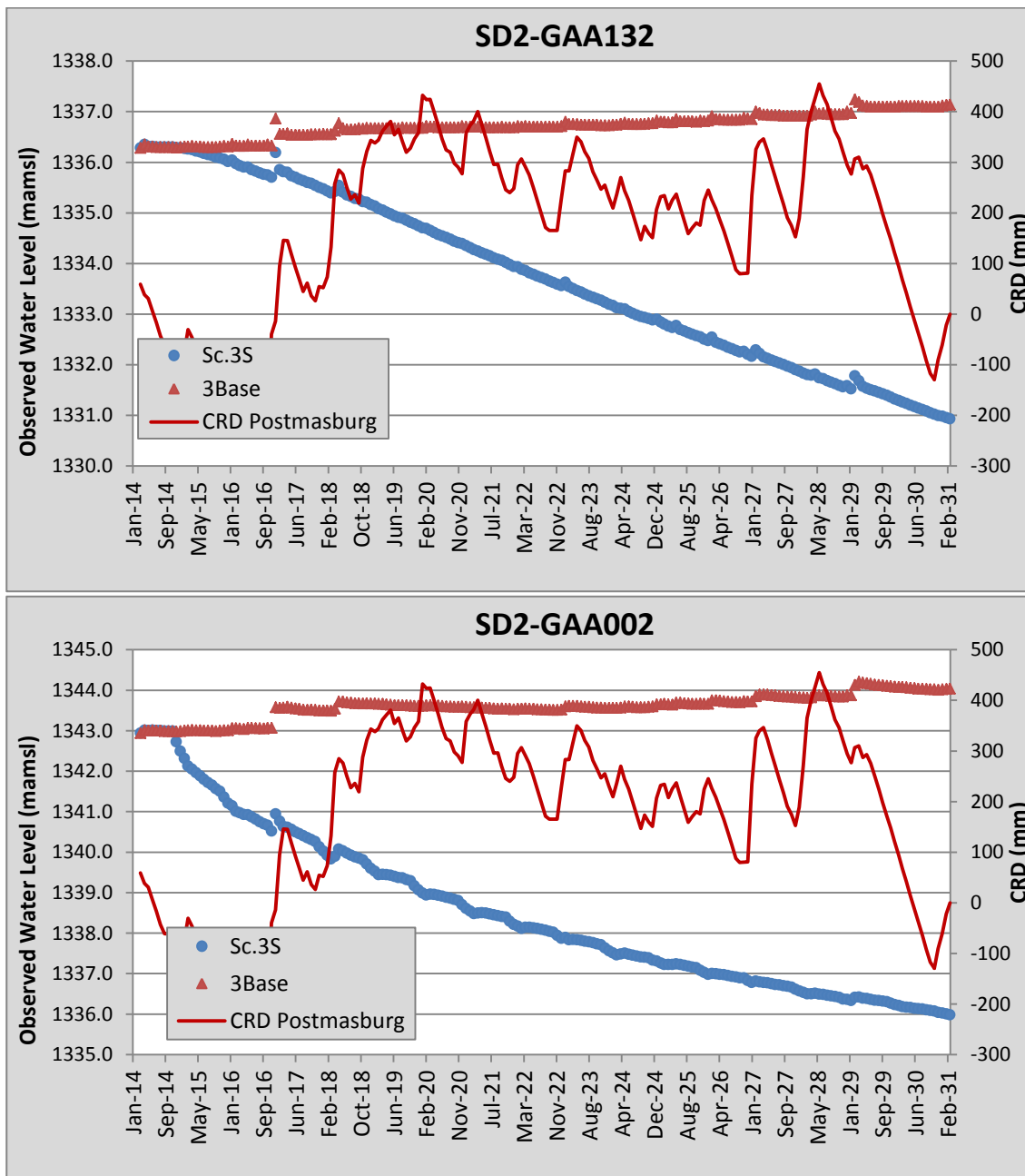
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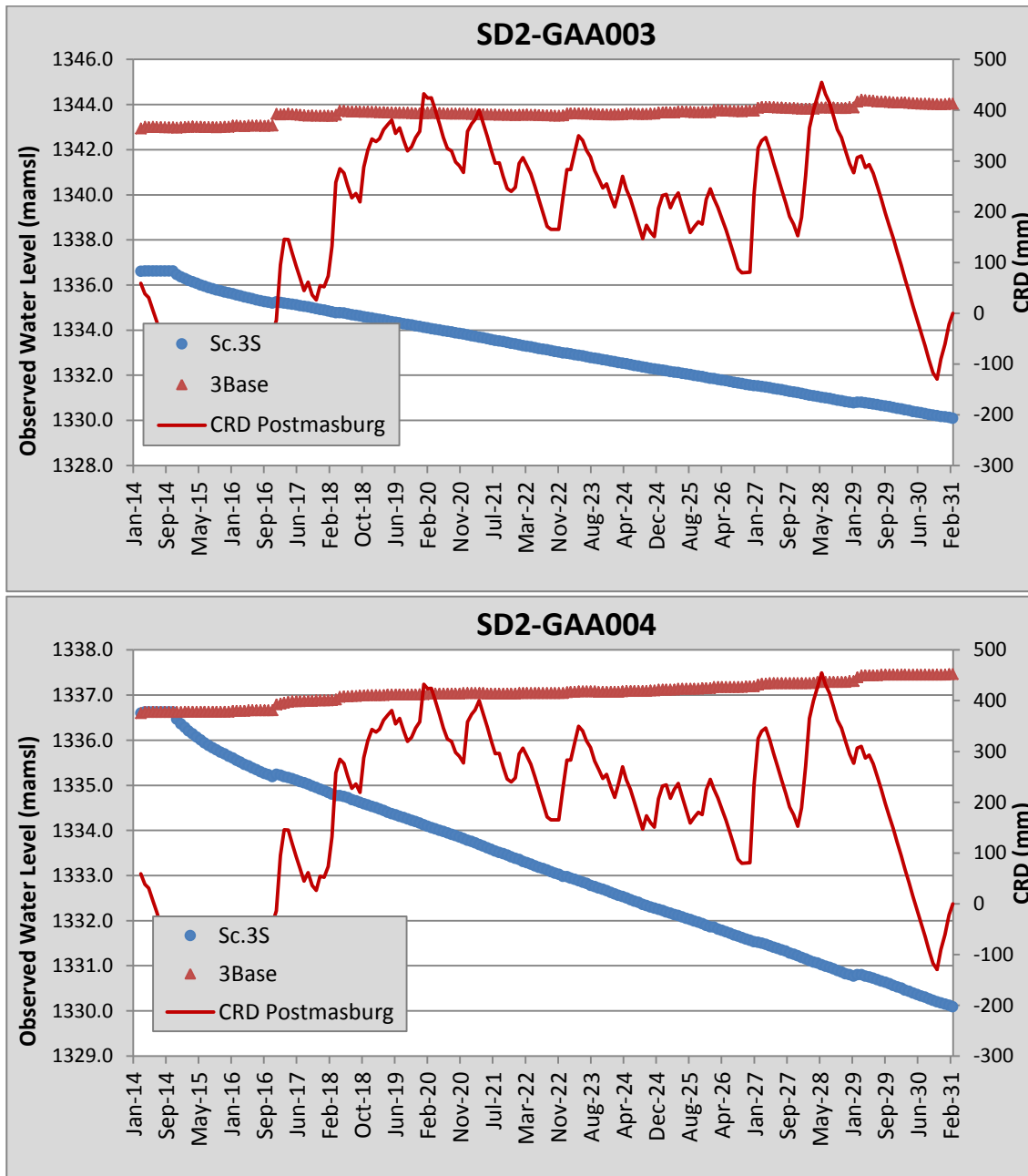
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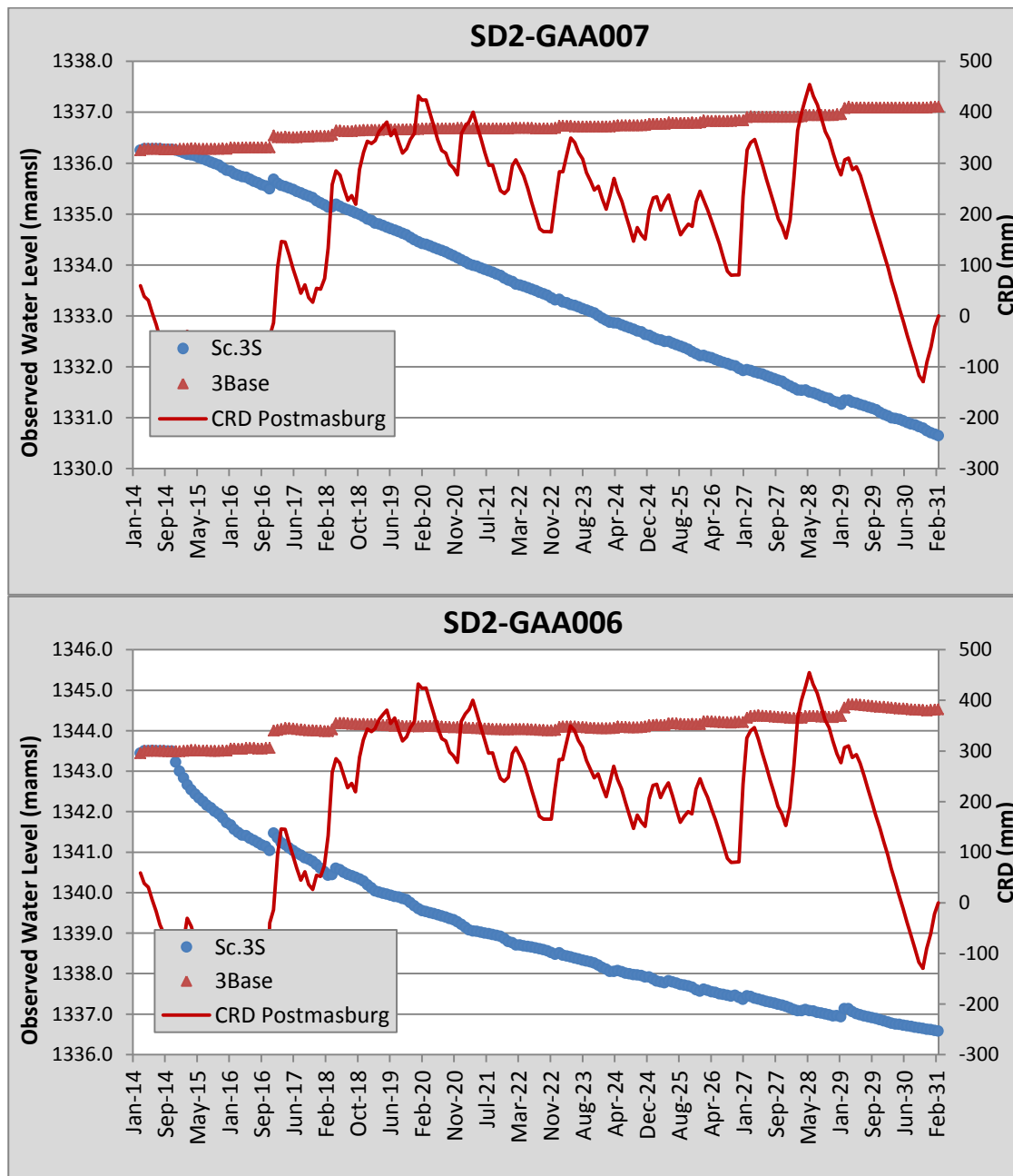
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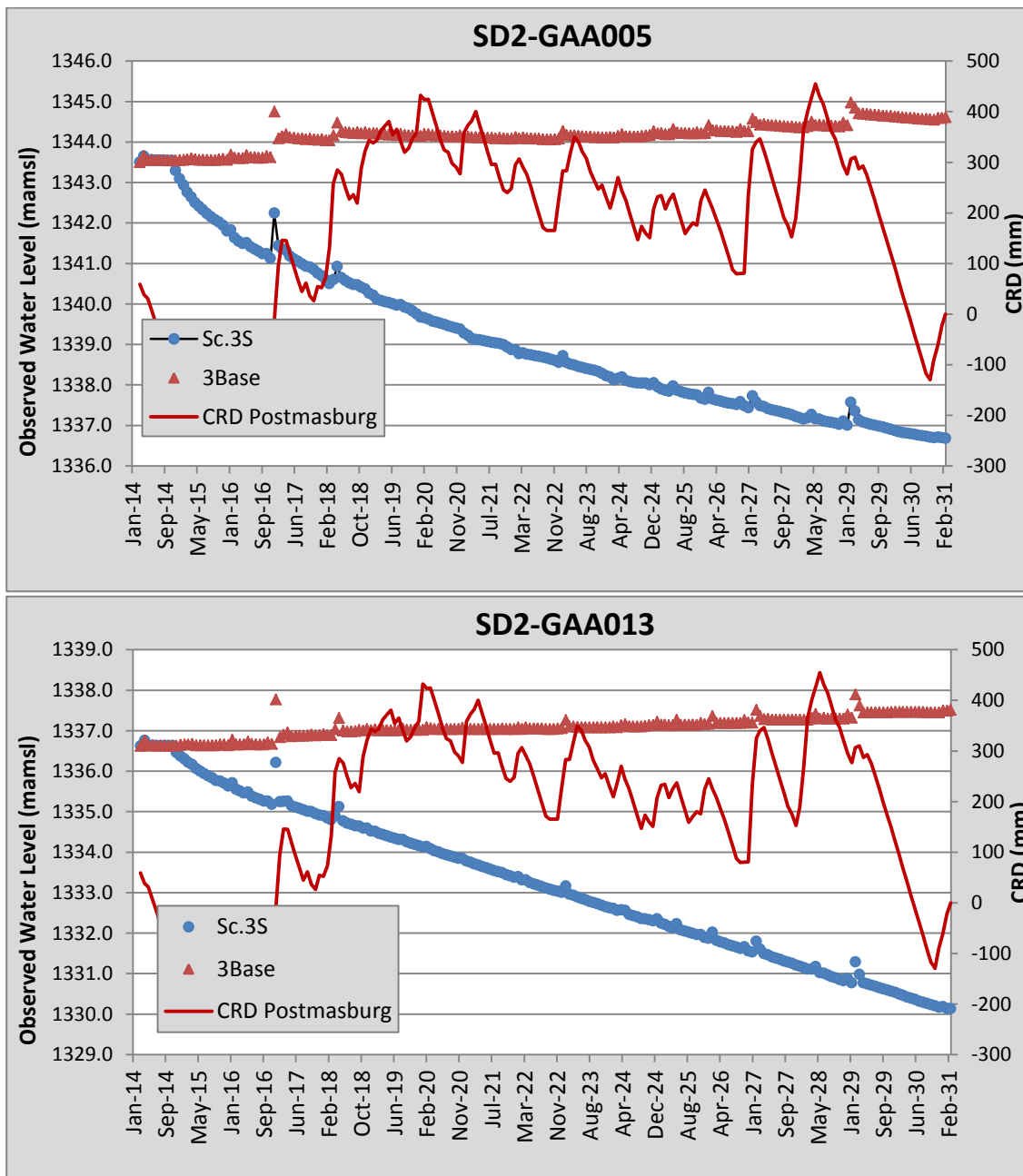
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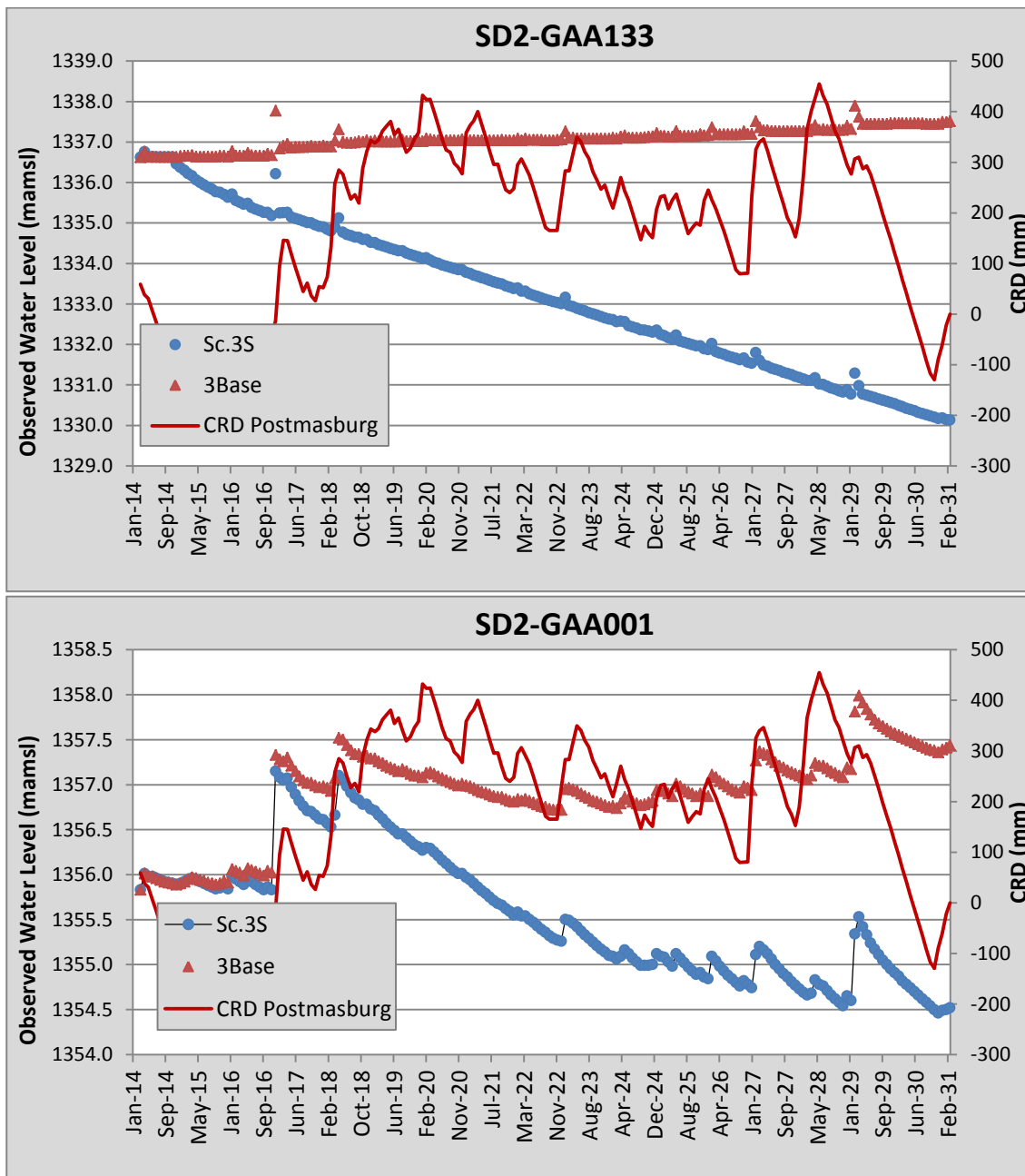
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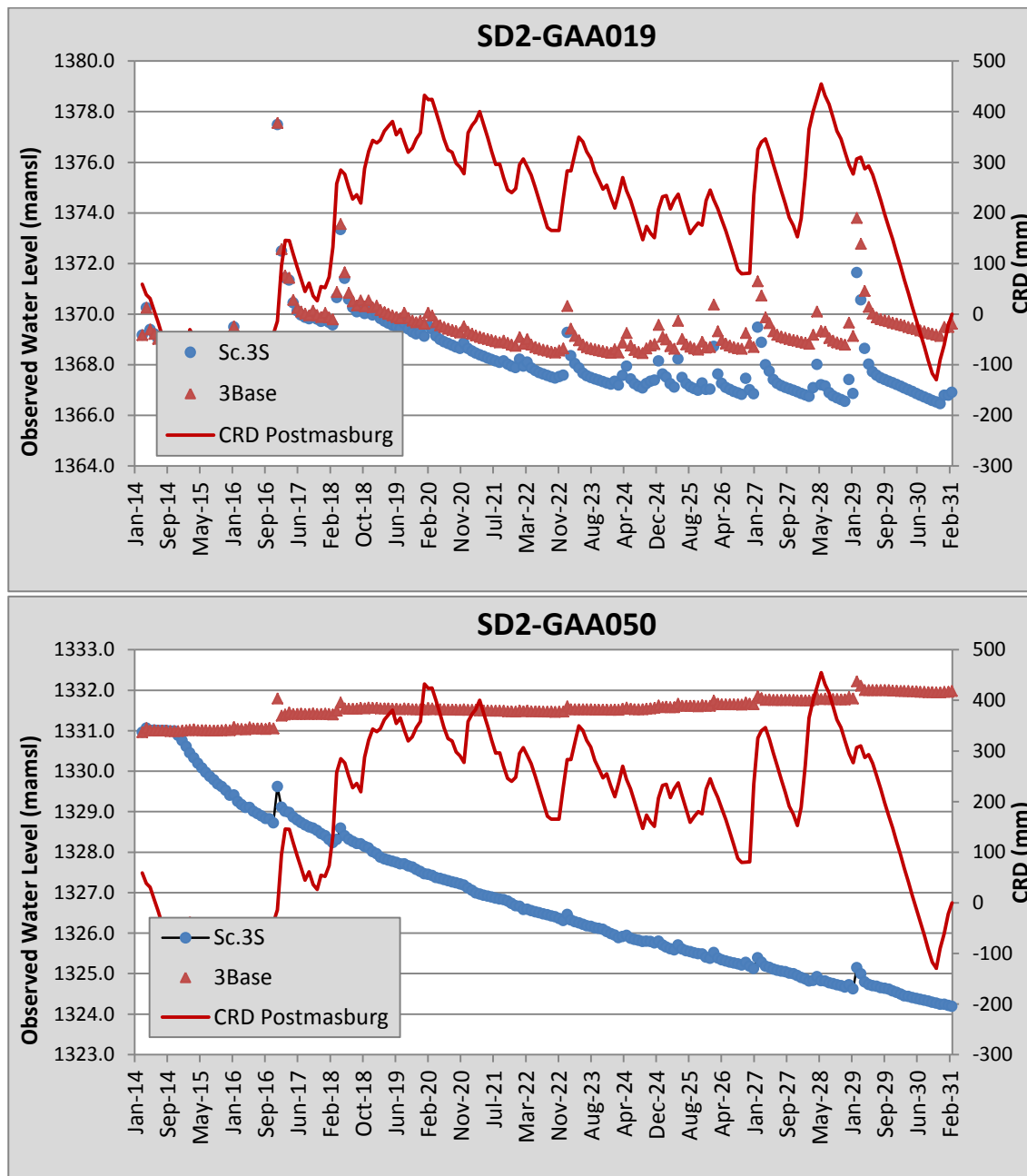
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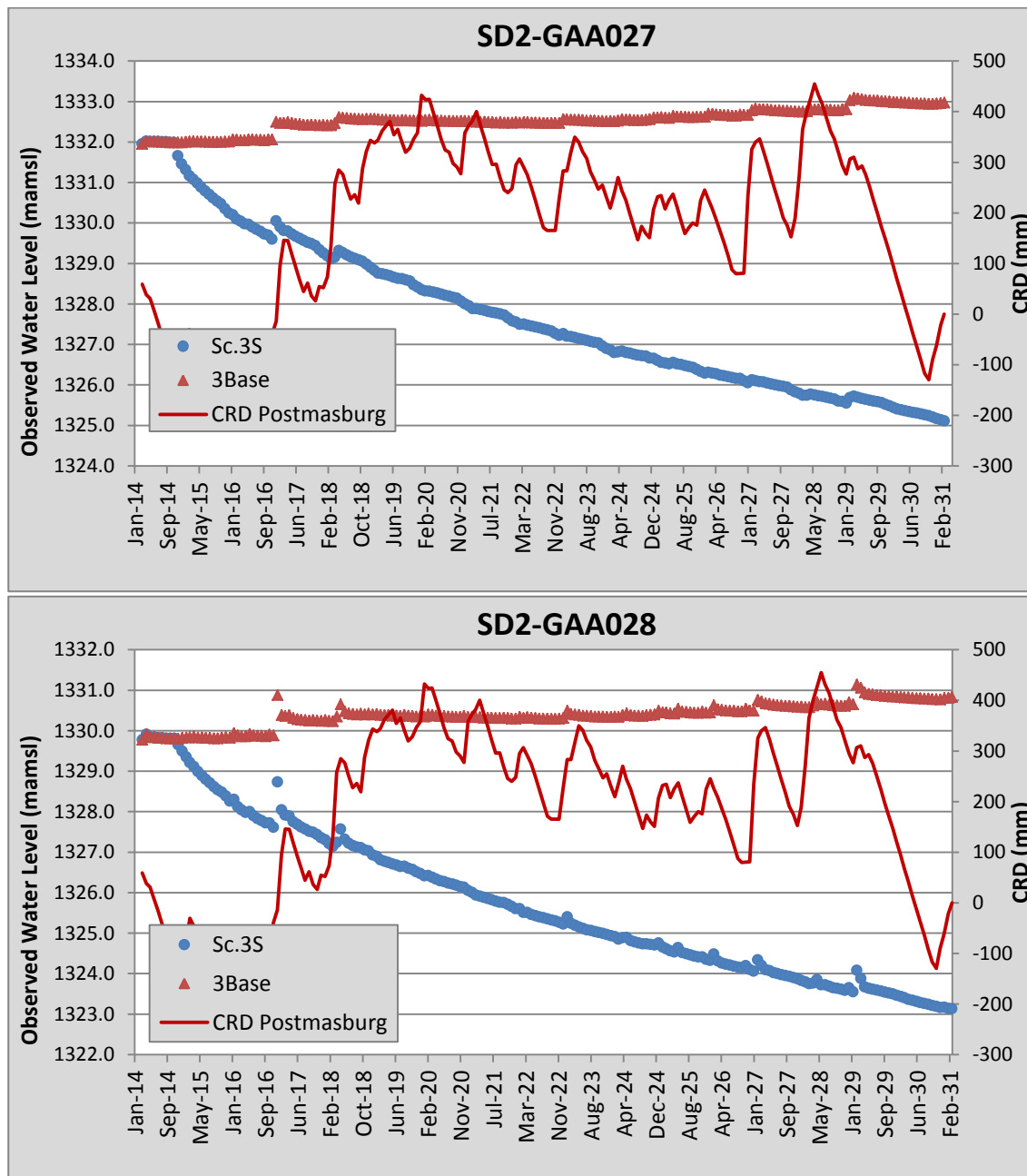
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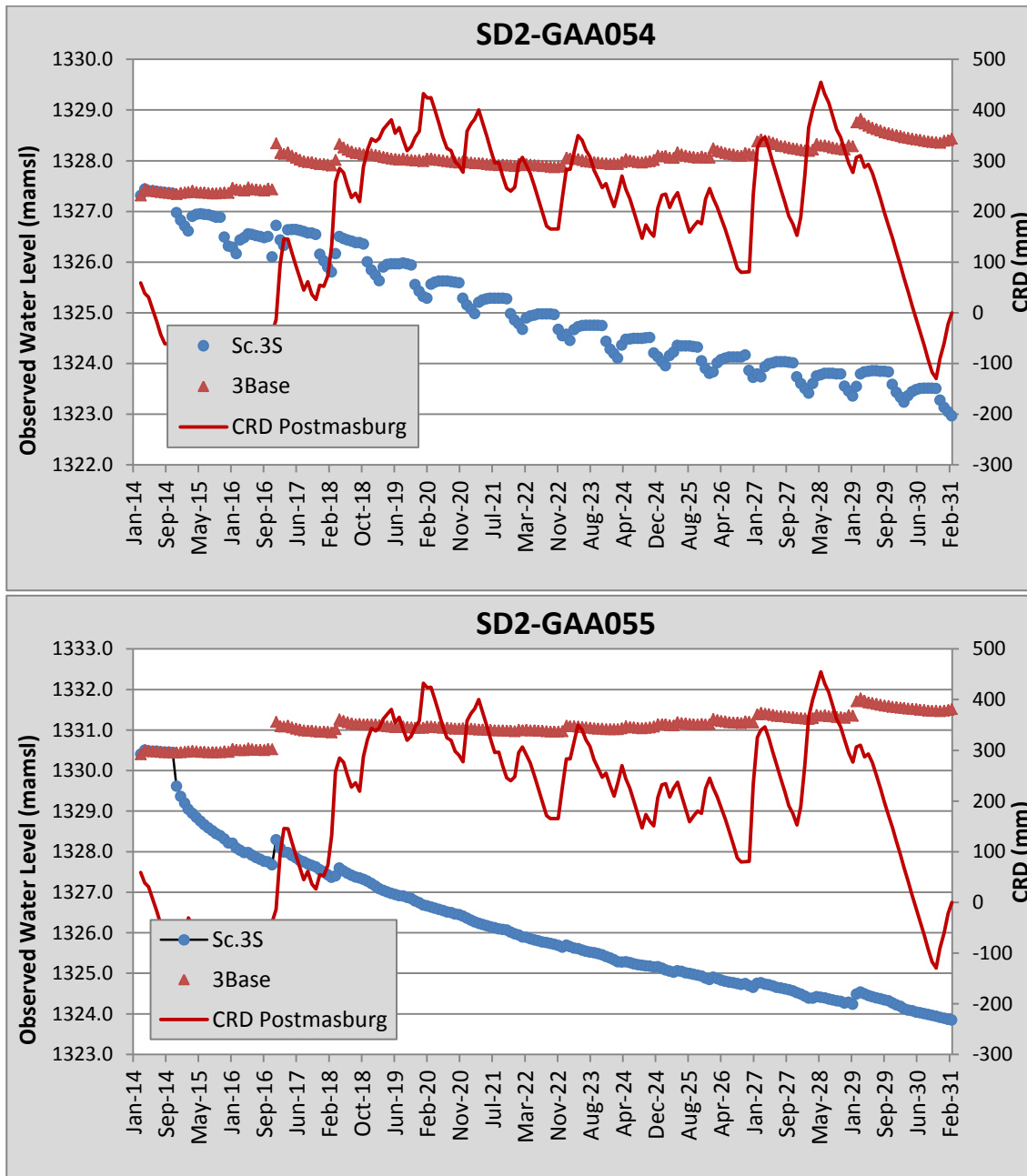
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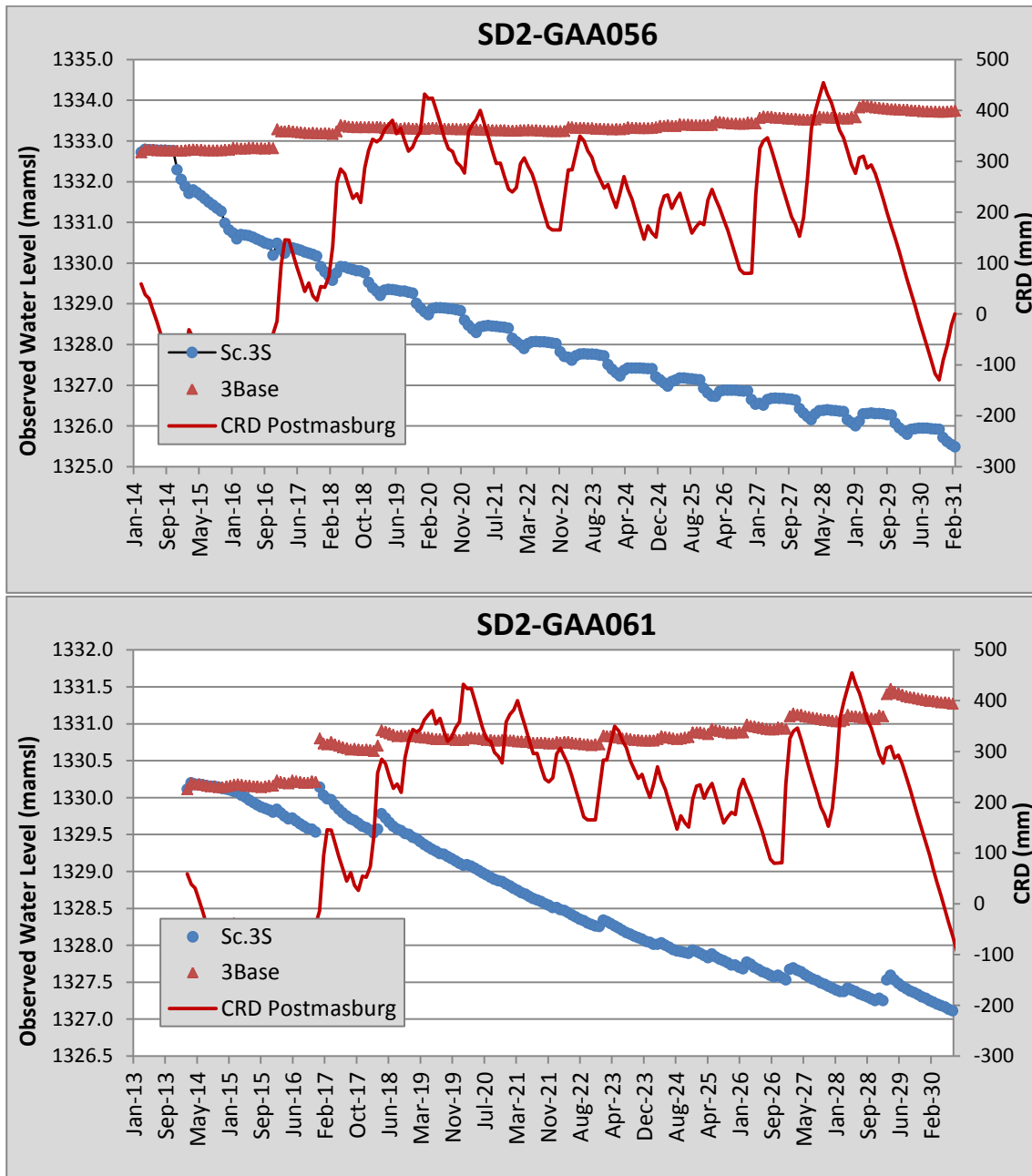
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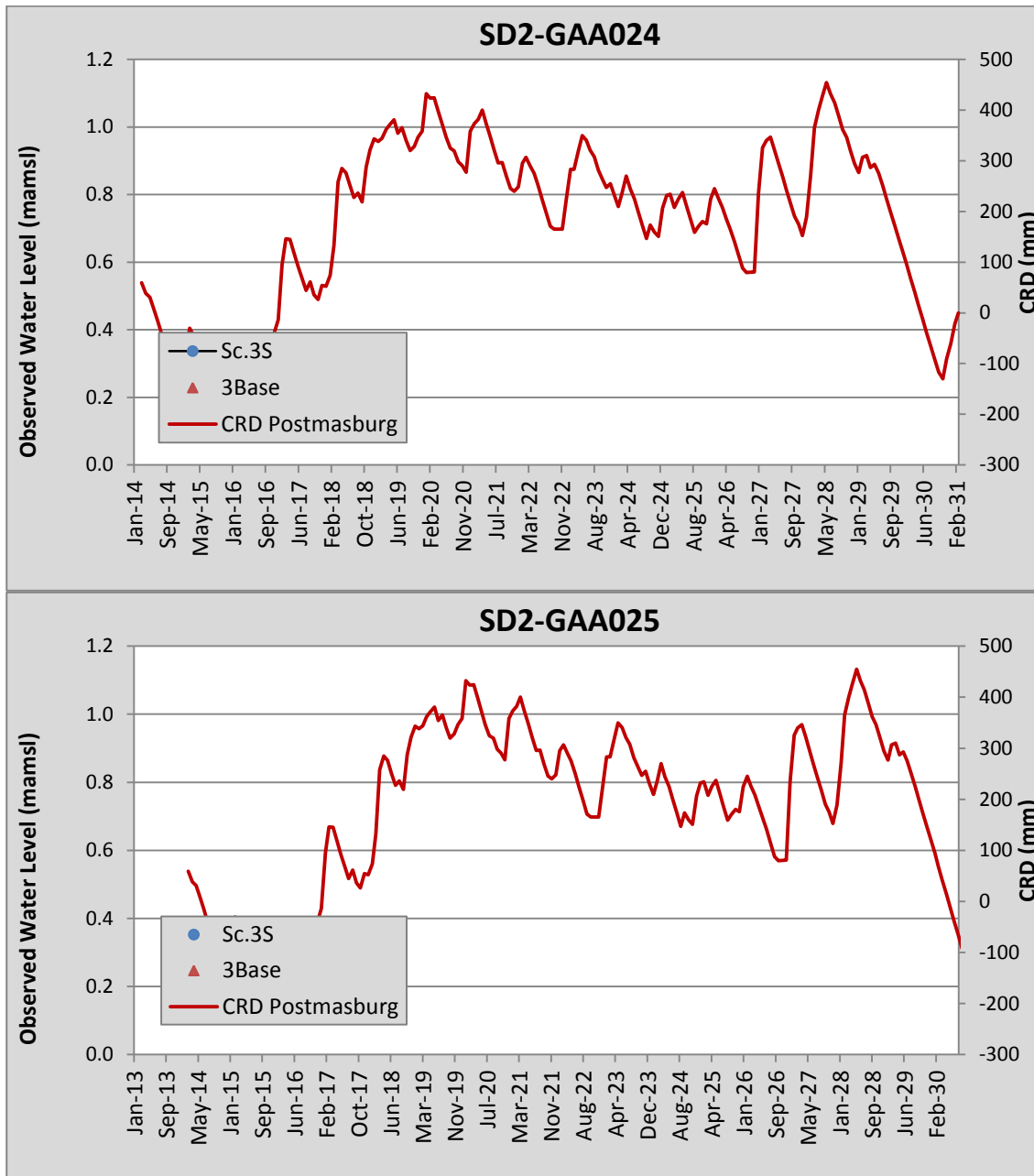
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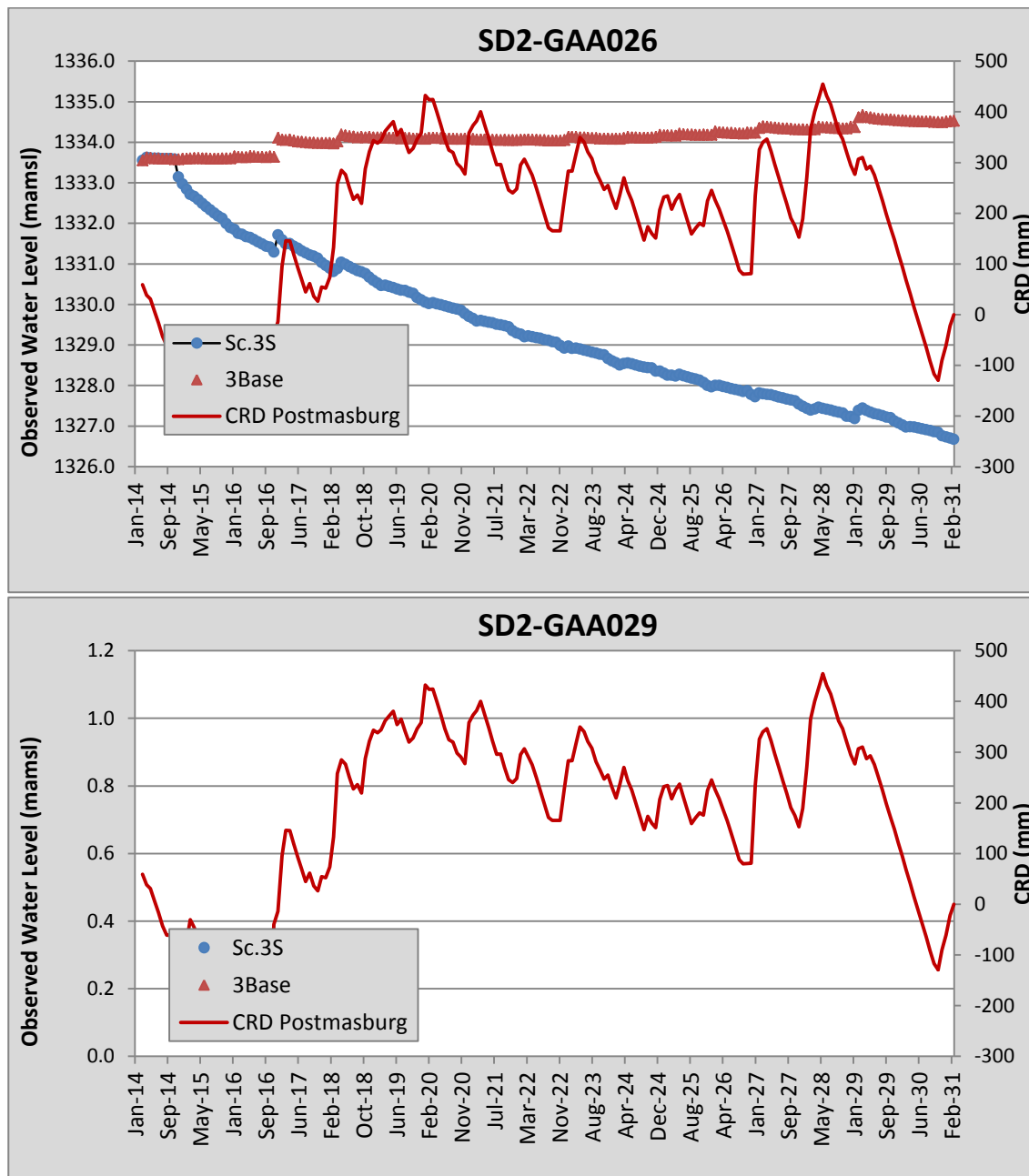
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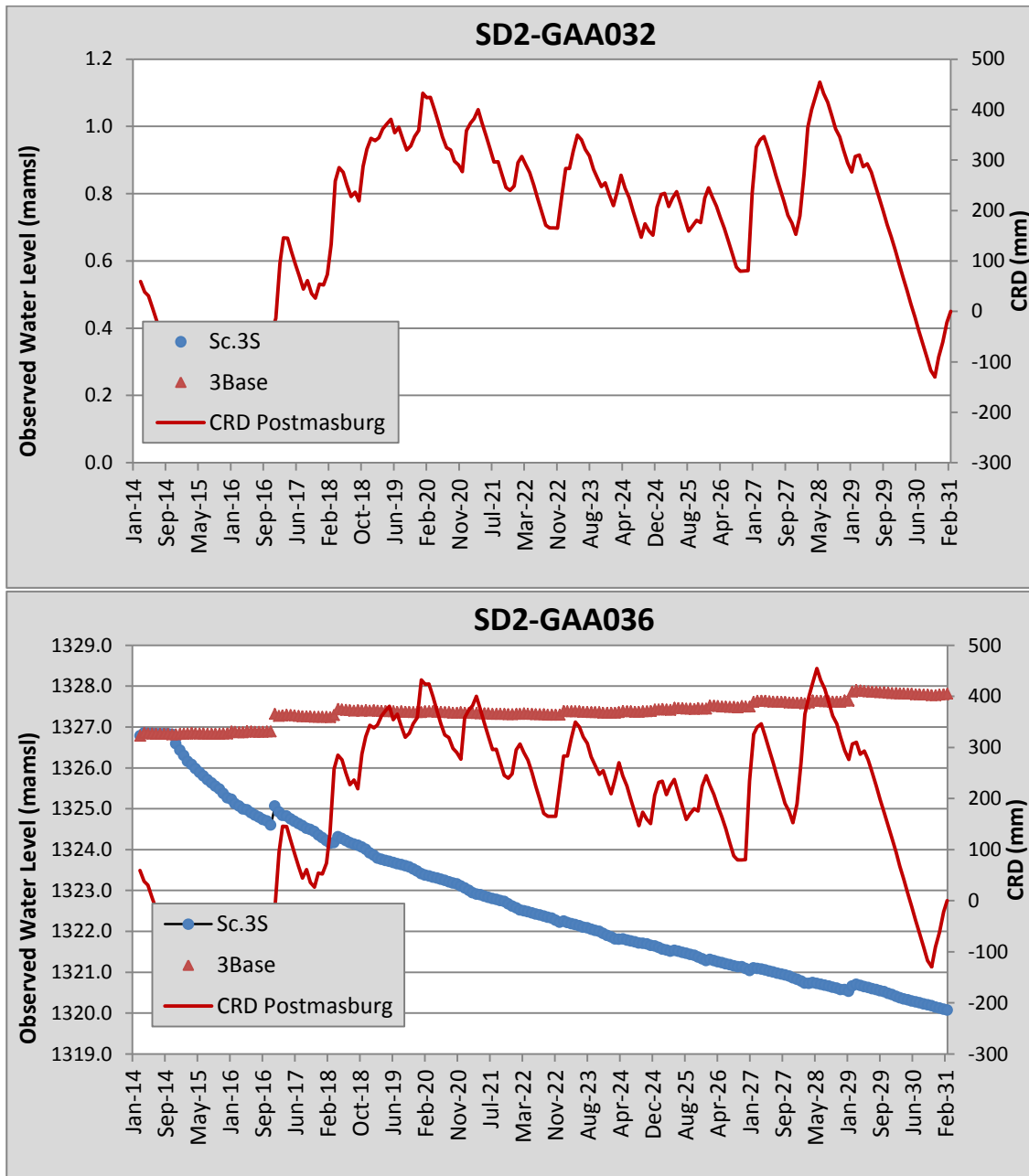
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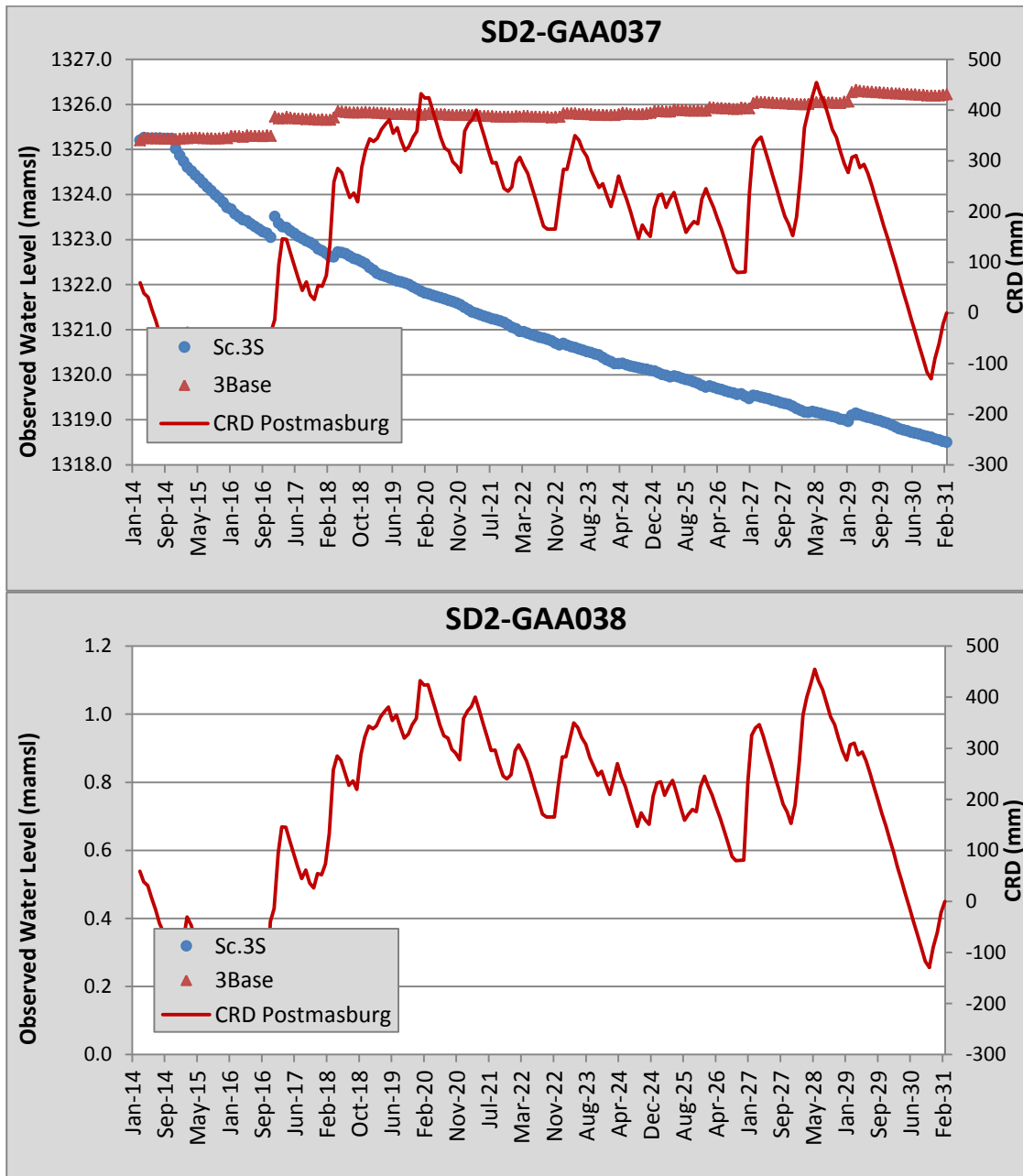
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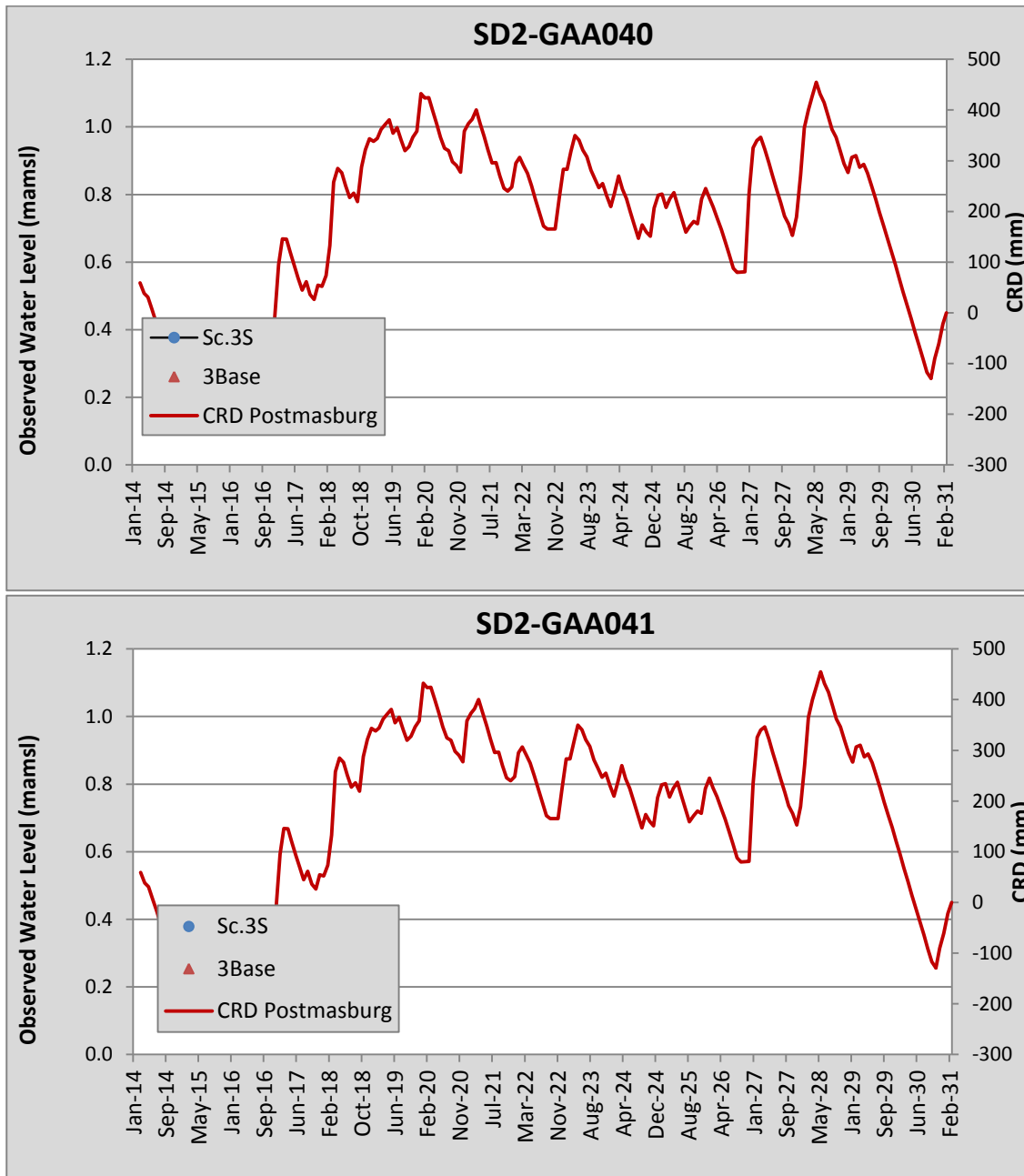
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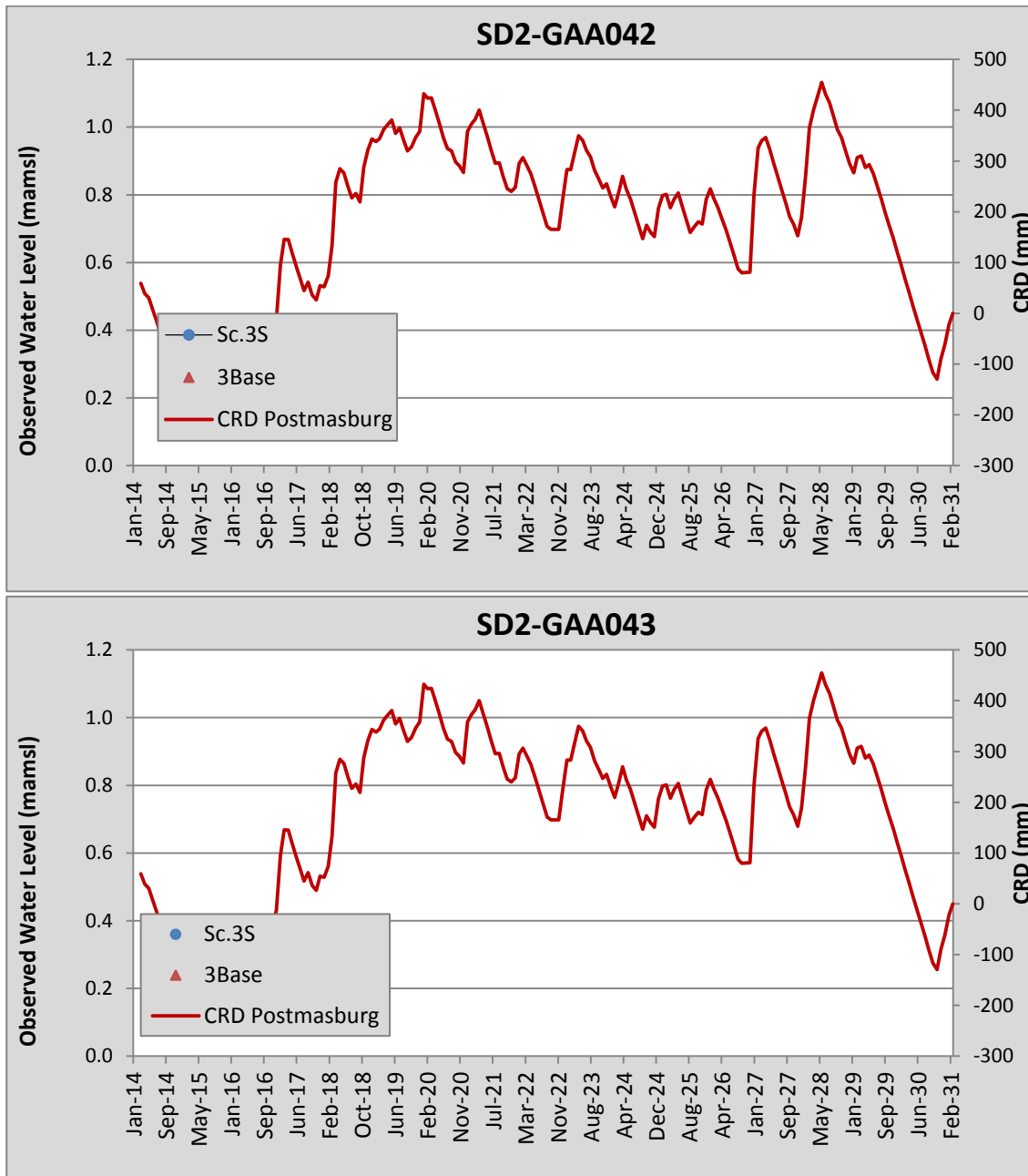
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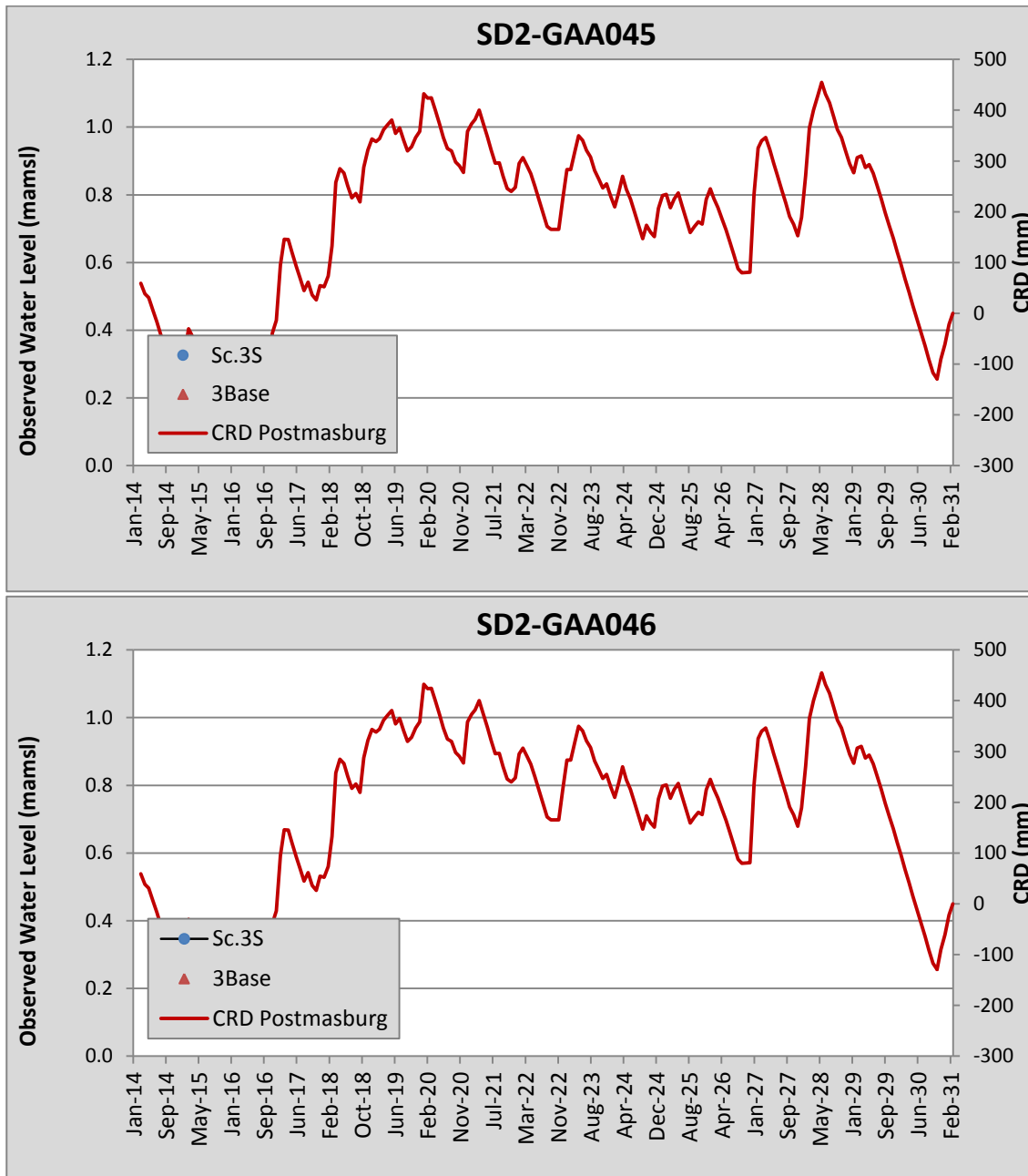
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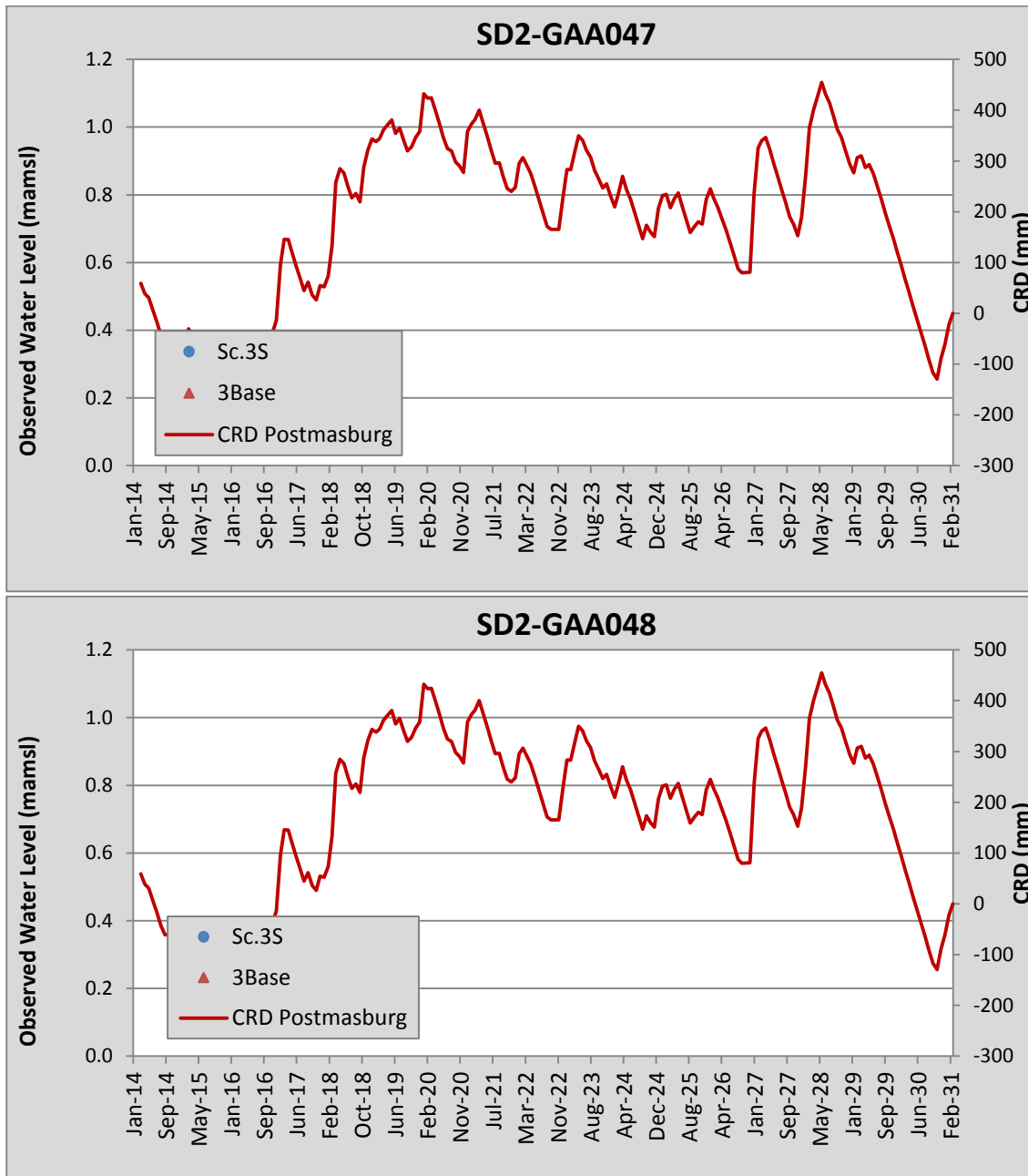
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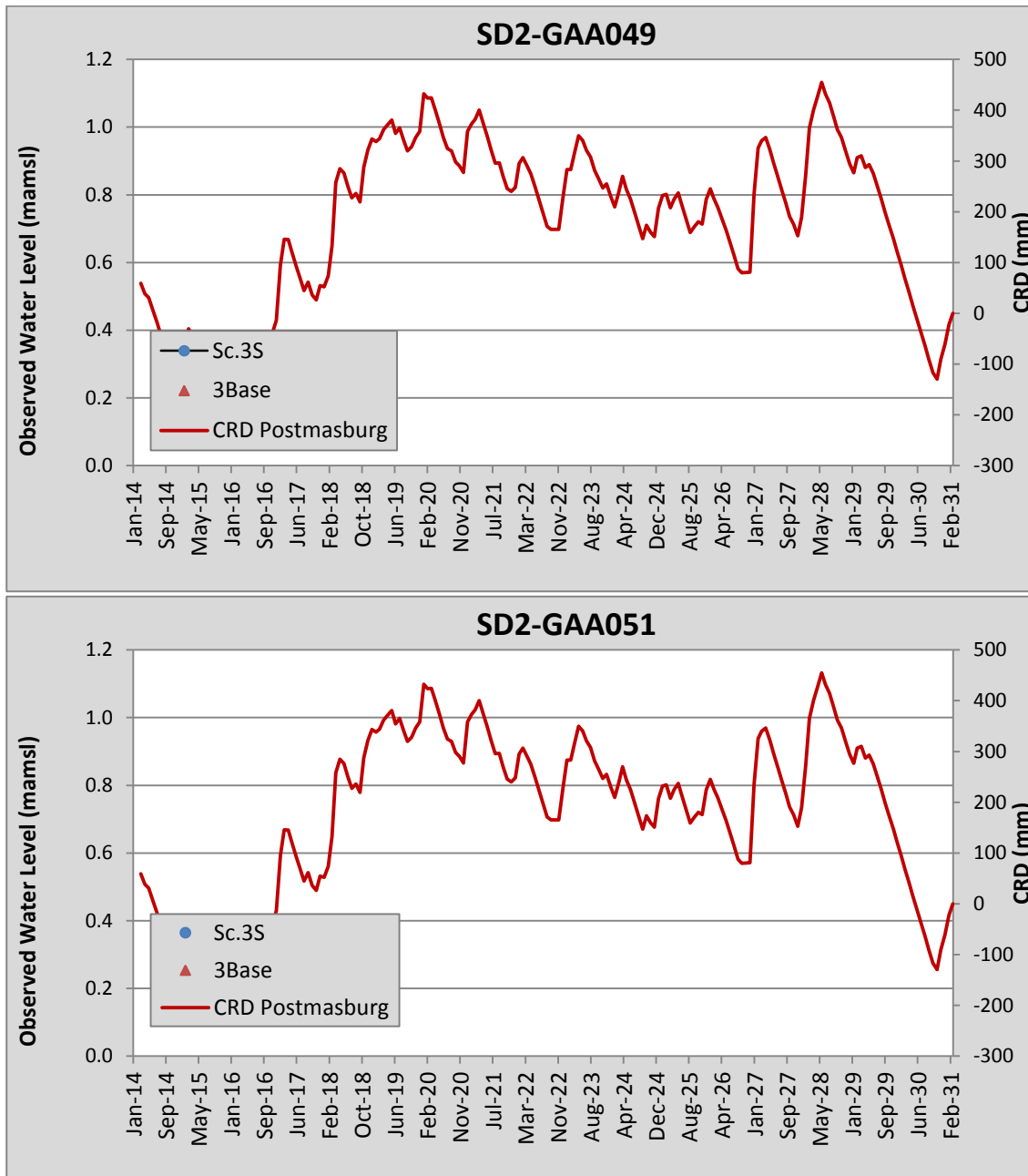
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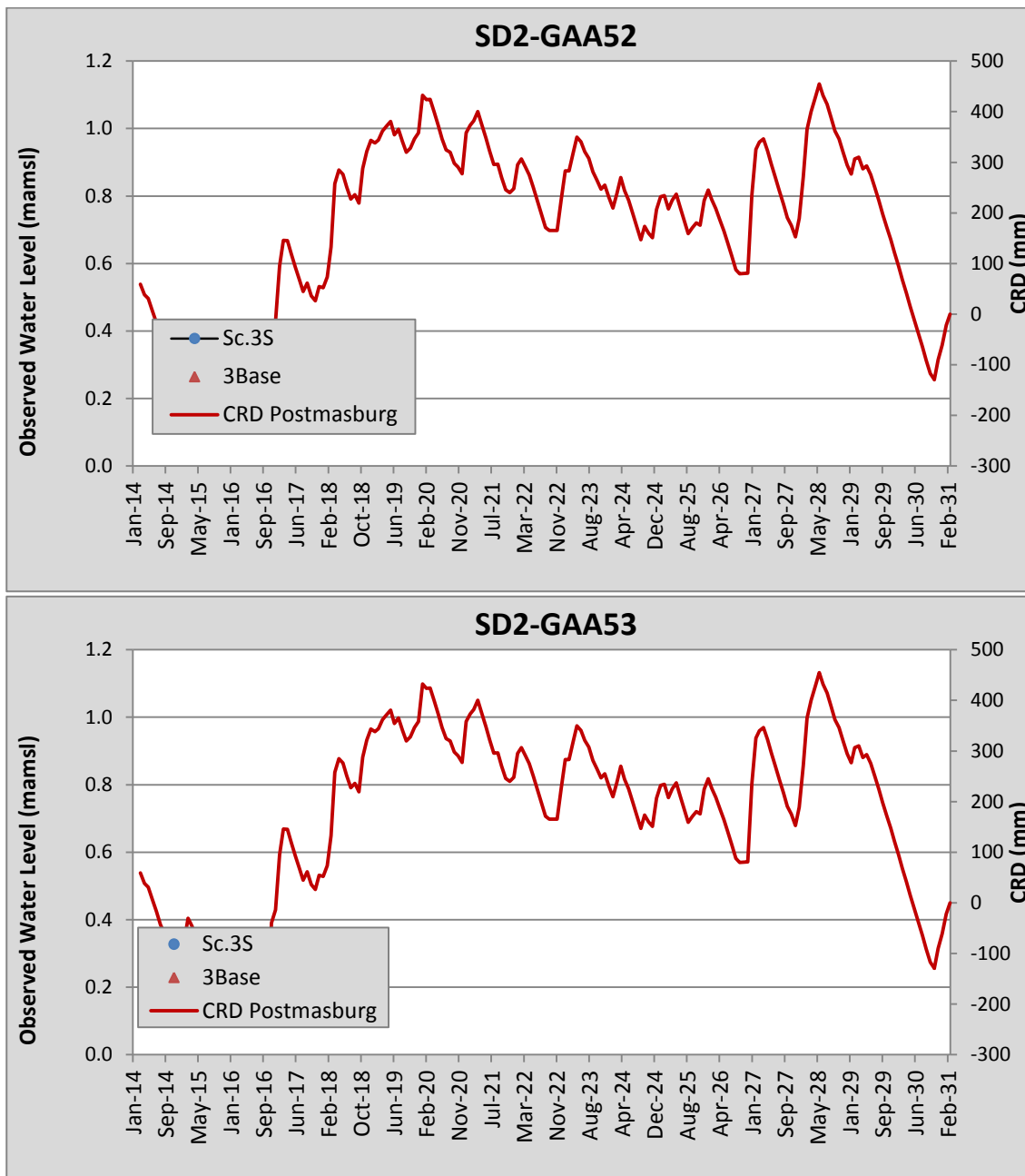
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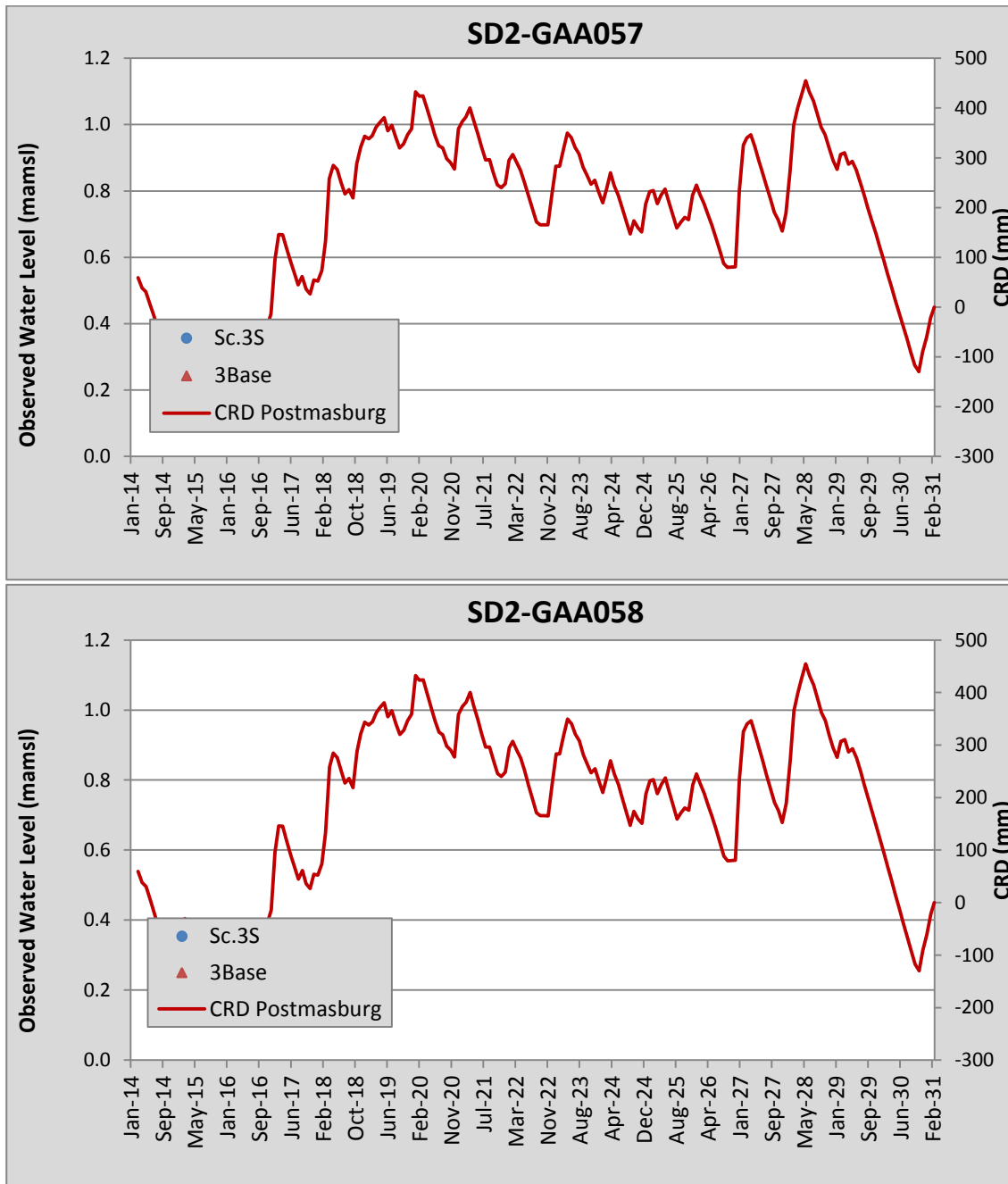
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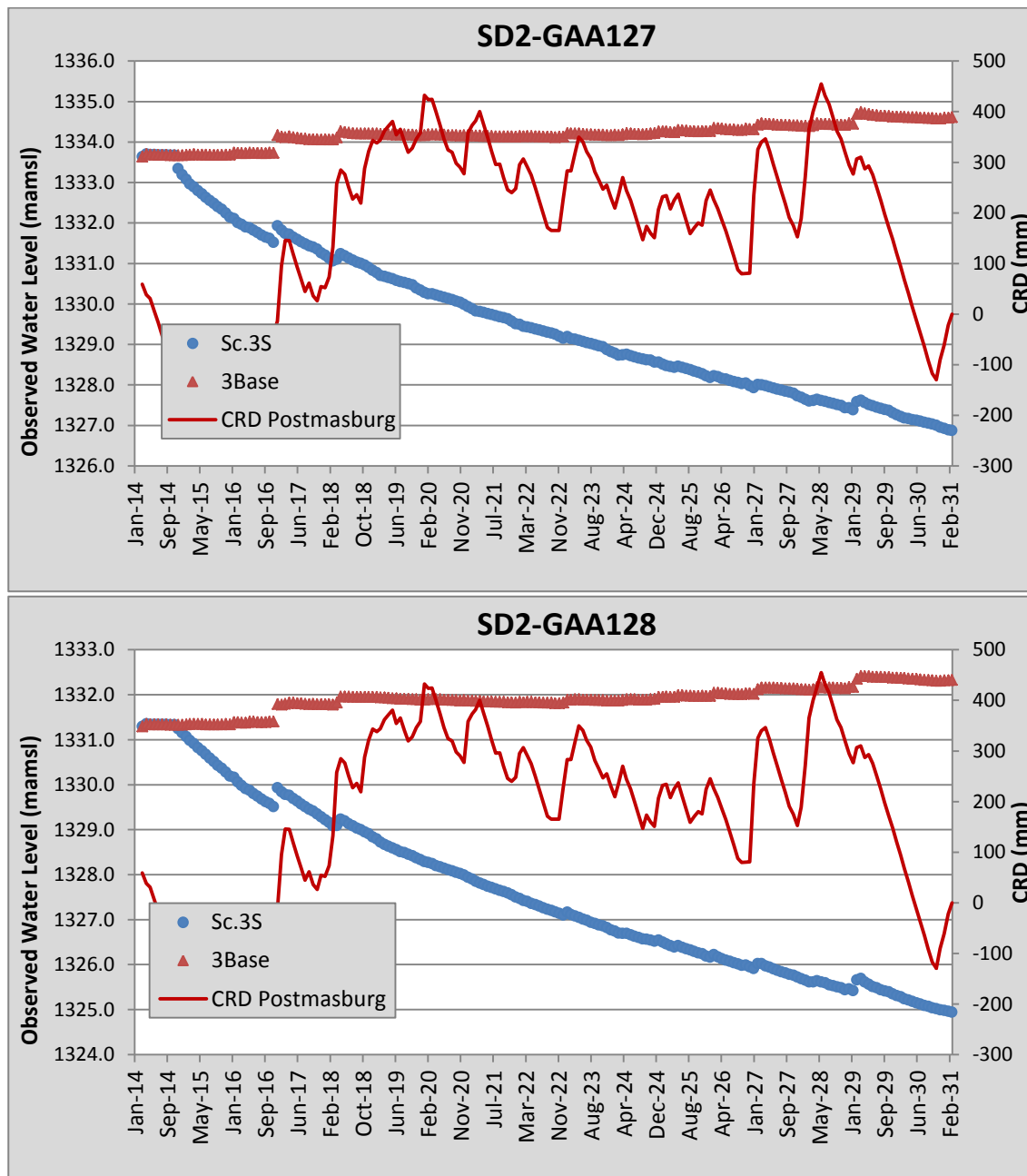
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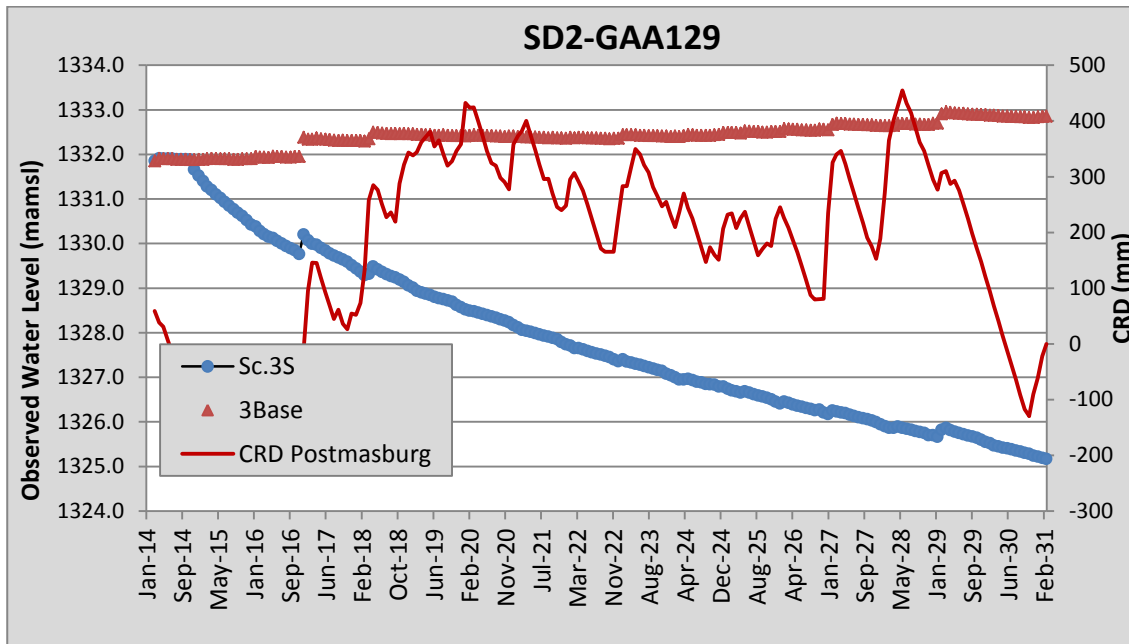
VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I





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VAAL GAMAGARA PIPELINE GROUNDWATER STUDY - VOLUME I





APPENDIX D

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