water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF WATER AND SANITATION

THE EVALUATION REPORT FOR GROENKLOOF BOREHOLES

AT

PRETORIA AREA

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TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND ACRONYMS

ARC	Agricultural Research Commission
BH	Boreholes
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
GIS	Geographical Information System
M	Meter
MM	Millimetre
NGA	National Groundwater Archive
SAWS	South African Weather Services

BOREHOLE EVALUATION REPORT

GROENKLOOF BOREHOLES – PRETORIA AREA

Visited on the *05/07/2017* by *Mmako Lesiba, Mashigo Patrick, Soldaat Solomon and Mathe Albert*

1. General Information

The baseline monitoring boreholes are situated within the Groenkloof Nature Reserve. The area is located approximately 3 km south Pretoria along the R21 provincial road to Kempton Park. The hydrogeological conditions within this area are pristine due to less or no human activities on the ground surface. The upper Apies River is crossing the Groenkloof Area (*see the figure 2*). The river is part of the Apies/Pienaars sub-management area. The sub-catchment area comprises of the Apies and Pienaars Rivers which are flowing the north westerly direction towards the confluence with the Crocodile River.

There are five DWS boreholes (geo-sites) actively being monitored on a monthly basis within the Groenkloof Nature Reserve. These boreholes monitored only water level (quantity) not quality due to lack of equipments that collect the groundwater samples accurately. The aim for drilling these boreholes was to gather baseline information, and ensure that groundwater resource monitoring network is adequately represented. The boreholes are monitoring on South Africa's main groundwater resources which the dolomite aquifer. Groundwater usage in 1995 was estimated to amount to 21.9 million m^3; this is mostly abstraction for urban supply from the aquifer in the Centurion area and irrigation abstraction in the Bapsfontein and Tarlton areas (*DWAF[1], 2006*).

The topographic gradient/slope within the reserve range from 1440 m on the upper reach to 1370 m on the lower reach. The groundwater movement in this area is north westerly direction towards (*see figure 6 & 7*) to the Apies River following the ground surface gradient. There are other boreholes within the 5 km radius at Centurion, Valhalla, Voortrekker and Zwartkop Nature Reserve, monitoring the dolomite aquifer but the groundwater drainage flow the opposite direction.

Latitude	-25.797327° S
Longitude	28.206661° E
Elevation	1400 m
Functional Since	*01/01/1984*

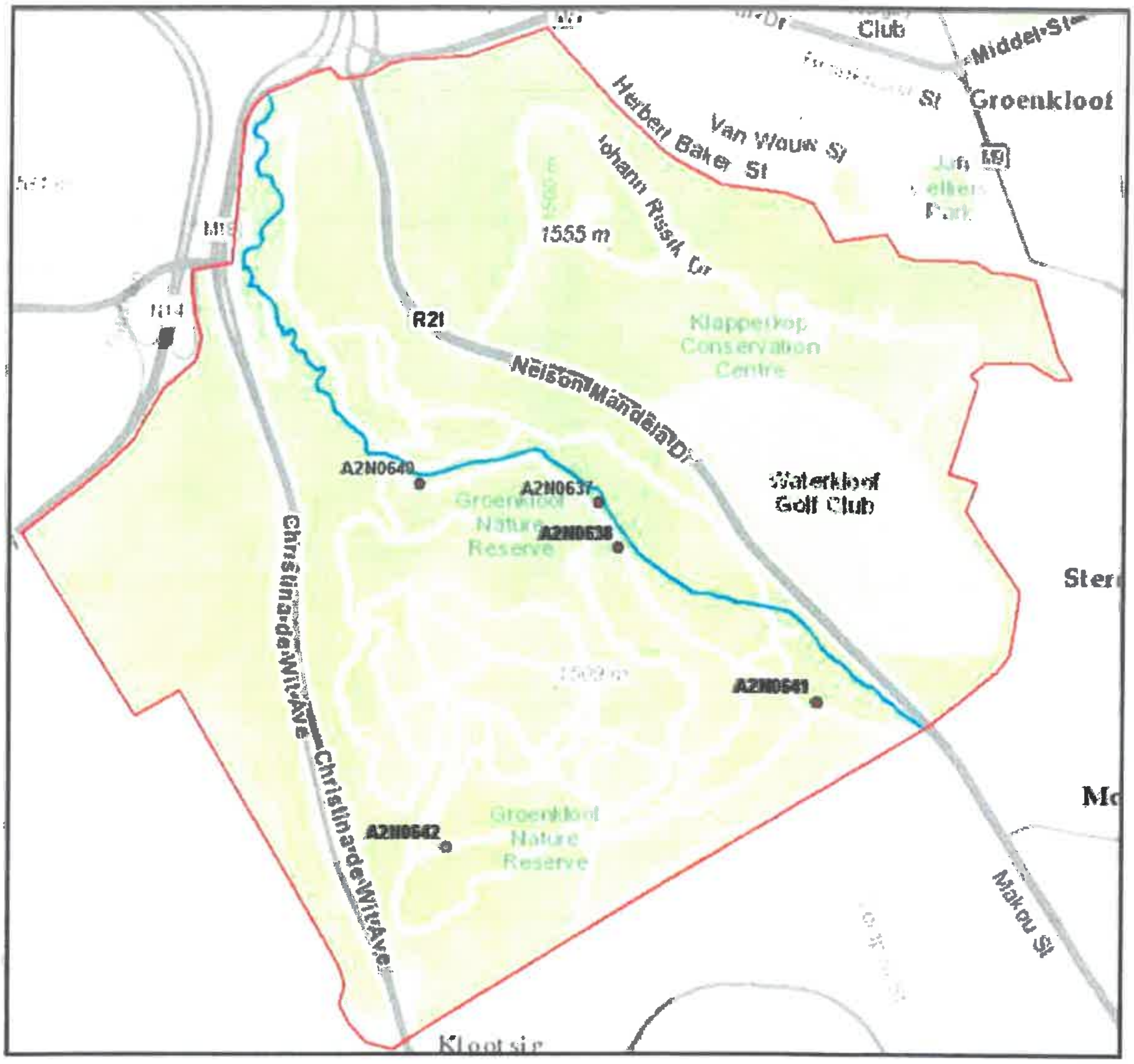

Figure 1: GIS map locality of boreholes within Groenkloof Nature Reserve.

Figure 2: Google earth map of boreholes within Groenkloof Nature Reserve

2. Geology

The area is underlain by dolomites rock belongs to the Malmani Subgroup of the Transvaal sequence. They comprise of four Formations (Eccles, Lyttelton, Monte Christo & Oakree), with the subdivision being on the basis on the chert content and type of algal structures. The chert-rich formations form the main aquifers (*DWAF*[2], *2006*).

The Malmani dolomite

Supergroup	Group	Subgroup	Formation	Thickness (m)	Description
Transvaal	Chunniespoort	Malmani	Eccles (Vme)	~ 380	Chert-rich, dark coloured dolomite with stromatolites and oolitic bands. Chert content increases to top
			Lyttelton (Vml)	~150	Chert-free, dark-coloured dolomite with large stromatolitic mounds
			Upper Monte Christo (Vmm)	~258	Chert-rich dolomite
			Middle Monte Christo (Vmm)	~162	Chert-poor dolomite
			Lower Monte Christo (Vmm)	~275	Chert-rich dolomite
			Oaktree (Vmo)	~200	Chert-poor dolomite with interlayered carbon-rich shale towards the base
			Black Reef (Vbr)	~30	Basal conglomerate and quartzite with interlayered carbon rich shale

Figure 3: Showing the subdivision and lithostratigraphy of the Malmani Subgroup (*DWAF[1], 2006*).

The dolomite is underlain by the Black Reef Formation (shale, impure quartzite and conglomerate) and overlain by the Pretoria Group (shale, siltstone, conglomerate in places and quartzite). The area has cross-cutting lineaments such as faults and dykes. The dykes are mostly not 100% impermeable but are at least several orders of magnitude less permeable (*DWAF[2], 2006*).

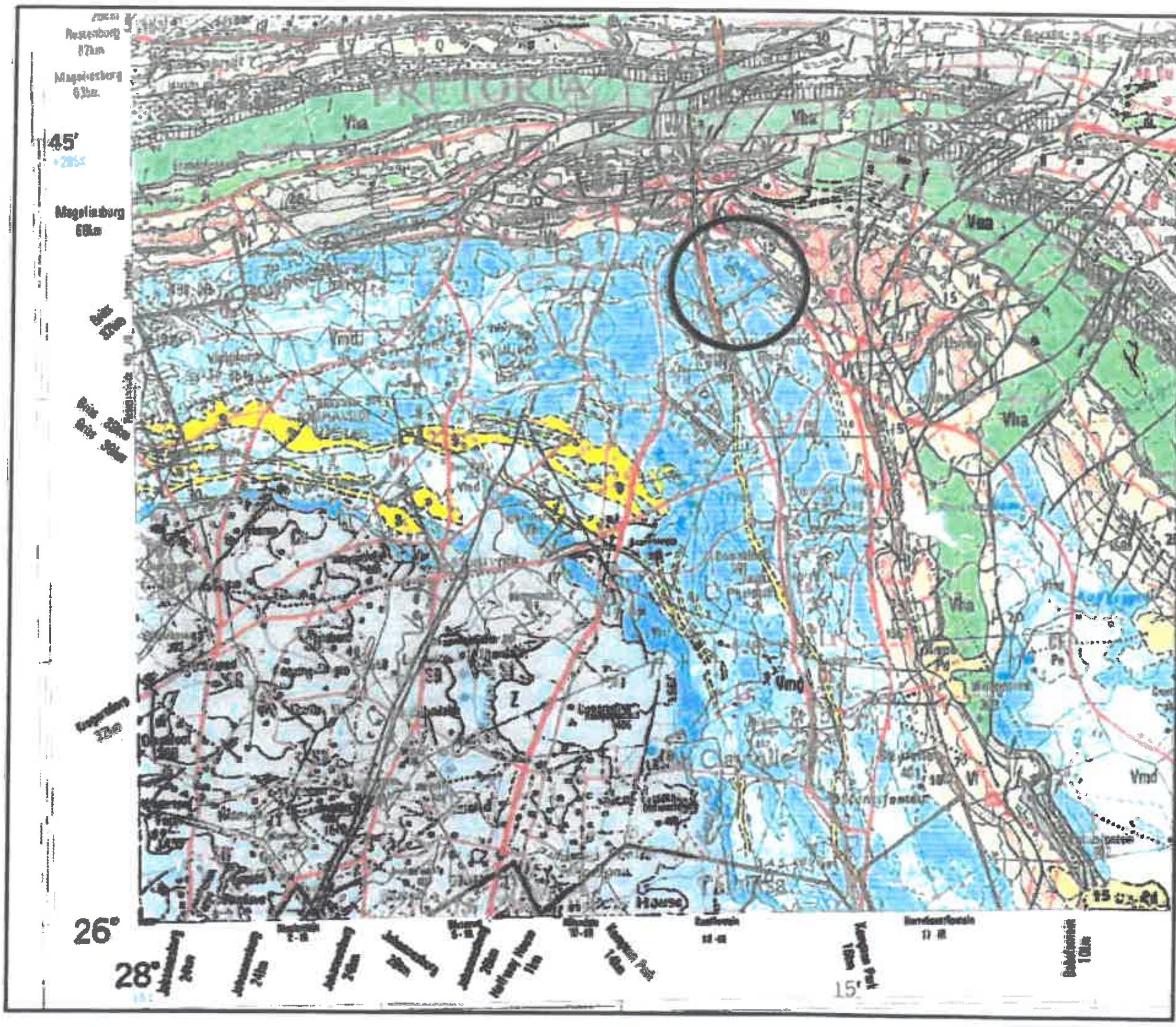

Figure 4: Showing the geology of the dolomite rock (light blue) within Groenkloof Nature Reserve (*sourced: a 1:250 000 geological map*)

3. Geohydrology

The dolomite has a relatively low primary permeability but the development of aquifer (karstic) features such as faults, joints and bedding planes, is through weathering of the carbonate rock (*DWAF[1], 2006*). The secondary fissures provided easy access to circulating groundwater and thus promoting deep weathering of the dolomite, largely by carbonate solution or karstification. The residues of this weathering are mainly brown clays and wad with chert rubble and boulders. The depth of weathering deposits varies up to ~150 m but is very unpredictable and pinnacles of fresh dolomite are common place adjacent to deeply weathered zones (*DWAF[2], 2006*). The rainwater dissolves atmospheric carbon dioxide to form a weak carbonic acid. The acid rain infiltrates and percolates through the fractures and bedding planes and dissolves the dolomite on its way through.

The flow direction seepage is downward towards the water table where the follows the topography towards the natural outlets such as river, spring, lakes or ocean (*DWAF[1], 2006*).

Groundwater in the dolomite aquifer is generally characterised by the major dissolved elements, Ca^{2+}, Mg^{2+} and HCO_3^-, where half of the HCO_3^- is balanced by Ca^{2+} and half by Mg^{2+}, and ultimately coming into equilibrium with calcite and dolomite. Dolomite groundwater is characterised by a consistent composition of $CaCO_3$ and $MgCO_3$ (*DWAF[1], 2006*). Transmissivity (T) values were not found National Groundwater Archive (NGA), but T is very variable in the dolomite, ranging from nearly impervious to ~ 30 000 m^3/day/m. The storage capacity from literature however is 15% for the first 30 m and from 30 m to 150 m is 1.5%. Borehole yields can be > 40 ℓ/s from boreholes up to 250 m deep. The average borehole yields vary from 2 – 10 ℓ/s. Water tables vary from < 10 m to 50 m (*DWAF[2], 2006*).

Table 1: Showing geological log of the Groenkloof boreholes *(sourced: from NGA)*.

A2N0637		A2N0638		A2N0640		A2N0641		A2N0641	
Depth (m)	Lithology	Depth (m)	Lithology	Depth (m)	Lithology	Depth (m)	Lithology	Depth (m)	Lithology
0.00	Soil	0.00	Chert	0.00	Soil	0.00	Soil	0.00	Soil
7.00	Soil	9.00	Chert	3.00	Chert	6.00	Chert	7.00	Chert
12.00	Chert	11.00	Chert	28.00	Chert	10.00	Chert	10.00	Dolomite
21.00	Chert	13.00	Chert	63.00	Chert	19.00	Chert	23.00	Dolomite
23.00	Chert	15.00	Chert	70.00	Chert	22.00	Chert	81.00	Dolerite
35.00	Chert	40.00	Chert			25.00	Dolomite		
42.00	Chert	48.00	Chert			33.00	Dolomite		
47.00	Chert	53.00	Chert			37.00	Dolomite		
66.00	Chert	58.00	Chert			39.00	Dolomite		
69.00	Chert	70.00	Chert			51.00	Dolomite		
80.00	Dolomite					57.00	Dolomite		
						68.00	Dolomite		
						114.00	Dolomite		
						119.00	Dolomite		
						146.00	Dolomite		
						148.00	Dolomite		

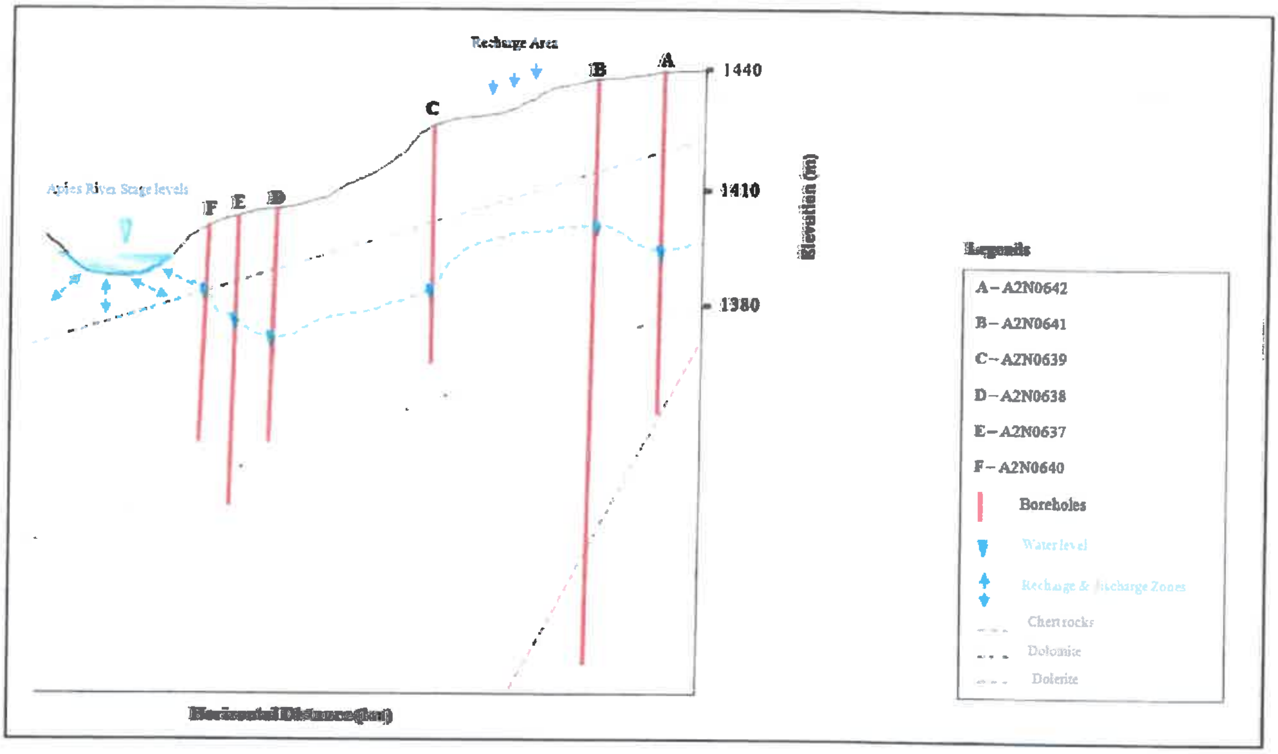

Figure 5: Showing the conceptual groundwater model of the Groenkloof system (*DWS, 2016*).

The conceptual model was derived from the geological profile log data, monthly groundwater level data, 1:250 000 geological map and literature survey (*DWS, 2016*). Normally the local rainfall (depending on the intensity) will land on the ground surface and then infiltrate into the soil where some of the water will exfiltrate through evapotranspiration, move laterally or percolate. The percolated water will flow downward towards the water table where it will follow the topographic landscape and discharge into the Apies River through the fractures, joints and bedding planes. The Apies River can be a feeding stream during rainy months but the most of the time it gain flow through groundwater discharge.

Table 2: Showing groundwater level data of the Groenkloof boreholes.

STATION NUMBER	AREA	DATE	ELEVATION (M)	GROUNDWATER LEVEL (M)
A2N0637	Groenkloof - Pretoria	05/07/2017	1400	-21.770
A2N0638	Groenkloof - Pretoria	05/07/2017	1410	-33.100
A2N0640	Groenkloof - Pretoria	05/07/2017	1390	-8.730
A2N0641	Groenkloof - Pretoria	05/07/2017	1430	-50.370
A2N0642	Groenkloof - Pretoria	05/07/2017	1440	-57.090
A2N0639 (closed)	Groenkloof - Pretoria	05/07/2017	1420	-46.340

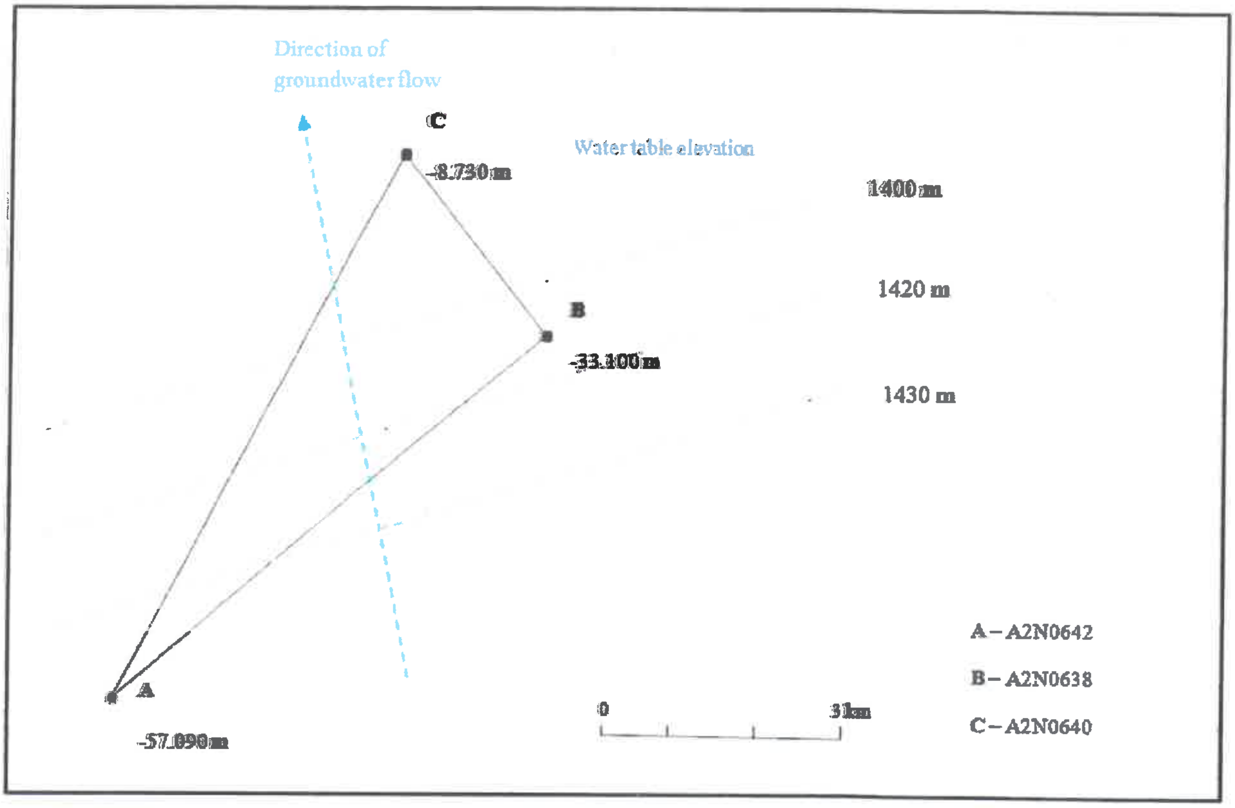

Figure 6: Showing the groundwater flow direction within the Groenkloof Nat. Res. ***(Simonis et al. 2011).***

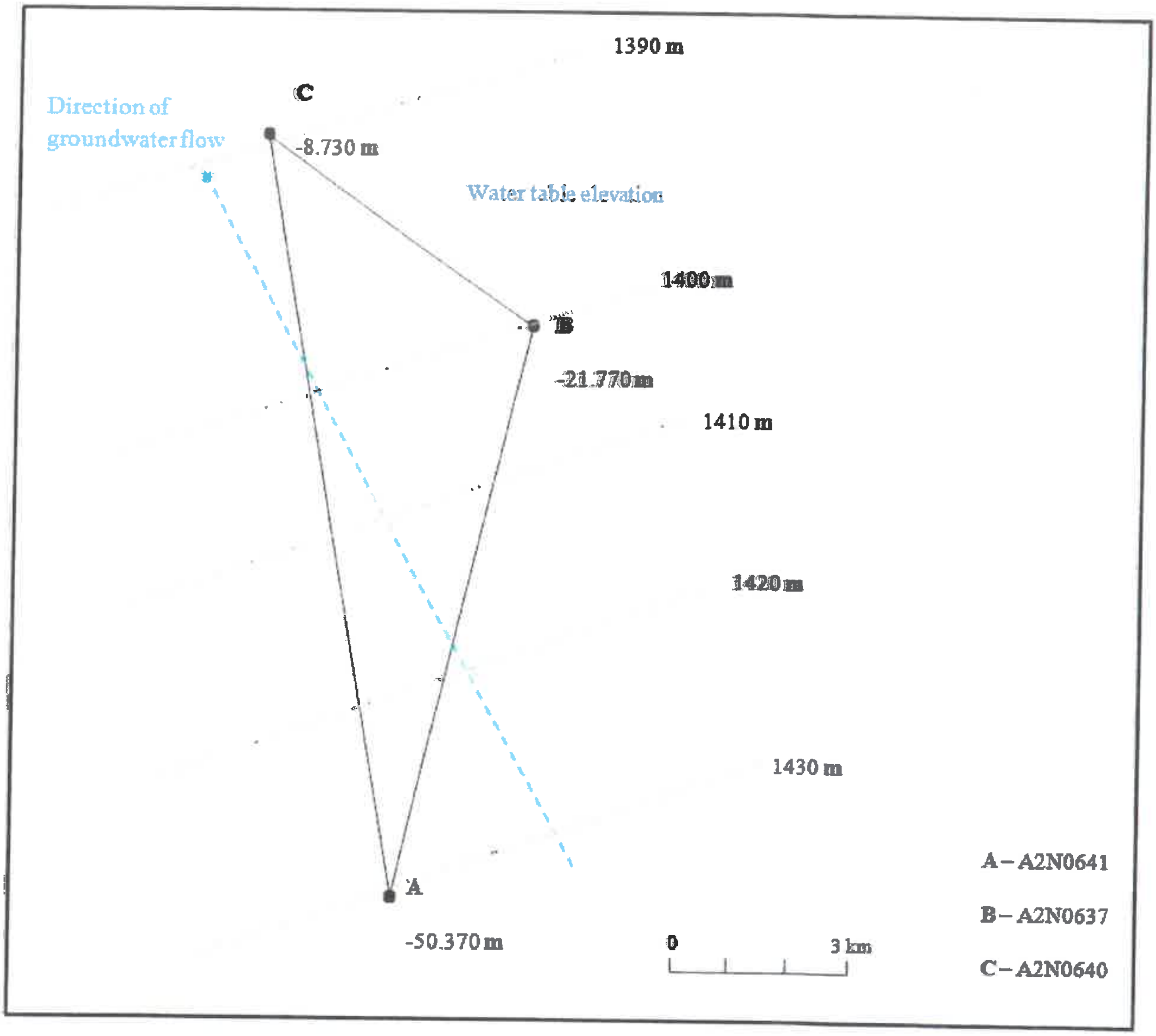

Figure 7: Showing the groundwater flow direction along the floodplain of Apies River. *(Simonis et al. 2011).*

Table 2 was used to construct a graphical method for determining the direction of groundwater flow from three groundwater level measurements. The procedure is to first to relate the field groundwater levels to a common datum (elevation) and then plot their position on the plan. Next, draw lines between the three groundwater level measurements and divide into a number of short, equal lengths in proportion to the difference in elevation at each end of the line. The next step is to join points of equal elevation on each of the lines and then to select a contour interval which is appropriate to the overall variation in water levels in the mapped area (here was 10 m in both maps). The direction of groundwater flow in the dolomatic aquifer was drawn at right angles to the contour lines on the potentiometric surface in the direction of decreasing hydraulic head.

4. Boreholes

The boreholes within Groenkloof Nature Reserve monitor groundwater level in the pristine environment. The construction of the boreholes is durable and reliable since it lasted for more than three decades. There are currently no instrumentation installed inside the wells. Due to the fact that the dolomite is unstable the boreholes were cased of the way down with a steel pipe casing *(see table 3)*. The casing are sealed on top (except A2N0639) with a small holes to allow the dip meter probe inside, however A2N0641 and A2N0642 have a steel cap on top (*see photo 4 & 5*). The sealed top is very important since it prevent termites from building shelter inside the wells. The surface casings are painted on regular basis by the Boskop-Hydrometry maintenance team in order to avoid rusting. The sanitary seal of concrete mixture was used to supports the sides of the holes and protecting water from contamination.

Table 3: Showing construction and well design information of the Groenkloof boreholes *(sourced from NGA)*.

STATION NUMBER	DATE	CONSTRUCTION METHOD	WATER STRIKES DEPTH (M)	AQUIFER	SURFACE CASING	CASING DIAMETER
A2N0637	07/09/1984	Rotary Air Percussion	39	Chert	Steel pipe casing	356 mm up to 72 m deep
			45	Chert		250 mm from 72 m to 100 m
			66	Chert		
			75	Chert		
A2N0638	25/09/1984	Rotary Air Percussion	53	Chert	Steel pipe casing	356 mm up to 96 m deep
			57	Chert		250 mm from 96 m to 104 m
			84	Chert		
			93	Dolomite		
			97	Dolomite		
A2N0639	13/03/1984	Rotary Air Percussion	No record	Chert	Steel pipe without a cap	250 mm up to 76 mm deep
A2N0640	02/12/1984	Rotary Air Percussion	No record	Chert	Steel pipe casing	406 mm up to 34 m deep
			No record	Chert		356 mm from 34 m to 49 m
			No record	Chert		254 mm from 49 m to 69 m
			No record	Chert		250 mm from 69 m to 76 m
A2N0641	30/11/1984	Rotary Air Percussion	No record	Dolomite	Steel pipe casing	406 mm up to 26 m deep
			No record	Dolomite		324 mm from 26 m to 84 m
			No record	Dolomite		219 mm from 84 m to 90 m
A2N0642	27/12/1984	Rotary Air Percussion	No record	Dolomite	Steel pipe casing	405 mm up to 77 m deep
			No record	Dolerite		356 mm from 77 m to 105 m
			No record	Dolerite		150 mm from 105 m to 130 m

Photo 1: View of the A2N0637 borehole site.

Photo 2: View of the A2N0638 borehole site.

Photo 3: View of the A2N0640 borehole site.

Photo 4: View of the A2N0641 borehole site.

Photo 5: View of the A2N0642 borehole site.

Photo 6: View of the closed borehole site.

5. Data

5.1. Water Quality Data

Currently Gauteng region lack equipments to collect groundwater samples, therefore groundwater quality status at this area is unknown. There also no records in the National Groundwater Achieve (NGA) database. However there are groundwater quality records from research (literature) done by the collaboration of DWAF (now DWS) and consultants (Golder Associates, SRK consulting etc.). But the study focused on the mining areas of Johannesburg, Cartonville, Potchefstroom, Orange Farm and Ventersdrop town.

5.2. Groundwater Level Data

Groundwater measurement is collected on monthly basis by the Boskop-Hydrometry using a water level dipper. The hydrograph below were obtained from Hydstra databank. From the hydrographs it is clear that the monitoring frequency was very poor in the 1980s and 90s. It was improved from late 90s to date; perhaps this was due to lack of resources (e.g. vehicle, trained personnel, etc.) and knowledge about groundwater. The boreholes are very good conditions.

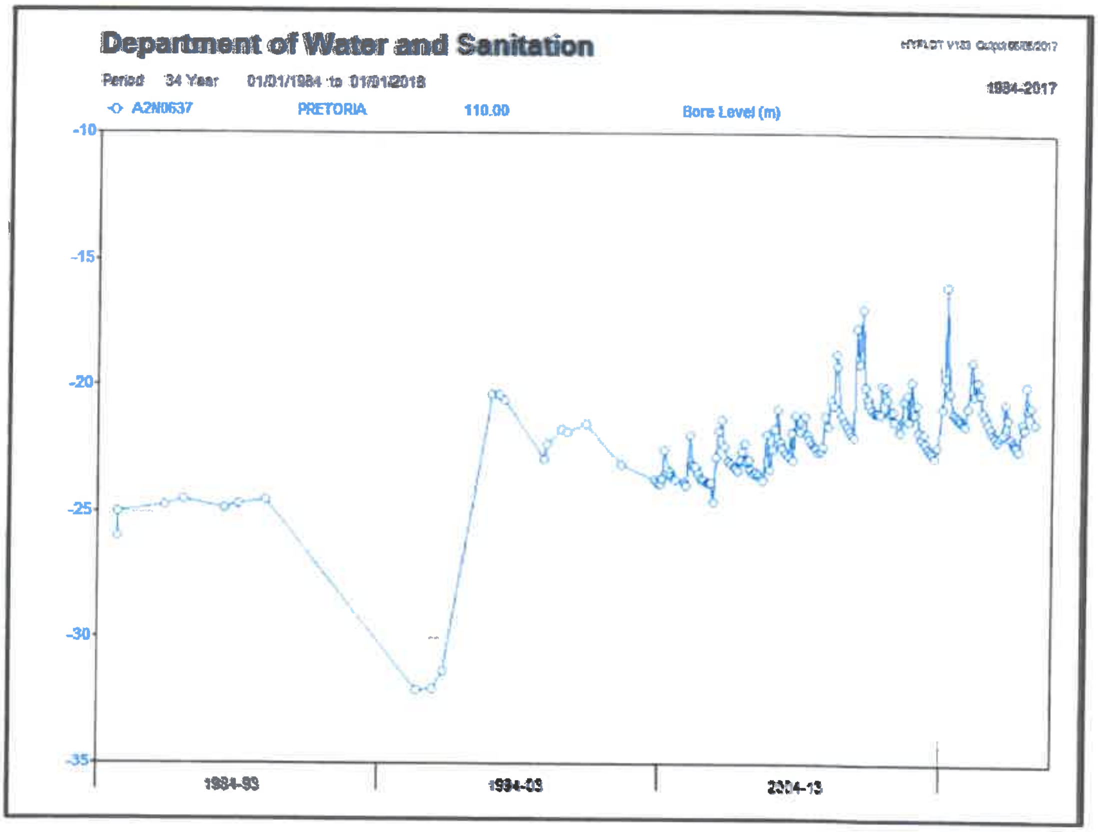

Figure 8: Showing the hydrograph of A2N0637 geo-site.

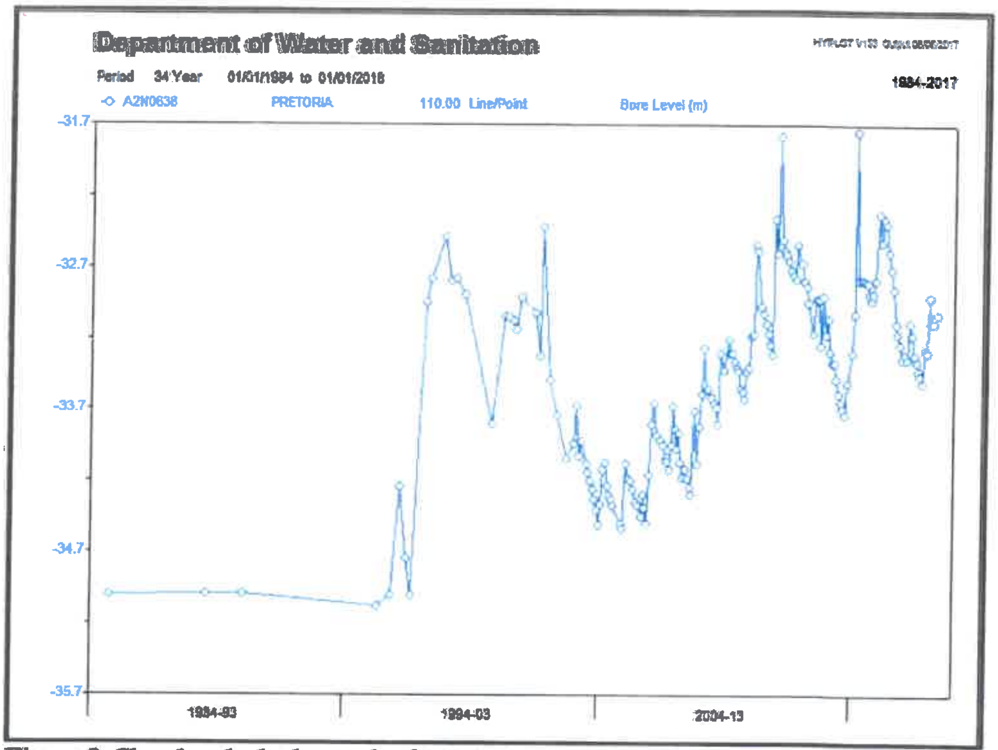

Figure 9: Showing the hydrograph of A2N0638 geo-site.

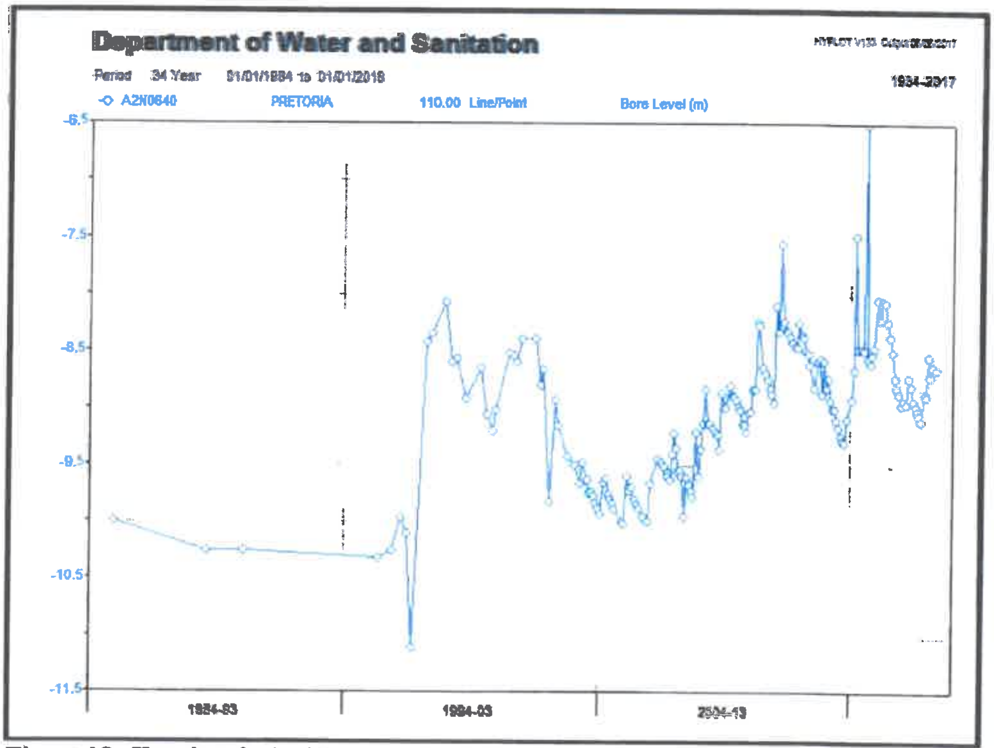

Figure 10: Showing the hydrograph of A2N0640 geo-site.

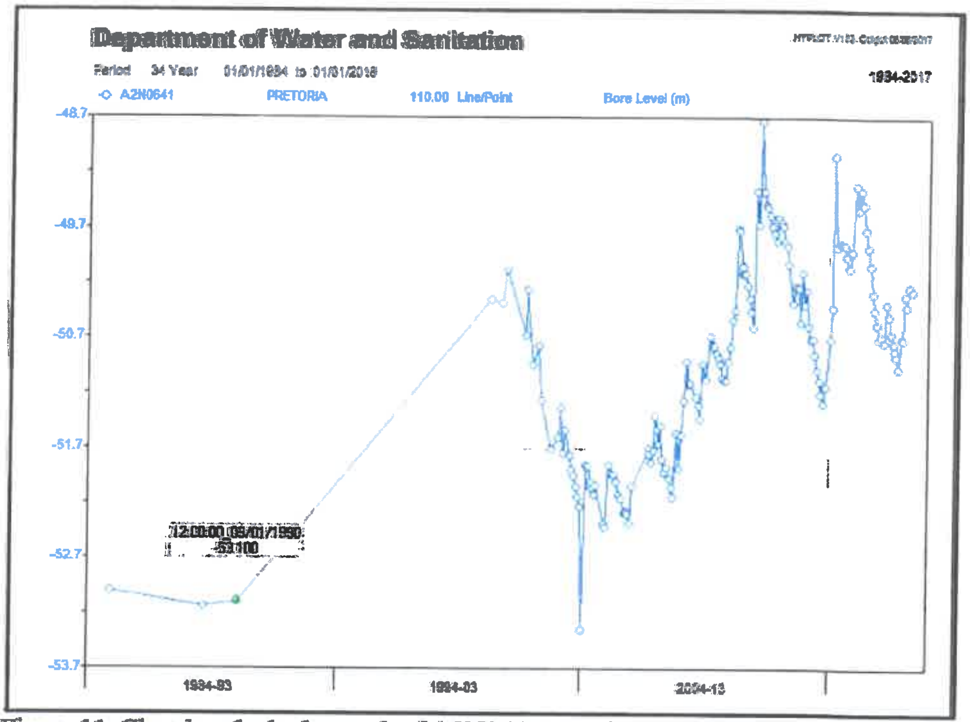

Figure 11: Showing the hydrograph of A2N0641 geo-site.

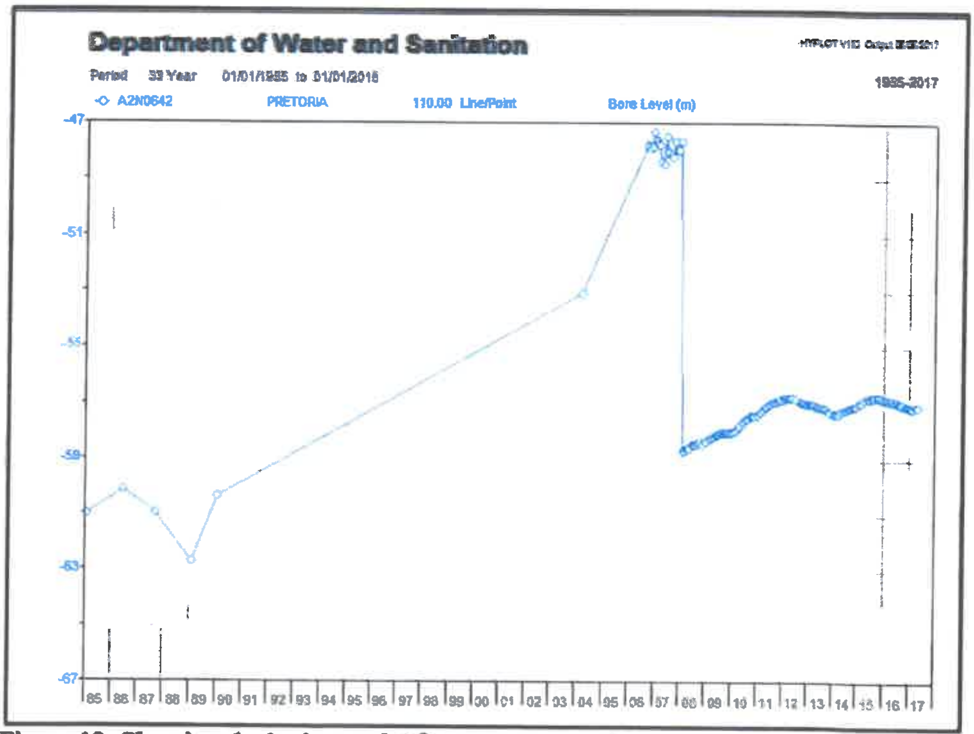

Figure 13: Showing the hydrograph of A2N0642 geo-site.

5.3. Rainfall Data

Precipitation, namely in the form of rainfall, provides the raw input of water to a catchment but its availability for supporting river flows, replenishing aquifer storage and supporting water supplies depends on catchments conditions such as soil type, geology, climate and land use that affect catchment runoff properties (Brassington, 1998). Rainfall in this report is use not to determine the amount of water percolating into the aquifer but to view the monthly reaction when rainfall occur. WRMF (Rain-IMS) program was used to select the rainfall station with at least 30 years data and < 25% missing data. For our study area a suitable rainfall station was from SAWS 0513345 W at Pretoria Burger Park. Three other stations from the surrounding area where used to patch the missing data of the selected station. The stations were from SAWS and ARC, namely:

- ✓ 0513380 W @ Waterkloof
- ✓ 0513374 W @ Pretoria
- ✓ 05135503 AW @ Rietvlei Dam

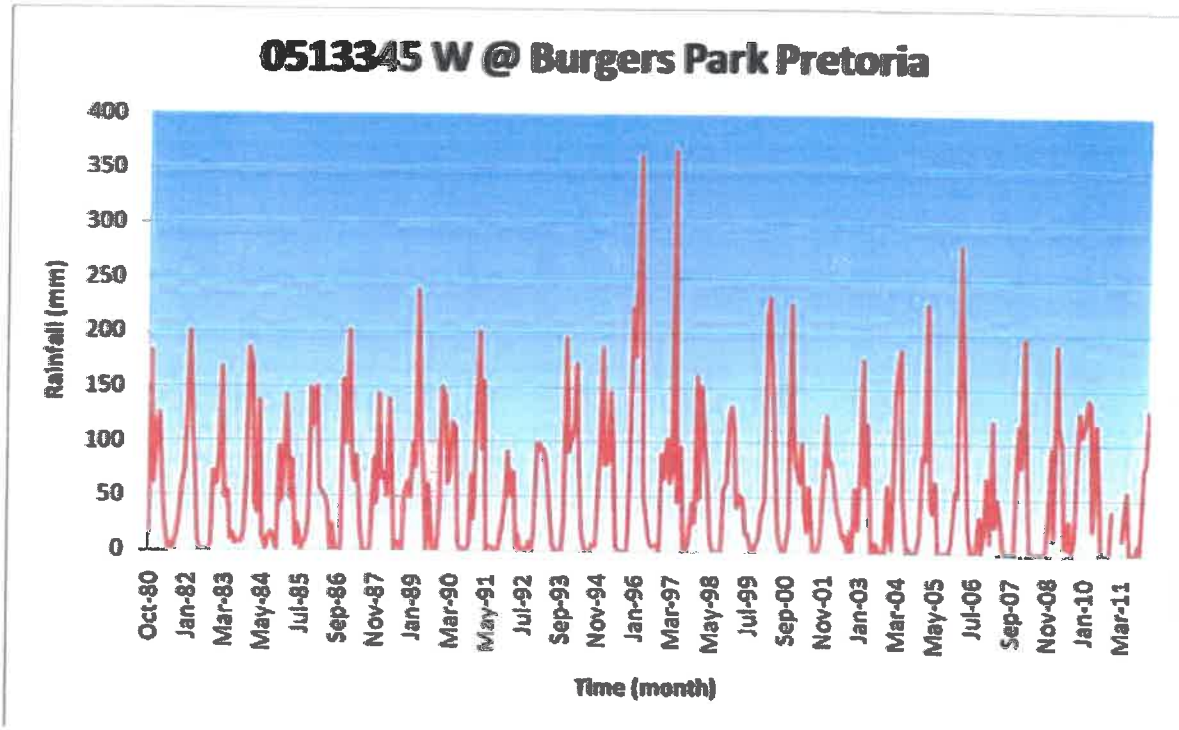

Figure 14: Showing the time series of the monthly rainfall data at Burgers Park in Pretoria.

6. Results

The hydrographs below clearly indicates that the groundwater table does not react immediately to rainfall events. But this is due to the fact that the groundwater occurrence depends mainly on infiltration capacity, soil moisture content, evapotranspiration rate, topography (influence flow rate) and geology (percolation). Rainfall is also a major contributor but it depend on the intensity and duration, for example high intense rainfall (which do not last long) will generate surface runoffs with high flow rate and thus less water will infiltrate, whereas low intense rainfall which last for the whole will produce less runoff but more water infiltrate, saturate the soil moisture content and percolate further down the water table. Therefore these entire factors must be considered when determining the groundwater quantity/flow and this can be achieved through the use of numerical models such as MIKE-SHE or MODE-FLOW model.

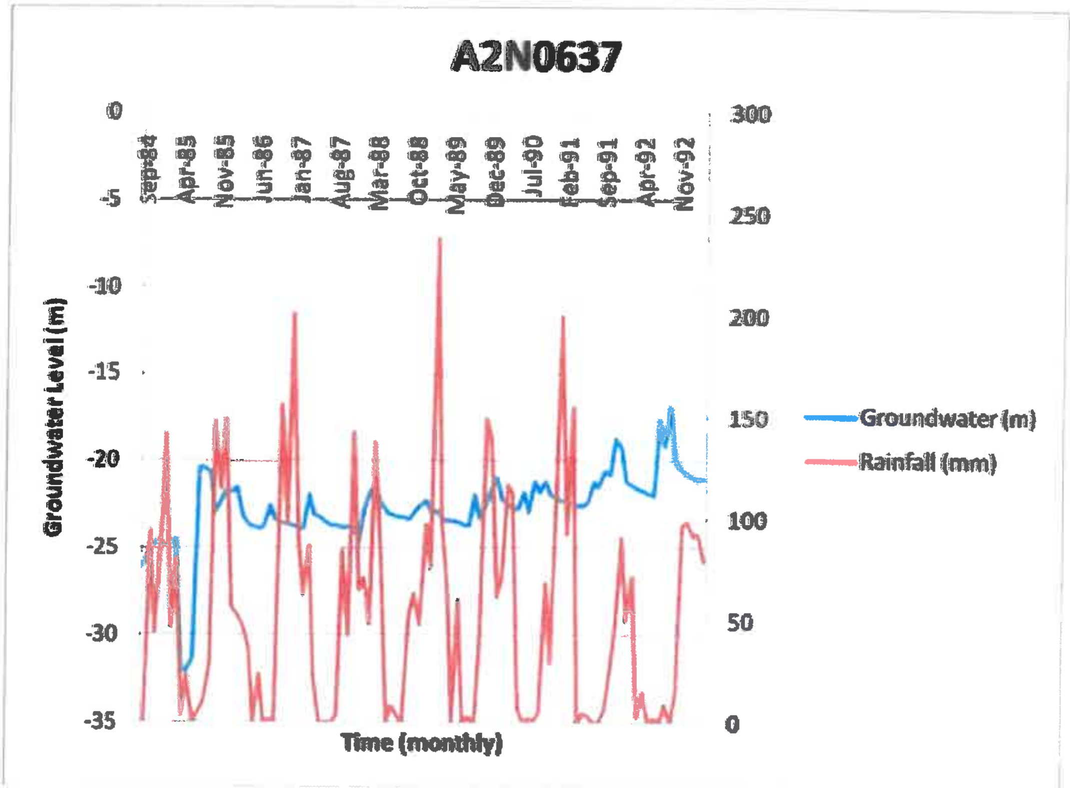

Figure 15: Showing a monthly time series of rainfall (mm) and groundwater level (m) of A2N0637 borehole.

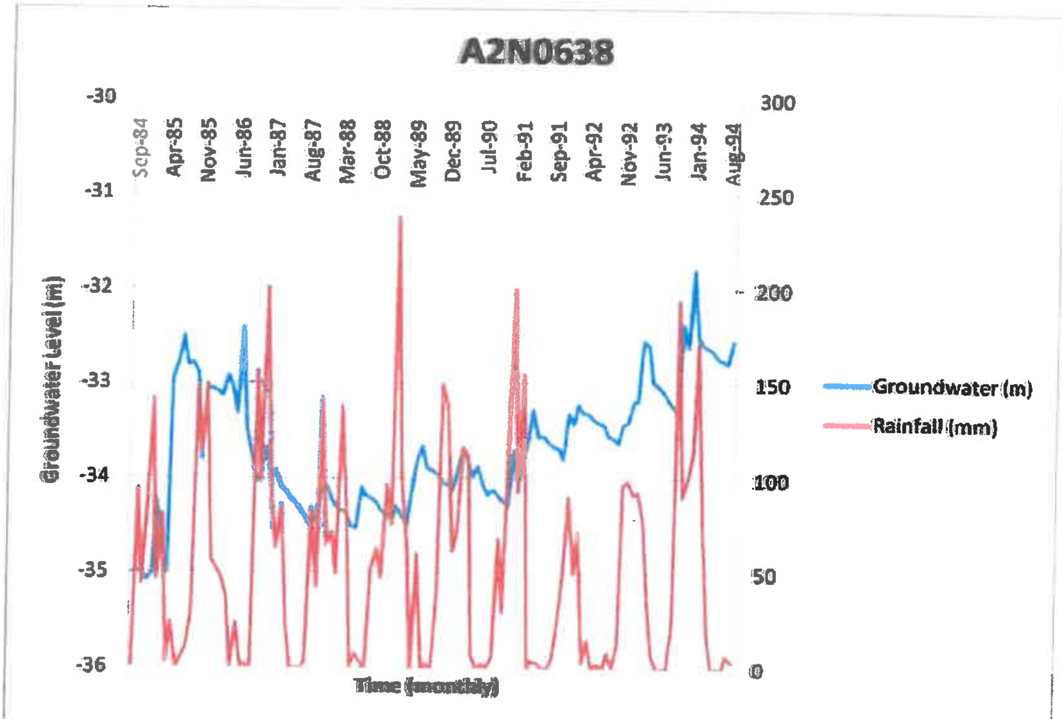

Figure 16: Showing a monthly time series of rainfall (mm) and groundwater level (m) of A2N0638 borehole.

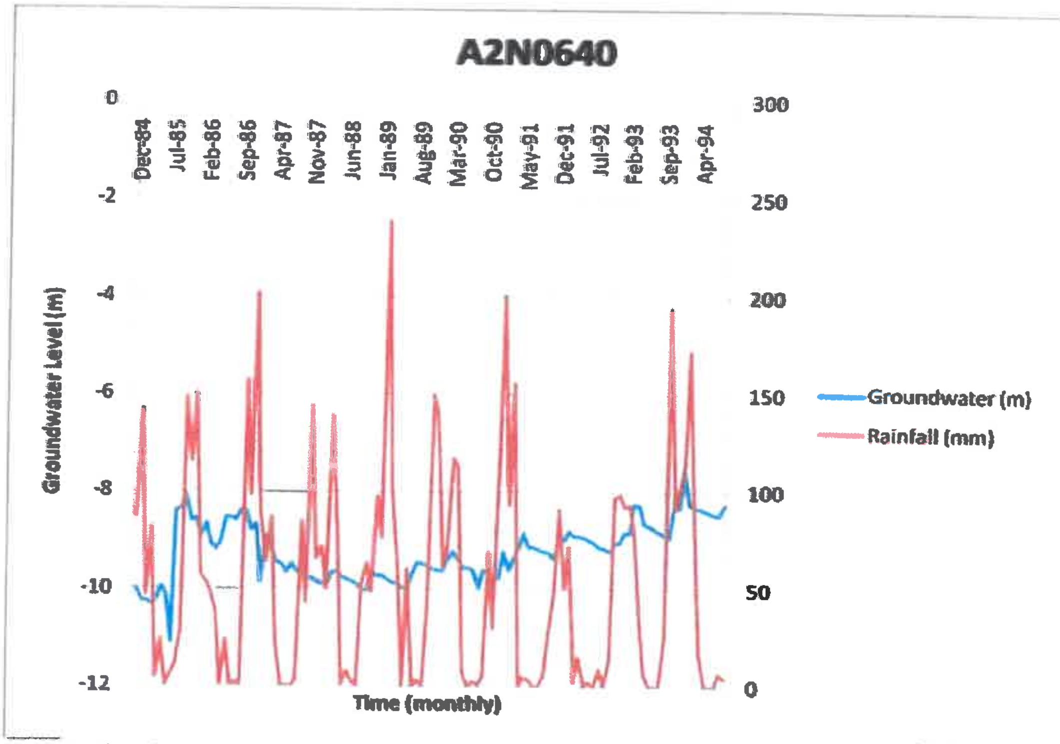

Figure 17: Showing a monthly time series of rainfall (mm) and groundwater level (m) of A2N0640 borehole.

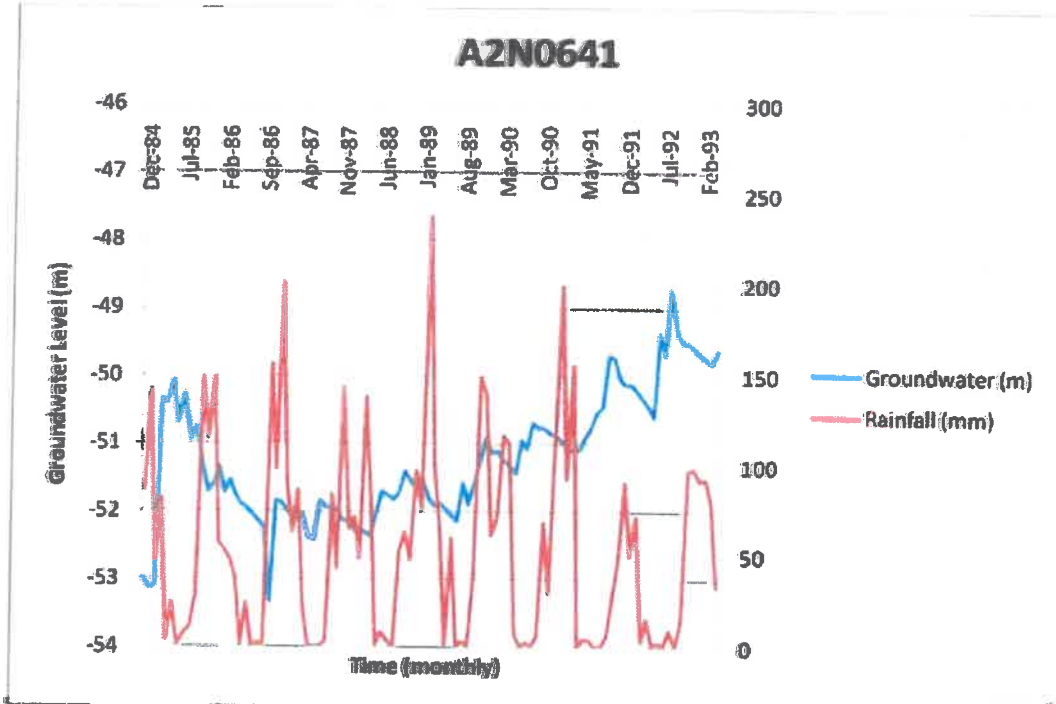

Figure 17: Showing a monthly time series of rainfall (mm) and groundwater level (m) of A2N0641 borehole.

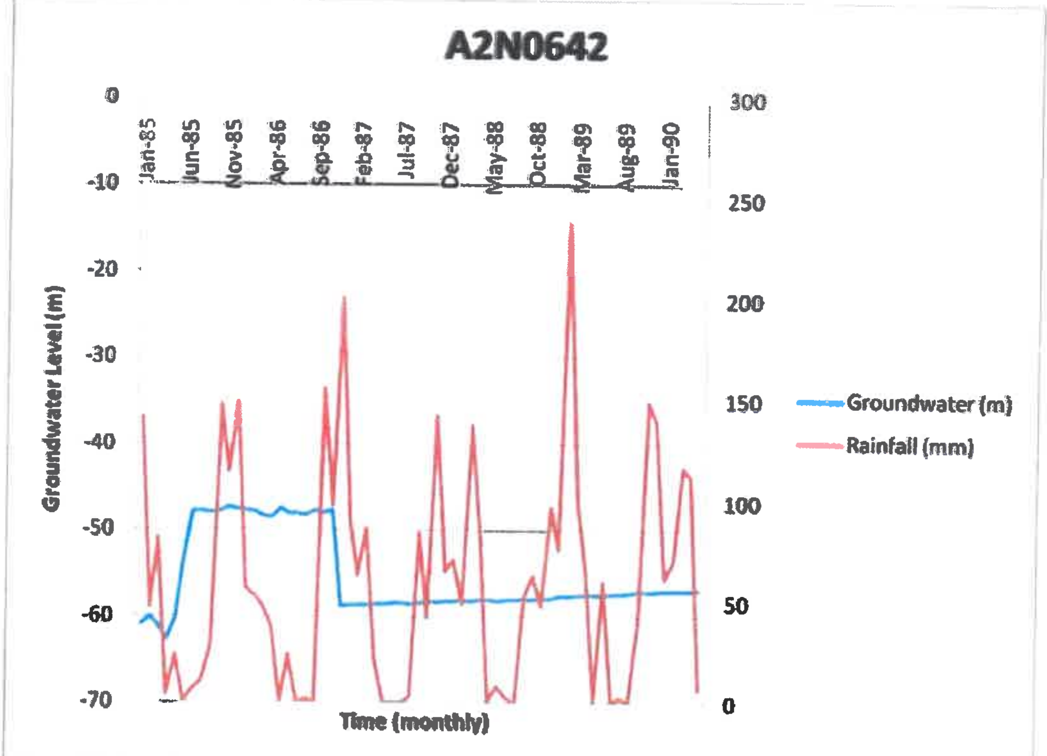

Figure 18: Showing a monthly time series of rainfall (mm) and groundwater level (m) of A2N0642 borehole.

7. Recommendations

- ✓ The equipments for testing the aquifer, in-situ or field quality monitoring and sampling groundwater should be purchased or ask help from DWS-Head Office or other regions like Limpopo.
- ✓ The A2N0639 borehole should be re-open since they will be no addition resources to monitor this site except the sealing of the top part.
- ✓ A numeric groundwater modelling should be use in order to fully understand the dynamics of this groundwater potential.
- ✓ Installing a automatic raingauge within the reserve in order to improve the monitoring frequency (daily monitoring is more ideal than monthly)
- ✓ Installing an automatic data logger that monitor on six hourly basis inside the wells together with a barometer logger that monitor the atmospheric pressure.

8. Summary

The dolomite aquifer within Groenkloof Nature Reserve is well monitored or represented by the 5 DWS boreholes. Water quality at the geo-sites is not being monitored which is a problem because the dolomites aquifer has the potential to become a secondary bulk raw water supply system to Pretoria and surrounding areas in order to accommodate the growing urban development. Groundwater modelling in this area is very crucial for estimating the groundwater dynamics and thus helps us make quality decision-making process about future water demands.

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