



# water & sanitation

Department:  
Water and Sanitation  
**REPUBLIC OF SOUTH AFRICA**

## **GROUNDWATER MONITORING OPTIMISATION WITHIN THE UPPER VAAL SUB-CATCHMENT AREA**

**PART A: EVALUATION AND RECOMMENDATIONS ON THE  
PROPOSED NETWORK AT MATHOPESTAD AREA**

**PART B: IMPLEMENTATION PLAN**

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## ABBREVIATIONS AND ACRONYMS

CA	Catchment Area
DEM	Digital Elevation Model
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
GIS	Geographical Information System
Hydstra	DWS data bank
/s	Litre per second
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
m and mm	metres and millimetre
m MSL	metres above Mean Sea Level
NGA	National Groundwater Archive
RSA	Republic of South Africa
SAWS	South African Weather Services

# **PART A : EVALUATION AND RECOMMENDATIONS ON THE PROPOSED NETWORK AT MATHOPESTAD AREA**

## **1. Background**

The Department of Water and Sanitation (DWS) commissioned a study to *Review, Evaluate, and Optimisation of the South African Water Resources Monitoring Network* using *AECOM SA* group as a consultant or professional services provider (PSP). The *AECOM SA* group assessed the DWS monitoring network for surface and groundwater programmes in the nine Water Management Areas (WMAs). Upon completion of the study, they made recommendation based on their assessment for new monitoring sites of which the DWS has to consider whether to implement them or not. However, before the implementation, recommended sites per WMA needed to be critically evaluated in terms of feasibility and level of priority, based on the outcomes presented by the *AECOM SA group*.

### **1.1 Aim**

The aim of this report is to technically assess, evaluate and review the existing/proposed groundwater monitoring network in the Mathopestad Area (which is a portion of the Upper Vaal Water Management Area) and ensure adequate spatial coverage, and select the feasible sites that are more representative for the monitoring network.

### **1.2 Desk Top Evaluation of the Proposed New Monitoring Sites**

The proposed baseline/trendline network monitoring were plotted using both GooglePro and ArcGIS programs. A total of 14 new sites were proposed for the Mathopestad Area. These consist of 3 new baseline, 2 existing trendline and 9 new trendline monitoring sites (Figure 1). The 2 existing trendline are currently groundwater quality (ZQM) monitoring sites, namely: ZQM B001 and ZQM B002. The sites were placed within a 10 km radius from each other. The sites evaluation was done by zooming on each site and using local knowledge of the topography, geology, groundwater trends, land use, infrastructure, water supply etc. Each proposed site was evaluated for factors such as accessibility to site and drilling, long-term accessibility for monitoring purposes, applicability for the type of monitoring and possible existing replacements.

## **2. Study Area and Data Analysis**

Mathopestad is a small township positioned approximately 50 km south west of Venterdorp town in the North West Province of the Republic of South Africa (RSA). The area is situated east of the Magaliesburg town, which is a small town on the provincial border between Gauteng and North West. The area is located in the C23F sub-catchment region which is the headwater of the main Mooi River (Figure 1). The Mooi River is one of the main tributaries of Vaal River and is flowing in southerly direction towards the confluence or junction through Potchefstroom Dam. Its hazard potential is ranked high due to poor maintenance and the development of sink holes.

The surface area of the catchment is roughly 1320 km<sup>2</sup>. The Klerkskraal Dam is built across on the Mooi River and was established in 1969. The main purpose of dam is for irrigation and emergency storage supply for Potchefstroom Area. The hydraulics structure is an Ogee Spillage with a length of about 1320m and height of 18m.

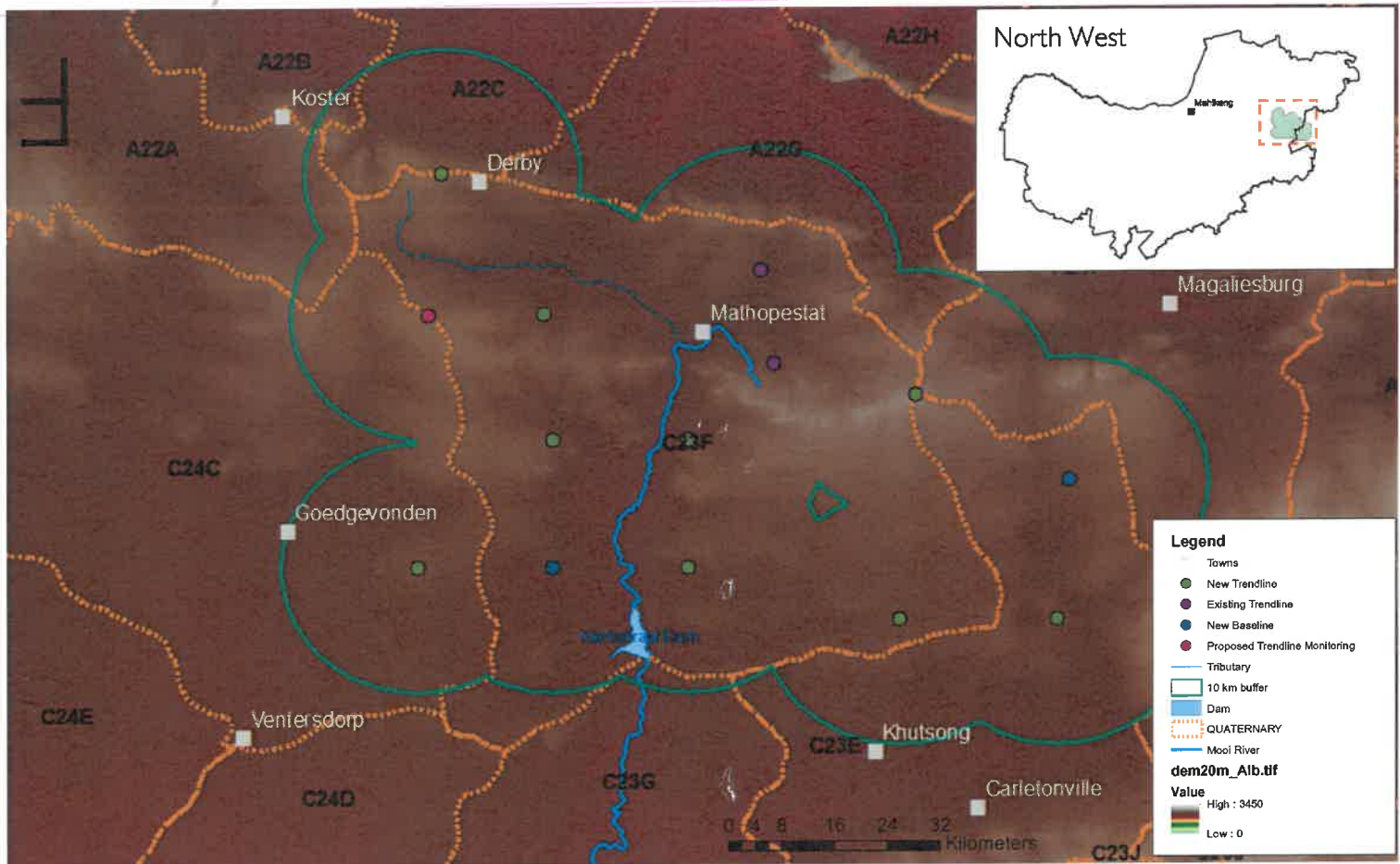


Figure 1: GIS map location showing the proposed geo-sites within C23F sub-catchment area (Mathopestad)

## 2.1 Climate

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). The climate in the C23F sub-catchment area is sub-tropical dry savanna, with the mean annual evaporation at 1,300 mm and far exceeding the rainfall of 600 mm (Jury 2016). The C2E018 DWS meteorological station (situated in Klerkskraal Dam) recorded the highest rainfall event of 120 mm on the 14 -15 February 1996. The second highest rainfall recorded was 90 m on the 25 - 26 July 2016 (Figure 2).

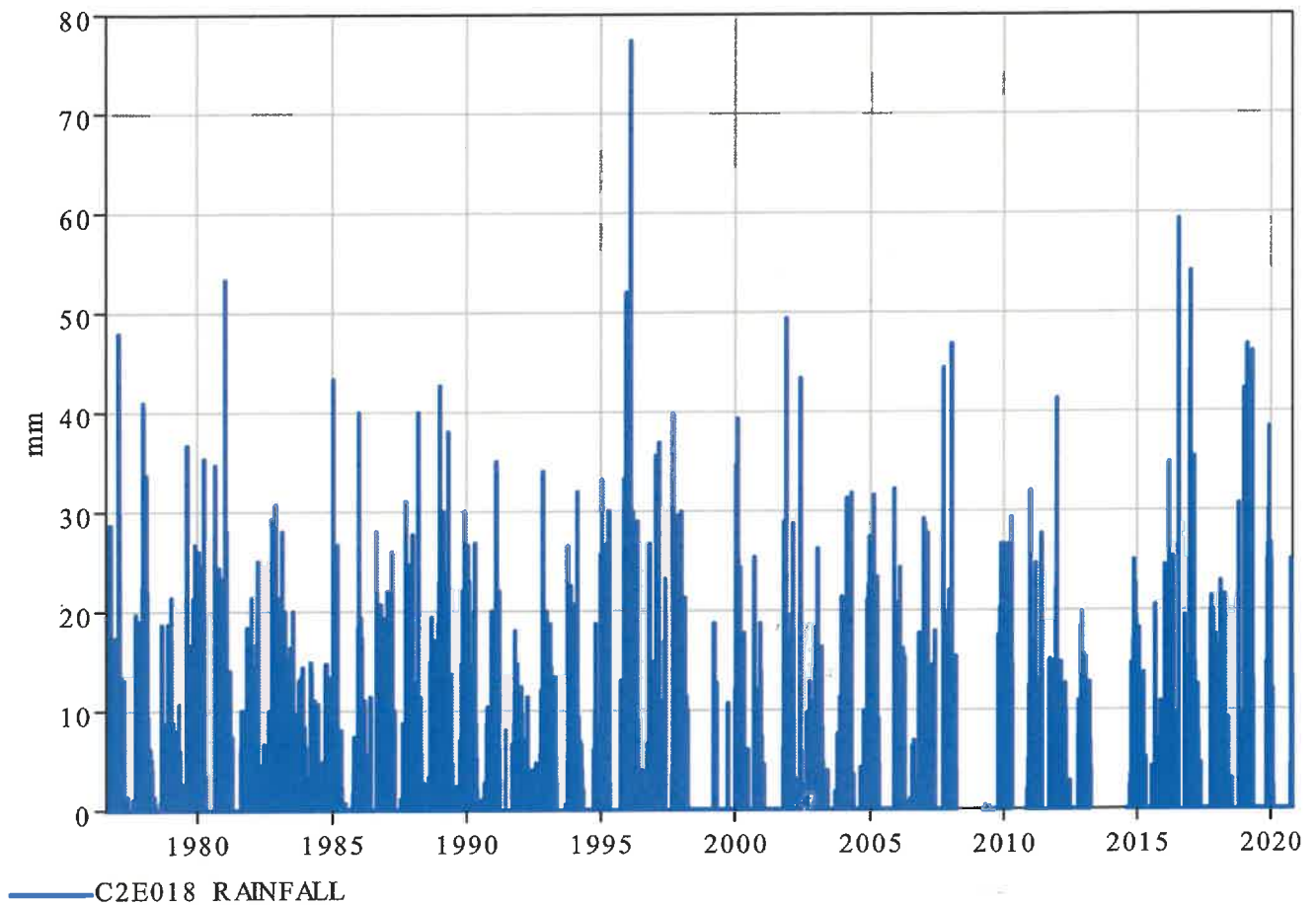


Figure 2: Showing the continuous rainfall records at Klerkskraal Dam (C2E018)

## 2.2 Geology and Geohydrology

The groundwater compartments are underlain by the Malmani Formation and Timeball Hill Formation which belongs to the Pretoria Subgroup of the Transvaal sequence. The Pretoria Subgroup formations are separated or intersected by the Pretoria Syenite dyke/sills (diabase) (Naidoo, 2014). The Timeball Hill Formation is composed of a coarsening upward carbonaceous shale, siltstone (fine grained sandstone) and hematite oolite-bearing quartzite, overlain by conglomerate, quartzite and shale of the Boshhoek Formation (Coetzee, 2009). Part of the site is underlain by a diabase (basaltic lava) sill of Hekpoort Formation that was intruded into the shale sequence (Aurecon, 2015).

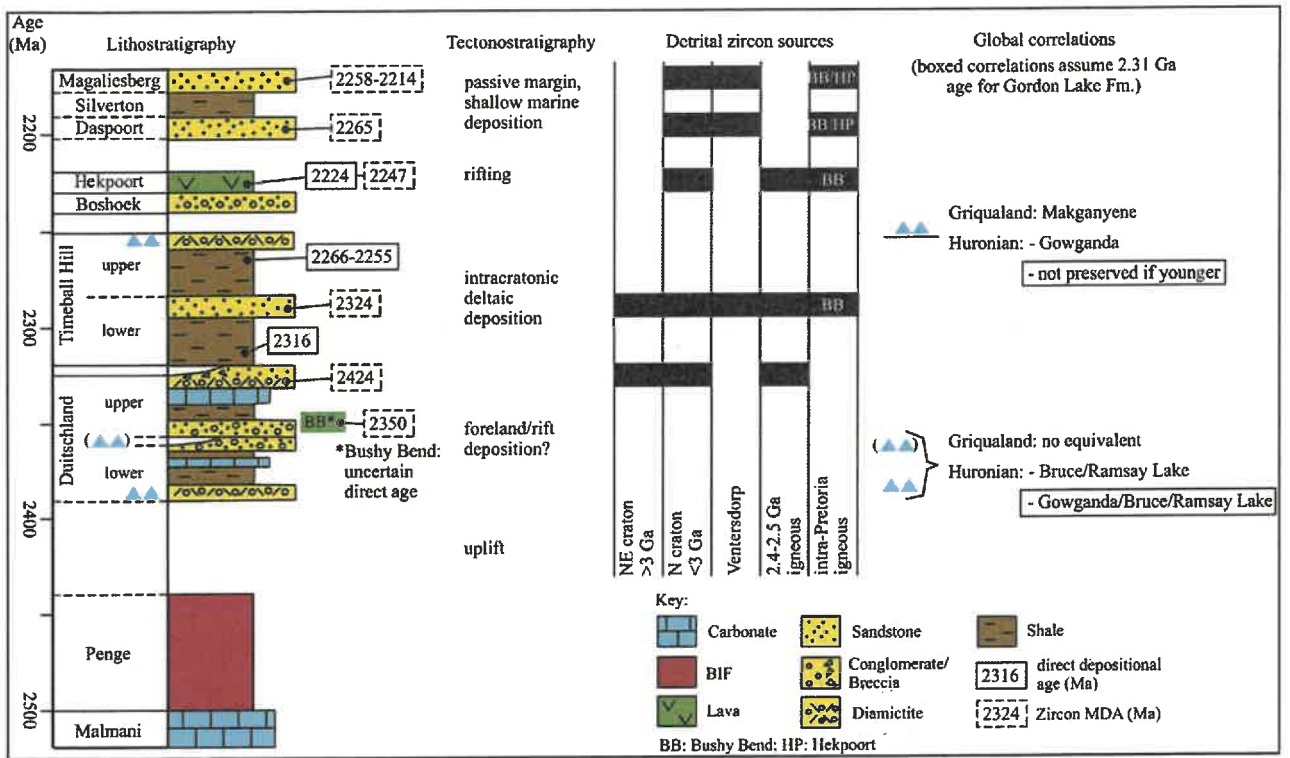


Figure 3: The subdivision and lithostratigraphy of the Pretoria Group (Schroder et al., 2016).

The Malmani Formation (on the lower part C23F) comprise of mainly dolomite/cherts rocks (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, 2006). The dolomite is underlain by the Black Reef Formation (shale, impure quartzite and conglomerate) and overlain by the Timeball Hill Formation (on the upper part C23F). Timeball Hill Formation compose of mainly shale, siltstone, conglomerate in places and quartzite rocks. The area has cross-cutting lineaments such as faults and dykes (Figure 3). The dykes are mostly not 100% impermeable but are at least several orders of magnitude less permeable (DWAF, 2006).

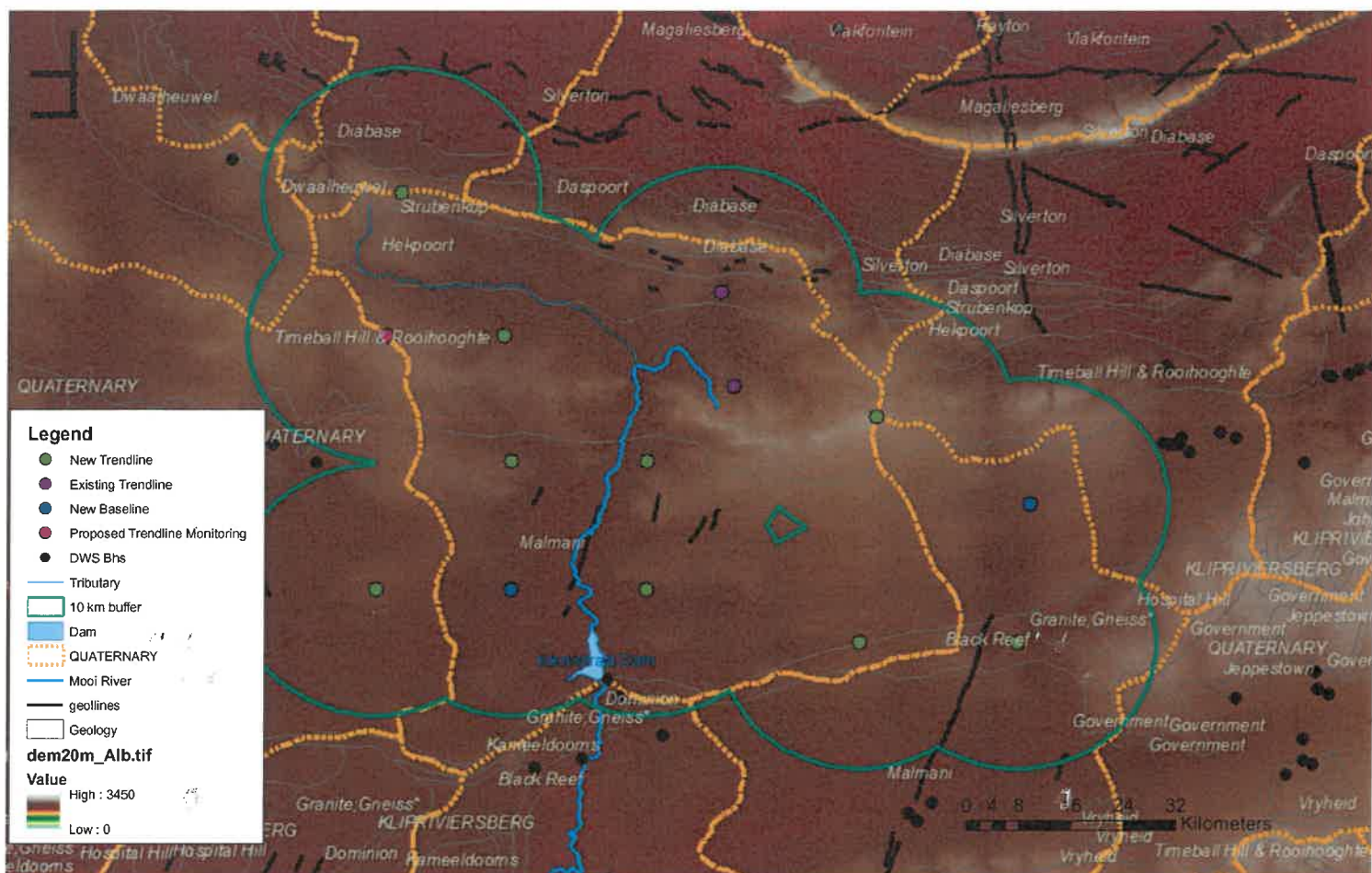


Figure 4: The geological formations and structures at C23F Sub-catchment area (sourced: a 1:250 000 geological map)

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, 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 commonly placed adjacent to deeply weathered zones (DWAF, 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, 2006).

Groundwater in the dolomite aquifer is generally characterised by the major dissolved elements,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  and  $\text{HCO}_3^-$ , where half of the  $\text{HCO}_3^-$  is balanced by  $\text{Ca}^{2+}$  and half by  $\text{Mg}^{2+}$ , and ultimately coming into equilibrium with calcite and dolomite. Dolomite groundwater is characterised by a consistent composition of  $\text{CaCO}_3$  and  $\text{MgCO}_3$  (DWAF<sup>1</sup>, 2006). Transmissivity (T) values were not found National Groundwater Archive (NGA), but

T is very variable in the dolomite, ranging from nearly impervious to  $\sim 30\,000\text{ m}^3/\text{day/m}$ . 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  $> 40\text{ l/s}$  from boreholes up to 250 m deep. The average borehole yields vary from 2 – 10 l/s. Water tables vary from  $< 10\text{ m}$  to 50 m (DWAF, 2006).

### **2.3 Topography and Land use**

The geomorphology of a region reflects the historical processes forming the land and water features within the catchment. Many geomorphic features can be described by the surface elevation and drainage network. The topography influences how water is precipitated, evaporated, stored and routed through the landscape. A topography driven flow system is one in which groundwater flows from higher elevation (recharge area) to lower elevation (discharge area). The soils in the upslope are more likely to be eroded and their topsoil as compared to fertile downslope where deposition occurs. The 20 meter elevation contours and spot heights data were obtained from the National Geo-spatial Information (NGI) section in the Department of Rural Development and Land Reform. Figure 3 shows the derived digital elevation model (DEM), where the elevation ranges vary from 1593 m above sea level (MSL) at the western and northern boundaries to 1526 m at the eastern and southern boundaries. The soils are sandy silt-loam and the groundwater recharge rate in this area is estimated to be 43.1 mm/month (Middleton and Bailey, 2009). The recharge is enhanced by the grassveld vegetation in C23F sub-catchment area. The land use is dominated by seasonal agricultural crop farming, which is likely to influence soil erosion during dry/windy season.

### **2.4 Available Groundwater Data**

#### **2.4.1 Boreholes or Geo-sites**

The Malmani Formation in this area (C23F) is well represented by DWS boreholes on the west, east and south sides. However, the north side, which is just upper stream of Klerkskraal Dam has no monitoring and hence new baseline/trendlines site are proposed (Figure 3). The construction of the boreholes is durable and reliable since it lasted for more than four decades (see photo 1, 2, 3 & 2). There are currently no instrumentations installed inside the monitoring station. However, in the past some of the boreholes were installed with the autographic chart recorders which are no longer functioning, but data is stored safely in the archives (photo 1). Due to the fact that the dolomite is unstable the boreholes were cased all the way down with a steel pipe casing. The casings are sealed on top (except for C2N0082 & C2N0180) with small holes to allow the dip meter probe inside. The sealed tops are 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. The Timeball Hill Formation (C23F) is represented existing trendline monitoring (2 ZQM quality monitoring). The condition of these ZQM borehole stations is unknown.



Photo 1: View of C2N0082 Geo-site



Photo 2: View of C2N0180 Geo-site



Photo 3: View of C2N1026 Geo-site



Photo 4: View of C2N1025 Geo-site

## 2.4.2 Groundwater Level Data

Groundwater level measurements on the western side of the Malmani Formation were collected on monthly for more 3 decades using a water level dipper meter (Figure 4). Water level fluctuated between -25 and -50 m below ground surface at C2N1025, while at C2N1026 ranged between -70 and -75 m mark. It can also be observed that from 2020 to date, data was mixed up between the two borehole stations. The existing monitoring on the eastern side (Tarlton) shows signs of recovery after 2 decades. The groundwater trend shows similar patterns from A2N0612 and A2N0615 borehole stations, range between (-53 and -58 m) and (-66 and -72m) respectively. The impact of the 2015/16 drought event can be observed were both wells received the lowest readings. The groundwater monitoring on the southern side, just downstream of Klerkskraal Dam, where data is collected using autographic chart recorder at C2N0082 borehole station. The groundwater level is fair shallow and fluctuate between -1 and -5 m below the ground surface. Figure 6 indicate that the Karst aquifers of Malmani Formation respond rapidly to rainfall events. The lowest record of -5.30 m on the 15/02/1996 quickly recovered to -1.90m on 20/02/1996 from the rainfall event of 125 mm recorded on 17 - 18/02/1996 at C2E018 meteorological station.

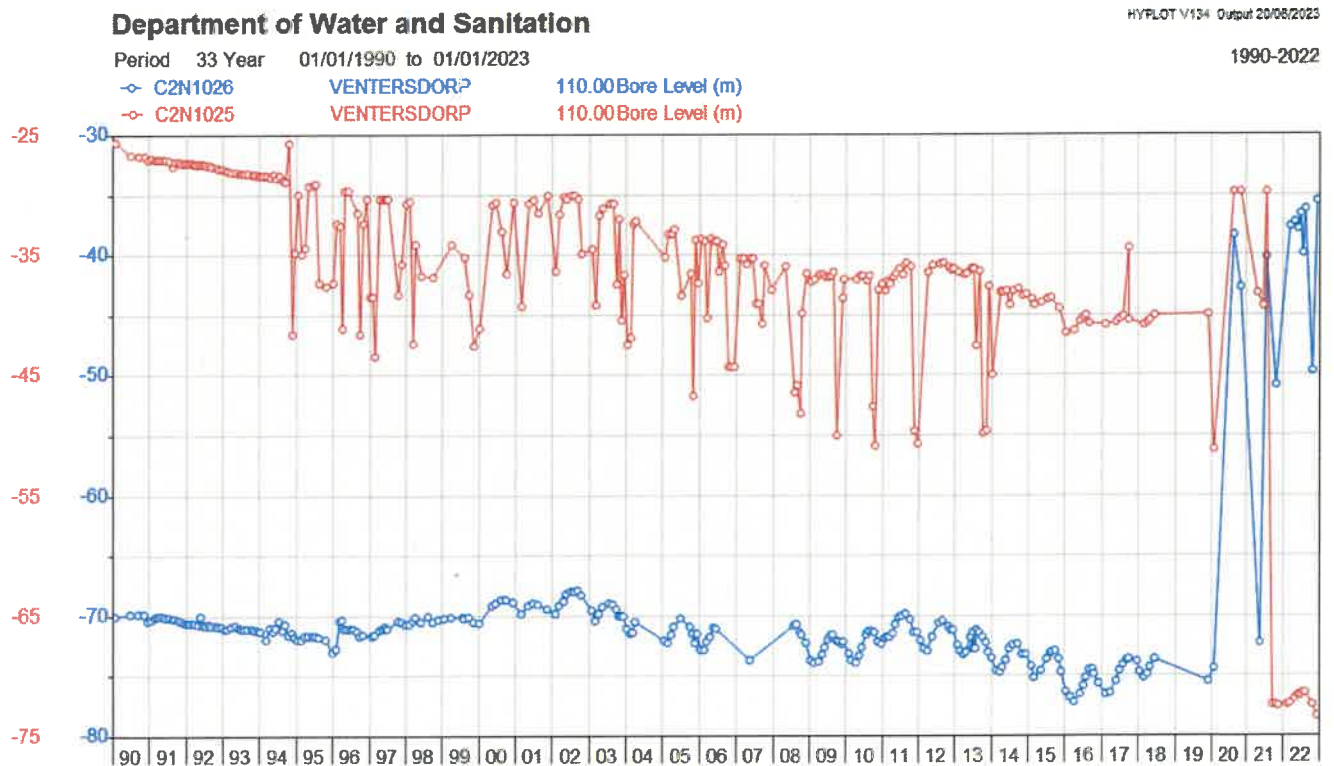


Figure 5: Showing continuous groundwater level series on the western side of C23F

Department of Water and Sanitation

HYPLOT V134 Output 20/08/2023

Period 37 Year 01/01/1987 to 01/01/2024

1987-2023

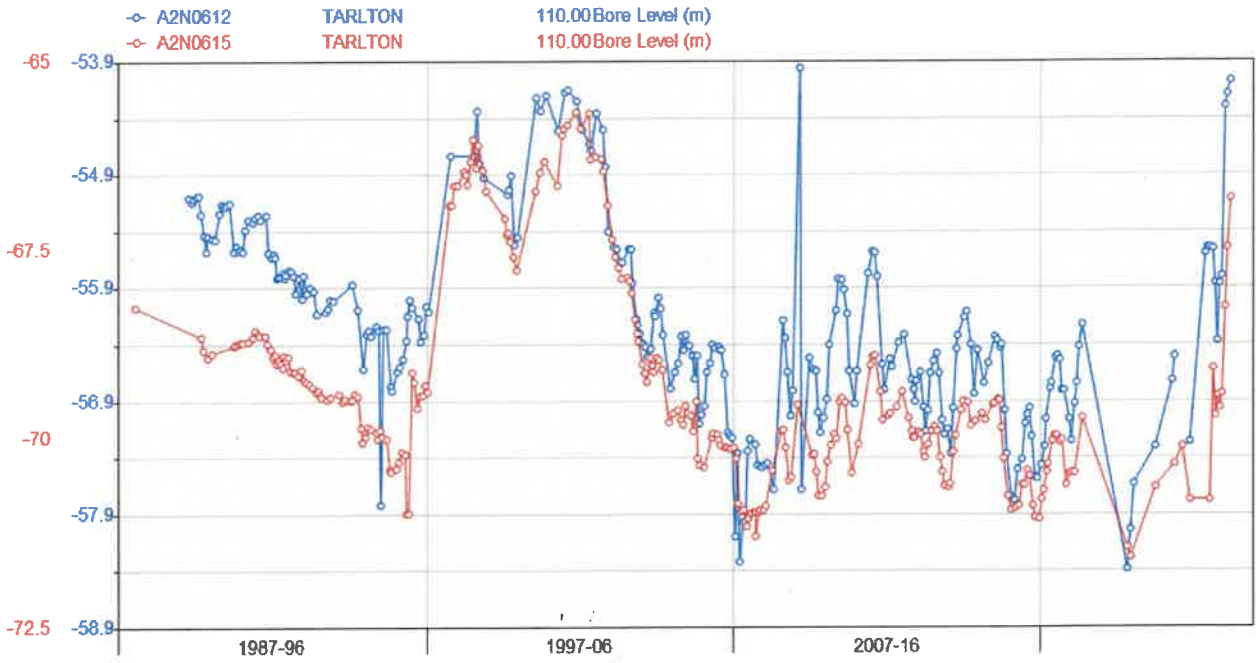


Figure 6: Showing continuous groundwater level series on the eastern side of C23F

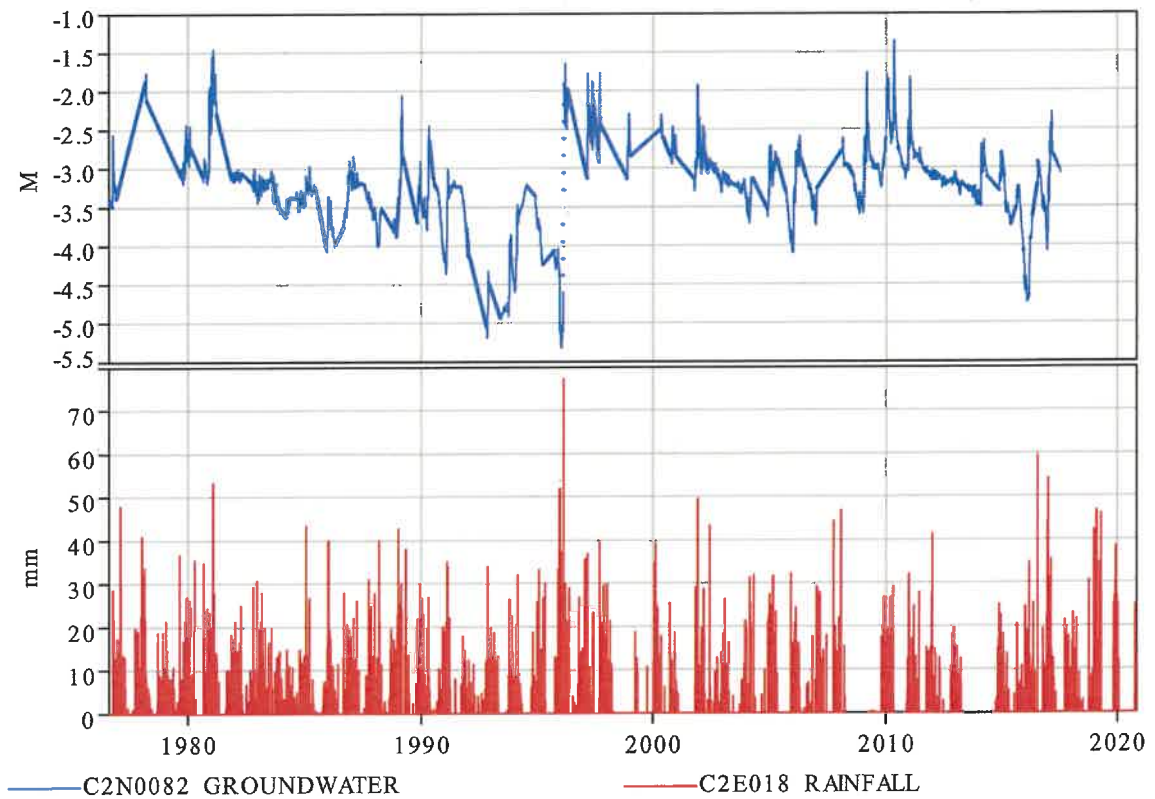


Figure 7: Showing continuous groundwater level series on the southern side of C23F

### 3 Ground Findings

A total of 14 new baseline/trendline proposed sites were visited on 17 - 19 May 2023 within the C23F sub-catchment region (Mathopestad Area). These consist of 3 new baseline, 2 existing trendline (ZQM sites) and 9 new trendline monitoring sites. The proposed sites are identified by numbers (e.g. 294, 295, etc.). The sites were placed within a 10 km radius from each other. Each proposed site was evaluated for factors such as accessibility to site and drilling, long-term accessibility for monitoring purposes, applicability for the type of monitoring and possible existing replacements.

#### 3.1 Site inspection on 17 May 2023

- The first point visited was **295**, which is a proposed trendline monitoring, located at -26.093687 S and 27.190526 E. This site is located inside a private farm and the access road is not easy during rainy season (*photo 5*). From the field observation it may be very difficult to drill a borehole inside this farm as the Owner could take advantage by installing a pump inside the well for crop irrigation. There is an NGA borehole located within a 1 km proximity to the proposed site, but it is currently being used for water supply in the farm (*photo 6*).
- The second point was **294**, which is also a proposed trendline monitoring, at -26.093771 S and 27.092849 E. The coordinate of this point is also located in a private farm with a lock gate (*photo 7*). This site can be easily be accessible by heavy machinery (Drilling Rig) to construct a monitoring borehole station. An NGA borehole was observed nearby (> 1 km radius) but it is utilised for production at the farm (*photo 8*). Perhaps there is a great need to engage the Farmer(s) in order to request permission on using the borehole as a monitoring point.



Photo 5: View of 295 proposed site



Photo 6: View of NGA site near 295



Photo 7: View of 294 proposed site



Photo 8: View of NGA site near 294

### 3.2 Site inspection on 18 May 2023

- The first point visited was **280**, which is proposed for trendline monitoring and it is located at -26.186093 S and 27.190617 E. This site appeared not to be suitable for trendline monitoring due to the fact that it is located inside the private property (*Photo 9*). However, the monitoring point can be established outside the property approximately 5 meters from the road for easy access at -26.195588 S and 27.166910 E, at an elevation of 1481 m MSL. There is no NGA borehole near this proposed site.
- The second point visited was **276**, which is proposed for baseline monitoring and it is positioned at -26.185424 S and 27.092276 E. The site is located inside a private farm (*photo 10*) and there was nobody nearby to give further information. There is an NGA borehole within close proximity to the proposed site, but it is currently used as a working windmill (*photo 11*).
- The next point visited was **311**, which is proposed for trendline monitoring and it is placed at 26.002999 S and 27.086608 E. This point appeared to be suitable for establishing a groundwater monitoring because it is positioned in an open field where it would easily be accessible (*photo 12*). There are no NGA boreholes located nearby that can be used as an alternative.
- The next point visited was **308**, which is proposed for trendline monitoring and is located in a private farm. This site is not suitable for trendline monitoring due to accessibility (*photo 13*). However, a monitoring point can be established outside the gate next to the gravel road at -26.068121 S and 27.361119 E, at elevation level of 1688 m MSL.
- The next point visited was **290**, which is a proposed baseline monitoring and is located inside Custodia Security facility (*photo 14*). This site is not suitable for baseline monitoring mainly due to accessibility. However, a monitoring point can be established outside the facility at -26.123874 S and 27.462784 E, at an elevation level of 1551 m MSL. There is no NGA borehole located close to the proposed site.
- The next point visited was **272**, which is proposed for trendline monitoring and it is located inside the private farm, at -26.224289 S and 27.457804 E. The site appeared to be

a suitable position for trendline monitoring due to accessibility (*photo 15*). However, the farm Owner(s) should be engaged and be informed on the potential plan by DWS to carry out groundwater monitoring in future. There is also an NGA borehole observed closer to the proposed site, but it is currently being used for water supply in the farm (*photo 16*)



*Photo 9: View of 280 proposed site*



*Photo 10: View of 276 proposed site*



*Photo 11: View of NGA site near 276*



*Photo 12: View of 311 proposed site*



*Photo 13: View of 308 proposed site*



*Photo 14: View of 290 proposed site*



Photo 15: View of 272 proposed site

Photo 16: View of NGA site near 272

### 3.3 Site inspection on 19 May 2023

- The point visited on the day is **273**, which is proposed for trendline monitoring and is located inside the farm at -26.224289 S and 27.343589 E. The site is not suitable for trendline monitoring due to accessibility (*photo 17*). There is no NGA borehole(s) located closer to the proposed site.



*Photo 17: View of 273 proposed site*

## **4 Conclusion**

The groundwater monitoring within the C23F sub-catchment region (Mathopestad Area) is partially monitored on the eastern, western and southern sides. Proposed monitoring sites identified by DWS (2016) report in this area, are mostly located inside the farms that are privately owned. However, the proposed point 311 appeared to be located in a pristine environment where groundwater monitoring will be favourable. The NGA boreholes which are located close to the proposed areas are mostly used for farming/irrigation.

## **5 Recommendations**

The Malmani Formation in the lower part C23F are fairly been monitored whereas the Timeball Hill and Hekpoort Formations has groundwater monitoring, except only for the quality on the existing ZQM. These boreholes should be converted into continuous groundwater monitoring due to the fact that it will be less expensive to carry it out. Drilling is recommended outside the properties as most of the proposed points are located inside private properties. The following are recommended:

- Proposed point number **295**, is not suitable for trendline monitoring mainly due to the fact that it is located inside the private farm and where the access route would be impossible during the rainy season
- Proposed point number **294**, appeared to be an ideal position to conduct trendline monitoring due to easy access. But there a need to engage the farmer with regards to the benefit of establishing a groundwater monitoring network in his/her farm. The new trendline monitoring is positioned in an area with high yield karst aquifers of Malmani Formations.
- Proposed point number **280**, is not suitable for trendline monitoring due to the fact that it is located inside the private property. The drilling can be done outside the property 5 meter from the road for easy access at -26.195588 S and 27.166910 E at an elevation of 1481 m MSL.

- Proposed point number **276**, is not suitable for baseline monitoring due to the fact that it is located inside the private property. Furthermore it was difficult to find a new position near the proposed site.
- Proposed point number **311**, is located in a pristine position, with no issues with the access therefore the drilling can be done on this proposed site. The new trendline monitoring is positioned in an area with low yield aquifers of Timeball Hill Formations.
- Proposed point number **308**, which is located in a private farm which makes it not suitable for trendline monitoring. The new proposed site can be drilled just outside the gate next to the gravel road at -26.068121 S and 27.361119 E, elevation level of 1688 m MSL.
- Proposed point number **290**, the proposed site is located inside Custodia Security facility which makes it not suitable for baseline monitoring. However, new position can be established just outside the facility at -26.123874 S and 27.462784 E, at an elevation level of 1551 m MSL.
- Proposed point number **272**, is located inside the farm therefore it is not suitable for trendline monitoring. The new proposed site is recommended outside the farm at -26.221145 S and 27.453664 E, at an elevation level of 1572 m MSL.
- Proposed point number **273**, the proposed site is located inside the farm and the new site is proposed outside the farm next to the N14 highway road for easy access.

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## **PART 2: IMPLEMENTATION PLAN**

There are four proposed sites that are recommended for establishing a groundwater monitoring, namely: trendlines (294, 311, and 308) and baseline (209). The following stages need to be undertaken in order for groundwater monitoring to be carry out effectively:

### **1. PLANNING**

#### **2. PHASES**

- 2.1. Desktop site verification
- 2.2. Field site verification
- 2.3. Geophysical work
- 2.4. Drilling and construction
- 2.5. Commissioning of new monitoring stations
- 2.6. Monitoring Frequency
- 2.7. Data storage
- 2.8. Information dissemination
- 2.9. Maintenance


### **3. BUDGET AND COSTS**

- 3.1. Geotechnical Services
- 3.2. Drilling Services

Complied by (Acting Scientist Manager – Geohydrological Services):

Name	Signature	Date
Lesiba Mmako		29/04/2023

Checked by (Director – Water Resource Support):

Name	Signature	Date
Nondumiso Mabe		29/06/2023

# Appendix A

