The Administrative Building
Albion Spring, 183 Main Rd
Rondebosch 7700
Postnet Suite #206
P Bag X18 Rondebosch 7701
South Africa
**T:** +27 (0) 21 659 3060
**F:** +27 (0) 21 685 7105
**E:** capetown@srk.co.za
www.srk.co.za

25 November 2017
509890 Prince Albert

Mr Johan Pieterse
Prince Albert Municipality
Private Bag X53
Prince Albert
6930

**Attention: Mr Pieterse**

**Report on Borehole Drilling and Aquifer Test: Klaarstroom**

## 1. Introduction

SRK Consulting (South Africa) (Pty) Ltd (SRK) was appointed by the Prince Albert Municipality conduct a geohydrological investigation at Klaarstroom. The exploration Phase consisted of the following:

- Borehole Siting;
- Borehole Drilling;
- Aquifer Test; and
- Water Quality Test.

## 2. Drilling

Gobora Drilling was appointed to drill the borehole at Klaarstroom. Drilling started on 26 May 2017 and was completed on 19 June 2017.

The details of the borehole construction are presented in **Table 1** and position of the borehole in **Figure** 1**.**

**Table 1: Borehole Construction Details**

| BH 1 | | | | |
|---|---|---|---|---|
| **BH Depth (m)** | **BH Diameter (mm)** | **Casing Type and Diameter** | **Blow Yield (L/s)** | **Rest Water Level (m bgl)** |
| 0-6 | 254 | 219 mm steel casing | 0.5 | 7.64 |
| 6-85 | 208 | Open hole | | |
| 85-250 | 171 | Open hole | | |
| **BH 2** | | | | |
| **BH Depth (m)** | **BH Diameter (mm)** | **Casing Type and Diameter** | **Blow Yield (L/s)** | **Rest Water Level (m bgl)** |
| 0-6 | 254 | 219 mm steel casing | 1.5 | 6.86 |
| 6-70 | 208 | Open hole | | |
| 70-250 | 171 | Open hole | | |
| **BH 3** | | | | |
| **BH Depth (m)** | **BH Diameter (mm)** | **Casing Type and Diameter** | **Blow Yield (L/s)** | **Rest Water Level (m bgl)** |
| 0-6 | 254 | 219 mm steel casing | 0.2 | 8.31 |
| 6-85 | 208 | Open hole | | |
| 85-250 | 171 | Open hole | | |
| **BH 4** | | | | |
| **BH Depth (m)** | **BH Diameter (mm)** | **Casing Type and Diameter** | **Blow Yield (L/s)** | **Rest Water Level (m bgl)** |
| 0-6 | 254 | 219 mm steel casing | 0.2 | 22.21 |
| 6-80 | 208 | 177 mm steel casing (30m perforated) | | |
| 80-250 | 171 | Open hole | | |
| **BH 5** | | | | |
| **BH Depth (m)** | **BH Diameter (mm)** | **Casing Type and Diameter** | **Blow Yield (L/s)** | **Rest Water Level (m bgl)** |
| 0-6 | 254 | 219 mm steel casing | 0.2 | 10.18 |
| 6-80 | 208 | 177 mm steel casing (30m perforated) | | |
| 80-250 | 171 | Open hole | | |
| **BH 6** | | | | |
| **BH Depth (m)** | **BH Diameter (mm)** | **Casing Type and Diameter** | **Blow Yield (L/s)** | **Rest Water Level (m bgl)** |
| 0-6 | 254 | 219 mm steel casing | 3 | 8.65 |
| 6-85 | 208 | Open hole | | |
| 85-250 | 171 | Open hole | | |


| | | |
|---|---|---|
| | **Klaarstroom GWI**<br>**Position of the Drill Site** | **Project No.**<br>**509890** |

**Figure 1: Klaarstroom drill position**

## 3. Borehole Testing Results

The pumping tests included step drawdown and constant discharge tests with subsequent recovery monitoring after each test. The purpose of the step-test is to establish the efficiency of a single borehole and to provide preliminary information on the yield of the borehole, both from a quantitative and qualitative perspective. The purpose of the constant discharge test is to determine the hydraulic properties of the aquifer adjacent to the tested borehole and to investigate, identify and characterise nearby hydraulic boundaries. This data, together with the recovery test results, is used to determine the optimal and safe yield and pumping schedule of the borehole.

**KS BH 1**

### Step Discharge Test

A total of three steps of 60 min duration each were conducted on borehole KS BH1 (**Table 2 and Figure** 2). The associated pumping rates varied between 0.57 and 1.07 L/s**. Figure 2** presents the water level in the borehole when pumped at these different rates, and the recovery response when the pump was switched off. The effective drawdown in the borehole was 92.74 m after 7 min into final step. The water level in the borehole recovered to 0.91 m after 180 min of pump shut-down, i.e. a 99 per cent recovery.

**Table 2: Details of Pumping Tests Conducted on BH 1**

| Step Drawdown Test | | | Constant Discharge Test | | |
|---|---|---|---|---|---|
| **Step** | **Pumping Rate (L/s)** | **Drawdown (m)** | **Pumping Rate (L/s)** | **Time (mins)** | **Drawdown (m)** |
| Step 1 | 0.57 | 25.66 | 0.25 | 2 520 | 28.19 |
| Step 2 | 0.76 | 82.74 | Recovery | 210 | 0.59 |
| Step 3 | 1.07 | 92.74 | | | |
| | | | Notes: | | |
| | | | Recovery to 97% of drawdown. | | |
| Recovery | 180 mins | 0.91 (99%) | | | |

## Constant Discharge Test

Based on the results of the step drawdown test, it was decided to undertake a constant discharge test at *c*.0.25 L/s . The borehole was pumped for 42 hours with a resultant drawdown of 28.19 m. The results are presented as a log-normal graph in **Figure 3**. The borehole recovered to 0.59 m 210 min after pump shutdown before recovery was stopped.

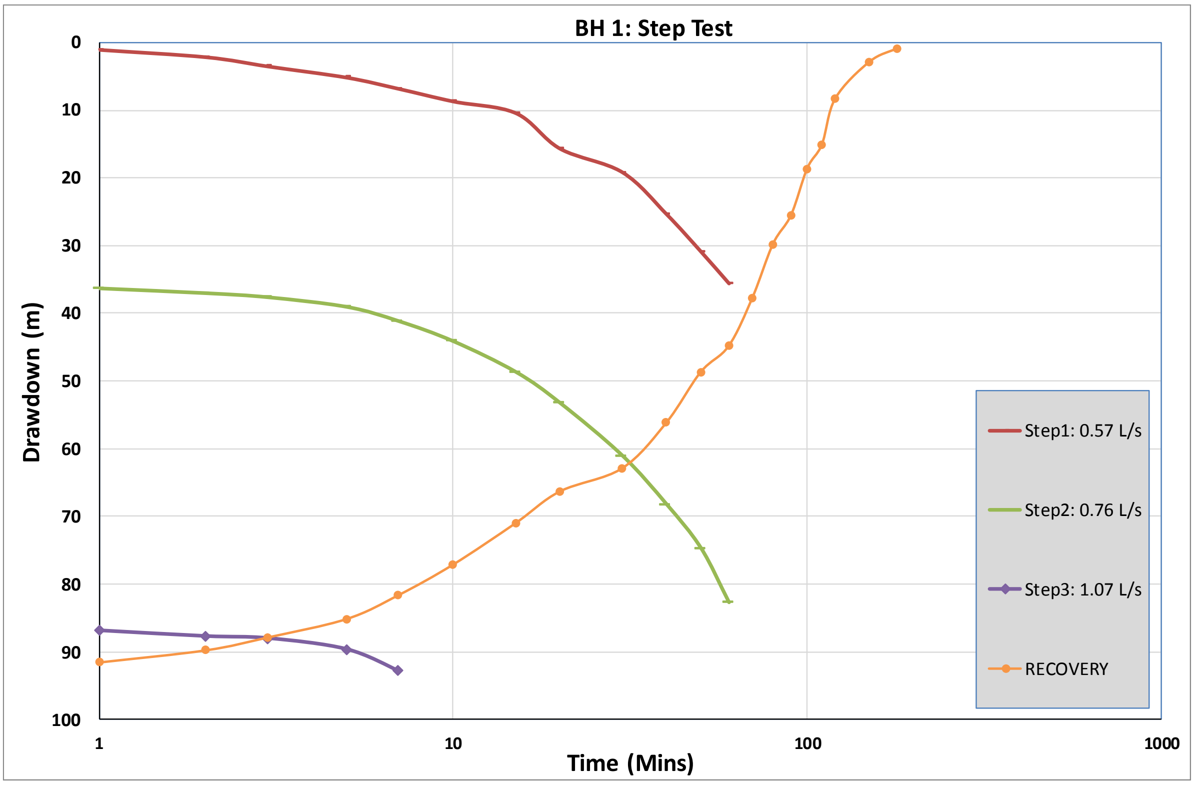


**Figure 2: Results of Step Drawdown Test**

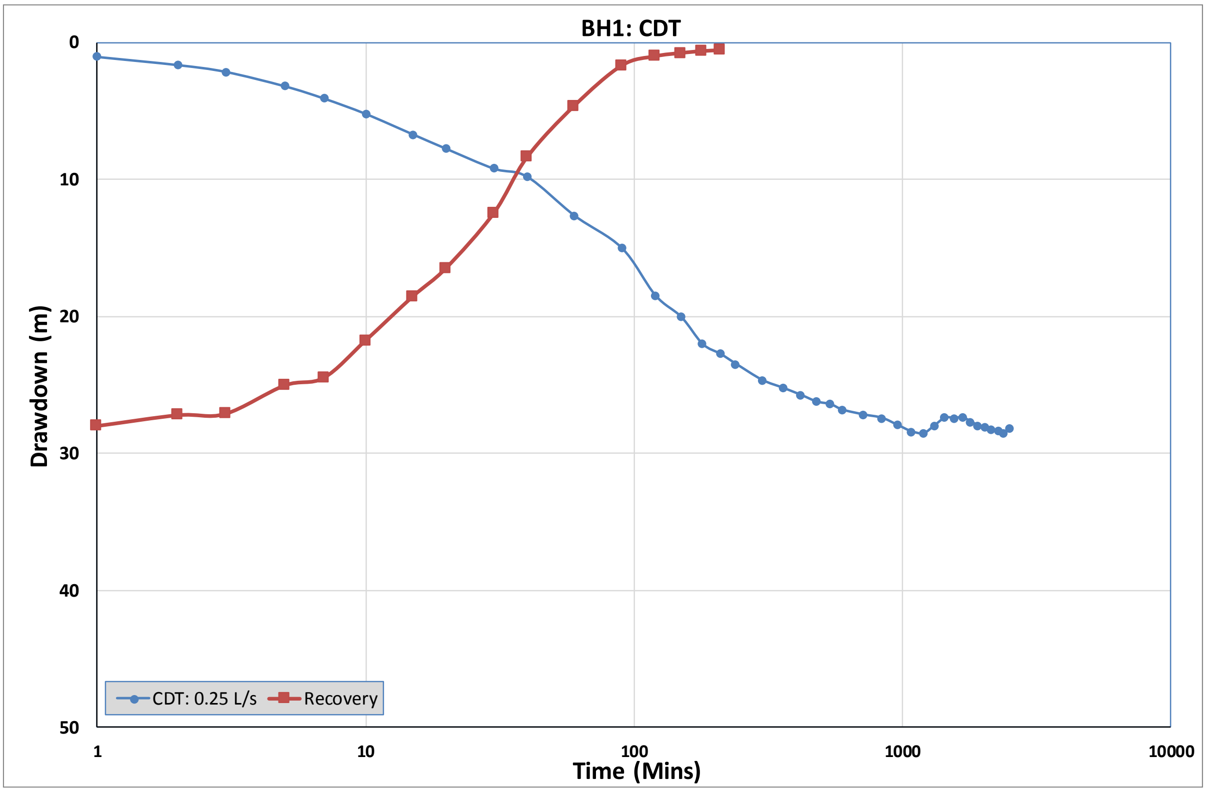


**Figure 3: Results of Constant Discharge Test**

## KS BH 6

### Step Discharge Test

A total of seven steps of 60 min duration each were conducted on borehole **KS BH6** (**Table 3 and Figure 4**). The associated pumping rates varied between 0.52 and 5.02 L/s**. Figure 4** presents the water level in the borehole when pumped at these different rates, and the recovery response when the pump was switched off. The effective drawdown in the borehole was 65.5 m after 50 min into final step. The water level in the borehole recovered to 2.11 m after 600 min of pump shut-down, i.e. a 96 per cent recovery.

**Table 3: Details of Pumping Tests Conducted on KS BH 6**

| Step Drawdown Test | | | Constant Discharge Test | | |
|---|---|---|---|---|---|
| **Step** | **Pumping Rate (L/s)** | **Drawdown (m)** | **Pumping Rate (L/s)** | **Time (mins)** | **Drawdown (m)** |
| Step 1 | 0.52 | 1.78 | 2.02 | 1 800 | 43.92 |
| Step 2 | 0.75 | 2.89 | Recovery | 1 560 | 2.05 |
| Step 3 | 1.01 | 4.49 | | | |
| Step 4 | 1.51 | 6.84 | | | |
| Step 5 | 2.01 | 9.34 | Notes: | | |
| Step 6 | 3.01 | 17.64 | Recovery to 95% of drawdown. | | |
| Step 7 | 5.02 | 65.5 | | | |
| Recovery | 600 mins | 2.11 (96%) | | | |

### Constant Discharge Test

Based on the results of the step drawdown test, it was decided to undertake a constant discharge test at *c.*2 L/s. The borehole was pumped for 30 hours with a resultant drawdown of 43.92 m. The results are presented as a log-normal graph in **Figure 3**. The borehole recovered to 2.05 m 1 560 min after pump shutdown before recovery was stopped.

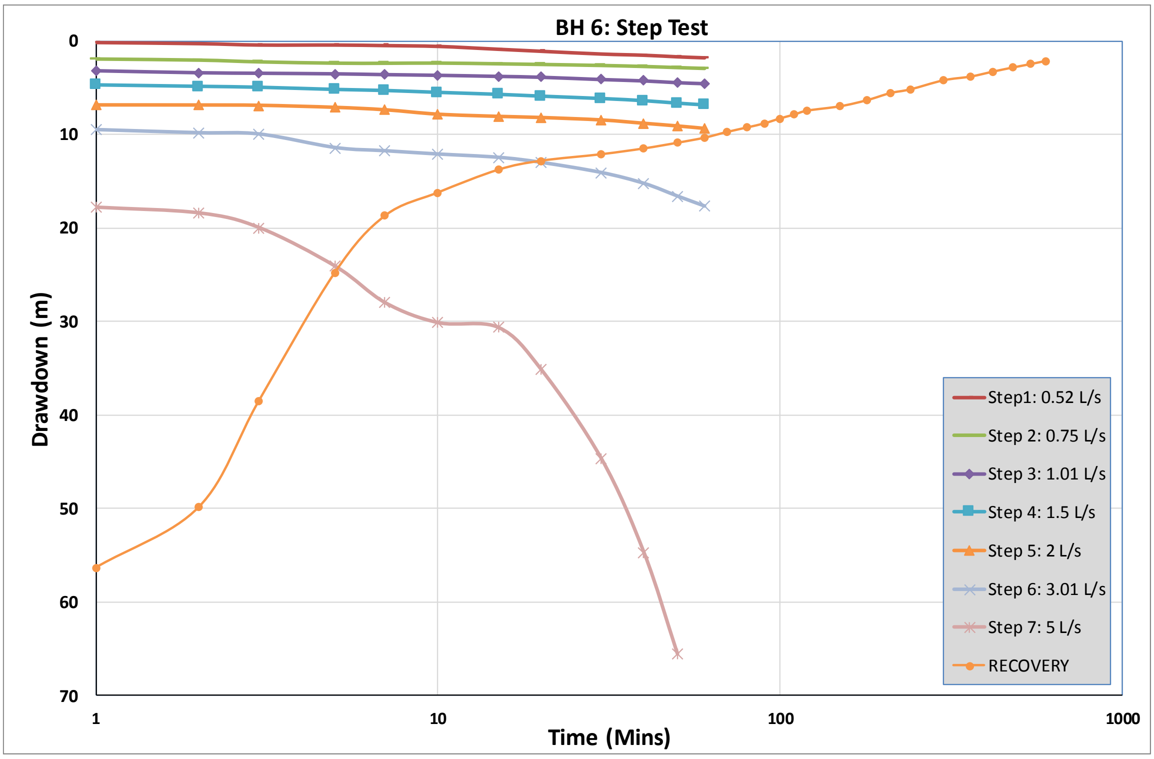


**Figure 4: Results of Step Drawdown Test**

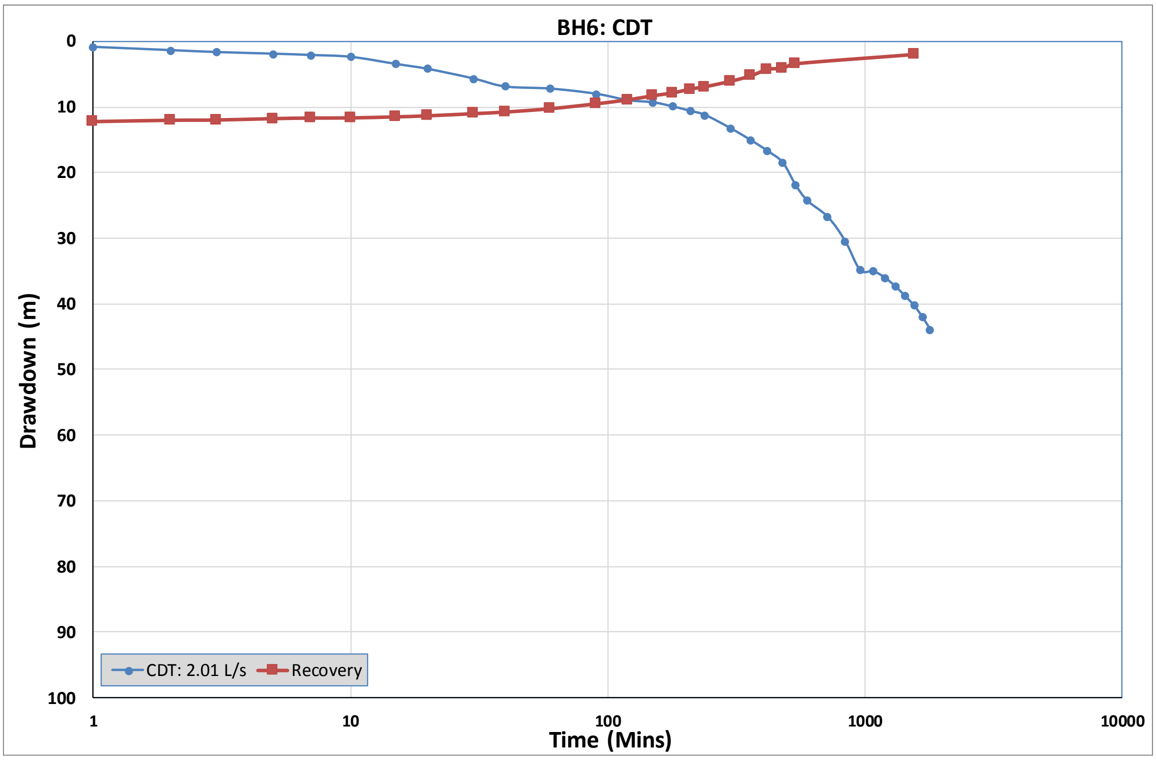


**Figure 5: Results of Constant Discharge Test**

## 4. Sustainable Yield

To estimate optimum pumping rates, pumping schedules and aquifer parameters, the test pumping data were analysed by means of an Excel based software package developed by Van Tonder et al

(2002). In the software package, various methods such as the Flow Characteristic method (FC-method), porous aquifer solutions (Theis, Cooper-Jacob and Hantush methods), fractional pumping test analysis (Barkers Generalised Radial Flow Model) and step drawdown analysis were used to estimate risk-based sustainable yields for the boreholes as well as aquifer parameters such as transmissivity (T) and the storage coefficient (S). In the FC-Analysis the following aquifer input parameters were used:

- Effective recharge of 5 mm per annum.
- Data were extrapolated for 2 year.

The summary of the results are presented in the Tables below.

**Table 4: Recommended Yield for Borehole BH 1A**

| Method | Sustainable Yield (L/s) | Std. Dev | Early T ($m^2/d$) | Late T ($m^2/d$) | Available Drawdown Used |
|---|---|---|---|---|---|
| **Basic FC** | 0.13 | 0.08 | 0 | 0.2 | 90 |
| **FC Inflection point** | 0.22 | 0.01 | | | |
| **Cooper Jacob** | 0.3 | 0.19 | | | 35 |
| **Average Yield (L/s)** | 0.22 | 0.09 | NOTES: Pump to be installed at 100 m bgl. | | |
| **Recommended abstraction rate** | | | | | |
| Hours per day of pumping at rate of. | 24 | 0.22 L/s | | | |
| | 16 | 0.25 L/s | | | |

Based on the single well test results, it is recommended that borehole BH1A may be pumped as follows:

- ***0.22 L/s for 24 h/day*** (18 $m^3$/day); or
- ***0.25 L/s for 16h/day*** (14$m^3$/day).

Borehole KS BH1 can be used to irrigate the sportsfield and should be pumped into tanks.

**Table 5: Recommended Yield for Borehole KS BH 6**

| Method | Sustainable Yield (L/s) | Std. Dev | Early T ($m^2/d$) | Late T ($m^2/d$) | Available Drawdown Used |
|---|---|---|---|---|---|
| **Basic FC** | 0.5 | 0.36 | 3 | 0.7 | 90 |
| **FC Inflection point** | 1.84 | 0.09 | | | 35 |
| **Cooper Jacob** | 0.60 | 0.39 | | 0.8 | 90 |
| **Average Yield (L/s)** | 0.94 | 0.68 | NOTES: Pump to be installed at 100 m bgl. | | |
| **Recommended abstraction rate** | | | | | |
| Hours per day of pumping at rate of. | 24 | 1 L/s | | | |
| | 12 | 1.5 L/s | | | |

Based on the single well test results, it is recommended that borehole KS BH 6 may be pumped as follows:

- ***1 L/s for 24 h/day*** (86 $m^3$/day); or
- ***1.50 L/s for 12h/day*** (65 $m^3$/day).

The daily limit for registering the borehole is 20$m^3$ and if more water is abstracted, the water use must be licensed.

## 5. Water Quality

Presented in **Table 6** are a summary of the water quality results. The laboratory certificates are listed in Appendix A. The results show that the EC of groundwater is high and mainly due to the elevated Chloride concentrations. It is also important that the water quality be compared to the existing borehole water quality.

The analyses indicated *E.coli* of 19 count/100ml at BH2 and 1 count/100ml at BH 3. The groundwater should be regularly monitored to detect if microbiological counts does not increase. The water should also be treated before use.

**Table 6: Water quality results**

| Constituent | BH 1 | BH 2 | BH 6 |
|---|---|---|---|
| pH (at 25°C) | 7.0 | 7.2 | 7.2 |
| Conductivity (at 25°C) (mS/m) | 351.4 | 193.2 | 274.3 |
| Turbidity | 0.62 | 12.33 | 7.38 |
| | mg/l | mg/l | mg/l |
| Fluoride (mg/l) | 0.0 | 0.1 | 0.0 |
| Calcium (as Ca) (mg/l) | 131.4 | 94.3 | 135 |
| Magnesium (as Mg) (mg/l) | 81.8 | 56.2 | 135 |
| Sodium (as Na) (mg/l) | 347.9 | 193.2 | 274.3 |
| Potassium (as K) (mg/l) | 3.4 | 3.6 | 3.7 |
| Chloride (as Cl) (mg/l) | 790 | 337 | 515.8 |
| Sulphate (as $SO_4$) (mg/l) | 234 | 117 | 173 |
| Ammonia Nitrogen (as N) (mg/l) | <0.28 | 0.4 | 0.38 |
| Nitrate & Nitrite Nitrogen (as N) (mg/l) | 0.02 | 0.05 | 0.03 |
| Iron (as Fe) (mg/l) | 0.1 | 0.1 | 0.1 |
| Manganese (as Mn) (mg/l) | 0.16 | 0.54 | 0.56 |

## 6. Recommendations

The recommendations arising from the exploration Phase of the project are:

**BH 1**

- The borehole can be pumped at ***0.22 L/s for 24 h/day*** (18 $m^3$/day) or ***0.25 L/s for 16h/day*** (14 $m^3$/day).
- Pump to be installed at 100 mbgl;
- Groundwater to be used for irrigating the sports field.

**BH 6**

- The borehole can be pumped at ***1 L/s for 24 h/day*** (86 $m^3$/day) or ***1.50 L/s for 12h/day*** (65 $m^3$/day).
- Pump to be installed at 100 mbgl;
- Groundwater to be treated before use.

Additional Recommendations

- A flow meter to measure total water use should be installed;
- An automatic datalogger should be installed to record the water level;
- A low-level cut-off switch should be installed 5 m above the pump intake; and
- The water use needs (not exceeding 20 $m^3$/d) to be registered with the DWS (*For assistance with the water use registration you may contact SRK for a quotation*);

## Prepared by

**SRK Consulting (South Africa) Pty Ltd**

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**Leon Groenewald Pr Sci Nat**
**Principal Hydrogeologist**