Future Flow
GROUNDWATER & PROJECT MANAGEMENT SOLUTIONS

Future Flow Reference: ADE.20.037
Client Reference:

REGISTRATION NO:
2008/094325/23

ADDRESS:
18 Claudius Place
Moreletapark, 0181
Postnet Suite 71
Private Bag X8
Elarduspark, 0047
Pretoria,
South Africa

CELLPHONE:
+27 (0) 83 633 4949

FACSIMILE:
+27 (0) 86 695 3846

E-MAIL:
martiens@ffgpm.co.za

WEBSITE:
www.ffgpm.co.za

MEMBER:
M.J. Prinsloo (Pr.Sci.Nat)

# VLNR LODGE
# WATER USE LICENCE APPLICATION
# AND
# ENVIRONMENTAL AUTHORISATION

## GROUNDWATER STUDY

for

Alta van Dyk Environmental Consultants

Future Flow Document: ADE.20.037 / VLNR Lodge WULA & EA_Report
03 December 2020

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**WATER USE LICENCE APPLICATION**
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| **Report Issue** | FINAL | | |
| **Reference Number** | ADE.20.037 | | |
| **Title** | VLNR Lodge WULA & EA – Groundwater study | | |
| | **Name** | **Signature** | **Date** |
| **Author** | Martiens Prinsloo (M.Sc.; Pr.Sci.Nat) | | 03 December 2020 |
| **Reviewed** | | | |

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This report is confidential to the client and we accept no responsibility of whatsoever nature to third parties to whom this report, or any part thereof, is made known. Any such parties rely on the report at their own risk.

# EXECUTIVE SUMMARY

## Introduction

Future Flow GPMS cc is contracted by Alta van Dyk Environmental Consultants (AVDE) to perform a hydrogeological study as part of the Venetia Limpopo Nature Reserve (VLNR) Lodge Project. The study area is located on the farm Lizzulea 62 MS, approximately 8.6 km north of Venetia Mine in the Limpopo Province of South Africa. VLNR is located approximately 80 km west of Musina, 40 km north-east of Alldays and 10 km south of the intersection of the international borders of Botswana, Zimbabwe and South Africa.

The VLNR is an amalgamation of former livestock farms that have been consolidated into a wildlife area by De Beers Consolidated Mines Limited primarily from 1991 onwards.

It is proposed that a lodge will be developed on the farm Lizzulea 62 MS for Tier 1 personnel of the mine. A total of 12 units and communal buildings are planned.

The aim of the investigation is to:

- Locate the optimal position for a water supply borehole;
- Install the borehole;
- Determine the sustainable yield of the borehole;
- Determine the groundwater quality; and
- Provide a report that complies with WUL regulation requirements.

## General site description

The proposed lodge lies on a small, local, west / east striking ridge, which lies at the foot of a larger north / south trending ridge. Topographical elevations at the top of the main ridge 1.4 km to the east of the proposed lodge area are 630 to 640 metres above mean sea level (mamsl). From the top of the main ridge, the topography slopes gently towards the west at an average gradient of 1:70 to where the proposed lodge lies at around 610 mamsl.

Within the immediate vicinity of the proposed lodge that topography dips towards the south, to where the Lizzulea dam lies at 600 mamsl.

To the west of the proposed lodge area the topography is very flat. Topographical gradients range in the order of 1:175 to 1:200 to the Kolope River that lies 5 km to the west of the proposed lodge.

The slope east of the lodge, from the higher lying main ridge to the lodge, is characterised by a number of unnamed, non-perennial streams that drain the slope in an east / west direction. Once the numerous smaller streams reach the flat lying area they all collect in a single stream (the Setoka River) that drains in a northern direction. The Lizzulea dam at which the lodge is planned lies in the southern reaches of the Setoka River.

The proposed lodge lies within the A63E quaternary catchment, which forms part of the Limpopo Water Management Area (WMA). The quaternary sub-catchment spans an area of 1 992 $km^2$.

The region is semi-arid with a subtropical climate of warm to hot summers and warm winters. The rainfall season extends from November to March. The closest rainfall station is the former Messina Agricultural Research Station for which mean annual rainfall between 1934 and 1990 was 339 mm. The mean annual rainfall at Pontdrif is 366 mm.

**Geology of the study area**

The VLNR contains a diverse array of geological substrates. Most of the reserve is flat, with hills of Karoo sandstone, conglomerate and shale, meta-quartzite, dolerite, diabase, and altered basic and ultra-mafic rocks occupying about 20% of the area. Undulating areas of calcrete and marble (mainly in the southeast) exposed by local uplift bring the area of lithosolic soils to about one-third.

Alluvial deposits are found in association with the Kolope, Setonki and Setoka Rivers which flow through the reserve. They vary in texture from sandy to clay-loam.

The VLNR is located within the Limpopo mobile belt. The country rock in the VLNR area appears as a complex arrangement of Proterozoic gneisses, amphibolites and metasediments of the Limpopo Group.

**Baseline groundwater conditions**

<u>Aquifer description</u>

Two aquifers occur in the area. These two aquifers are associated with the upper weathered material and the underlying competent and fractured rock material.

*Upper weathered material aquifer*

The weathered material aquifer forms due to the vertical infiltration of recharging rainfall through the weathered material being retarded by the lower permeability of the underlying competent rock material. Groundwater that collects above the contact between the weathered and unweathered material migrates down gradient along the contact to lower lying areas.

Aquifer thickness data obtained from drilling of the water supply borehole show a thickness of 6 m.

The borehole yields in this aquifer are seasonally variable due to the strong dependence on rainfall recharge. Generally, it can be said that the yields of this aquifer during the rainy season can be around 0.5 to 2 L/s while sustainable yields will decrease markedly during the dry season. In some areas this aquifer will be laid completely dry during the dry season. This can be seen in the results from the drilling of the water supply borehole for the lodge. No groundwater strikes were recorded in the weathered material aquifer.

Effectively 1.9 % of the mean annual rainfall recharges the groundwater table.

*Fractured rock aquifer*

The competent rock is subjected to fracturing that takes place during intrusion of diabase dykes into the host geology, as well as tectonic movements associated with the Limpopo mobile belt. Groundwater flows in the lower aquifer are associated with the secondary fracturing in the competent rock and as such will be along discrete pathways associated with the fractures. Faults and fractures can be a significant source of groundwater depending on whether the fractures have been filled with secondary mineralisation.

Aquifer transmissivity

The aquifer transmissivities calculated from the pumping phase data is consistent between 0.09 and 0.13 $m^2$/day. The transmissivity calculated from the recovery data is 0.56 $m^2$/day.

Depth to groundwater level

The depth to groundwater level was measured in the water supply borehole to be 9.12 m.

In the absence of large scale groundwater abstraction of artificial recharge in the area, it is assumed that the groundwater levels will mimic topography, albeit at a lesser gradient. It is expected that groundwater will flow from the main higher lying ridge 1.4 km east of the lodge to the lower lying area where the lodge will be located and on towards the Kolope River 5 km west of the proposed lodge. Groundwater flows can also be directed in a north-westerly direction along the drainage direction of the Setoka River.

Potential groundwater pollutants

The borehole will be used for water supply to the lodge. It is not expected that the groundwater abstraction will impact the groundwater quality in the aquifers.

A 10 kL Famsys package plant will be used for sewage treatment. The plant will be installed below ground, with the lids above ground. The plant is designed to produce effluent in terms of the current Water Act with specific reference to the Special Limits, defined in the SA law.

Sludge can be stored in the anaerobic zone, for removal by a honeysucker every 2-3 months if inflow remains at high levels. In practice sewage inflow will vary and duration for sludge removal will be much longer.

The plant suppliers recommend that the outflow water be put through a channel, where plants can be placed to remove the nutrient naturally.

The weathered material aquifer will be vulnerable to contamination from the outflow water in the output channel. However, this risk is localised and the impact will be negligible in the context of the sub-catchment.

<u>Groundwater qualities</u>

The groundwater sample that was collected from the water supply borehole during the aquifer test was submitted to an ISO17025 / SANAS accredited laboratory for analysis. The analysis results are compared to the SANS 241:2015 drinking water standards.

Chloride, fluoride, sodium and cadmium exceed the drinking water standards:

- At chloride concentrations above 400 mg/L a salty taste becomes quite distinctive and objectionable at greater than 600 mg/L. At chloride concentrations greater than 2 000 mg/L nausea may occur. At chloride concentrations greater than 200 mg/L, there is likely to be a significant shortening of the lifetime of domestic appliances as a result of corrosion;
- At fluoride concentrations above 8 mg/L severe tooth damage, especially to the temporary and permanent teeth of infants, softening the enamel and dentine will occur on continuous use of the water. Crippling skeletal fluorosis is likely to appear on long-term exposure;
- At sodium concentrations between 600 and 1 000 mg/L the water will have a very salty taste and health effects may be expected. The water is very undesirable for infants or persons on a sodium restricted diet; and
- Cadmium concentrations between 0.01 and 0.02 mg/L are the threshold for health damage with continuous exposure. Single incidence of exposure will not have observable effects.

Analysis of the groundwater character shows that the groundwater is sodium (cation) and chloride (anion) dominant. This is a reflection of the natural geology of the area.

The high chloride concentrations will increase the corrosiveness of the water. For the domestic user a corrosive or aggressive water may necessitate premature replacement of plumbing, tanks, geysers and household appliances. A scaling water may result in impaired water flow rates, especially in hot water systems, necessitate premature replacement of hot water plumbing, result in increased power consumption and require frequent replacement of heating elements as a result of poor heat transfer across the scale layer.

A water which is corrosive to metal fittings can usually be rendered less corrosive by increasing its alkalinity or pH, and reducing the sulphate and chloride content. Alkalinity addition is the more simple procedure since removal of sulphate and chloride would necessitate using a desalination technique.

**Aquifer characterisation**

For aquifer vulnerability reference is made to the aquifer vulnerability map of South Africa which shows a low aquifer vulnerability for the project area.

The aquifers present in the area are classified as minor aquifer based on the low aquifer potential and sustainable yields, but of high importance to the local landowners as it is their sole source of water for domestic and agricultural (stock watering and irrigation) purposes.

**Sub-catchment water balance**

The groundwater resource volume within the sub-catchment in which the water supply borehole is located, is calculated based on the sub-catchment area (90.48 $km^2$ calculated for sub-catchment within the A63E quaternary catchment that was delineated), the average annual rainfall (358 mm for GRA II report) and the recharge percentage (1.92 % from GRA II report). Recharge into the sub-catchment from rainfall is calculated to be in the order of 621 945 $m^3$/a, or 1 705 $m^3$/day.

The proposed groundwater abstraction for use at the lodge is 150 L/person/day. Assuming a maximum number of people of 26, it is calculated that the proposed maximum abstraction via the groundwater supply borehole is 1 423.5 $m^3$/a, or 3.9 $m^3$/day.

More than 90 % of the sub-catchment lies within the Venetia Limpopo Nature Reserve. There are 9 additional boreholes that are used for water supply of which two (boreholes H18-0695 and H18-0772) fall within the same sub-catchment as the lodge borehole. The groundwater use at borehole H18-0695 is stated to be 432 $m^3$/day, while the water use at H18-0772 is given as 57.6 $m^3$/day. This gives a total abstraction from the aquifer in the sub-catchment from existing boreholes of 489.6 $m^3$/day.

The water balance is calculated:

| | | |
|---|---|---|
| Inflows: | | |
| | Recharge into catchment: | 1 705 $m^3$/day |
| Outflows: | | |
| | Proposed abstraction for VLNR lodge: | 3.9 $m^3$/day |
| | <u>Existing abstraction from sub-catchment</u> | <u>489.6 $m^3$/day</u> |
| Balance: | | 1 211.5 $m^3$/day |

From this it can be seen that the sub-catchment can sustain the proposed groundwater abstraction for the lodge.

**Impact assessment**

Construction phase

During construction of the lodge surface infrastructure will be constructed. It is assumed that water will be drawn from the water supply borehole for civil works. The required water supply volume during the construction phase is stated to be 40 $m^3$/month for 10 months (1.33 $m^3$/day). This is less than the sustainable yield of the water supply borehole of 21.6 $m^3$/day that was calculated from the aquifer test data.

The groundwater level around the water supply borehole will be drawn down due to groundwater abstraction. The zone of influence of the dewatering cone is calculated using Sichardt's equation to be 20 m. Sichardt's equation is widely acknowledged to under estimate the zone of influence somewhat. Therefore, a value of 100 m is assumed to be conservative. Based on this calculation the dewatering cone does not impact any of the surface streams. There are also no other boreholes within the zone of influence.

It is assumed that under good housekeeping regulations, there will be little to no hydrocarbon spills or other impacts on the groundwater environment.

Operational phase

Similar to the construction phase there will be a drawdown in groundwater level around the water supply borehole. The zone of influence can be calculated similar to that of the construction phase. From that it can be seen that the expected long-term zone of influence will extend up to 100 m from the proposed water supply borehole. There are no other boreholes or streams that fall within the zone of influence.

Groundwater abstraction through the water supply borehole is not expected to impact the groundwater qualities.

A 10 kL Famsys package plant will be used for sewage treatment. The plant will be installed below ground, with the lids above ground. The plant is designed to produce effluent in terms of the current Water Act with specific reference to the Special Limits, defined in the SA law.

Sludge can be stored in the anaerobic zone, for removal by a honeysucker every 2-3 months if inflow remains at high levels. In practice sewage inflow will vary and duration for sludge removal will be much longer.

The plant suppliers recommend that the outflow water be put through a channel, where plants can be placed to remove the nutrient naturally.

The weathered material aquifer will be vulnerable to contamination from the outflow water in the output channel. However, this risk is localised and the impact will be negligible in the context of the sub-catchment. It is not expected that pollution from the outflow water will impact any surface streams or other boreholes in the area.

Long term post-closure phase

After closure the groundwater abstraction will stop and any drawdown in groundwater level will stop and the groundwater level will recover to pre-usage levels.

Contamination from the lodge will decrease due to the rehabilitation of the area. This will reduce or remove impacts on the groundwater environment.

**Recommendations**

Monitoring program

*Groundwater level monitoring program*

A monitoring program should be implemented to monitor the groundwater level in the water supply borehole. The groundwater level should be measured near the end of one of the two 6 hour resting phases every day. A time series plot of the obtained groundwater levels for each day should be compiled. It is recommended that should any trend of decreasing groundwater levels over time be identified, one of two options be pursued:

- Decrease the groundwater abstraction volumes; or
- Installing an additional water supply borehole.

To ease the monitoring, it is recommended that an electronic logger be installed that can be down-loaded on a regular (weekly or monthly) interval.

*Groundwater quality monitoring program*

Groundwater samples should be collected and submitted for chemical analysis in order to monitor the groundwater quality. From the groundwater chemical analysis results from this study, it can be seen that fluoride, sodium and cadmium are present in concentrations that can impact human health (the high chloride concentrations are expected to lead to scaling and salty taste to the water, but no human health impacts are expected).

Elements that have to be analysed for are:

- General parameters (pH, EC, Alkalinity, Hardness)
- Major cations (Ca, Mg, Na, K);
- Major anions (Cl, $SO_4$, $NO_3$, $NH_4$, $PO_4$, F);
- Metals (Al, Fe, Mn, Cr, Cu, Ni, Zn, Co, Cd, Pb);
- Biological / organic parameters (BOD, COD);

- Bacteriological (Heterotrophic plate count).

Groundwater samples should be monitored on a quarterly basis.

Water treatment

As mentioned above, from the groundwater chemical analysis results from this study, it can be seen that fluoride, sodium and cadmium are present in concentrations that can impact human health. It is recommended that water treatment options be investigated to reduce the element concentrations.

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# 1. Introduction and terms of reference

## 1.1. Background information

Future Flow GPMS cc is contracted by Alta van Dyk Environmental Consultants (AVDE) to perform a hydrogeological study as part of the Venetia Limpopo Nature Reserve (VLNR) Lodge Project. The study area is located on the farm Lizzulea 62 MS, approximately 8.6 km north of Venetia Mine in the Limpopo Province of South Africa. VLNR is located approximately 80 km west of Musina, 40 km north-east of Alldays and 10 km south of the intersection of the international borders of Botswana, Zimbabwe and South Africa.

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It is proposed that a lodge will be developed on the farm Lizzulea 62 MS for Tier 1 personnel of the mine. A total of 12 units and communal buildings are planned.

## 1.2. Aim of the investigation

The aim of the investigation is to:

- Locate the optimal position for a water supply borehole;
- Install the borehole;
- Determine the sustainable yield of the borehole;
- Determine the groundwater quality; and
- Provide a report that complies with Water Use Licence (WUL) and environmental authorisation (EA) regulation requirements.

# 2. Geographical setting

## 2.1. Topography and drainage

The proposed lodge lies on a small, local, west / east striking ridge, which lies at the foot of a larger north / south trending ridge (please refer to Figure 2.1). Topographical elevations at the top of the ridge are 630 to 640 metres above mean sea level (mamsl). From the top of the main ridge, which lies around 1.4 km east of the proposed lodge area, the topography slopes gently towards the west at an average gradient of 1:70 to where the proposed lodge lies at around 610 mamsl.

Within the immediate vicinity of the proposed lodge that topography dips towards the south, to where the Lizzulea dam lies at 600 mamsl.

To the west of the proposed lodge area the topography is very flat. Topographical gradients range in the order of 1:175 to 1:200 to the Kolope River that lies 5 km to the west of the proposed lodge.

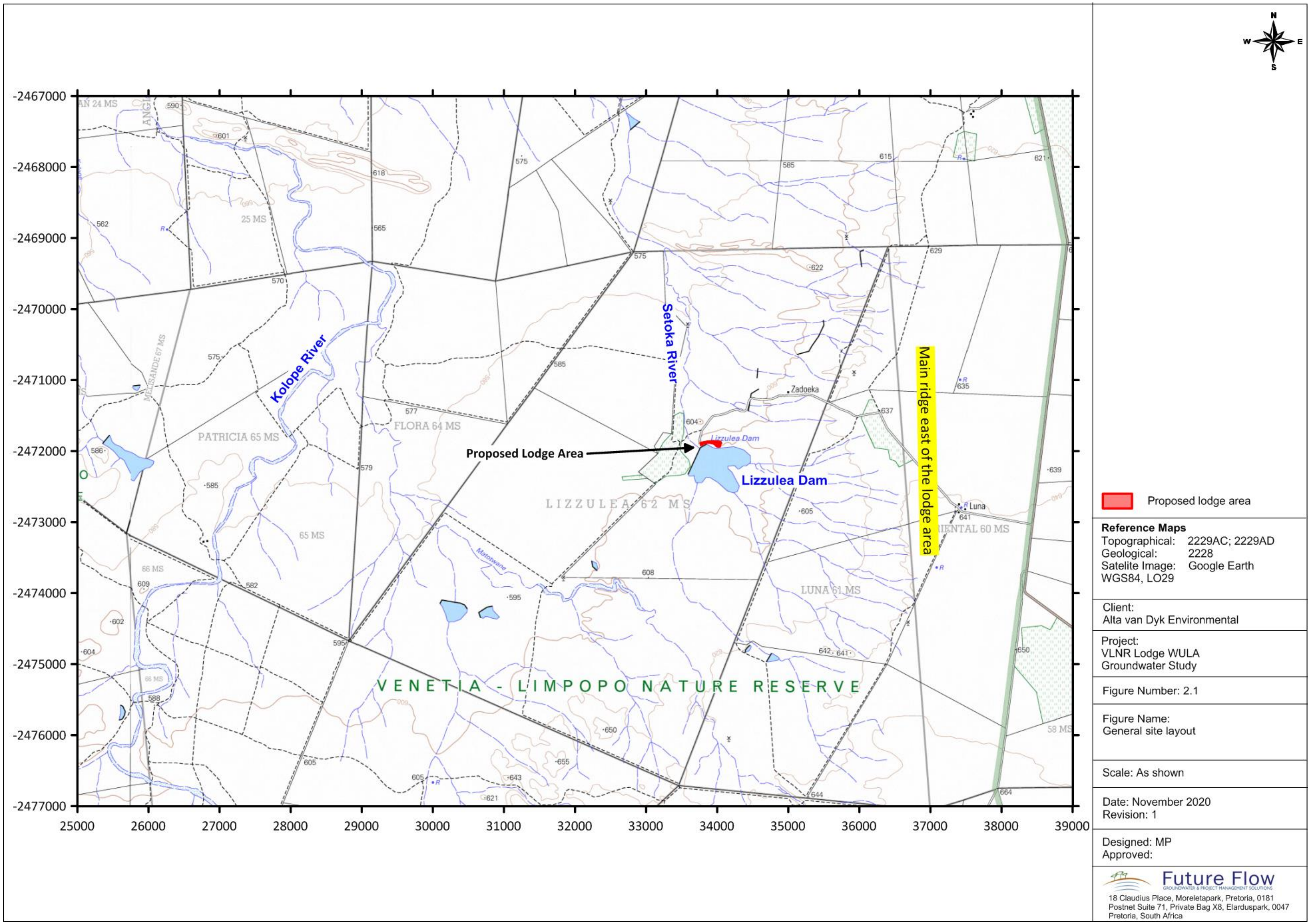
The slope east of the lodge, from the higher lying main ridge to the lodge, is characterised by a number of unnamed, non-perennial streams that drain the slope in an east / west direction (Figure 2.1). Once the numerous smaller streams reach the flat lying area they all collect in a single stream (the Setoka River) that drains in a northern direction. The Lizzulea dam at which the lodge is planned lies in the southern reaches of the Setoka River.

The proposed lodge lies within the A63E quaternary catchment, which forms part of the Limpopo Water Management Area (WMA). Reference to the Groundwater Resource Assessment II report (Department: Water Affairs and Forestry, 2006) show that the quaternary sub-catchment spans an area of 1 992 $km^2$.

## 2.2. Climate

Reference is made to the De Beers Ecology Division overarching management plan for a description of the climate at VLNR (De Beers Consolidated Mines Limited, 2015):

> "The region is semi-arid with a subtropical climate of warm to hot summers and warm winters. The rainfall season extends from November to March. The closest rainfall station with an appropriate long-term record is the former Messina Agricultural Research Station (29° 12'-29° 23' E'; 22° 15'-22° 30' S), for which mean annual rainfall between 1934 and 1990 was 339 mm with a coefficient of variation (CV) of 37%. The mean annual rainfall at Pontdrif (about 10 km N of the NW corner of VLNR) is 366 mm (31-year record), with a 36% CV (Page & O'Connor, 2012). The temporal pattern of rainfall is in close agreement with the quasi 18-year cycle proposed for southern Africa (Tyson and Preston-Whyte, 2000). Severe droughts, up to three years in duration, are characteristic. Rainfall has been recorded at a number of locations across VLNR since the reserve was established in the early 1990s. On-reserve recording has further revealed that the marginally higher elevation, eastern portion of VLNR receives slightly more rainfall on average than the lower altitude western portion.
>
> The range for temperature at Musina (80 km E) is: average minimum monthly of 7.2 °C (June, July) to 20.3 °C (December); average maximum monthly of 24.7 °C (June) to 32 °C (October, November, December). Mean annual evaporation of 2 200 mm (Midgley et al. 1984) is six-fold greater than the mean annual rainfall."


Kolope River
Setoka River
Proposed Lodge Area
Lizzulea Dam
Main ridge east of the lodge area
VENETIA - LIMPOPO NATURE RESERVE
PATRICIA 65 MS
FLORA 64 MS
LIZZULEA 62 MS
LUNA 61 MS
Zadoeka
Luna
Proposed lodge area
Reference Maps
Topographical: 2229AC; 2229AD
Geological: 2228
Satelite Image: Google Earth
WGS84, LO29
Client:
Alta van Dyk Environmental
Project:
VLNR Lodge WULA
Groundwater Study
Figure Number: 2.1
Figure Name:
General site layout
Scale: As shown
Date: November 2020
Revision: 1
Designed: MP
Approved:
Future Flow
18 Claudius Place, Moreletapark, Pretoria, 0181
Postnet Suite 71, Private Bag X8, Elarduspark, 0047
Pretoria, South Africa

## 3. Scope of work

### 3.1. WUL Regulation requirements

As part of the Water Use Licence Application (WULA), a groundwater study has to be performed according to the regulations set out by the Department of Water and Sanitation (DWS). These regulations require a geohydrological report discussing the groundwater conditions at various levels of detail, depending on the scale of the abstraction. Following the requirement for small scale abstractions (<60 % of the recharge on the property), the following aspects have to be addressed:

- Geology of the area;
- Hydrocensus of the area;
- Proximity to surface water discharges (springs, seeps, wetlands, streams, rivers, lakes), and groundwater dependent ecosystem;
- Geo-referenced map of the property with boreholes, physical structures and current pollution sources indicated;
- Monitoring program.

Desktop studies, aquifer testing and chemical analysis of the groundwater were used to develop a groundwater conceptual model of the study area. Analytical calculations were used to perform the environmental impact assessment.

### 3.2. Project scope of work

The scope of work includes:

- Project initiation:
  - Collection and evaluation of all available data including site specific information supplied by the client, as well as public domain information (geological and hydrogeological maps etc.);
- Installation of the water supply borehole:
  - Ground geophysical investigation to identify preferential groundwater flow paths such as fault zones, intrusive contact zones and fractures that could form preferential groundwater flow pathways;
  - Installation of a water supply borehole;
  - Testing of the borehole to determine the sustainable yield of the borehole; and
  - Laboratory testing of the groundwater to determine the groundwater quality.
- Reporting:
  - The findings of the study are discussed.

## 4. Methodology

### 4.1. Desk study

A desk study of the available information was done before the field investigation started. Data that was reviewed included:

- Geological map of the area (1:250 000 map 2228) to identify the general host geology and locate regional structures or geological contact close to the proposed lodge position;
- Satellite imagery of the area (Google Earth as well as World Imagery included for Global Mapper software) to identify lineaments as well as potential target areas taking into account surface layouts, surface lineaments and surface streams.

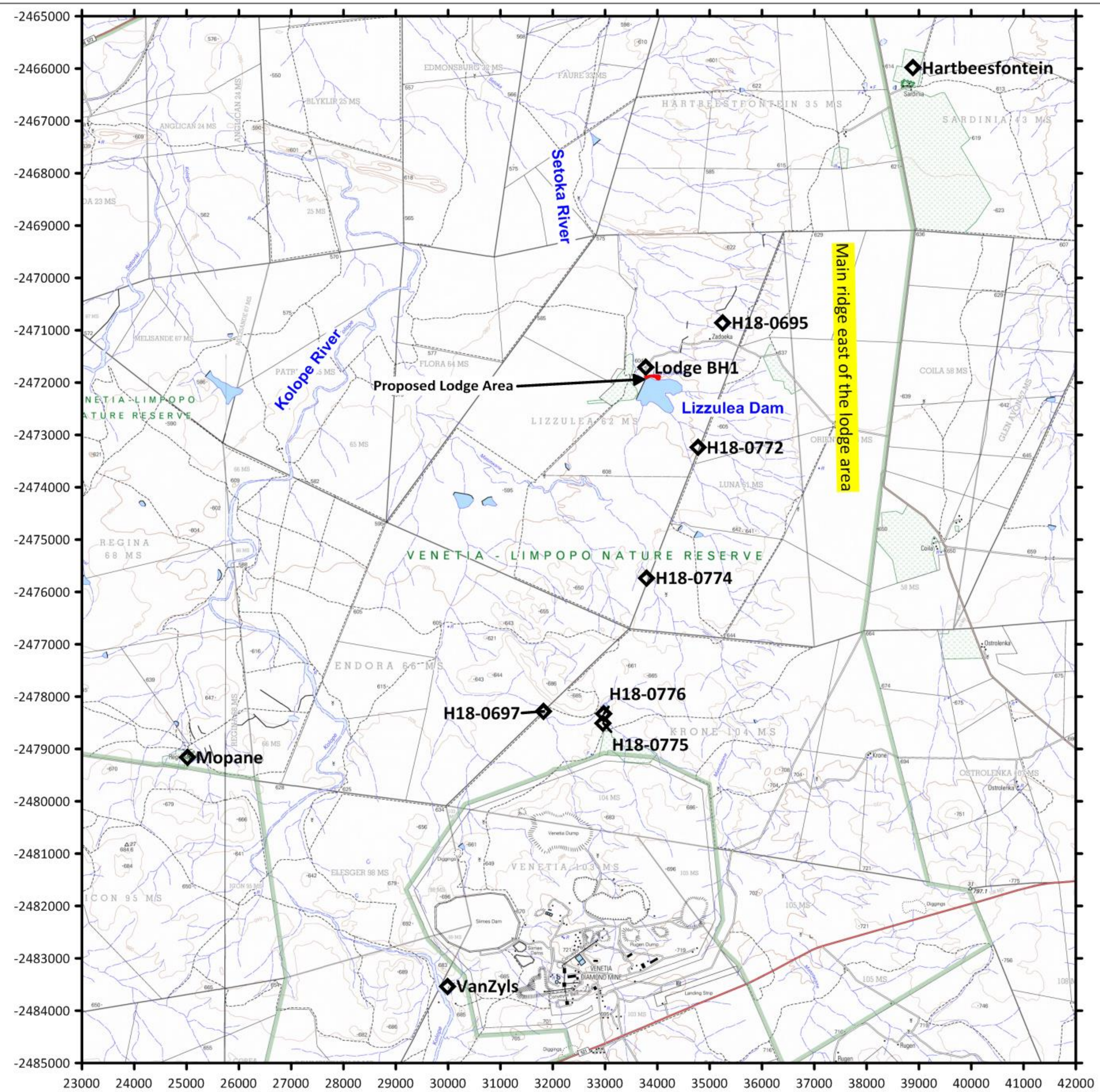
### 4.2. Hydrocensus

The proposed lodge is located within the Venetia Limpopo Nature Reserve. There are 9 groundwater boreholes that are being used. Please refer to Table 4.1 for the borehole details that were provided. The borehole positions are shown in Figure 4.1.

The boreholes closest to the proposed lodge lies 1.6 (H18-0 695) to 1.9 km (H18-0772) away, while the furthest are around 12 km to the south (Mopane and Van Zyl's). Groundwater use from the boreholes generally ranges between 1.4 and 58 $m^3$/day, with borehole H18-0695 being anomalously high at 432 $m^3$/day. The total abstraction from the currently used boreholes is 636.4 $m^3$/day. Abstraction from the lodge borehole will be added to this to increase the total to 640.3 $m^3$/day.

**Table 4.1: Hydrocensus borehole details**

| Borehole | East | South | Elevation | Water use volume |
|---|---|---|---|---|
| | (WGS84, LO29) | (WGS84, LO29) | mamsl | $m^3$/day |
| Lodge BH1 | 33 774 | -2 471 714 | 601.52 | 3.9 |
| Hartbeesfontein | 38 891 | -2 465 985 | 610.15 | 1.4 |
| VanZyl's | 29 995 | -2 483 532 | 656.37 | Not in use |
| Mopane | 25 015 | -2 479 160 | 631.83 | 1.4 |
| H18-0695 | 35 255 | -2 470 856 | 613.63 | 432.0 |
| H18-0697 | 31 828 | -2 478 280 | 635.00 | 17.3 |
| H18-0772 | 34 779 | -2 473 238 | 609.70 | 57.6 |
| H18-0774 | 33 801 | -2 475 733 | 628.36 | 11.5 |
| H18-0775 | 32 967 | -2 478 507 | 645.49 | 57.6 |
| H18-0776 | 32 982 | -2 478 323 | 644.70 | 57.6 |




**Reference Maps**
Topographical: 2229AC; 2229AD
Geological: 2228
Satelite Image: Google Earth
WGS84, LO29

Client:
Alta van Dyk Environmental

Project:
VLNR Lodge WULA
Groundwater Study

Figure Number: 4.1

Figure Name:
Hydrocensus borehole positions

Scale: As shown

Date: November 2020
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GROUNDWATER & PROJECT MANAGEMENT SOLUTIONS
18 Claudius Place, Moreletapark, Pretoria, 0181
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### 4.3. Geophysical survey and results

A ground geophysical survey was done to identify the optimal borehole position. The survey area was planned before mobilisation to site. The survey area took into consideration:

- Results from the desk study (detailed in Section 4.1 of this report);
- Proposed position of the lodge;
- Accessibility for the drill rig.

The survey was performed using the magnetic method. The survey consisted of a number of traverses in a north / south direction to locate:

- The west / east trending geological contact between the Beaufort Formation and the Red Rock member of the Clarens Formation seen from the geological map just north of the proposed lodge position. This contact could be a source of water as seen from the presence of a spring on this contact zone, close to the Setoka River;
- Any west / east trending regional faults and'/or dykes seen from the geological map. These structures cut across geological contacts and could be a potential source of groundwater.

The traverses used a 5 m station spacing, which is considered to be sufficient to locate the regional geological contact zone. The survey located the geological contact seen from the geological map of the area. A borehole point was identified for drilling of the water supply borehole.

### 4.4. Drilling of water supply borehole

One water supply borehole was drilled as part of the investigation (Lodge BH1). The borehole was drilled to a depth of 78 m. Casing was inserted to a depth of 18 m in the borehole to stabilise the borehole and prevent collapse of the borehole because weathered shale was intercepted to that depth.

A groundwater strike was intercepted at 48 m depth, on the contact between the sandstone and the underlying mudstone. The blow-out yield of the borehole was 1 L/s (50 L per 50 seconds). No groundwater strikes were recorded in the weathered material, indicating that the weathered material aquifer is dry in this area. The borehole draws water from the more consistent fractured rock aquifer which should not be impacted by seasonal rainfall cycles. The lithologies intercepted were as summarised in Table 4.2.

**Table 4.2: Water supply lithologies**

| Depth (mbgl) | Lithology |
|---|---|
| 0 – 6 | Red-brown overburden |
| 6 – 18 | Dark grey weathered shale |
| 18 – 48 | Dark brown sandstone |
| 48 – 54 | Brown mudstone |
| 54 - 78 | Brown sandstone |

### 4.5. Aquifer testing

An aquifer test was performed on the borehole. The test followed the regulation set out in the Water Use Licence guidelines. The borehole water will be used for supply to the lodge, not bulk water supply or irrigation. Therefore, it was planned that the aquifer test would involve an 8 hour constant rate pump test followed by recovery measurement. However, due to free roaming lion and other animals, the working hours were restricted to daytime only for the safety of site personnel. The constant rate pumping phase was done at a rate of 1.0 litre per second (L/s).

During the test the groundwater level response (drawdown and recovery) was recorded using an automatic level logger which was set to record the groundwater level on 30 second intervals for the duration of the test.

The obtained data was interpreted to calculate the aquifer transmissivity as well as the sustainable yield of the water supply borehole. The aquifer transmissivity was calculated suing both the FC-method and the AquiferWin32 software package. The sustainable yield of the water supply borehole is calculated using the FC-method.

AquiferWin32 is an internationally developed and used software program. The FC-method was developed by the Institute for Groundwater Studies at the University of the Free State, Bloemfontein.

Analysis of the data using the FC-method shows a limited fracture network. Groundwater level drawdown achieved at 1.0 L/s is around 40.5 m while the borehole is 78 m deep. Recovery could only be measured for around 20 minutes before the equipment had to be removed before nightfall. During the time of recovery the groundwater level recovered 25 m (61.5 % of the total drawdown) was achieved.

The sustainable yield of the borehole is calculated as 0.5 L/s for 6 hours, followed by 6 hour recovery. The borehole can thus be pumped for 12 hours out of every 24, yielding a total volume of 21.6 $m^3$/day. This meets the water use requirement of the lodge which is currently estimated at 3.9 $m^3$/day when applying a use of 150 L/person/day and a maximum of 26 people.

It is important that a strict monitoring program be followed for the water supply borehole. It is recommended that the groundwater level recovery be monitored. The groundwater level at the end of one of the 6 hour recovery periods mentioned above should be recorded every day. A time series plot of these groundwater levels should be compiled. It is recommended that should any trend of decreasing groundwater levels over time be identified, one of two options be pursued:

- Decrease the groundwater abstraction volumes; or
- Installing an additional water supply borehole.

### 4.6. Sampling and chemical analysis

A water sample was collected from the water supply borehole near the end of the pumping test. The sample was submitted to an ISO17025 / SANAS accredited laboratory for analysis.

### 4.7. Groundwater recharge calculations

From groundwater recharge calculations, reference is made to the Groundwater Resource Assessment II report from the Department of Water and Sanitation published in 2006 (then Department of Water Affairs and Forestry (Department: Water Affairs and Forestry, 2006)). The report show that recharge into the A63E quaternary catchment within which the proposed lodge will be located is approximately 1.92 % of the 358 mm average annual rainfall. This equates to 6.86 mm/a or 13.6722 $Mm^3/a$.

The balance for the sub-catchment within which the groundwater abstraction borehole is located is discussed in Section 8 of this report.

### 4.8. Groundwater modelling

Because this application is for a single borehole, yielding relatively low volumes, located within a nature reserve with no other private groundwater users within kilometres' radius, no numerical modelling is done.

### 4.9. Groundwater availability assessment

For the groundwater availability assessment reference is made to the lithologies present in the area, the prevalence of potentially groundwater carrying geological structures, and the aquifer transmissivity calculated from the aquifer test that was done.

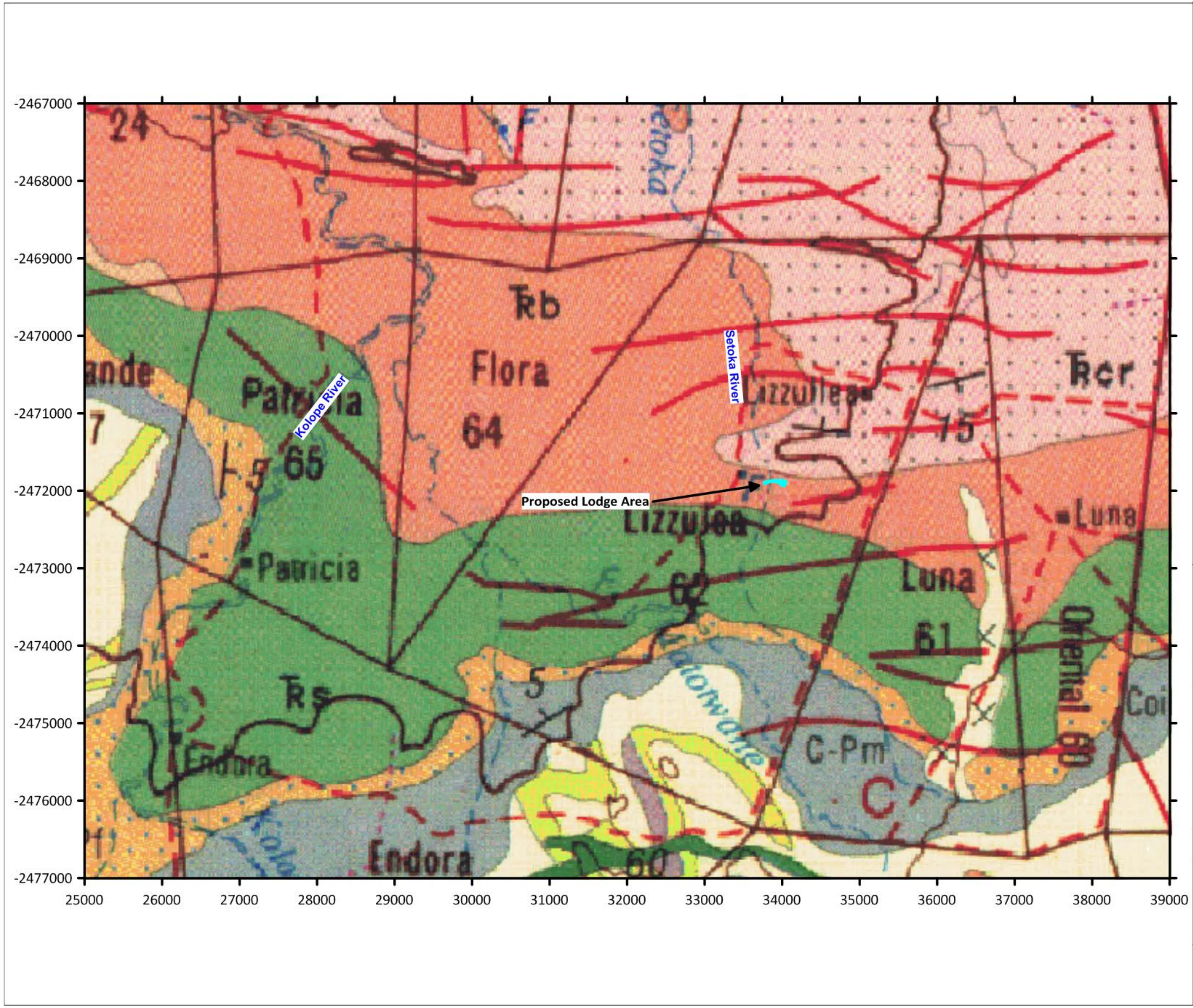
Based on this, it is concluded that there is a low groundwater availability within the region.

## 5. Prevailing groundwater conditions

### 5.1. Geology of the study area

A description of the geology of the study area is taken from the De Beers Ecology Division overarching management plan for a description of the climate at VLNR (De Beers Consolidated Mines Limited, 2015):

> "The VLNR contains a diverse array of geological substrates. Most of the reserve is flat, with hills of Karoo sandstone, conglomerate and shale, meta-quartzite, dolerite, diabase, and altered basic and ultra-mafic rocks occupying about 20% of the area. Undulating areas of calcrete and marble (mainly in the southeast) exposed by local uplift bring the area of lithosolic soils to about one-third.
>
> About one-third of the reserve consists of a flat landscape on deep (>3 m) palaeo-fluvial deposits of clay-loam texture, which are relatively fertile. Alluvial deposits are found in association with the Kolope, Setonki and Setoka Rivers which flow through the reserve. They vary in texture from sandy to clay-loam.
>
> Most of the remainder of VLNR is covered with relatively infertile, sandy loam soils up to 1 m in depth derived *in situ*, mainly from gneisses and from Karoo sandstones.
>
> Hills and scarp slopes have been formed as a consequence of backward retreat owing to erosion by this river system. These include a conspicuous ridge of hills, consisting predominantly of Clarens sandstone and underlying red mudstones and siltstones, that stretches from Halcyon in the west across to Edmondsburg in the east, relatively rugged sandstone hills in the north-east corner of VLNR on Faure and Hartebeesfontein, a scarp slope along the edge of the plateau-like portion along the eastern boundary (Hartebeesfontein, Luna, Oriental, Krone east), and conspicuous diabase dykes stretching from Krone through Venetia onto Drumsheugh and Elesger in the southern portion of the VLNR.
>
> The VLNR is located within the Limpopo mobile belt, which is an ancient collision zone of the Kaapvaal and Zimbabwe craton. The country rock in the VLNR area appears as a complex arrangement of Proterozoic gneisses, amphibolites and metasediments of the Limpopo Group. The Limpopo Group is believed to have a thickness of about 10 km and is overthrust onto Archean rocks of the Zimbabwean craton. The VLNR is characterised by shallow soils associated with calcrete or granite gneisses and deeper soils at the foot slopes and valley bottoms."




**Geological legend**

Tr cr Red Rocks Member - Clarens Formation
Tr b Beaufort Group
Tr s Solitude Formation
C-Pm Dwyka Formation

Proposed lodge area

**Reference Maps**
Topographical: 2229AC; 2229AD
Geological: 2228
Satelite Image: Google Earth
WGS84, LO29

Client:
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VLNR Lodge WULA
Groundwater Study

Figure Number: 5.1

Figure Name:
Regional geology of the study area

Scale: As shown

Date: November 2020
Revision: 1

Designed: MP
Approved:

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Postnet Suite 71, Private Bag X8, Elarduspark, 0047
Pretoria, South Africa

## 5.2. Hydrogeology

Two aquifers occur in the area and are associated with a) the upper weathered material, and b) the underlying competent and fractured rock material.

### 5.2.1. Aquifers present in the area

#### 5.2.1.1. Weathered material aquifer

The upper aquifer forms due to the vertical infiltration of recharging rainfall through the weathered material being retarded by the lower permeability of the underlying competent rock material. Groundwater that collects above the contact between the weathered and unweathered material migrates down gradient along the contact to lower lying areas.

Aquifer thickness data obtained from drilling of the water supply borehole show a thickness of 6 m.

The borehole yields in this aquifer are seasonally variable due to the strong dependence on rainfall recharge. Generally, it can be said that the yields of this aquifer during the rainy season can be around 0.5 to 2 L/s while sustainable yields will decrease markedly during the dry season. In some areas this aquifer will be laid completely dry during the dry season. This can be seen in the results from the drilling of the water supply borehole for the lodge. No groundwater strikes were recorded in the weathered material aquifer.

The groundwater quality in undisturbed areas is good due to the dynamic recharge from rainfall. This aquifer is, however, more likely to be affected by contaminant sources situated on surface.

#### 5.2.1.2. Fractured rock aquifer

Although the lower permeability of the unweathered competent rock will retard vertical infiltration of groundwater, a percentage of the water in the upper aquifer will recharge the lower aquifer. Direct recharge from rainfall can occur where the fractured, competent rock outcrops. In areas where the stream bases of the non-perennial rivers are located directly on top of the competent rock the aquifer can be directly recharged from the surface stream.

The competent rock is subjected to fracturing that takes place during intrusion of diabase dykes into the host geology, as well as tectonic movements associated with the Limpopo mobile belt.

Groundwater flows in the lower aquifer are associated with the secondary fracturing in the competent rock and as such will be along discrete pathways associated with the fractures. Faults and fractures can be a significant source of groundwater depending on whether the fractures have been filled with secondary mineralisation.

### 5.2.2. Aquifer transmissivity

The transmissivity of the fractured rock aquifer was calculated from the aquifer test data. The data was analysed using the FC-method as well as the AquiferWin32 software. The obtained transmissivities are summarised in Table 5.1.

The aquifer transmissivities calculated from the pumping phase data is consistent between 0.09 and 0.13 m$^2$/day. The transmissivity calculated from the recovery data is 0.56 m$^2$/day. The transmissivity calculated from the recovery data is influenced by the fact that recovery did not continue to at least 90 %. More reliance is placed on the pumping phase data.

**Table 5.1: Aquifer transmissivity**

| Borehole | Transmissivity (m$^2$/day) | | | |
|---|---|---|---|---|
| | FC-Method (late time) | Theis | Cooper-Jacob | Recovery |
| BH1 | 0.09 | 0.11 | 0.13 | 0.56 |

### 5.2.3. Depth to groundwater level

The depth to groundwater level was measured in the water supply borehole to be 9.12 m

In the absence of large scale groundwater abstraction of artificial recharge in the area, it is assumed that the groundwater levels will mimic topography, albeit at a lesser gradient. It is expected that groundwater will flow from the higher lying main ridge 1.4 km east of the lodge to the low lying area where the lodge will be located and on towards the Kolope River 5 km west of the proposed lodge. Groundwater flows can also be directed in a north-westerly direction along the drainage direction of the Setoka River. Please refer to Figure 5.2 for a conceptual depiction of the groundwater levels and flow patterns in the area.

### 5.2.4. Groundwater potential contaminants

The borehole will be used for water supply to the lodge and there will be no contamination to the aquifer from the groundwater abstraction.

A 10 kL Famsys package plant will be used for sewage treatment. The plant will be installed below ground, with the lids above ground.

The main process used in the *Famsystem* plant is a standard activated sludge system, where the BOD is broken down using air and bacteria, which grow in this medium. The bacteria grow naturally and no additional bio-chemicals have to be added in the process. The chlorine consumption for the plant is about 50 mg per day and chlorine pills will be used.

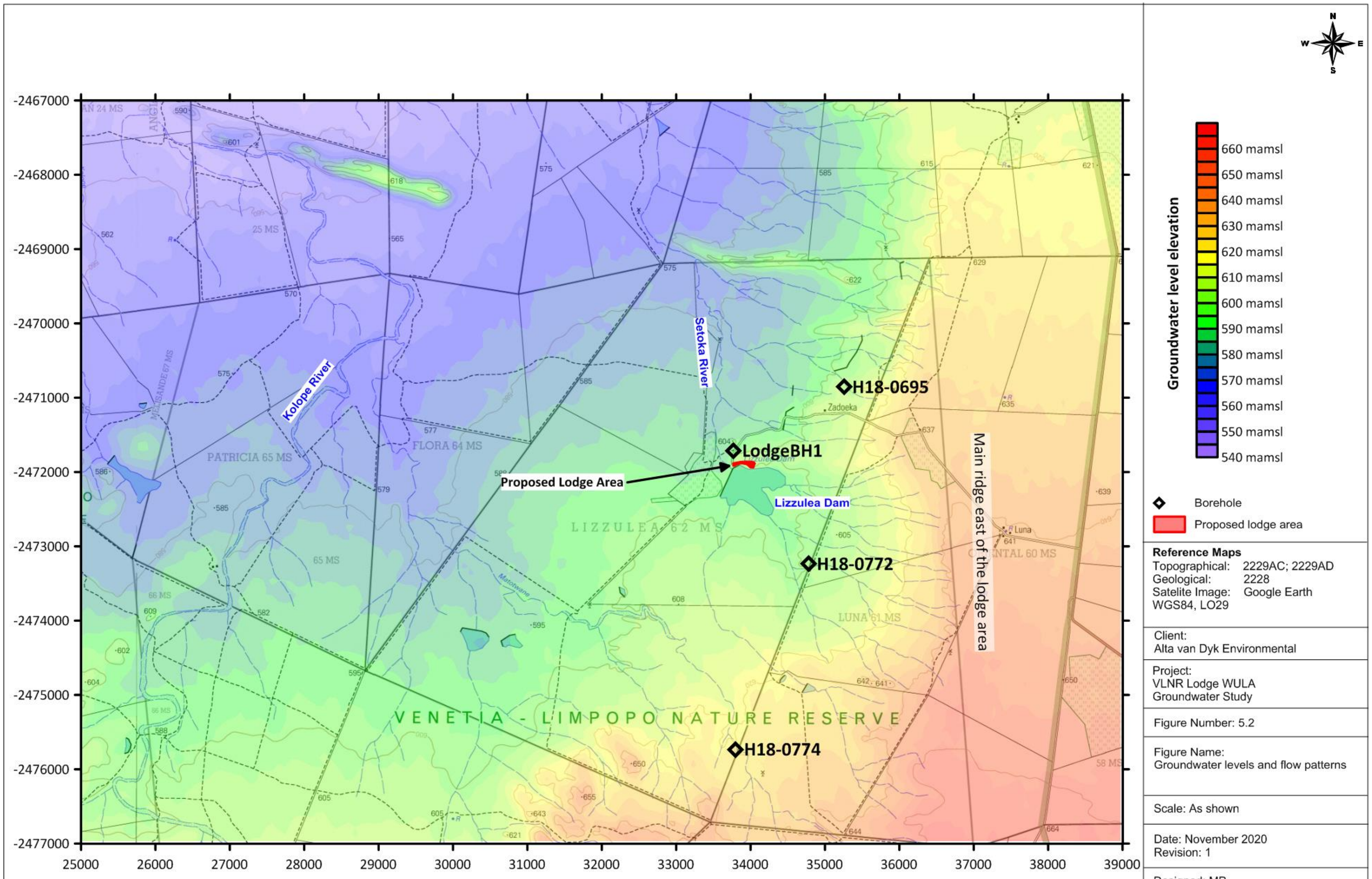
The raw sewage is introduced into a series of zones, where it is contacted with air, blown into the tanks by means of a special blower so that the natural aerobic bacteria break down the sewage. The plant does not need a septic tank.

The plant is designed to produce effluent in terms of the current Water Act with specific reference to the Special Limits, defined in the SA law.

Sludge can be stored in the anaerobic zone, for removal by a honeysucker every 2-3 months if inflow remains at high levels. In practice sewage inflow will vary and duration for sludge removal will be much longer.

The plant suppliers recommend that the outflow water be put through a channel, where plants can be placed to remove the nutrient naturally.

The weathered material aquifer will be vulnerable to contamination from the outflow water in the output channel. However, this risk is localised and the impact will be negligible in the context of the sub-catchment.




Reference Maps
Topographical: 2229AC; 2229AD
Geological: 2228
Satelite Image: Google Earth
WGS84, LO29

Client:
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Project:
VLNR Lodge WULA
Groundwater Study

Figure Number: 5.2

Figure Name:
Groundwater levels and flow patterns

Scale: As shown

Date: November 2020
Revision: 1

Designed: MP
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Postnet Suite 71, Private Bag X8, Elarduspark, 0047
Pretoria, South Africa

### 5.2.5. Groundwater quality

#### 5.2.5.1. Element concentrations

The groundwater sample that was collected from the water supply borehole during the aquifer test was submitted to an ISO17025 / SANAS accredited laboratory for analysis. The analysis results are summarised in Table 5.2. The data in the table is compared to the SANS 241:2015 drinking water standards (SABS, 2015). The standard represents a numerical limit of the listed element concentrations that will protect the health of the consumer over a lifetime of consumption. All elements that exceed the guidelines are highlighted and their aesthetic and health impacts discussed below at the hand of the health and aesthetic impact information contained in the South African Water Quality Guidelines (SAWQG) for domestic use as published by the Department of Water Affairs in 1996 (Department of Water Affairs and Forestry, 1996). The SANS241:2015 drinking water guidelines are used to determine compliance with drinking water requirements rather than the SAWQG because of the age of the SAWQ guidelines.

From Table 5.2 it can be seen that the groundwater quality is relatively poor with chloride, fluoride, sodium and cadmium exceeding the SANS241:2015 water quality guideline.

The source of the elevated sodium and chloride is considered to be due to the presence of the calcrete that occur in the area (please refer to Section 5.1 of this report). The element concentrations in the groundwater are also increased due to the fact that evaporation in the area is around 2 200 mm/a while the rainfall range between 339 and 360 mm/a (please refer to Section 2.2 of this report).

**TDS and EC:** The total dissolved solids (TDS) and electrical conductivity (EC) parameters exceed the SANS241:2015 guidelines. These parameters are dependent on the individual parameter concentrations, and with chloride and sodium being present in such high concentrations, the TDS (2 290 mg/L) and EC (394 mS/m) exceed the guideline values of 1 200 mg/L for TDS and 170 mS/m for EC.

**Chloride:** The chloride concentration is measured at 891 mg/L, which exceeds the SANS241:2015 drinking water quality guideline of 300 mg/L.

Chloride is of concern in domestic water supplies because elevated concentrations impart a salty taste to water and accelerate the corrosion rate of metals. High concentrations of chloride can also be detrimental to chloride-sensitive garden plants.

Chloride is only detectable by taste at concentrations exceeding approximately 200 mg/L. A salty taste becomes quite distinctive at 400 mg/L and objectionable at greater than 600 mg/L. At chloride concentrations greater than 2 000 mg/L nausea may occur, while at 10 000 mg/L vomiting and dehydration may be induced.

Chloride accelerates the corrosion rate of iron and certain other metals well below the concentration at which it is detectable by taste. The threshold for an increased corrosion rate is approximately 50 mg/L. At chloride concentrations greater than 200 mg/L, there is likely to be a significant shortening of the lifetime of domestic appliances as a result of corrosion.

**Fluoride:** The fluoride concentration was measured to be 11.5 mg/L, exceeding the SANS241:2015 guideline value of 1.5 mg/L.

The presence of fluoride in drinking water reduces the occurrence of dental caries in adults and children. A small amount of fluoride is necessary for proper hardening of dental enamel and to increase resistance to attack on tooth enamel by bacterial acids. In humans and animals, fluoride accumulates in the skeleton.

If fluoride is ingested, it is almost completely absorbed, where after it is distributed throughout the body. Most of the fluoride is retained in the skeleton and a small proportion in the teeth. The difference between concentrations of fluoride that protect tooth enamel and those that cause discolouration is marginal. Discolouration of dental enamel and mottling occurs at concentrations in the range of 1.5 - 2.0 mg/L in persons whose teeth are undergoing mineralisation. Generally, children up to seven years of age are susceptible.

High doses of fluoride interfere with carbohydrate, lipid, protein, vitamin, enzyme and mineral metabolism. Skeletal fluorosis may occur when concentrations of fluoride in water exceed 3 - 6 mg/L and becomes crippling at intakes of 20 - 40 mg/day. This is equivalent to a fluoride concentration of 10 - 20 mg/L, for a mean daily water intake of two litres. Systemic toxicity and interference with bone formation and metabolism occur at high concentrations.

Chronic effects on the kidneys have been observed in persons with renal disorders and rarer problems, including effects on the thyroid gland, which may occur with long-term exposure to high fluoride concentrations. Acute toxic effects at high fluoride doses include haemorrhagic gastroenteritis, acute toxic nephritis and injury to the liver and heart- muscle tissues. Many symptoms of acute fluoride toxicity are associated with the ability of fluoride to bind to calcium. Initial symptoms of fluoride toxicity include vomiting, abdominal pain, nausea, diarrhoea and convulsions.

At concentrations above 8 mg/L severe tooth damage, especially to the temporary and permanent teeth of infants, softening the enamel and dentine will occur on continuous use of the water. Crippling skeletal fluorosis is likely to appear on long-term exposure.

**Sodium:** The sodium concentration measured 710 mg/L, exceeding the SANS241:2015 drinking water quality guideline of 200 mg/L.

The taste threshold for sodium in water varies from 135 - 200 mg/L, depending on the associated anion. The common ones include chloride, sulphate, nitrate, bicarbonate and carbonate.

Sodium intake can exacerbate certain disease conditions. Persons suffering from hypertension, cardiovascular or renal diseases, should restrict their sodium intake. In the case of bottle-fed infants, sodium intake should also be restricted.

At concentrations between 600 and 1 000 mg/L the water will have a very salty taste and health effects may be expected. The water is very undesirable for infants or persons on a sodium restricted diet.

**Cadmium:** The cadmium concentration measured 0.016 mg/L which exceed the SANS241:2015 guideline value of 0.003 mg/L.

The presence of cadmium in the aquatic environment and in drinking water is of concern because it bioaccumulates. At elevated concentrations cadmium is acutely toxic and can cause severe renal damage with renal failure. Cadmium also causes acute gastroenteritis which closely mimics the gastroenteritis caused by micro-organisms. The half-life of cadmium in the body is several decades, hence, it is important to avoid exposure. Cadmium poisoning is very difficult to treat due to rapid and irreversible uptake by the kidneys. Immediate medical attention should be sought if cadmium poisoning is suspected. Zinc and ethylenediamine tetra-acetic acid may be used to ameliorate the effects of cadmium.

As a precautionary measure, it is recommended that a concentration of 0.005 mg/L not be exceeded because of the potentially acute and/or irreversible effects of cadmium on human health (Department of Water Affairs and Forestry, 1996).

Concentrations between 0.01 and 0.02 mg/L are the threshold for health damage with continuous exposure. Single incidence of exposure will not have observable effects.

#### 5.2.5.2. Groundwater character

Analysis of the groundwater character shows that the groundwater is sodium (cation) and chloride (anion) dominant. This is a reflection of the natural geology of the area.

The high chloride concentrations will increase the corrosiveness of the water. For the domestic user a corrosive or aggressive water may necessitate premature replacement of plumbing, tanks, geysers and household appliances. A scaling water may result in impaired water flow rates, especially in hot water systems, necessitate premature replacement of hot water plumbing, result in increased power consumption and require frequent replacement of heating elements as a result of poor heat transfer across the scale layer.

A water which is corrosive to metal fittings can usually be rendered less corrosive by increasing its alkalinity or pH, and reducing the sulphate and chloride content. Alkalinity addition is the more simple procedure since removal of sulphate and chloride would necessitate using a desalination technique.

**Table 5.2: Groundwater chemical analysis results**

| Analysis | Units | SANS 241:2015 guideline value | BH1 |
|---|---|---|---|
| pH | | ≥5 - ≤9.7 | 7.9 |
| Electrical Conductivity (EC) | mS/m | ≤170 | 394 |
| Total Dissolved Solids (TDS) | mg/L | ≤1 200 | 2290 |
| Total Alkalinity | mg/L $CaCO_3$ | N/L | 549 |
| Chloride (Cl) | mg/L | ≤300 | 891 |
| Sulphate ($SO_4$) | mg/L | ≤500 (health) | 156 |
| Nitrate ($NO_3$) | mg/L | ≤11 | 1.02 |
| Ammonium ($NH_4$) | mg/L | N/L | 0.225 |
| Phosphate ($PO_4$) | mg/L | N/L | 0.037 |
| Fluoride (F) | mg/L | ≤1.5 | 11.5 |
| Calcium (Ca) | mg/L | N/L | 62.4 |
| Magnesium (Mg) | mg/L | N/L | 76.4 |
| Sodium (Na) | mg/L | ≤200 | 710 |
| Potassium (K) | mg/L | N/L | 13.1 |
| Aluminium (Al) | mg/L | ≤0.3 | 0.012 |
| Iron (Fe) | mg/L | ≤2 (health) | <0.004 |
| Manganese (Mn) | mg/L | ≤0.4 (health) | 0.002 |
| Chromium (Cr) | mg/L | ≤0.05 | <0.003 |
| Copper (Cu) | mg/L | ≤2 | 0.055 |
| Nickel (Ni) | mg/L | ≤0.07 | <0.002 |
| Zinc (Zn) | mg/L | ≤5 | <0.002 |
| Cobalt (Co) | mg/L | N/L | <0.003 |
| Cadmium (Cd) | mg/L | ≤0.003 | 0.016 |
| Lead (Pb) | mg/L | ≤0.01 | <0.004 |
| Total Hardness | mg/L $CaCO_3$ | N/L | 471 |
| Bi-carbonate | mg/L $CaCO_3$ | N/L | 545 |

N/L: Not listed in SANS: 241:2015

Exceed the SANS241:2015 standard limit

# 6. Aquifer characterisation

## 6.1. Groundwater vulnerability

For aquifer vulnerability reference is made to the aquifer vulnerability map of South Africa which shows a low aquifer vulnerability for the project area. Vulnerability of groundwater is a relative, non-measurable and dimensionless property which is based on the concept that some land areas are more vulnerable to groundwater contamination than others. Maps showing groundwater vulnerability assist with the identification of areas more susceptible to contamination than others. They are useful in planning, policy formulation and decision-making for groundwater management and protection. Overlaying these maps with maps showing the location of contamination sources and land use enables the creation of risk maps.

Based on the low vulnerability of the area, it is concluded that the aquifer is not particularly vulnerable to contamination from surface, or shallow sources such as the sewage treatment package plant due to a combination of the depth to groundwater level (weathered material aquifer is dry in the area), and the aquifer transmissivity which will retard contaminant migration.

## 6.2. Aquifer classification

The aquifers present in the area are classified as minor aquifer based on the low aquifer potential and sustainable yields, but of high importance to the local landowners as it is their sole source of water for domestic and agricultural (stock watering and irrigation) purposes.

# 7. Groundwater modelling

Because this application is for a single borehole, yielding relatively low volumes, located within a nature reserve with no other private groundwater users within kilometres' radius, no numerical modelling is done.

# 8. Sub-catchment water balance

## 8.1. Groundwater resource volume available within the sub-catchment

The groundwater resource volume within the sub-catchment in which the water supply borehole is located, is calculated based on the sub-catchment area, the average annual rainfall and the recharge percentage.

The sub-catchment within which the borehole falls was calculated using a watershed calculation tool (Global Mapper). The sub-catchment is shown in Figure 8.1. The sub-catchment falls within the greater A63E quaternary sub-catchment and measures 90.48 $km^2$.

Assuming homogenous conditions within the quaternary catchment, the annual recharge from rainfall can be assumed for the smaller sub-catchment. The Groundwater Resource Assessment II document (Department: Water Affairs and Forestry, 2006), state that recharge from rainfall is 1.92 % of the mean annual rainfall. Rainfall is stated to be 358 mm/a.

Using the above, it is calculated that recharge into the sub-catchment from rainfall is in the order of 621 945 $m^3$/a, or 1 705 $m^3$/day.

### 8.2. Groundwater abstraction from the sub-catchment

The groundwater abstraction from the sub-catchment consists of:

- The proposed groundwater abstraction for the lodge; and
- The existing groundwater abstraction from the sub-catchment.

#### 8.2.1. Proposed groundwater abstraction for the lodge

The proposed groundwater abstraction for use at the lodge is 150 L/person/day. Assuming a maximum number of people of 26, it is calculated that the proposed maximum abstraction via the groundwater supply borehole is 1 423.5 $m^3$/a, or 3.9 $m^3$/day.

#### 8.2.2. Existing groundwater abstraction from the sub-catchment

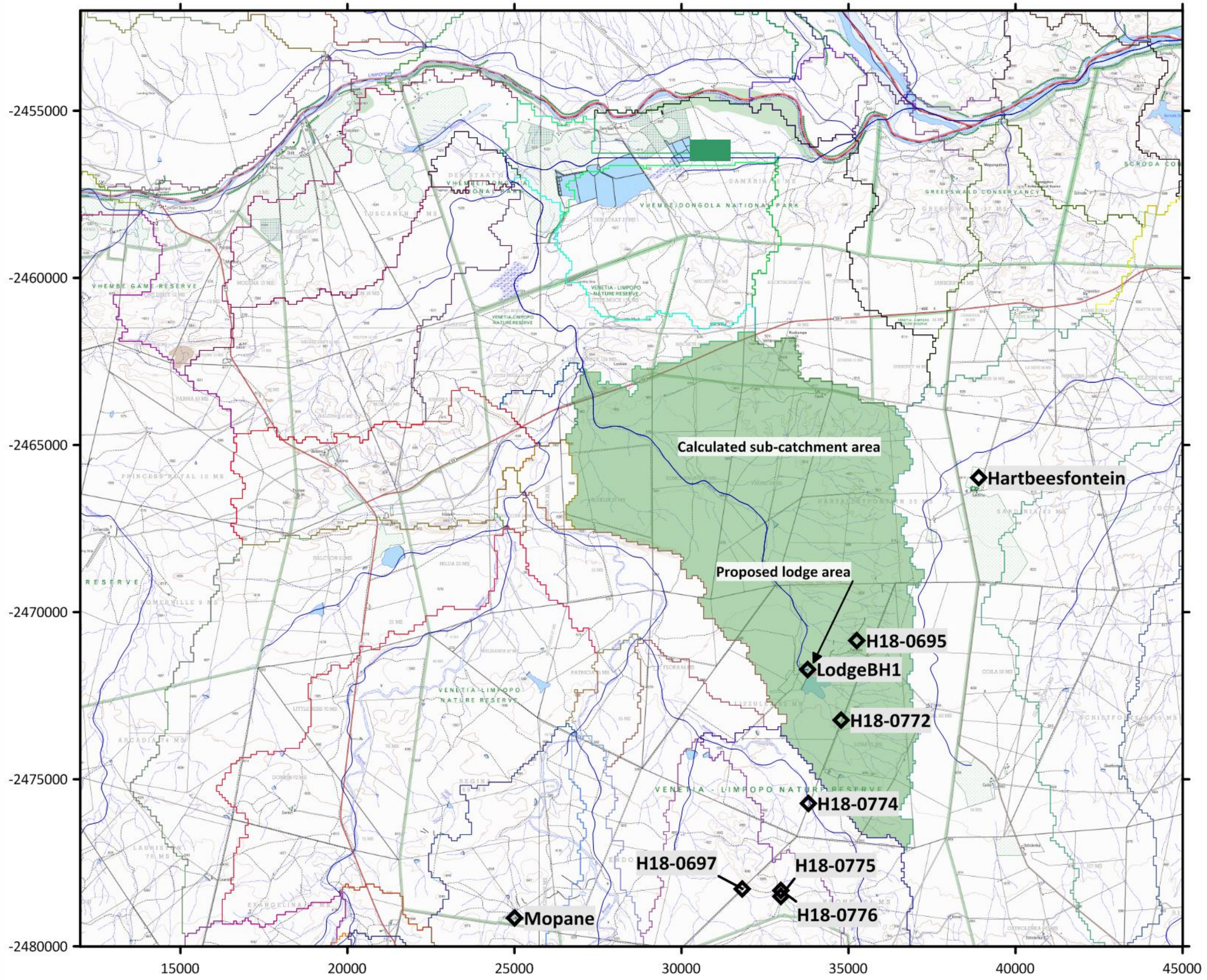
More than 90 % of the sub-catchment lies within the Venetia Limpopo Nature Reserve. Information supplied shows that there are 9 additional boreholes that are used for water supply (please refer to Table 4.1). Plotting the boreholes show that boreholes H18-0695 and H18-0772 fall within the same sub-catchment as the lodge borehole (please refer to Figure 8.1).

The groundwater use at borehole H18-0695 is stated to be 432 $m^3$/day, while the water use at H18-0772 is given as 57.6 $m^3$/day. This gives a total abstraction from the aquifer in the sub-catchment from existing boreholes of 489.6 $m^3$/day.

### 8.3. Sub-catchment water balance

| | | |
|---|---|---|
| Inflows: | | |
| | Recharge into catchment: | 1 705 $m^3$/day |
| Outflows: | | |
| | Proposed abstraction for VLNR lodge: | 3.9 $m^3$/day |
| | Existing abstraction from sub-catchment | 489.6 $m^3$/day |
| Balance: | | 1 211.5 $m^3$/day |

From this it can be seen that the sub-catchment can sustain the proposed groundwater abstraction for the lodge.




N W E S

◇ Hydrocensus borehole

**Reference Maps**
Topographical: 2229AC; 2229AD
Geological: 2228
Satelite Image: Google Earth
WGS84, LO29

Client:
Alta van Dyk Environmental

Project:
VLNR Lodge WULA
Groundwater Study

Figure Number: 8.1

Figure Name:
Sub-catchment of the study area

Scale: As shown

Date: November 2020
Revision: 1

Designed: MP
Approved:

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Postnet Suite 71, Private Bag X8, Elarduspark, 0047
Pretoria, South Africa

## 9. Impact assessment

The environmental impact assessment is conducted based on the available information and the analytical impact assessment that was done. Impacts from the proposed groundwater abstraction for use at the lodge were evaluated and include:

- Impacts on groundwater levels, flow patterns and volumes;
- Impacts on groundwater qualities and plume migration;
- Impacts on surface water quantities due to groundwater abstraction; and
- Impacts on surface water qualities due to poor quality groundwater seeping into the surface water in the form of baseflow contribution.

During the risk assessment the risk to the groundwater levels and quality were evaluated. Each of the identified risks was then rated. The rating methodology used is as described in **Error! Reference source not found.**.

The significance of the identified impacts will be determined using an accepted methodology from the Department of Environmental Affairs and Tourism Guideline document on EIA Regulations, April 1998. As with all impact methodologies, the impact is defined in a semi-quantitative way and will be assessed according to methodology prescribed in the following section.

**Table 9.1: Scale utilised for the evaluation of the Environmental Risk Ratings**

| Evaluation Component | Rating | Scale | Description / criteria |
|---|---|---|---|
| **MAGNITUDE of negative impact** (at the indicated spatial scale) | 10 | Very high | Bio-physical and/or social functions and/or processes might be *severely* altered. |
| | 8 | High | Bio-physical and/or social functions and/or processes might be *considerably* altered. |
| | 6 | Medium | Bio-physical and/or social functions and/or processes might be *notably* altered. |
| | 4 | Low | Bio-physical and/or social functions and/or processes might be *slightly* altered. |
| | 2 | Very low | Bio-physical and/or social functions and/or processes might be *negligibly* altered. |
| | 0 | Zero | Bio-physical and/or social functions and/or processes will remain *unaltered.* |
| **MAGNITUDE of POSITIVE IMPACT** (at the indicated spatial scale) | 10 | Very high | Positive: Bio-physical and/or social functions and/or processes might be *substantially* enhanced. |
| | 8 | High | **Positive**: Bio-physical and/or social functions and/or processes might be *considerably* enhanced. |
| | 6 | Medium | **Positive**: Bio-physical and/or social functions and/or processes might be *notably* enhanced. |
| | 4 | Low | **Positive**: Bio-physical and/or social functions and/or processes might be *slightly* enhanced. |
| | 2 | Very low | **Positive**: Bio-physical and/or social functions and/or processes might be *negligibly* enhanced. |
| | 0 | Zero | **Positive**: Bio-physical and/or social functions and/or processes will remain *unaltered.* |
| **DURATION** | 5 | Permanent | **Impact in perpetuity. –** |
| | 4 | Long term | Impact ceases after operational phase/life of the activity > 60 years. |
| | 3 | Medium term | Impact might occur during the operational phase/life of the activity – 60 years. |
| | 2 | Short term | Impact might occur during the construction phase - < 3 years. |
| | 1 | Immediate | **Instant impact.** |
| **EXTENT** | 5 | International | **Beyond the National boundaries.** |

| | | | |
|---|---|---|---|
| (or spatial scale/influence of impact) | 4 | **National** | Beyond provincial boundaries, but within National boundaries. |
| | 3 | **Regional** | Beyond 5 km of the site boundaries and within the provincial boundaries. |
| | 2 | **Local** | Within a 5 km radius of the lodge. |
| | 1 | **Site-specific** | **On site or within 100 meters of the site boundaries.** |
| | 0 | **None** | **Zero extent.** |
| **IRREPLACEABLE** loss of resources | 5 | **Definite** | **Definite** loss of irreplaceable resources. |
| | 4 | **High potential** | **High** potential for loss of irreplaceable resources. |
| | 3 | **Moderate potential** | **Moderate** potential for loss of irreplaceable resources. |
| | 2 | **Low potential** | **Low** potential for loss of irreplaceable resources. |
| | 1 | **Very low potential** | **Very low** potential for loss of irreplaceable resources. |
| | 0 | **None** | **Zero potential.** |
| **REVERSIBILITY** of impact | 5 | **Irreversible** | Impact **cannot** be reversed. |
| | 4 | **Low irreversibility** | **Low** potential that impact might be reversed. |
| | 3 | **Moderate reversibility** | **Moderate** potential that impact might be reversed. |
| | 2 | **High reversibility** | **High** potential that impact might be reversed. |
| | 1 | **Reversible** | Impact **will be** reversible. |
| | 0 | **No impact** | No impact. |
| **PROBABILITY** (of occurrence) | 5 | **Definite** | >95% chance of the potential impact occurring. |
| | 4 | **High probability** | 75% - 95% chance of the potential impact occurring. |
| | 3 | **Medium probability** | 25% - 75% chance of the potential impact occurring |
| | 2 | **Low probability** | 5% - 25% chance of the potential impact occurring. |
| | 1 | **Improbable** | <5% chance of the potential impact occurring. |
| | 0 | **No probability** | **Zero probability.** |

| **Evaluation Component** | **Rating scale and description / criteria** |
|---|---|
| **CUMULATIVE** impacts | **High**: The activity is one of several similar past, present or future activities in the same geographical area, and might contribute to a very significant combined impact on the natural, cultural, and/or socio-economic resources of local, regional or national concern.<br>***Medium**:* The activity is one of a few similar past, present or future activities in the same geographical area, and might have a combined impact of moderate significance on the natural, cultural, and/or socio-economic resources of local, regional or national concern.<br>***Low**:* The activity is localised and might have a negligible cumulative impact.<br>***None**:* No cumulative impact on the environment. |

Once the Environmental Risk Ratings have been evaluated for each potential environmental impact, the Significance Score of each potential environmental impact is calculated by using the following formula:

- **SS (Significance Score) = (magnitude + duration + extent + irreplaceable + reversibility) x probability.**

The maximum Significance Score value is 150.

The Significance Score is then used to rate the Environmental Significance of each potential environmental impact as per Table 8.2 below. The Environmental Significance rating process is completed for all identified potential environmental impacts both before and after implementation of the recommended mitigation measures.

**Table 9.2: Scale used for the evaluation of the Environmental Significance Ratings**

| Significance Score | Environmental Significance | Description / criteria |
|---|---|---|
| 125 – 150 | Very high (VH) | An impact of very high significance will mean that the project cannot proceed, and that impacts are irreversible, regardless of available mitigation options. |
| 100 – 124 | High (H) | An impact of high significance which could influence a decision about whether or not to proceed with the proposed project, regardless of available mitigation options. |
| 75 – 99 | Medium-high (MH) | If left unmanaged, an impact of medium-high significance could influence a decision about whether or not to proceed with a proposed project. Mitigation options should be relooked at. |
| 40 – 74 | Medium (M) | If left unmanaged, an impact of moderate significance could influence a decision about whether or not to proceed with a proposed project. |
| <40 | Low (L) | An impact of low is likely to contribute to positive decisions about whether or not to proceed with the project. It will have little real effect and is unlikely to have an influence on project design or alternative motivation. |
| + | Positive impact (+) | A positive impact is likely to result in a positive consequence/effect, and is likely to contribute to positive decisions about whether or not to proceed with the project. |

## 9.1. Construction phase

During construction of the lodge surface infrastructure will be constructed. It is assumed that water will be drawn from the water supply borehole for civil works. The required water supply volume during the construction phase is stated to be 40 $m^3$/month for 10 months (1.33 $m^3$/day). This is less than the sustainable yield of the water supply borehole of 21.6 $m^3$/day that was calculated from the aquifer test data.

The groundwater level around the water supply borehole will be drawn down due to groundwater abstraction. The zone of influence of the dewatering cone depends on several factors including the depth of the groundwater level drawdown below the regional groundwater level, recharge from rainfall to the aquifers, the aquifer transmissivity, and aquifer storativity amongst others. An analytical calculation of the theoretical zone of influence is done using Sichardt's equation:

$$R_i = 3000 D_0 \sqrt{k}$$

Where:

$R_i$ = radius of the zone of influence;
$D_0$ = maximum drawdown in groundwater level (assumed to be not more than 40 m); and
k = aquifer hydraulic conductivity (2.894 x $10^{-8}$ m/sec for the fractured rock aquifer).

From the above it is calculated that the maximum zone of influence for the water supply borehole is 20 m. Sichardt's equation is widely acknowledged to under estimate the zone of influence somewhat. Therefore, a value of 100 m is assumed to be conservative. Based on this calculation the dewatering cone (shown in Figure 9.1) does not impact any of the surface streams. There are also no other boreholes within the zone of influence.

It is assumed that under good housekeeping regulations, there will be little to no hydrocarbon spills or other impacts on the groundwater environment.

## 9.2. Operational phase

Similar to the construction phase there will be a drawdown in groundwater level around the water supply borehole. The zone of influence can be calculated similar to that in Section 9.1. From that it can be seen that the expected long-term zone of influence will extend up to 100 m from the proposed water supply borehole. There are no other boreholes, or streams that fall within the zone of influence.

Groundwater abstraction through the water supply borehole is not expected to impact the groundwater qualities.

A 10 kL Famsys package plant will be used for sewage treatment as discussed in Section 5.2.4 of this document. The plant will be installed below ground, with the lids above ground.

The plant is designed to produce effluent in terms of the current Water Act with specific reference to the Special Limits, defined in the SA law.

Sludge can be stored in the anaerobic zone, for removal by a honeysucker every 2-3 months if inflow remains at high levels. In practice sewage inflow will vary and duration for sludge removal will be much longer.

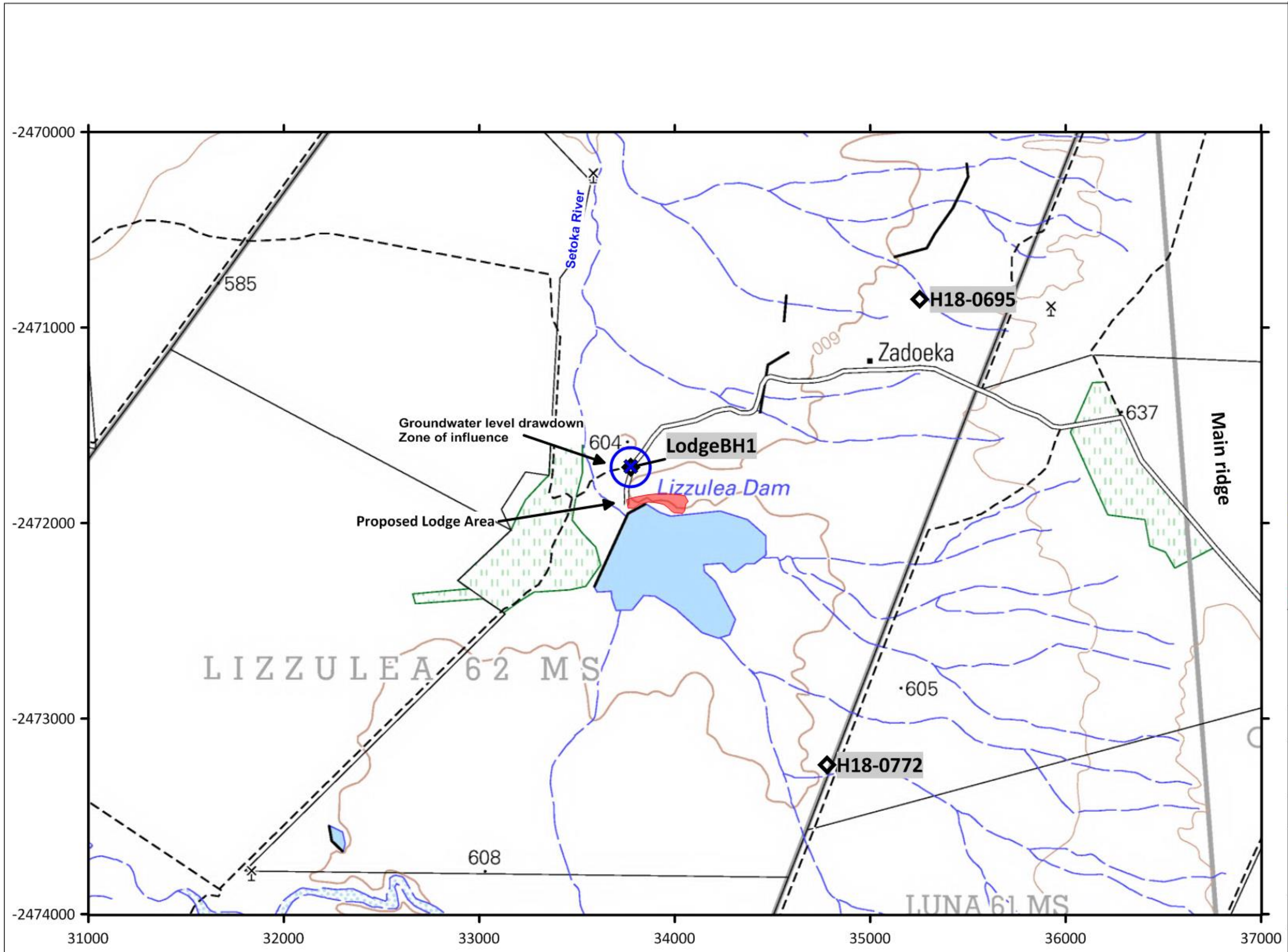
The plant suppliers recommend that the outflow water be put through a channel, where plants can be placed to remove the nutrient naturally.

The weathered material aquifer will be vulnerable to contamination from the outflow water in the output channel. However, this risk is localised and the impact will be negligible in the context of the sub-catchment. It is not expected that pollution from the outflow water will impact any surface streams or other boreholes in the area.

## 9.3. Long term post-closure phase

After closure the groundwater abstraction will stop and any drawdown in groundwater level will also cease. The groundwater level will recover to pre-usage levels.

Contamination from the lodge will decrease due to the rehabilitation of the area. This will reduce or remove impacts on the groundwater environment.




Reference Maps
Topographical: 2229AC; 2229AD
Geological: 2228
Satelite Image: Google Earth
WGS84, LO29

Client:
Alta van Dyk Environmental

Project:
VLNR Lodge WULA
Groundwater Study

Figure Number: 9.1

Figure Name:
Groundwater level drawdown
zone of influence
(Construction & operational phases)

Scale: As shown

Date: November 2020
Revision: 1

Designed: MP
Approved:

Future Flow
GROUNDWATER & PROJECT MANAGEMENT SOLUTIONS
18 Claudius Place, Moreletapark, Pretoria, 0181
Postnet Suite 71, Private Bag X8, Elarduspark, 0047
Pretoria, South Africa

**Table 9.3: Impact rating – Construction phase**

| POTENTIAL ENVIRONMENTAL IMPACT | ACTIVITY | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION | | | | | | | | Cumulative | Status | RECOMMENDED MITIGATION MEASURES/ REMARKS | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Magnitude | Duration | Extent | Irreplacibility | Reversibility | Probability | TOTAL | Significance | | | | Magnitude | Duration | Extent | Irreplacibility | Reversibility | Probability | TOTAL | Significance |
| **Groundwater Impact Assessment** | | | | | | | | | | | | | | | | | | | | |
| Impacts on groundwater volumes due to groundwater abstraction from the water supply borehole | Abstraction groundwater from supply borehole | 2 | 2 | 1 | 2 | 1 | 5 | 40 | M | | Negative | Monitor groundwater levels<br>Reduce water requirement where possible | 2 | 2 | 1 | 1 | 1 | 5 | 35 | L |
| Impacts on groundwater volumes due to surface construction of infrastructure | Construction of VLNR Lodge | 2 | 1 | 1 | 1 | 1 | 1 | 6 | L | | Negative | Monitor groundwater levels | 2 | 1 | 1 | 1 | 1 | 1 | 6 | L |
| Impacts on groundwater quality due to construction activities | Construction of VLNR Lodge | 2 | 5 | 1 | 3 | 5 | 3 | 48 | M | | Negative | Monitor the groundwater quality;<br>Safe storage of chemicals, hydrocarbons and other pollutants.<br>Proper maintenance of vehicles; | 2 | 5 | 1 | 1 | 4 | 3 | 39 | L |
| Impacts on surface water volumes due to groundwater abstraction from the water supply borehole | Abstraction from water supply borehole | 2 | 2 | 1 | 1 | 1 | 1 | 7 | L | | Negative | Monitor groundwater levels;<br>Monitor stream flow volumes;<br>Reduce water requirement where possible;<br>Manage pump schedule to minimise prolonged periods of constant pumping. | 2 | 1 | 1 | 1 | 1 | 1 | 6 | L |
| Impacts on surface water quality due to poor quality seepage from the pollution source areas | Construction of VLNR Lodge | 2 | 3 | 1 | 3 | 5 | 2 | 28 | L | | Negative | Proper maintenance of construction vehicles;<br>Management of water;<br>Storage of chemicals and other possible pollution sources. | 2 | 3 | 1 | 3 | 5 | 1 | 14 | L |

**Table 9.4: Impact rating – Operational phase**

| POTENTIAL ENVIRONMENTAL IMPACT | ACTIVITY | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION | | | | | | | | Cumulative | Status | RECOMMENDED MITIGATION MEASURES/ REMARKS | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Magnitude | Duration | Extent | Irreplacibility | Reversibility | Probability | TOTAL | Significance | | | | Magnitude | Duration | Extent | Irreplacibility | Reversibility | Probability | TOTAL | Significance |
| **Environmental noise assessment** | | | | | | | | | | | | | | | | | | | | |
| Impacts on groundwater volumes due to groundwater abstraction from the water supply borehole | Abstraction groundwater from supply borehole | 2 | 4 | 1 | 3 | 2 | 5 | 60 | M | | Negative | Monitor groundwater levels;<br>Reduce water requirement where possible. | 1 | 4 | 1 | 3 | 1 | 5 | 50 | M |
| Impacts on groundwater quality due to operational activities | Operation of VLNR Lodge | 6 | 5 | 2 | 3 | 3 | 4 | 76 | MH | | Negative | Monitor the groundwater quality;<br>Proper maintenance of vehicles;<br>Safe storage of chemicals, hydrocarbons and other pollutants. | 2 | 2 | 2 | 3 | 1 | 3 | 30 | L |
| Impacts on surface water volumes due to groundwater abstraction from the water supply borehole | Abstraction groundwater from supply borehole | 2 | 2 | 1 | 1 | 1 | 1 | 7 | L | | Negative | Monitor groundwater levels;<br>Reduce water requirement where possible;<br>Manage pump schedule to minimise prolonged periods of constant pumping. | 2 | 1 | 1 | 1 | 1 | 1 | 6 | L |
| Impacts on surface quality due to poor quality seepage from the pollution source areas | Operation of VLNR Lodge | 2 | 3 | 1 | 3 | 5 | 2 | 28 | L | | Negative | Management of chemicals, food and nutrients. | 2 | 5 | 1 | 3 | 5 | 1 | 16 | L |

**Table 9.5: Impact rating – Long term post-closure phase**

| POTENTIAL ENVIRONMENTAL IMPACT | ACTIVITY | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION | | | | | | | | Cumulative | Status | RECOMMENDED MITIGATION MEASURES/ REMARKS | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | D | S | I | R | P | TOTAL | SP | | | | M | D | S | I | R | P | TOTAL | SP |
| **Environmental noise assessment** | | | | | | | | | | | | | | | | | | | | |
| Legacy impacts on groundwater quality due to operational activities | Operation of VLNR Lodge | 1 | 5 | 2 | 3 | 3 | 4 | 56 | M | | Negative | Monitor the groundwater quality; Rehabilitate and remove storage areas for chemicals, hydrocarbons and other pollutants. | 1 | 3 | 1 | 3 | 3 | 3 | 33 | L |
| Legacy impacts on surface quality due to poor quality seepage from the pollution source areas | Operation of VLNR Lodge | 1 | 2 | 1 | 1 | 5 | 1 | 10 | L | | Negative | Rehabilitate and remove storage areas for chemicals, hydrocarbons and other pollutants. | 1 | 5 | 1 | 1 | 3 | 1 | 11 | L |

# 10. Conclusions and recommendations

## 10.1. General site conditions

- The proposed lodge lies on a small, local, west / east striking ridge, which lies at the foot of a larger north / south trending ridge. Topographical elevations at the top of the ridge are 630 to 640 mamsl. From the top of the main ridge, which lies around 1.4 km east of the proposed lodge area, the topography slopes gently towards the west at an average gradient of 1:70 to where the proposed lodge lies at around 610 mamsl. Within the immediate vicinity of the proposed lodge that topography dips towards the south, to where the Lizzulea dam lies at 600 mamsl. To the west of the proposed lodge area the topography is very flat. Topographical gradients range in the order of 1:175 to 1:200 to the Kolope River that lies 5 km to the west of the proposed lodge;
- The slope east of the lodge, from the higher lying main ridge to the lodge, is characterised by a number of unnamed, non-perennial streams that drain the slope in an east / west direction. Once the numerous smaller streams reach the flat lying area they all collect in a single stream (the Setoka River) that drains in a northern direction. The Lizzulea dam at which the lodge is planned lies in the southern reaches of the Setoka River;
- The proposed lodge lies within the A63E quaternary catchment, which forms part of the Limpopo Water Management Area (WMA);
- The region is semi-arid with a subtropical climate of warm to hot summers and warm winters. The rainfall season extends from November to March. The closest rainfall station is the former Messina Agricultural Research Station for which mean annual rainfall between 1934 and 1990 was 339 mm. The mean annual rainfall at Pontdrif is 366 mm.

## 10.2. Geology of the study area

- The VLNR contains a diverse array of geological substrates. Most of the reserve is flat, with hills of Karoo sandstone, conglomerate and shale, meta-quartzite, dolerite, diabase, and altered basic and ultra-mafic rocks occupying about 20% of the area. Undulating areas of calcrete and marble (mainly in the southeast) exposed by local uplift bring the area of lithosolic soils to about one-third;
- Alluvial deposits are found in association with the Kolope, Setonki and Setoka Rivers which flow through the reserve. They vary in texture from sandy to clay-loam; and
- The VLNR is located within the Limpopo mobile belt. The country rock in the VLNR area appears as a complex arrangement of Proterozoic gneisses, amphibolites and metasediments of the Limpopo Group.

## 10.3. Baseline groundwater conditions

- Aquifers present on site:
  - Two aquifers occur in the area. These two aquifers are associated with the upper weathered material and the underlying competent and fractured rock material;

        - Upper weathered material aquifer: The aquifer forms due to the vertical infiltration of recharging rainfall through the weathered material being retarded by the lower permeability of the underlying competent rock material. Groundwater that collects above the contact between the weathered and unweathered material migrates down gradient along the contact to lower lying areas. Aquifer thickness data obtained from drilling of the water supply borehole show a thickness of 6 m. The borehole yields in this aquifer are seasonally variable due to the strong dependence on rainfall recharge. Generally, it can be said that the yields of this aquifer during the rainy season can be around 0.5 to 2 L/s while sustainable yields will decrease markedly during the dry season. In some areas this aquifer will be laid completely dry during the dry season;
        - Fracture rock aquifer: The competent rock is subjected to fracturing that takes place during intrusion of diabase dykes into the host geology, as well as tectonic movements associated with the Limpopo mobile belt. Groundwater flows in the lower aquifer are associated with the secondary fracturing in the competent rock and as such will be along discrete pathways associated with the fractures. Faults and fractures can be a significant source of groundwater depending on whether the fractures have been filled with secondary mineralisation;
    - Effectively 1.9 % of the mean annual rainfall recharges the groundwater table;
- Aquifer transmissivity: The aquifer transmissivities calculated from the pumping phase data is consistent between 0.09 and 0.13 $m^2$/day. The transmissivity calculated from the recovery data is 0.56 $m^2$/day;
- Depth to groundwater level:
    - The depth to groundwater level was measured in the water supply borehole to be 9.12 m;
    - In the absence of large scale groundwater abstraction of artificial recharge in the area, it is assumed that the groundwater levels will mimic topography, albeit at a lesser gradient. It is expected that groundwater will flow from the higher lying ridge east of the lodge to the low lying area where the lodge will be located and on towards the Kolope River 5 km west of the proposed lodge. Groundwater flows can also be directed in a north-westerly direction along the drainage direction of the Setoka River;
- Groundwater qualities:
    - The groundwater sample that was collected from the water supply borehole during the aquifer test was submitted to an ISO17025 / SANAS accredited laboratory for analysis. The analysis results are compared to the SANS 241:2015 drinking water standards;
    - Chloride, fluoride, sodium and cadmium exceed the drinking water standards;
        - Chloride is only detectable by taste at concentrations exceeding approximately 200 mg/L. A salty taste becomes quite distinctive at 400 mg/L and objectionable at greater than 600 mg/L. At chloride concentrations greater than 2 000 mg/L nausea may occur, while at 10 000 mg/L vomiting and dehydration may be induced. Chloride accelerates the corrosion rate of iron

and certain other metals well below the concentration at which it is detectable by taste. The threshold for an increased corrosion rate is approximately 50 mg/L. At chloride concentrations greater than 200 mg/L, there is likely to be a significant shortening of the lifetime of domestic appliances as a result of corrosion;

    - At fluoride concentrations above 8 mg/L severe tooth damage, especially to the temporary and permanent teeth of infants, softening the enamel and dentine will occur on continuous use of the water. Crippling skeletal fluorosis is likely to appear on long-term exposure;
    - At sodium concentrations between 600 and 1 000 mg/L the water will have a very salty taste and health effects may be expected. The water is very undesirable for infants or persons on a sodium restricted diet;
    - Cadmium concentrations between 0.01 and 0.02 mg/L are the threshold for health damage with continuous exposure. Single incidence of exposure will not have observable effects;
  - Analysis of the groundwater character shows that the groundwater is sodium (cation) and chloride (anion) dominant.

### 10.4. Aquifer characterisation

- For aquifer vulnerability reference is made to the aquifer vulnerability map of South Africa which shows a low aquifer vulnerability for the project area;
- The aquifers present in the area are classified as minor aquifers based on the low aquifer potential and sustainable yields, but of high importance to the local landowners as it is their sole source of water for domestic and agricultural (stock watering and irrigation) purposes.

### 10.5. Sustainable yield of the water supply borehole

- The sustainable yield of the borehole is calculated as 0.5 L/s for 6 hours, followed by 6 hour recovery. The borehole can thus be pumped for 12 hours out of every 24, yielding a total volume of 21.6 $m^3$/day. This meets the water use requirement of the lodge which is currently estimated at 3.9 $m^3$/day when applying a use of 150 L/person/day and a maximum of 26 people.
- It is important that a strict monitoring program be followed for the water supply borehole. It is recommended that the groundwater level recovery be monitored. The groundwater level at the end of one of the 6 hour recovery periods should be recorded every day. A time series plot of these groundwater levels should be compiled. It is recommended that should any trend of decreasing groundwater levels over time be identified, one of two options be pursued:
  - Decrease the groundwater abstraction volumes; or
  - Installing an additional water supply borehole.

### 10.6. Sub-catchment water balance

Inflows:

Recharge into catchment: 1 705 $m^3$/day

Outflows:

Proposed abstraction for VLNR lodge: 3.9 $m^3$/day

Existing abstraction from sub-catchment 489.6 $m^3$/day

Balance: 1 211.5 $m^3$/day

From this it can be seen that the sub-catchment can sustain the proposed groundwater abstraction for the lodge.

## 10.7. Impact assessment

### 10.7.1. Construction phase

- During construction of the lodge surface infrastructure will be constructed. It is assumed that water will be drawn from the water supply borehole for civil works. The required water supply volume during the construction phase is stated to be 40 $m^3$/month for 10 months (1.33 $m^3$/day). This is less than the sustainable yield of the water supply borehole of 21.6 $m^3$/day that was calculated from the aquifer test data;
- The groundwater level around the water supply borehole will be drawn down due to groundwater abstraction. The zone of influence of the dewatering cone is calculated to be 20 m. Sichardt's equation is widely acknowledged to under estimate the zone of influence somewhat. Therefore, a value of 100 m is assumed to be conservative. Based on this calculation the dewatering cone does not impact any of the surface streams. There are also no other boreholes within the zone of influence;
- It is assumed that under good housekeeping regulations, there will be little to no hydrocarbon spills or other impacts on the groundwater environment.

### 10.7.2. Operational phase

- Similar to the construction phase there will be a drawdown in groundwater level around the water supply borehole. The zone of influence can be calculated similar to that of the construction phase. From that it can be seen that the expected long-term zone of influence will extend up to 100 m from the proposed water supply borehole. There are no other boreholes, or streams that fall within the zone of influence;
- Groundwater abstraction through the water supply borehole is not expected to impact the groundwater qualities;
- A 10 kL Famsys package plant will be used for sewage treatment. The plant will be installed below ground, with the lids above ground. The plant is designed to produce effluent in terms of the current Water Act with specific reference to the Special Limits, defined in the SA law. Sludge can be stored in the anaerobic zone, for removal by a honeysucker every 2-3 months if inflow remains at high levels. In practice sewage inflow will vary and duration for sludge removal will be much longer. The plant suppliers recommend that the outflow water be put through a channel, where plants can be placed to remove the nutrient naturally.

- The weathered material aquifer will be vulnerable to contamination from the outflow water in the output channel. However, this risk is localised and the impact will be negligible in the context of the sub-catchment. It is not expected that pollution from the outflow water will impact any surface streams or other boreholes in the area.

#### 10.7.3. Long term post-closure phase

- After closure the groundwater abstraction will stop and any drawdown in groundwater level will also cease and the groundwater level will recover to pre-usage levels.
- Contamination from the lodge will decrease due to the rehabilitation of the area. This will reduce or remove impacts on the groundwater environment.

### 10.8. Recommendations

#### 10.8.1. Groundwater level monitoring program

A monitoring program should be implemented to monitor the groundwater level in the water supply borehole. The groundwater level should be measured near the end of one of the two 6 hour resting phases every day. A time series plot of the obtained groundwater levels for each day should be compiled. It is recommended that should any trend of decreasing groundwater levels over time be identified, one of two options be pursued:

- Decrease the groundwater abstraction volumes; or
- Installing an additional water supply borehole.

To ease the monitoring, it is recommended that an electronic logger be installed that can be down-loaded on a regular (weekly or monthly) interval.

#### 10.8.2. Groundwater quality monitoring program

Groundwater samples should be collected and submitted for chemical analysis in order to monitor the groundwater quality. From the groundwater chemical analysis results from this study, it can be seen that fluoride, sodium and cadmium are present in concentrations that can impact human health (the high chloride concentrations are expected to lead to scaling and salty taste to the water, but no human health impacts are expected).

Elements that have to be analysed for are:

- General parameters (pH, EC, Alkalinity, Hardness)
- Major cations (Ca, Mg, Na, K);
- Major anions (Cl, $SO_4$, $NO_3$, $NH_4$, $PO_4$, F);
- Metals (Al, Fe, Mn, Cr, Cu, Ni, Zn, Co, Cd, Pb);
- Biological / organic parameters (BOD, COD);
- Bacteriological (Heterotrophic plate count).

Groundwater samples should be monitored on a quarterly basis.

#### 10.8.3. Water treatment

As mentioned above, from the groundwater chemical analysis results from this study, it can be seen that fluoride, sodium and cadmium are present in concentrations that can impact human health. It is recommended that water treatment options be investigated to reduce the element concentrations.

# APPENDIX A

# GROUNDWATER CHEMICAL ANALYSIS RESULTS

## Test Report

Page 1 of 1

**Client:** Future Flow Cc
**Address:** 8 Victoria Link, Route 21 Corporate Park, Irene, 0062
**Report no:** 94487
**Project:** Veletia Mine

**Date of report:** 02 November 2020
**Date accepted:** 23 October 2020
**Date completed:** 02 November 2020
**Date received:** 23 October 2020

| Lab no: | | | | 56324 |
|---|---|---|---|---|
| Date sampled: | | | | 21-Oct-20 |
| Aquatico sampled: | | | | No |
| Sample type: | | | | Water |
| Locality description: Analyses | | | | BH1 |
| | | Unit | Method | |
| A | pH @ 25°C | pH | ALM 20 | 7.90 |
| A | Electrical conductivity (EC) @ 25°C | mS/m | ALM 20 | 394 |
| A | Total dissolved solids (TDS) | mg/l | ALM 26 | 2290 |
| A | Total alkalinity | mg CaCO3/l | ALM 01 | 549 |
| A | Chloride (Cl) | mg/l | ALM 02 | 891 |
| A | Sulphate ($SO_4$) | mg/l | ALM 03 | 156 |
| A | Nitrate ($NO_3$) as N | mg/l | ALM 06 | 1.02 |
| A | Ammonium ($NH_4$) as N | mg/l | ALM 05 | 0.225 |
| A | Orthophosphate ($PO_4$) as P | mg/l | ALM 04 | 0.037 |
| A | Fluoride (F) | mg/l | ALM 08 | 11.5 |
| A | Calcium (Ca) | mg/l | ALM 30 | 62.4 |
| A | Magnesium (Mg) | mg/l | ALM 30 | 76.4 |
| A | Sodium (Na) | mg/l | ALM 30 | 710 |
| A | Potassium (K) | mg/l | ALM 30 | 13.1 |
| A | Aluminium (Al) | mg/l | ALM 31 | 0.012 |
| A | Iron (Fe) | mg/l | ALM 31 | <0.004 |
| A | Manganese (Mn) | mg/l | ALM 31 | 0.002 |
| A | Chromium (Cr) | mg/l | ALM 31 | <0.003 |
| A | Copper (Cu) | mg/l | ALM 31 | 0.055 |
| A | Nickel (Ni) | mg/l | ALM 31 | <0.002 |
| A | Zinc (Zn) | mg/l | ALM 31 | <0.002 |
| A | Cobalt (Co) | mg/l | ALM 31 | <0.003 |
| A | Cadmium (Cd) | mg/l | ALM 31 | 0.016 |
| A | Lead (Pb) | mg/l | ALM 31 | <0.004 |
| A | Total hardness | mg CaCO3/l | ALM 26 | 471 |
| A | Bicarbonate alkalinity | mg CaCO3/l | ALM 26 | 545 |

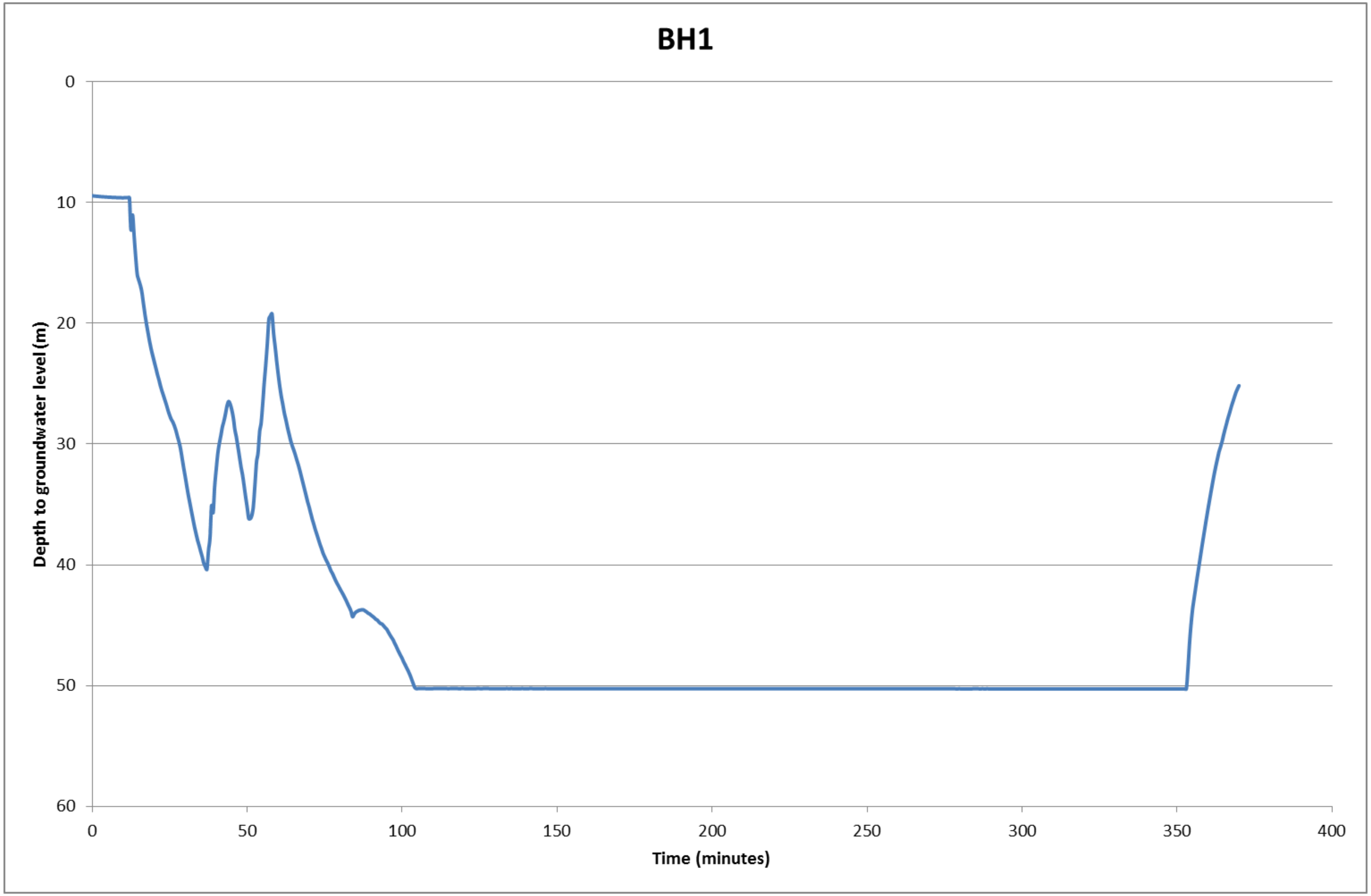
A = Accredited N = Non accredited Out = Outsourced Sub = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine ATR = Alternative test report ; Results only apply to the samples as received and tested; Results reported against the limit of detection; Results marked 'Non SANAS Accredited' in thi are not included in the SANAS Schedule of Accreditation for this laboratory; Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation; The report shall not be reproduced except in full without approval of the laboratory
The results apply to the sample received.

H. Holtzhausen
Technical Signatory

www.aquatico.co.za 89 Regency Drive, R21 Corporate Park, Centurion, South Africa Tel: +27 12 450 3800 Fax: +27 12 450 3851

# APPENDIX B

# AQUIFER TEST RESULTS


BH1
Depth to groundwater level (m)
0
10
20
30
40
50
60
0
50
100
150
200
250
300
350
400
Time (minutes)