

# Navachab Underground Mine Readiness Plan - Groundwater

Report Prepared for

**Navachab Gold Mine**

Report Number 562072



Report Prepared by

The logo for srk consulting, featuring a stylized orange 'V' shape followed by the text 'srk consulting' in a sans-serif font.

June 2021

# Navachab Underground Mine Readiness Plan - Groundwater

## Navachab Gold Mine

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**June 2021**

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# Executive Summary

## Introduction and Objectives

Navachab Gold Mine (NGM) is progressing with an underground mine from the current open pit with an initial trial underground mining currently underway. As part of the overall planning of the underground mining, SRK Consulting South Africa (Pty) (Ltd) was commissioned by NGM (SRK proposals 566733 and 562072) to assess the groundwater occurrence with respect to the underground operations.

The objectives of the study were to gain an understanding of the groundwater conditions likely to be encountered in an underground operation and, to this end, advantage was taken of the geotechnical drill program and packer testing was conducted on the five coreholes drilled.

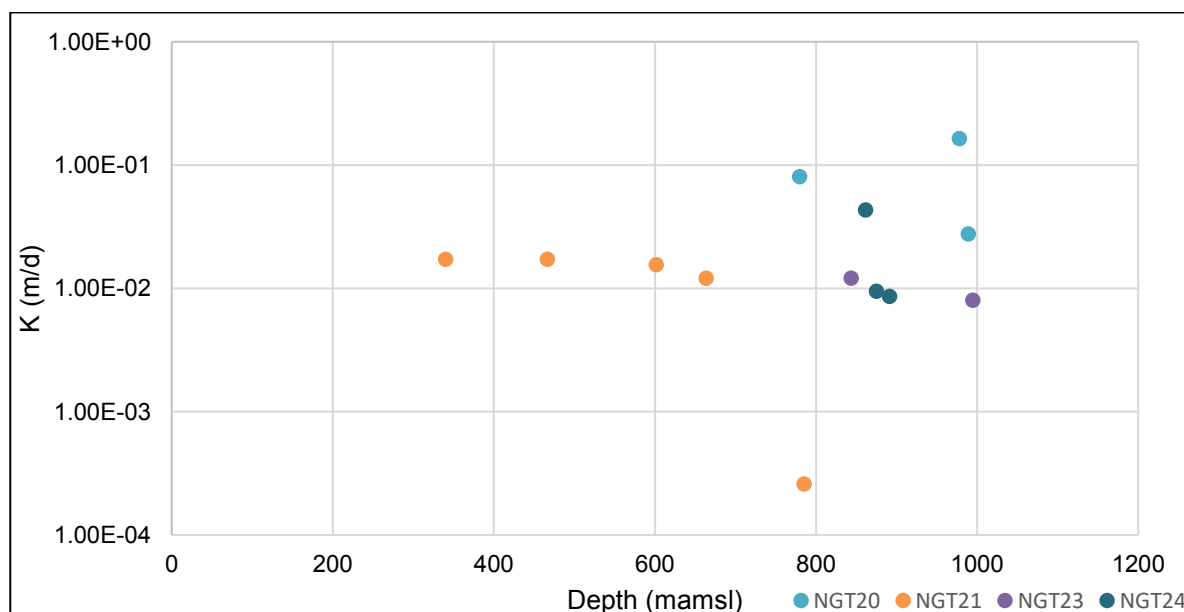
Groundwater investigations into the Karibib Formation were conducted to investigate the potential for groundwater to be brought to the workings via geological structures. Groundwater investigations into the Karibib Formation were preceded by geophysical surveys using the resistivity method to select anomalies on which structures associated with occurrence of groundwater on which drilling would be conducted.

## Interpretations and findings

### Packer testing

Interpretation of the packer testing data indicates that fractured contact/shears have hydraulic conductivities largely between  $1 \times 10^{-2}$  m/d and  $1 \times 10^{-1}$  m/d. A relatively high hydraulic conductivity at  $1.6 \times 10^{-1}$  m/d was measured in corehole NGT22 located to the northwest of the North Pit in a sheared fault. At the same corehole, artesian conditions were encountered during drilling.

The figure below summaries the distribution of the calculated hydraulic conductivity values in meters below mean sea level. Fractures with hydraulic conductivities values in the range of 0.1 to 1 m/d have the ability to carry relatively significant amounts of water to the workings and moderate flows are likely from the 0.01 to 0.1 m/d zones.



**Distribution of Hydraulic Conductivity, K with Depth.**

### Geophysical surveys and percussion drilling

The geophysical survey was limited in nature due to the current pushback happening to the west of the North Pit and the presence of rock dumps to the north and northeast. Four anomalies indicated by low resistivity zones were nonetheless identified, and these were interpreted to be potential zones of weakness in the CM and where groundwater could occur.

Due to heavy haulage close to and on the road to the western pushback, only two (DW24R and DW25R) of the four anomalies identified on the Karibib Formation could be drilled. In discussion with the client, a third (DW23R) drilling position located on a magnetic anomaly on the contact of the Oberwasser (Upper Schist) and the Okawayo Formations (MDM) was drilled.

| Borehole | Local coordinate |          |           | Drilled depth (m) | Static water level (mbgl) (1/2/21) | Geophysics anomaly |
|----------|------------------|----------|-----------|-------------------|------------------------------------|--------------------|
|          | Y (m)            | X (m)    | Z (mamsl) |                   |                                    |                    |
| DW23R    | 4474.563         | 1460.718 | 1130      | 210               | 44.7                               | Previous Magnetics |
| DW24R    | 3747.508         | 1877.386 | 1141      | 200               | Dry and destroyed                  | D3                 |
| DW25R    | 3709.792         | 1813.790 | 1143      | 200               | 59.3                               | D4                 |

The limited investigation does suggest that there may be a connection from the CM to the MDM and MC via fractures. A western pit pushback into the Karibib Fm. is under consideration by the mine. The pushback is likely to expose some of the karst which would then produce water. Anecdotal evidence (*pers. comm.* Mr J Walkers) and the percussion drilling confirms the presence of karsts, but these seem to be small, isolated and of low yield.

Whilst the indication is that at Navachab there may not be a large, predictable source of water there are exceptions as demonstrated by the water intersected at NGT22. The water table is relatively deeper at 45 to 60 mbgl but provides a head behind the western wall.

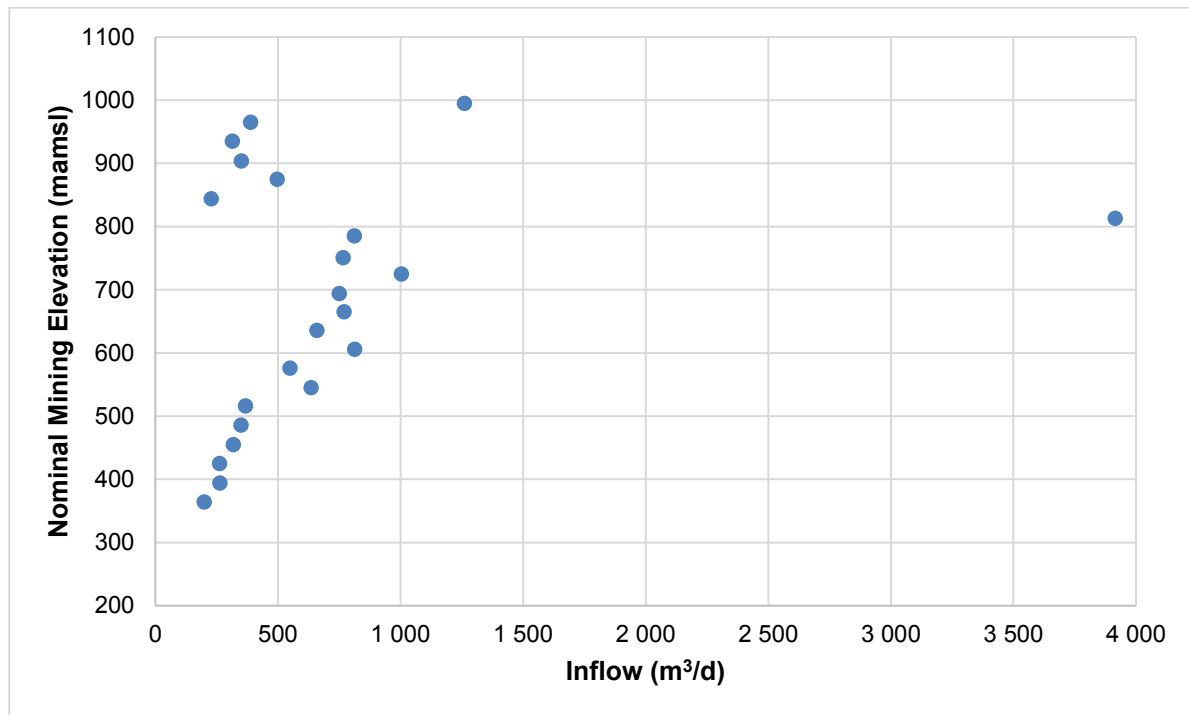
### Groundwater quality

Results of the laboratory analyses indicate that the groundwater is brackish to saline (Mayer *et al*, 2005) indicated by the TDS in the range 1 222 to 3 912 mg/l which is typical for arid conditions with low and erratic recharge and may lead to corrosion to some infrastructure. The relatively high proportion of sulphide in the pit sump is related to the oxidation of the sulphide minerals present.

### Estimated groundwater inflow

The underground mining tunnels will be located within the MC, the orebody, and LS in the main and estimated inflows are in the range of 199 to 1 260 m<sup>3</sup>/d for the various mining levels. Inflows into the shallower mining areas are expected to reduce as the deeper levels develop, the aquifer storage depletes and depressurisation around tunnels occurs. The calculated inflows are therefore the expected rates per tunnel during tunnel development and will reduce over time.

Overall, the inflows per level are relatively low, generally decreasing with depth and can be managed with haulage drains directed to a sump(s). The figure below summaries the estimated groundwater inflows per level of mining.



#### Estimated inflows for Each Level of Mining

### Recommendations

SRK makes the following recommendations:

- If groundwater inflow into the workings results in gradual accumulation of groundwater, temporary collection sump(s) should be constructed during mine development and operation so that the accumulated groundwater can be managed with haulage drains directed to a sump(s).
- During development and operation, groundwater inflow volumes into the workings should be measured so that any required adjustments to groundwater management can be implemented to ensure safe and dry mining.
- Consideration should be given to:
  - Documentation of groundwater occurrence depths together with description of the geological structure associated with it and inflow volumes in the trial mine and apply the findings to the full underground mine.
  - The groundwater level monitoring piezometers that could be affected by the western pushback should be replaced to continue monitoring of groundwater levels. We propose that additional groundwater monitoring piezometers should be considered around the northern pit.
  - During cover drilling to poor ground conditions, groundwater occurrence and flow volume should be conducted.

# Table of Contents

|                                                                  |           |
|------------------------------------------------------------------|-----------|
| Executive Summary .....                                          | ii        |
| Disclaimer.....                                                  | vii       |
| List of Abbreviations .....                                      | viii      |
| <b>1 Introduction .....</b>                                      | <b>1</b>  |
| <b>2 Packer Testing.....</b>                                     | <b>2</b>  |
| 2.1 Results .....                                                | 2         |
| 2.1.1 NGT20 (GT01) .....                                         | 4         |
| 2.1.2 NGT21 (GT02) .....                                         | 4         |
| 2.1.3 NGT22 (GT03) .....                                         | 6         |
| 2.1.4 NGT23 (GT04) .....                                         | 7         |
| 2.1.5 NGT24 (GT05) .....                                         | 9         |
| 2.2 Packer Testing Summary.....                                  | 10        |
| <b>3 Groundwater Investigation in the Karibib Formation.....</b> | <b>12</b> |
| 3.1 Geophysical Survey .....                                     | 12        |
| 3.2 Percussion Drilling .....                                    | 12        |
| 3.3 Slug Testing .....                                           | 14        |
| 3.4 Groundwater Quality .....                                    | 15        |
| 3.4.1 Environmental Isotopes.....                                | 16        |
| <b>4 Piezometric Surface .....</b>                               | <b>17</b> |
| <b>5 Conceptual Groundwater Model .....</b>                      | <b>19</b> |
| <b>6 Estimated Groundwater Inflow.....</b>                       | <b>19</b> |
| <b>7 Conclusions and Recommendations.....</b>                    | <b>21</b> |
| <b>8 References .....</b>                                        | <b>22</b> |
| <b>Appendices .....</b>                                          | <b>23</b> |
| <b>Appendix A: Geophysical Survey Report.....</b>                | <b>24</b> |
| <b>Appendix B: Laboratory Certificates .....</b>                 | <b>25</b> |

## List of Tables

|                                                                     |    |
|---------------------------------------------------------------------|----|
| Table 2-1: Summary of Packer Tests .....                            | 3  |
| Table 3-1: Summary of DW boreholes .....                            | 12 |
| Table 3-2: Water Quality .....                                      | 15 |
| Table 3-3: Salinity Classification (source Mayer et al, 2005) ..... | 16 |
| Table 3-4: Isotope Results .....                                    | 17 |
| Table 6-1: Calculated Inflow Per Nominal Mining Level .....         | 20 |

## List of Figures

|                                                                              |    |
|------------------------------------------------------------------------------|----|
| Figure 1-1: Corehole and Percussion Borehole Locations .....                 | 1  |
| Figure 2-1: NGT20 - K vs. Downhole Depth .....                               | 5  |
| Figure 2-2: NGT21 - K vs. Downhole Depth .....                               | 6  |
| Figure 2-3: NGT23 - K vs. Downhole Depth .....                               | 9  |
| Figure 2-4: NGT24 - K vs. Downhole Depth .....                               | 9  |
| Figure 2-5: Distribution of K with Depth .....                               | 10 |
| Figure 2-6: Relative K values (modified after Freeze and Cherry, 1979) ..... | 11 |
| Figure 3-1: Location of geophysical surveys (Source LDA Geophysics) .....    | 13 |
| Figure 3-2: Piper Plot .....                                                 | 16 |
| Figure 3-3: $\delta^{18}\text{O}$ vs $\delta\text{D}$ Plot .....             | 17 |
| Figure 4-1: Piezometric Surface .....                                        | 18 |
| Figure 6-1: Estimated Inflows Per Mining Level .....                         | 21 |

## Disclaimer

The opinions expressed in this Report have been based on the information supplied to SRK Consulting (South Africa) (Pty) Ltd (SRK) by Navachab Gold Mine (NGM). The opinions in this Report are provided in response to a specific request from NGM to do so. SRK has exercised all due care in reviewing the supplied information. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them. Opinions presented in this report apply to the site conditions and features as they existed at the time of SRK's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which SRK had no prior knowledge nor had the opportunity to evaluate.

# List of Abbreviations

## Geology

|     |                             |
|-----|-----------------------------|
| PEG | Pegmatite                   |
| CM  | Contorted Marble            |
| US  | Upper Schist                |
| MDM | Marble and Dolomitic Marble |
| MC  | Calc Silicate Marble        |
| LS  | Lower Schist                |
| MC  | Calcsilicate Marble         |

## Other

|     |                    |
|-----|--------------------|
| NGM | Navachab Gold Mine |
|-----|--------------------|

# 1 Introduction

Navachab Gold Mine (NGM) is progressing with an underground mine from the current open pit. The initial trial underground mining is underway. As part of the overall planning of the underground mining, SRK Consulting South Africa (Pty) (Ltd) was commissioned by NGM (SRK proposals 566733 and 562072) to assess the groundwater occurrence with respect to the underground operations. Advantage was taken of the geotechnical drill program and packer testing was conducted on the five coreholes drilled. Groundwater investigations into the Karibib Formation were conducted to investigate the potential for groundwater to be brought to the workings via geological structures.

This report presents the packer testing and preliminary groundwater investigation of the Karibib Formation results and discusses the implications of these. The locations of the packer test coreholes and groundwater investigation boreholes are presented in Figure 1-1.

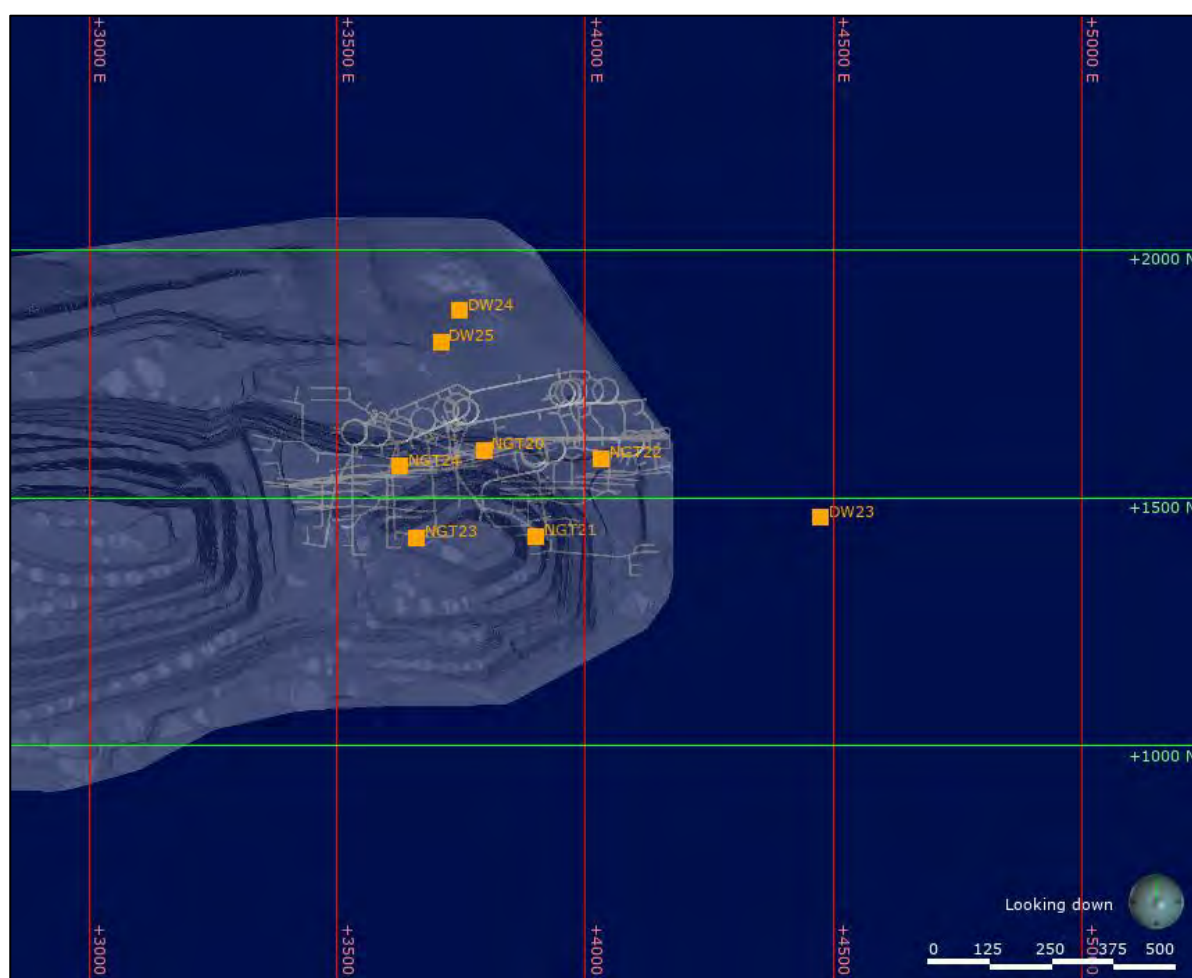


Figure 1-1: Corehole and Percussion Borehole Locations

## 2 Packer Testing

In packer testing, water is injected into the hole using the drilling rig pump to induce flow into the selected test zone. The selected testing pressure is generally estimated at 1.5 times the vertical depth (m) in the rock to overcome hydrostatic pressure, but low enough to avoid opening of joints and fissures and hydrofracturing of the rock. The volume of water “taken” into the test interval is recorded at one-minute intervals until the flow has stabilized. All the tests were conducted at the drilling progressing using a single packer system.

The volume of water taken is then used with the selected injection pressure to calculate hydraulic conductivity (K) for the specific test zones. Fractures, shears, and contact zones, that may act as zones of preferential groundwater flow pathways were target test zones. Typical zones selected for packer testing are included in the description of tests at each corehole

The packer tests are conducted at various depths below the water table in areas of the corehole where the packer can effectively seal the annular space above the test zone so that all injected water is directed into the test interval. Before the packer tests were conducted at each selected interval, the coreholes were flushed by pumping clean water through drill rods to remove drill cuttings.

### 2.1 Results

Packer testing results for each corehole are presented below with results of all tests summarised in Table 2-1.

**Table 2-1: Summary of Packer Tests**

| Hole         | Hole length (m) | Hole Inclination (°) | m From | m To   | Thickness (m) | Target              | K (m/d)              | Brief geology                                                                                                 |
|--------------|-----------------|----------------------|--------|--------|---------------|---------------------|----------------------|---------------------------------------------------------------------------------------------------------------|
| <b>NGT20</b> | 470.65          | 75                   | 81.85  | 87.65  | 5.8           | Fracture/contact    | BD                   | Contact, marble/US, slightly fractured and slightly vuggy                                                     |
|              |                 |                      | 102.85 | 131.65 | 28.8          | Fractured and vuggy | $2.8 \times 10^{-2}$ | Marble (Okawayo), moderately fractured and moderately vuggy.                                                  |
|              |                 |                      | 125.85 | 131.65 | 5.8           | Fracture/contact    | $1.6 \times 10^{-1}$ | PEG, LS (Spes Bona) contact, lamprophyre intrusion (Danheim), slightly sheared and brecciated                 |
|              |                 |                      | 331.85 | 335.65 | 3.8           | Fractured zone      | $8.0 \times 10^{-2}$ | PEG, LS contact, fractured with calcite infills                                                               |
| <b>NGT21</b> | 749.81          | 68                   | 106.81 | 410.81 | 304           | Fracture/shear      | $2.6 \times 10^{-4}$ | Fractured/sheared US                                                                                          |
|              |                 |                      | 368.81 | 410.81 | 42            | Fractured zone      | $1.2 \times 10^{-2}$ | Fractured/sheared US with calcite infills, possible fault, Sec Bona formation, LS                             |
|              |                 |                      | 427.81 | 485.81 | 58            | Fractured contact   | $1.6 \times 10^{-2}$ | MC/Pegmatite contact with quartz veins. Brecciated and sheared                                                |
|              |                 |                      | 581.81 | 623.81 | 42            | Fractured contact   | $1.7 \times 10^{-2}$ | MDM/US contact, fractured/sheared                                                                             |
|              |                 |                      | 727.81 | 749.81 | 22            | Bottom of hole      | BD                   | US                                                                                                            |
| <b>NGT22</b> | 452.81          | 75                   | 177.9  | 188.65 | 10.75         | Fractured zone      | BD                   | MDM with marble intercalations and minor calc-silicate lenses, moderately fractured from 176 to 189m          |
|              |                 |                      | 349.06 | 407.81 | 58.75         | Fractured zone      | $6.6 \times 10^{-1}$ | Brecciated and shear faults, US                                                                               |
| <b>NGT23</b> | 452.65          | 70                   | 111.25 | 158.65 | 47.4          | Fractured zone      | $8.0 \times 10^{-3}$ | Lower Schist and Calc-Silicate contact                                                                        |
|              |                 |                      | 172.65 | 347.65 | 175           | Shear/fracture      | UD                   | Lower Schist                                                                                                  |
|              |                 |                      | 188.65 | 347.65 | 159           | Shear/fracture      | UD                   | Lower Schist and Calc-Silicate contact                                                                        |
|              |                 |                      | 235.65 | 347.65 | 112           | Fractured zone      | $1.2 \times 10^{-2}$ | Lower Schist                                                                                                  |
| <b>NGT24</b> | 350.65          | 70                   | 122.65 | 300.65 | 178           | Fracture/shear      | $8.6 \times 10^{-3}$ | Sheared/fractured contact between MC + pegmatite with calcite and chlorite infill                             |
|              |                 |                      | 157.65 | 300.65 | 143           | Fracture/contact    | $9.5 \times 10^{-3}$ | Fractured pegmatite with calcite and chlorite infill and stains respectively. Major contact Okawayo/spec Bona |
|              |                 |                      | 257.65 | 300.65 | 43            | Fracture/contact    | $4.3 \times 10^{-2}$ | Fractured, sheared, brecciated US with calcite, fractured pegmatite at 273.7 – 276 m                          |

- BD: Below detection, i.e. no flow detected during testing at the target zone      UD: Undefined due to excessive leakage

### 2.1.1 NGT20 (GT01)

This corehole was drilled from an elevation of 1102 metres above mean seal level (mamsl) targeting upper schist (US), marble and dolomite marble (MDM), marble-calc-silicate (MC), lamprophyre intrusion and lower schist (LS) units. Photos 2-1 and 2-2. show typical zones that would be targeted for testing.

Three packer tests were conducted with calculated hydraulic conductivity values ranging from below detection at downhole depth interval of 81 – 88 m within slightly fractured/vuggy contact of MDM and US to  $1.6 \times 10^{-1}$  m/d at downhole depth interval of 125 – 132 m on fractured contact between the LS and lamprophyre intrusion. The hydraulic conductivity values with downhole depth (Figure 2-1) show no trend with depth.



Photo 2-1: Typical Test Zone Across a Fault Breccia NGT20



Photo 2-2: Typical test zone at fractured contact zone NGT20

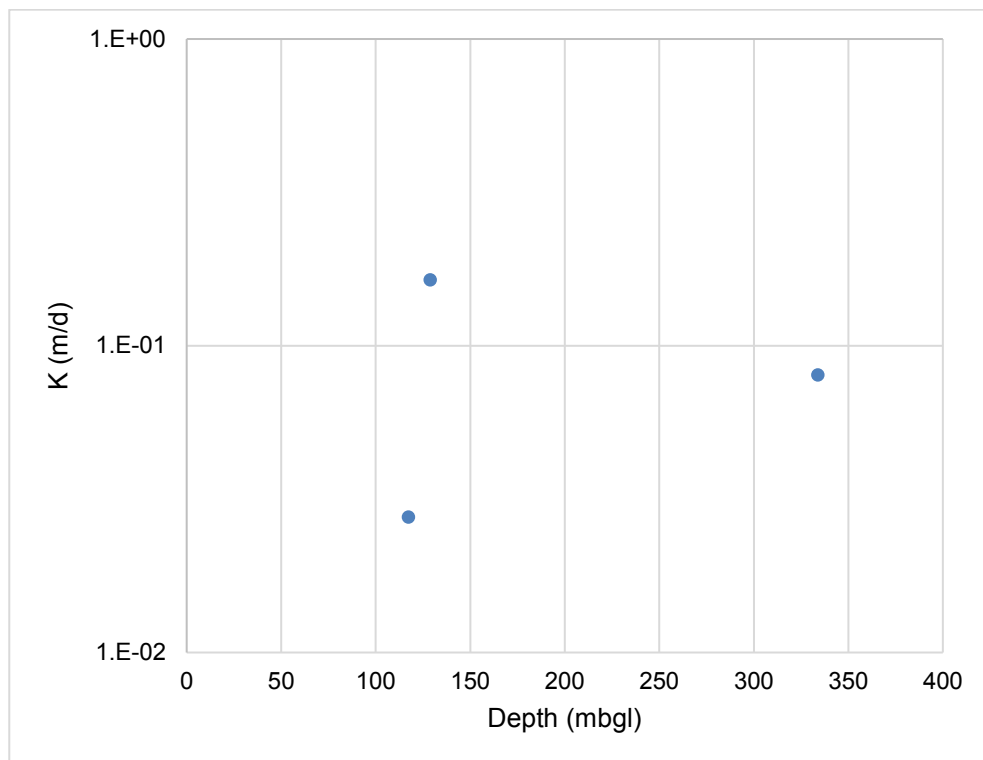


**Figure 2-1: NGT20 - K vs. Downhole Depth**

### 2.1.2 NGT21 (GT02)

NGT21 is the deepest corehole drilled to a downhole depth of 750 m starting from elevation 1025 mamsl. The target lithologies included LS, MC, and MDM. Below a depth of 727 m, the corehole intersected US, which was unexpected, but encountered due to hole deflection and helped to correct the MDM/US contact as there was sparse drilling done historically.

Five packer tests were conducted with calculated hydraulic conductivity values ranging from below detection within a fractured zone in US at downhole depth interval 727 – 740 m to  $1.7 \times 10^{-2}$  m/d in a shear/fracture zone within intensely jointed (low RQD) MDM/US at a downhole depth interval of 581 – 624 m. The hydraulic conductivities with depth (Figure 2-2), suggest that apart from one very low value at relatively shallower depth, the remaining values do not show significant change with depth and all within the same order of magnitude. Typical test sections are shown in Photos 2-3



**Photo 2-3: Typical test zone across a fracture – NGT21**

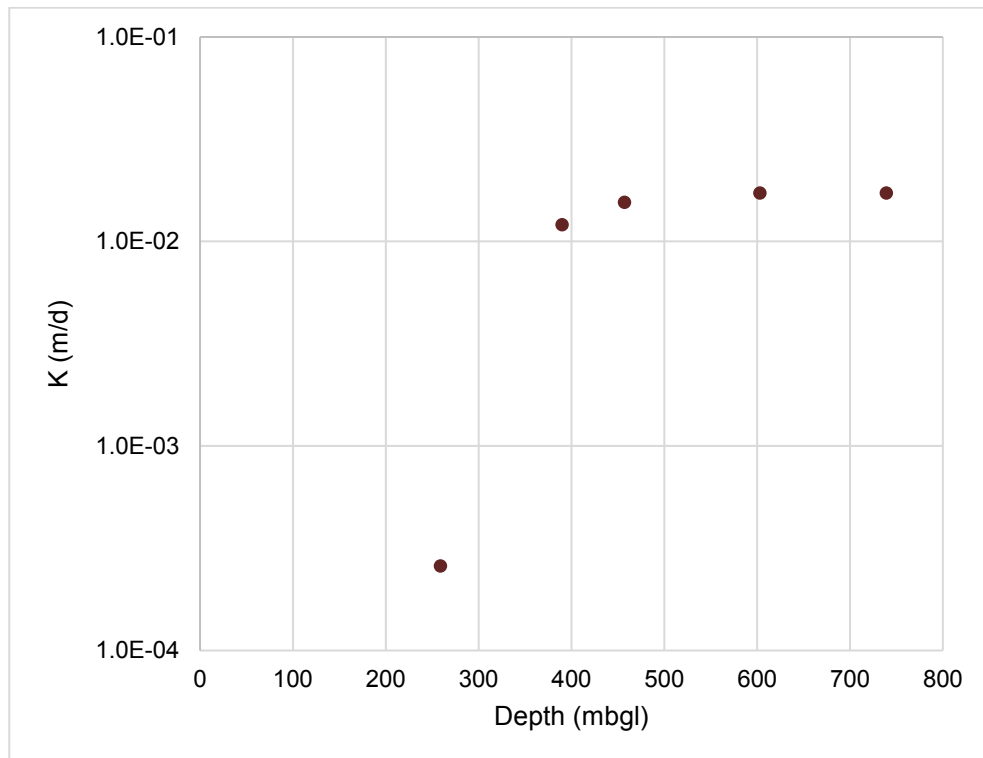


**Figure 2-2: NGT21 - K vs. Downhole Depth**

### 2.1.3 NGT22 (GT03)

The corehole was drilled from an elevation of 1125 mamsl targeting a downhole depth of 600 m in US and LS. The formation in the corehole is extensively fractured with low RQD below 400 m which caused excessive wash down during drilling leading to drilling abandonment at a depth of 452.8 m (Photos 2-4).

During drill rod changes, significant hydrostatic pressures (significant flow of groundwater to the top of the hole) were noted suggesting possible artesian conditions. Due to the unstable formation, only two packer tests were successfully conducted with calculated hydraulic conductivities of below detection at a depth interval of 178 – 189 m located in jointed rock, to  $6.6 \times 10^{-1}$  m/d at depth interval of 349 – 408 m tested in brecciated/sheared fault (Photo 2-5).



**Photo 2-4: Low RQD and fracturing NGT22**



**Photo 2-5: Typical test zone fractured shear NGT22**

#### **2.1.4 NGT23 (GT04)**

The corehole was drilled from elevation 1001 mamsl to a downhole depth of 450 m targeting LS and MC. Four packer tests were conducted all in fractured/shear zones within the LS and MC.

Two of the four tests both located above 200 m were not successful due to the injected water daylighting at a distance of 10 m south of the corehole likely to be along a shear zone intersected in the corehole at downhole depth interval 191 – 194 m. The shear zone intersected at the corehole is likely to be the same intersected at NGT22 to the north of the pit. The hydraulic conductivity value within the unsuccessful intervals is likely to be relatively high because of the shear zone that led to water injected for packer testing to daylighting on the surface.

The two successfully tested intervals have hydraulic conductivity values of  $8.0 \times 10^{-3}$  m/d at downhole depth interval of 111 - 159 m in a fractured zone at the contact of LS and MC and  $1.2 \times 10^{-2}$  m/d at downhole depth interval of 235 – 348 m which included zones of shear faults and fractured zones with vuggy zones and possible cavities at downhole depth interval 338 – 339 m.

The two calculated hydraulic conductivity values (Figure 2-3) are in the same order of magnitude, with photos of the test zones shown in Photos 2-6 and 2-7.



Photo 2-4: Fractured zone NGT23



Photo 2-5: Typical test zone across a shear/fractured zone NGT23

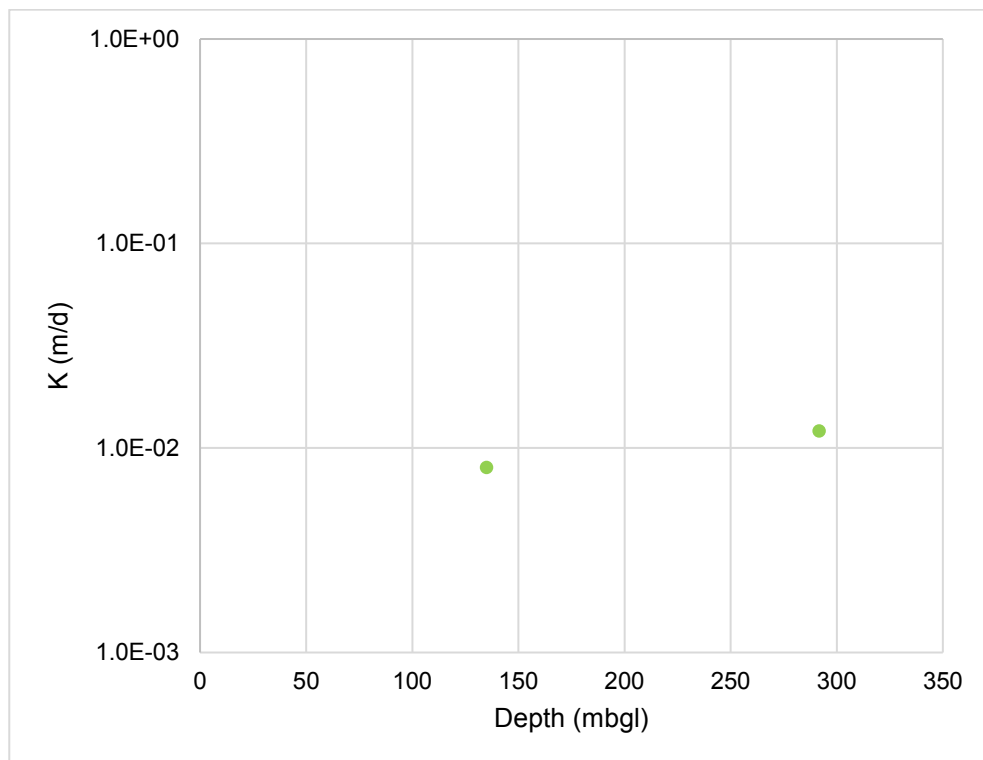


**Figure 2-3: NGT23 - K vs. Downhole Depth**

### 2.1.5 NGT24 (GT05)

The corehole was drilled at elevation 1 090 mamsl to a downhole depth of 350 m targeting MDM, MC, and LS with pegmatite intrusions. Three packer tests were successfully conducted in fractured contact zones. Hydraulic conductivity values ranged from  $8.6 \times 10^{-3}$  m/d at a downhole depth interval of 122 – 300 m at a sheared/fractured contact between MC and pegmatite to  $4.3 \times 10^{-2}$  m/d at a downhole depth interval of m 257 – 300 m at a fractured/sheared LS with fractured pegmatite. The typical fractures zones within the test interval are shown in Photo 2-8.

The distribution of hydraulic conductivities with depth (Figure 2-4) are within one order of magnitude.

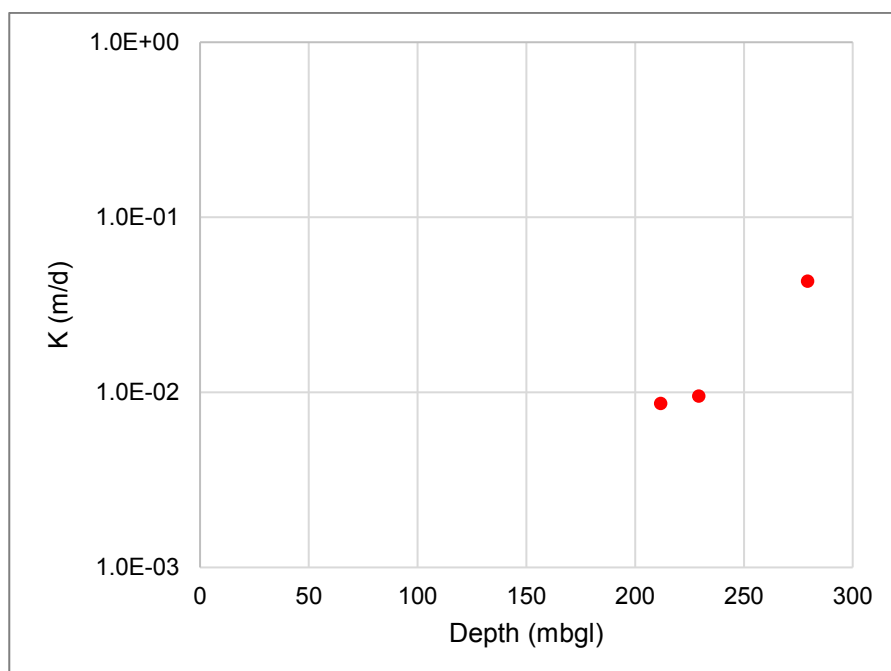


**Figure 2-4: NGT24 - K vs. Downhole Depth**



Photo 2-6: Fractured zone NGT24

## 2.2 Packer Testing Summary

The various lithological units themselves have little permeability. Fractures and fractured contact/shears were the primary zones tested with hydraulic conductivities largely between  $1 \times 10^{-2}$  and  $1 \times 10^{-1}$  m/d (Figure 2-5), a relatively narrow range and no significant variation with depth. This implies the chance of inflow is equal irrespective of depth. A relatively high hydraulic conductivity at  $1.6 \times 10^{-1}$  m/d was measured in corehole NGT22 (Photos 2-3), in a sheared fault with the possibility of cavities above and below the fault zone. At the same corehole, artesian conditions were encountered during drilling.

Results in Table 2-1 have been compared to relative universal results (Freeze and Cherry 1979) in Figure 2-6. The Low, Intermediate and High are relative indication of hydraulic conductivity, with the site data within the low to intermediate range. Fractures with hydraulic conductivities values in the range of 0.1 to 1 m/d have the ability to carry relatively significant amounts of water to the workings and moderate flows are likely from the 0.01 to 0.1 m/d zones.

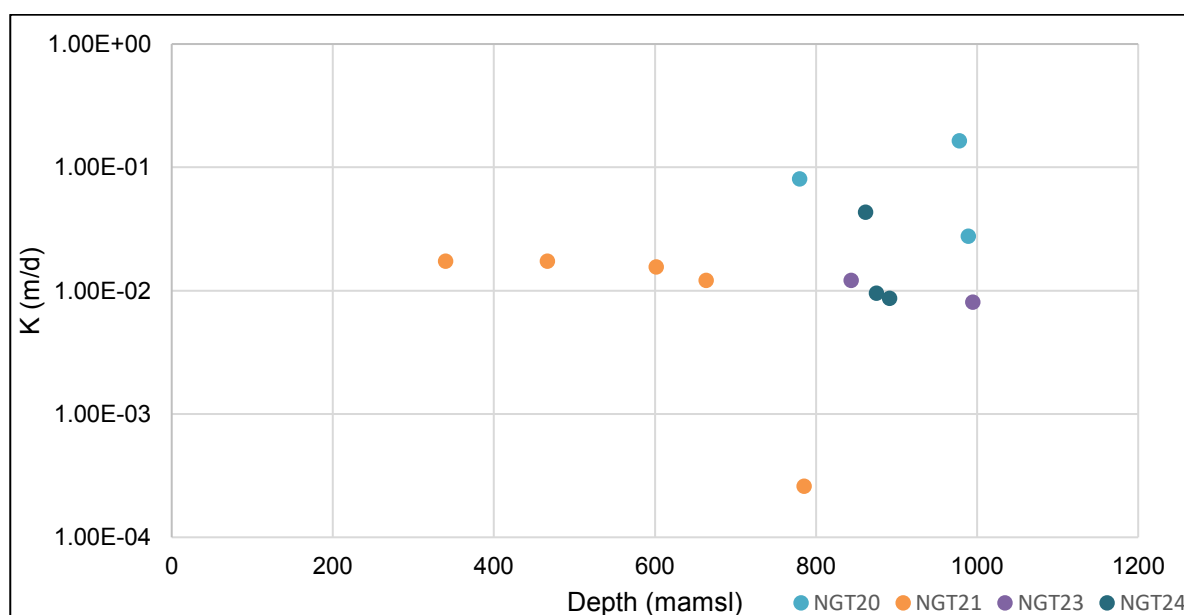


Figure 2-5: Distribution of K with Depth

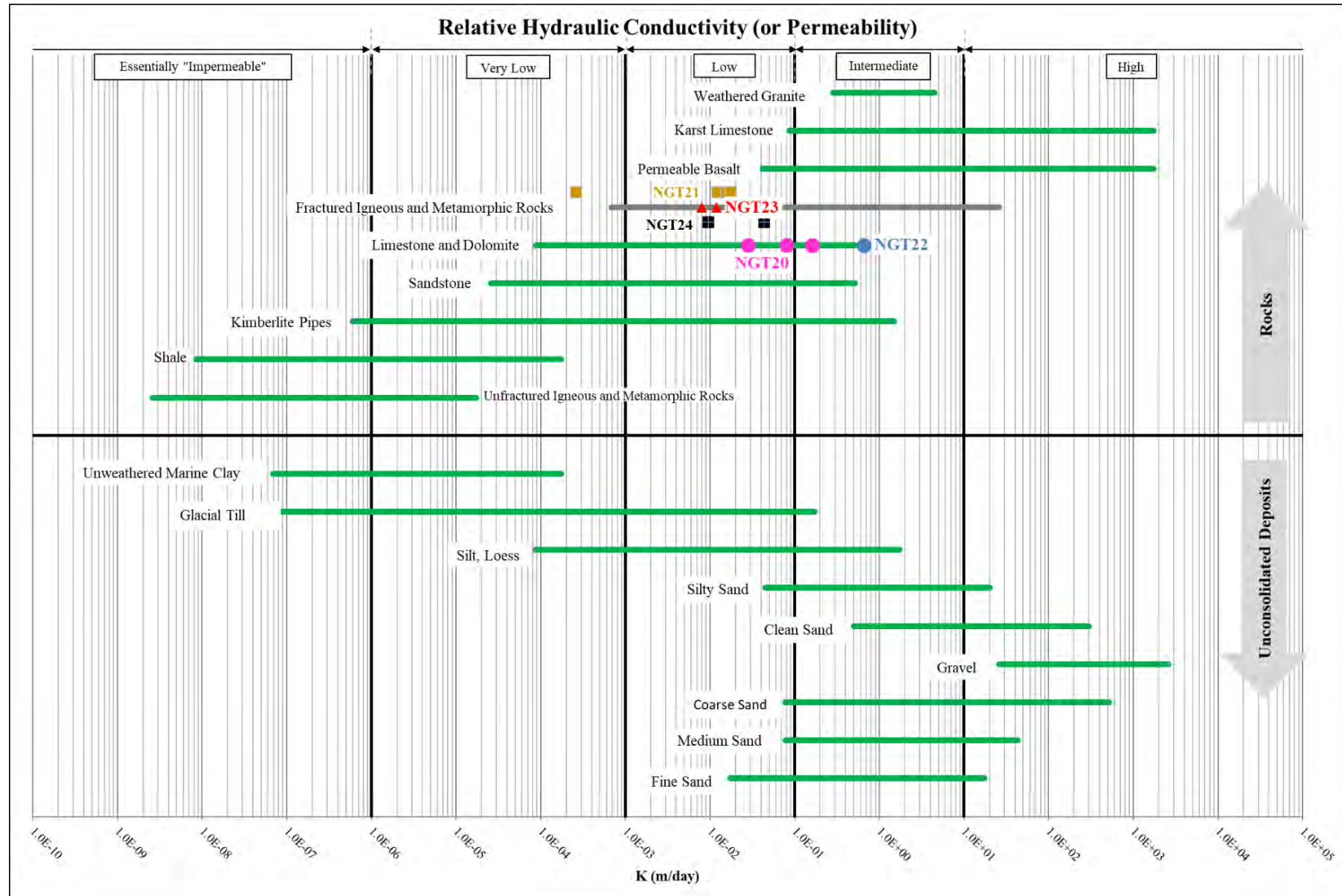


Figure 2-6: Relative K values (modified after Freeze and Cherry, 1979)

### 3 Groundwater Investigation in the Karibib Formation

The investigation comprised drilling boreholes using the down-hole-percussion method with the aim that where appreciable volumes of groundwater were encountered, pumping tests would be conducted to estimate bulk hydraulic parameters within the formation. To assist with the site selection for the drilling positions, a geophysical survey was conducted.

#### 3.1 Geophysical Survey

A resistivity survey, conducted by Geophysics LDA directly appointed by NGM, was used to identify potential structures and karst features within the Karibib Fm. The survey was limited in nature due to the current pushback happening to the west of the North Pit and the presence of rock dumps to the north and northeast. Anomalies nonetheless were identified, indicated by low resistivity zones, and these were interpreted to be potential zones of weakness in the CM and where groundwater could occur. In all Geophysics LDA reported four anomalies that could be targeted for drilling.

A simple rationale on the selection of low resistivity zones as targets for drilling, can be found on the US EPA website at the following link and is reproduced below:

*Subsurface cavities most commonly occur as solution cavities in carbonate rocks. They may be empty or filled with soil or water. In favourable circumstances, either type may offer a good resistivity contrast with the surrounding rock since carbonate rocks, unless porous and saturated, usually have high resistivities, whereas soil or water fillings are usually conductive, and the air in an empty cavity is essentially nonconductive. Wenner or Schlumberger arrays may be used with horizontal profiling to detect the resistivity anomalies produced by cavities, although reports in the literature indicate mixed success. The probability of success by this method depends on the site conditions and on the use of the optimum combination of electrode spacing and interval between successive stations. Many of the unsuccessful surveys are done with an interval too large to resolve the anomalies sought.*  
[https://archive.epa.gov/esd/archive-geophysics/web/html/resistivity\\_methods.html](https://archive.epa.gov/esd/archive-geophysics/web/html/resistivity_methods.html)

The full geophysical survey report is included in Appendix A.

#### 3.2 Percussion Drilling

Three percussion boreholes (Table 3-1) were drilled, two on anomalies inferred from the resistivity geophysical survey conducted by Geophysics LDA (named DW24 and DW25) and one (DW23) on a previously conducted magnetics geophysical survey. Target depths of maximum depths of 200 m were envisaged since groundwater levels in the Karibib Fm. are expected to be between 50 and 100 m and not deeper than 200 m. Drill chips that were collected for every meter were logged in consultation with the mine geologists.

**Table 3-1: Summary of DW boreholes**

| Borehole | Local coordinate |          |           | Drilled depth (m) | Static water level (mbgl) (1/2/21) | Geophysics anomaly |
|----------|------------------|----------|-----------|-------------------|------------------------------------|--------------------|
|          | Y (m)            | X (m)    | Z (mamsl) |                   |                                    |                    |
| DW23R    | 4474.563         | 1460.718 | 1130      | 210               | 44.7                               | Previous Magnetics |
| DW24R    | 3747.508         | 1877.386 | 1141      | 200               | Dry and destroyed                  | D3                 |
| DW25R    | 3709.792         | 1813.790 | 1143      | 200               | 59.3                               | D4                 |

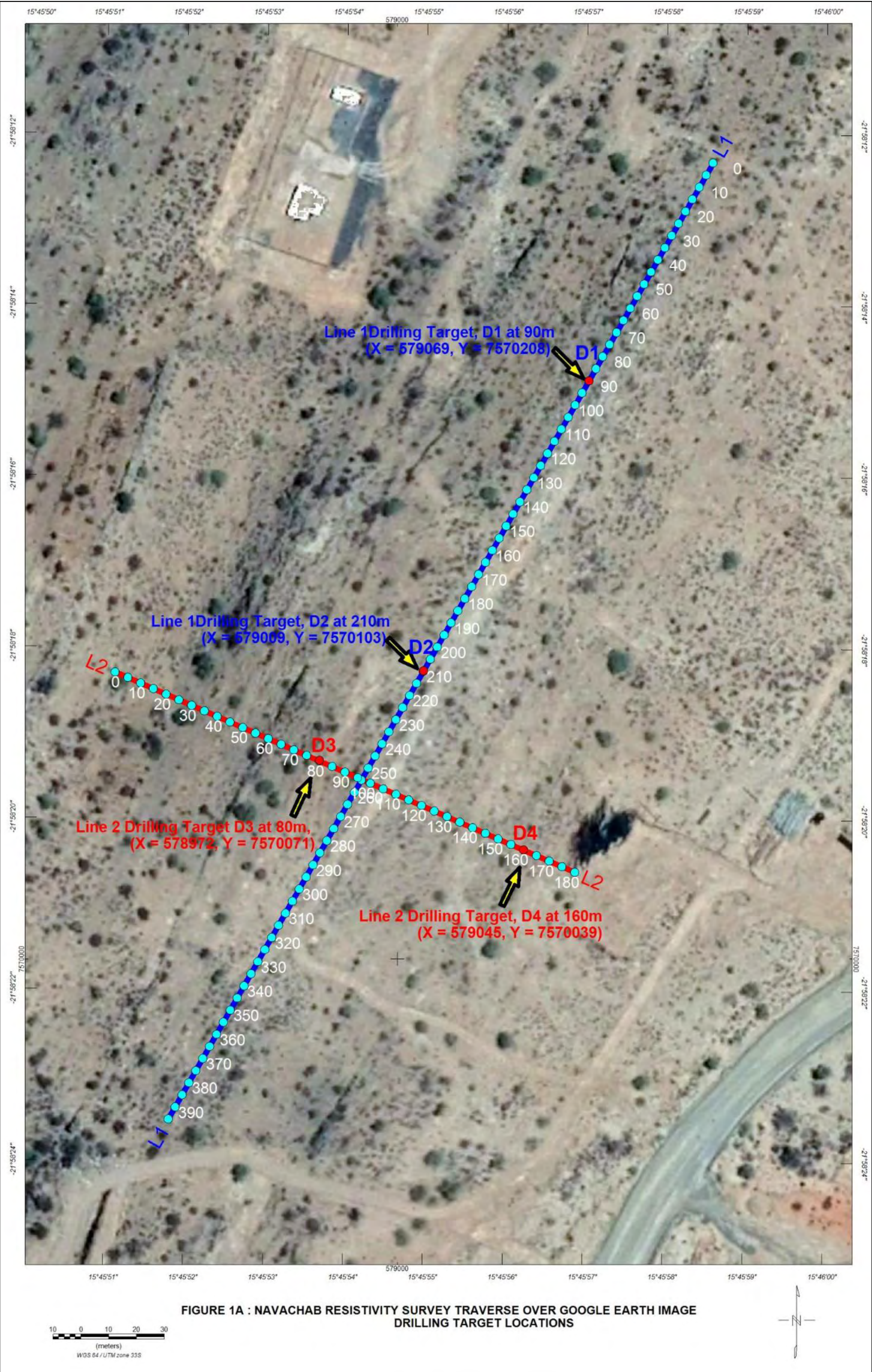


Figure 3-1: Location of geophysical surveys (Source LDA Geophysics)

**DW24R**

The borehole was drilled in the Karibib Formation (CM) to a depth of 200 m on a low resistivity anomaly. Apart from slightly fractured zones across the profile, there was no evidence of karsts and the borehole was dry on completion and was still dry a month after drilling.

**DW25R**

The borehole was drilled in the Karibib Formation on an inferred low resistivity anomaly. Several fractured and partially oxidized zones were noted throughout the profile with very moist fractured zones at 118 -120 m, 126 - 130 and 160 – 168 m intervals. An inferred coarse sand filled karstic zone was encountered at depth interval of 120 - 122 m.

The static water level measured on 1 February 2021 was 59.3 meters below ground level indicates that there is slow groundwater seepage between the interval 118m – 122m. The shallower static groundwater level compared to the depth of intersection indicates the presence of confining conditions to groundwater.

**DW23R**

As a result of drilling two boreholes in the Karibib Fm. which did not yield measurable groundwater flow, SRK in consultation with the client proposed to drill a third borehole, DW23, to the north of the existing North Pit to further characterise additional possible sources of groundwater. This motivation was further enhanced by the findings at the NGT22 geotechnical coreholes which had to be suspended due to inferred excessive ingress of groundwater that had silty/clay washdowns.

The borehole was drilled on a magnetic anomaly inferred to be close to the contact between the Oberwasser (Upper Schist) and the Okawayo Formations (MDM). This borehole was drilled to broaden the understanding of the groundwater occurrence along the MDM/US contact zone. The selection of this location was motivated in SRK memo dated 10 December 2020.

The chips were damp at the contact between marble (MDM -Okawayo) and Marble Calc-silicate (MC) Formations at depth interval of 190 – 202 m. The dampness at the contact indicates that the fractured contact allows a small amount of groundwater to flow through. If the flow were substantial, a measurable blow-out yield would have been encountered during the drilling. The static water level of 44.7 mbgl was measured on 1 February 2021, indicating the confining conditions i.e. the groundwater is under pressure.

### 3.3 Slug Testing

Due to very low groundwater yields, slug testing instead of pumping tests was attempted at boreholes DW23 and DW25 to obtain hydraulic conductivities.

A slug test is a method of estimating hydraulic properties of aquifer materials in the immediate vicinity of a well by measuring the water-level response in a borehole after a near-instantaneous change in hydraulic head. The slug tests attempted at the site involved insertion of a mechanical slug (PVC pipe of measured volume blocked at both ends) in an attempt to raise the water level which would then be monitored at set time intervals as it draws back to the static level. The change in the water level as it moves towards static the set time intervals would then be used to calculate the hydraulic conductivity.

Due to the relatively large diameter of the boreholes, insufficient water displacement was achieved to enable meaningful calculations.

### 3.4 Groundwater Quality

Groundwater from percussion boreholes, DW 23R and DW 25R, the northern seepage and pit sump were sampled for laboratory analyses. Major cations and anions were analysed by NamWater in Namibia and isotope analysis consisting of deuterium and Oxygen-18 were analysed by iThemba laboratory in Johannesburg.

The hydrochemistry of DW 23R drilled into the MDM is Na-Cl/SO<sub>4</sub> dominant and DW 25R drilled into the CM is Ca-HCO<sub>3</sub>/SO<sub>4</sub> dominant (Figure 3-2). The hydrochemistry of the MDM was previously characterised as Ca/Mg-SO<sub>4</sub>/HCO<sub>3</sub> dominant whilst the CM as Ca-HCO<sub>3</sub> dominant (Steven and Bardenhorst, 2006). This could suggest that there is some mixing with footwall schist (LS) water which is typically characterised as Ca/Na-Cl/SO<sub>4</sub> with the MDM water at DW23. The relatively high proportion of sulphide in the pit sump is related to the oxidation of the sulphide minerals present.

Laboratory Certificates are included in Appendix B.

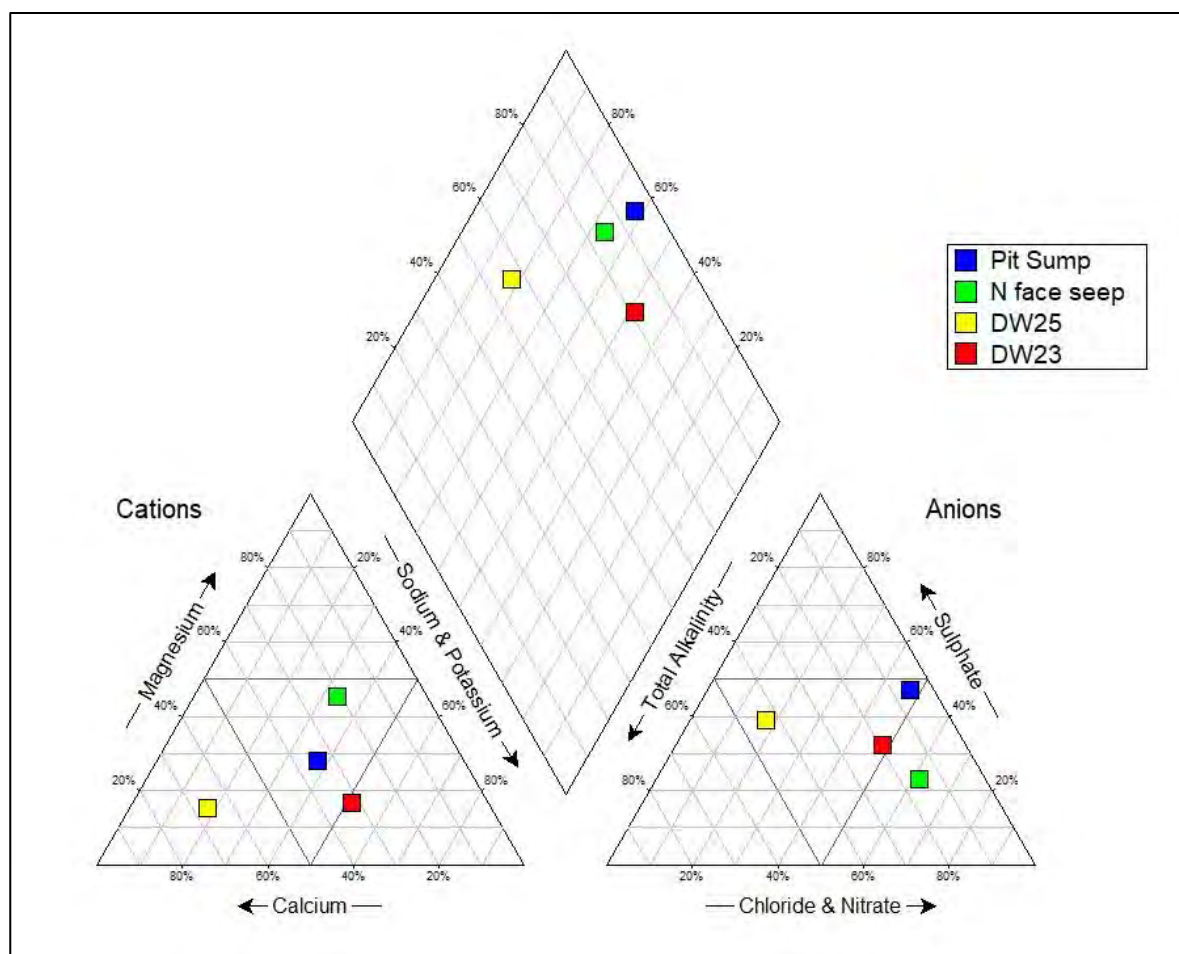
**Table 3-2: Water Quality**

| Determinant                           | Unit | DW23  | DW25  | North face seepage | Pit water |
|---------------------------------------|------|-------|-------|--------------------|-----------|
| pH                                    | ()   | 7.9   | 7.7   | 8.3                | 7.9       |
| Conductivity mS/m                     | mS/m | 221.0 | 182.4 | 314.0              | 569.0     |
| TDS                                   | mg/l | 1481  | 1222  | 2104               | 3812      |
| Sodium as Na                          | mg/l | 230   | 74    | 230                | 510       |
| Potassium as K                        | mg/l | 9     | 7     | 14                 | 22        |
| Sulphate as SO <sub>4</sub>           | mg/l | 360   | 335   | 350                | 1430      |
| Nitrate as N                          | mg/l | 2.0   | 62.7  | 17.6               | 40.1      |
| Nitrite as N                          | mg/l | <0.1  | <0.1  | <0.1               | <0.1      |
| Fluoride as F                         | mg/l | 2.1   | 1.5   | 0.6                | 1.4       |
| Chloride as Cl                        | mg/l | 399   | 115   | 687                | 1069      |
| Total Alkalinity as CaCO <sub>3</sub> | mg/l | 136   | 238   | 148                | 104       |
| Total Hardness as CaCO <sub>3</sub>   | mg/l | 480   | 750   | 1010               | 1858      |
| Calcium as CaCO <sub>3</sub>          | mg/l | 318   | 613   | 323                | 1025      |
| Magnesium as CaCO <sub>3</sub>        | mg/l | 163   | 138   | 688                | 833       |
| Iron as Fe                            | mg/l | 0.04  | 0.02  | <0.01              | 0.01      |
| Manganese as Mn                       | mg/l | 0.07  | 0.08  | <0.01              | <0.01     |
| Zinc as Zn                            | mg/l | <0.01 | <0.01 | 0.01               | <0.01     |
| Nickel as Ni                          | mg/l | <0.01 | <0.01 | <0.01              | <0.01     |

According to the classification by Mayer *et al*, (2005) (Table 3-3) the water is brackish to saline indicated by relatively high TDS, which is typical for arid conditions with low and erratic recharge.

**Table 3-3: Salinity Classification (source Mayer et al, 2005)**

| Salinity status | Salinity (mg/l) | Description and use                                            |
|-----------------|-----------------|----------------------------------------------------------------|
| Fresh           | < 500           | Drinking and all irrigation                                    |
| Marginal        | 500 –1 000      | Most irrigation, adverse effects on ecosystems become apparent |
| Brackish        | 1 000 – 2 000   | Irrigation certain crops only; useful for most stock           |
| Saline          | 2 000 – 10 000  | Useful for most livestock                                      |
| Highly saline   | 10 000–35 000   | Very saline groundwater, limited use for certain livestock     |
| Brine           | >35 000         | Seawater: some mining and industrial uses exist                |

**Figure 3-2: Piper Plot**

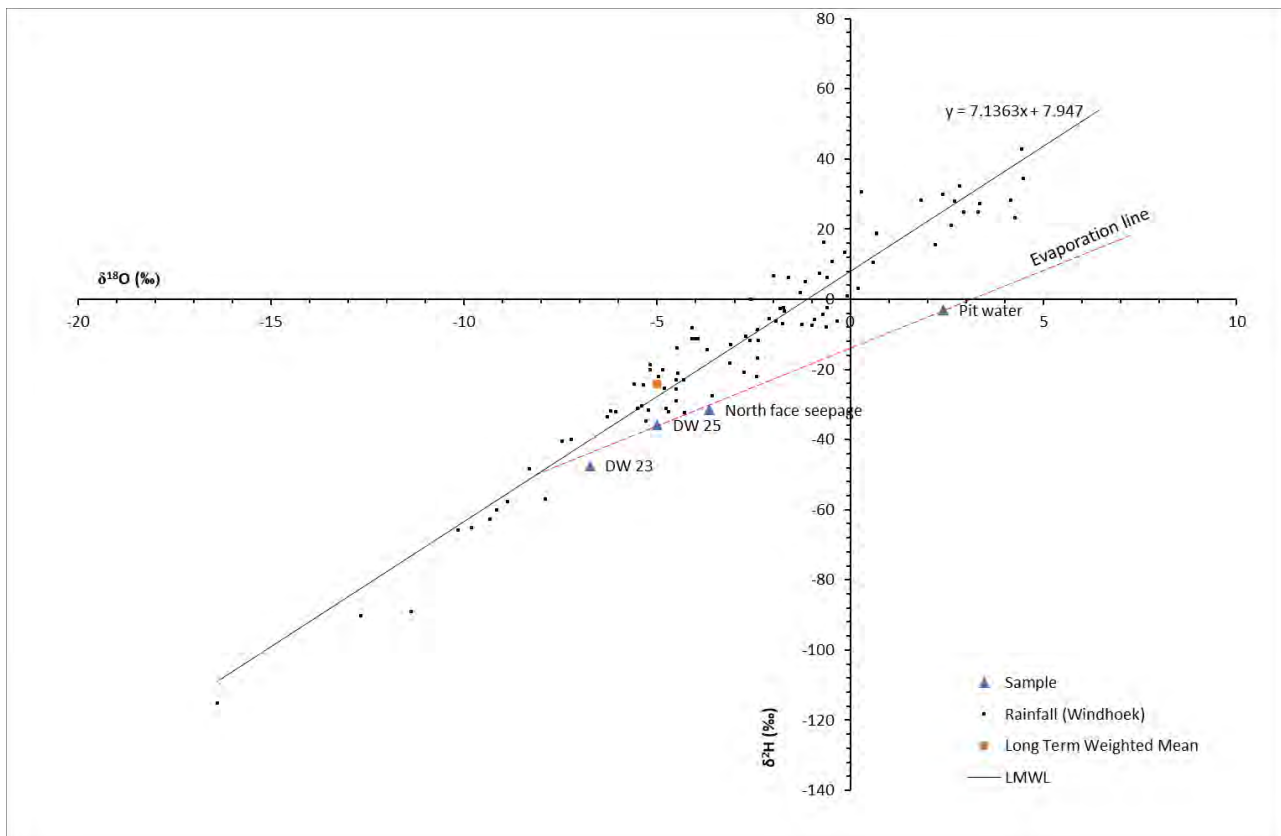
### 3.4.1 Environmental Isotopes

Results of the isotope analyses collected at the same time as the water quality samples are presented in Table 3-4. Rainfall, oxygen-18 and deuterium signatures generally plot along a linear line defining the local meteoric water line. However, for Navachab such a data set is not available and therefore the historic data collected for Windhoek is plotted as an indication of the meteoric water line.

The isotope data indicate that the groundwater originates as precipitation (Figure 3-3) with DW 23R and DW 25R plotting close to the meteoric line. The pit sump as expected has a strong evaporation signal. The seepage on the north face also has an evaporative signature reflecting evaporation of the water as it seeps into the pit. The north face seepage and the intersected water at DW 25 are likely of the same origin i.e. there is possibly a connection between the karst and seepage in the pit.

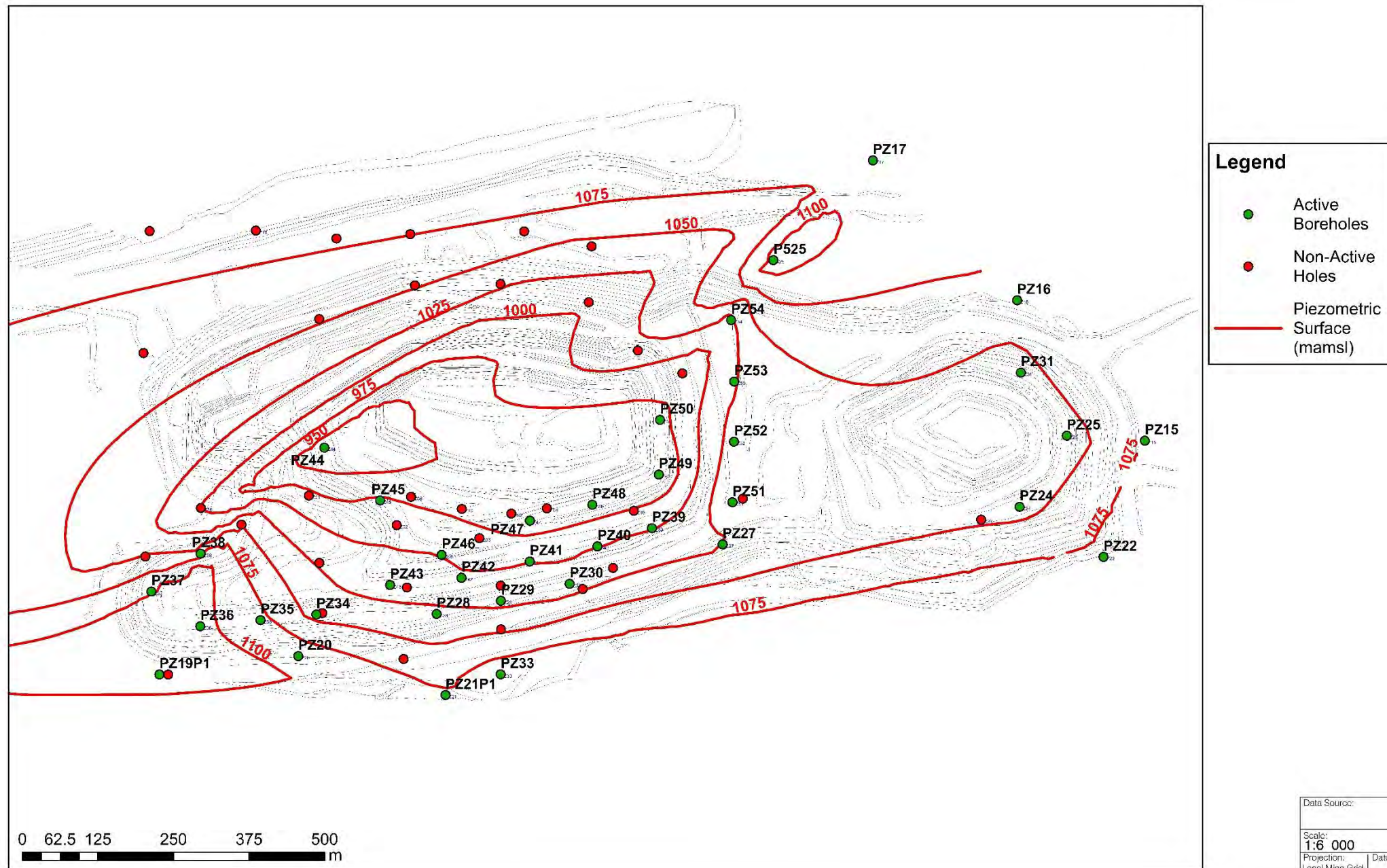
**Table 3-4: Isotope Results**

| Sample Name        | $\delta D$ (‰) | $\delta^{18}O$ (‰) |
|--------------------|----------------|--------------------|
| DW 23              | -47.4          | -6.74              |
| DW 25              | -35.8          | -5.00              |
| North face seepage | -31.4          | -3.65              |
| Pit water          | -3.1           | 2.40               |

**Figure 3-3:  $\delta^{18}O$  vs  $\delta D$  Plot**

## 4 Piezometric Surface

The latest groundwater level data (November 2019) from 36 on-site monitoring piezometers were integrated and processed to construct a piezometric surface of the mine area and is illustrated in Figure 4-1. The distortion of the piezometric surface in the NW of the pit is likely related to the presence of an NW-SE geological structure which forms a preferential pathway and results in a zone of depressurisation relative to the surroundings. The MDM unit (Okawayo Fm) with which seepage is associated is also a likely contributing factor to this depressurisation.



## 5 Conceptual Groundwater Model

The motivation for the explorative groundwater investigation in the Karibib Fm. is based on a report by Steven and Bardenhorst (2006) which indicated that the Karibib Fm. at Navachab, has potential groundwater storage but the extent of which was unknown. The fractures identified by the packer testing would then be fed by the groundwater potentially stored in the Karibib Fm.

Anecdotal evidence (*pers. comm.* Mr J Walkers) and the percussion drilling confirms the presence of karsts, but these seem to be small, isolated and of low yield. The geophysical survey although identified some structures, was limited in extent (Geophysics LDA: General Limitations, Page 1). The water table is relatively deeper at 45 to 60 mbgl but provides a head behind the western wall.

The limited investigation however does suggest that there may be a connection from the CM to the MDM and MC via fractures. A western pit pushback into the Karibib Fm. is under consideration by the mine. The pushback is likely to expose some of the karst which would then produce water.

Whilst the indication is that at Navachab there may not be a large, predictable source of water there are exceptions as demonstrated by the water intersected at NGT22.

## 6 Estimated Groundwater Inflow

Conceptually it is expected some groundwater would enter the mine and the inflow rates to assist with planning infrastructure were estimated using the Goodman *et. al.* (1965) analytical equation for tunnel inflow:

$$\frac{Q}{L} = \frac{2\pi(k)(D)}{\ln \frac{4D}{d}}$$

Where:

K = hydraulic conductivity

D = head of water

d = tunnel diameter

L = tunnel length

This solution is idealised for horizontal tunnels and assumes the aquifer is homogeneous, isotropic, and semi-infinite. The following assumptions were applied:

- All tunnels are 5.5 m in diameter.
- The head of water will reduce to below tunnel floor once the lower and new level is developed.
- Only the main development tunnels are considered, cross cuts etc. are not included.
- Hydraulic conductivity values from the packer testing were used.
- The current Leapfrog lithological model was used to assign flow per geological segment of a tunnel.

Given the heterogeneity of groundwater occurrence and inherent assumption in the Goodman equation, the approach applied is deemed reasonable.

The underground mining tunnels will be located within the MC, the orebody, and LS in the main and inflows are in the range of 199 to 1 260 m<sup>3</sup>/d for the various mining levels (Table 6-1). Inflows into the shallower mining areas are expected to reduce as the deeper levels develop, the aquifer storage depletes and depressurisation around tunnels occurs. The calculated inflows are therefore the expected rates per tunnel during tunnel development and will diminish over time. Some development at the nominal 813 and 785 elevations will be into the MDM, which has a higher permeability. The 813 level is located approximately 100 m below the main pit and there is this potential larger driving head, which results in the estimated larger inflow. The hydraulic conductivity and head are the main drivers

for the inflows here, and should the actual head be lower than assumed or the heads reduce rapidly in response to dewatering of fractures, inflows may be significantly lower associated with the MDM.

Overall, the inflows per level are relatively low, generally decrease with depth (

**Figure 6-1)** and can be managed with haulage drains directed to a sump(s).

**Table 6-1: Calculated Inflow Per Nominal Mining Level**

| <b>Nominal Mining Level<br/>(mamsl)</b> | <b>Inflow<br/>(m<sup>3</sup>/d)</b> |
|-----------------------------------------|-------------------------------------|
| 995                                     | 1 260                               |
| 965                                     | 388                                 |
| 935                                     | 313                                 |
| 904                                     | 351                                 |
| 875                                     | 497                                 |
| 844                                     | 228                                 |
| 813                                     | 3 915*                              |
| 785                                     | 811                                 |
| 751                                     | 765                                 |
| 725                                     | 1 003                               |
| 694                                     | 749                                 |
| 665                                     | 769                                 |
| 636                                     | 658                                 |
| 606                                     | 812                                 |
| 576                                     | 549                                 |
| 545                                     | 635                                 |
| 516                                     | 367                                 |
| 486                                     | 349                                 |
| 455                                     | 318                                 |
| 425                                     | 261                                 |
| 394                                     | 263                                 |
| 364                                     | 199                                 |
| <i>Minimum</i>                          | <i>199</i>                          |
| <i>Maximum</i>                          | <i>3915*</i>                        |

\*influence by assumed driving head of 100 m

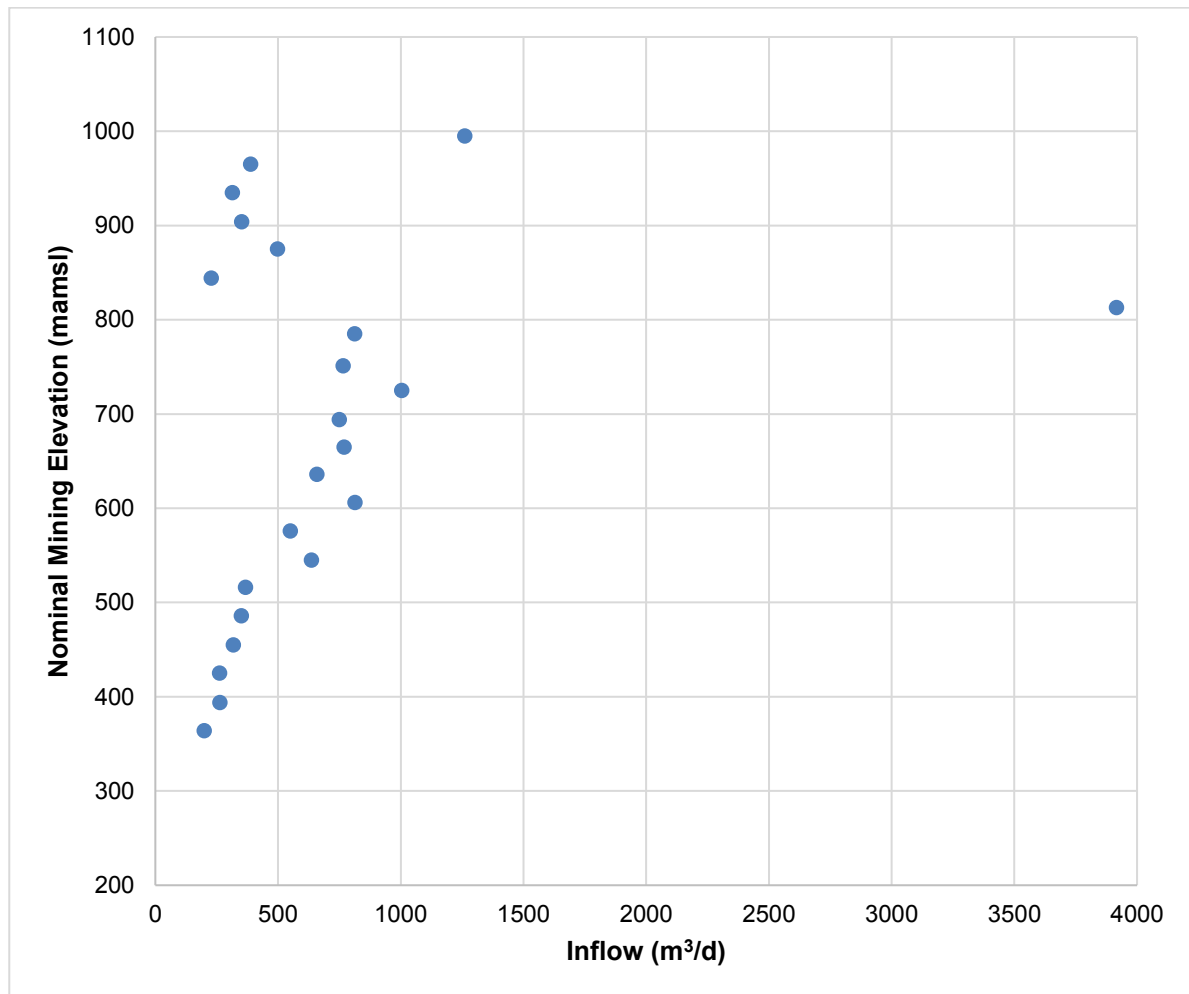


**Figure 6-1: Estimated Inflows Per Mining Level**

## 7 Conclusions and Recommendations

Estimated groundwater inflows into the proposed underground workings are relatively low in the range 199 m³/d to 1 260 m³/d and can be managed via tunnel drainages. The two boreholes drilled in the Karibib Fm. indicate that this formation may not be a large source of groundwater. However, the groundwater bearing zones are heterogeneous and potential sources of groundwater in pockets within the CM cannot be totally ruled out as observed at corehole NGT22. Higher inflows may be experienced when development occurs in the MDM/MC and associated with discrete fault zones, probably those orientated north south. The groundwater at the tested locations is brackish to saline, typical of an arid environment and may lead to corrosion to some infrastructure.

SRK makes the following recommendations:

- If groundwater inflow into the workings results in gradual accumulation of groundwater, temporary collection sump(s) should be constructed during mine development and operation so that the accumulated groundwater can be managed with haulage drains directed to a sump(s).
- During development and operation, groundwater inflow volumes into the workings should be measured so that any required adjustments to groundwater management can be implemented to ensure safe and dry mining.
- Consideration should be given to:

- Documentation of groundwater occurrence depths together with a description of the geological structure associated with it and inflow volumes in the trial mine and apply the findings to the full underground mine.
- The groundwater level monitoring piezometers that could be affected by the western pushback should be replaced to continue monitoring of groundwater levels. We propose that additional groundwater monitoring piezometers should be considered around the northern pit.
- During cover drilling to poor ground conditions, groundwater occurrence and flow volume should be conducted.

**Prepared by**

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 Ismail Mahomed

## 8 References

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Mayer X.M, Ruprecht J.K and Bari M.A. Stream salinity status and trends in south west Western Australia. Department of Environment, Salinity and land use impacts series. Report No. SLUI 38 (2005). [https://archive.epa.gov/esd/archive-geophysics/web/html/resistivity\\_methods.html](https://archive.epa.gov/esd/archive-geophysics/web/html/resistivity_methods.html)

Steven, N. and Bardenhorst, F. The Navachab Gold Mine, Namibia: 2000 – 2005 Hydrogeological Summary. Presentation to Hydrogeological Association of Namibia, 23rd – 25th March 2006, Windhoek.

*pers. comm.* Mr J Walkers.

All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

## **Appendices**

## **Appendix A: Geophysical Survey Report**

# Resistivity Tomography Survey Report

Prepared for



Farm Navachab 58, Karibib District, Karibib

Geophysical Resistivity survey to identify Karst, Geological structures in the  
Karibib formation : Marbles for Ground water model

Prepared by



**Geophysics LDA**

1051 Dr. W Swiegers Street, Swakopmund

**Report Review History:**

| Revision No: | Date:           | Prepared by:                                                                                                                       |
|--------------|-----------------|------------------------------------------------------------------------------------------------------------------------------------|
| Zero         | 28 October 2020 | Brain Makone (Pr.Sci.Nat)<br>MSc. Exploration Geophysics                                                                           |
|              |                 | <p>DocuSigned by:</p>  <p>E6F89E301C2D469...</p> |

**Authors qualifications and affiliations:**

Brain Makone is a professional Exploration Geophysicist with extensive experience in ground geophysical surveying services responsible for management, planning, auditing of all exploration and technical projects in the region. Brain Makone started his career 15 years ago as a field geophysicist and has progressed through the years to an expert in exploration geophysics he is also a registered Scientist with the South African Council for Natural and Scientific Professions (Pr Sci Nat # 400033/12).

**Declaration of independence:**

The author of this report is independent professional consultant with no vested interest in the project, other than remuneration for work associated with the compilation of this report.

**General limitations:**

1. The investigation has been conducted in accordance with generally accepted engineering practice, and the opinions and conclusions expressed in the report are made in good faith based on the information at hand at the time of the investigation.
2. The contents of this report are valid as of the date of preparation. However, changes in the condition of the site can occur over time as a result of either natural processes or human activity. Consequently, this report should not be relied upon after an eclipsed period of one year without a review by this firm for verification of validity. This warranty is in lieu of all other warranties, either expressed or implied.
3. The investigation is conducted within the constraints of the budget and time and therefore limited information was available mostly due to poor galvanic contact during the resistivity survey. Although the confidence in the information is reasonably high, some variation in the ground conditions should be expected.



## **Geophysical Resistivity survey to identify Karst, Geological structures in the Karibib formation : Marbles for Ground water model**

### **Table of Contents**

|                                                            |   |
|------------------------------------------------------------|---|
| 1. Location and Geological setting of the Survey Area..... | 3 |
| 2. Resistivity Tomography Survey.....                      | 4 |
| 2.1. Resistivity Data Processing.....                      | 5 |
| 2.2. Resistivity Data Compilation.....                     | 6 |
| 2.3. Electrical resistivity of rocks.....                  | 6 |
| 3. Discussion of Results .....                             | 7 |
| 4. Recommendations .....                                   | 8 |

### List of Figures

|                                                                                                            |   |
|------------------------------------------------------------------------------------------------------------|---|
| Figure 1 : Local Geology of the Survey area .....                                                          | 3 |
| Figure 2 : Resistivity Survey area .....                                                                   | 4 |
| Figure 3 : ABEM Terrameter LS2 Resistivity system.....                                                     | 5 |
| Figure 4 : Typical values for electrical resistivity of rocks (adapted from Palacky 1987).....             | 7 |
| Figure 5 : Line 1 (400m) Electrical Resistivity Tomography pseudosection.....                              | 8 |
| Figure 6 : Line 2 (200m) Electrical Resistivity Tomography pseudosection.....                              | 8 |
| Figure 1A : Navachab Resistivity Survey Traverse over Google Earth image<br>Drilling Target Locations..... | 9 |

## 1. Location and Geological setting of the Survey Area

The resistivity survey was carried out in the Gecko area in Karibib district in central Namibia. The area has numerous quartz vein hosted gold prospects due to the presence of a large hydrothermal system (after Creus, Pieter Koenraad, MSc Thesis (2011-12)). The site local geology is within the Navachan synform and is mainly dolomitic marble.

## Geology of the Navachab Synform

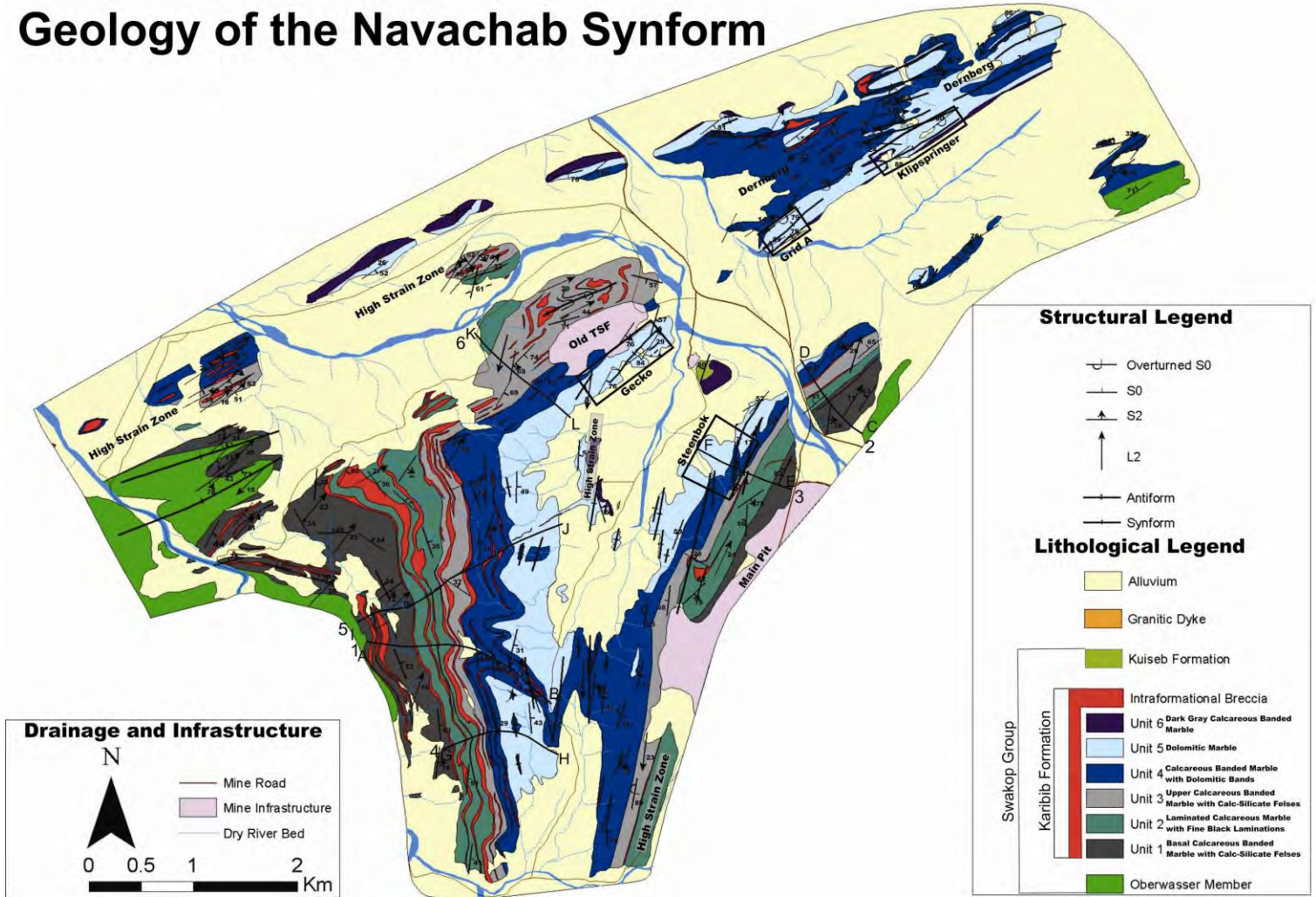


Figure 1: Local Geology of the Survey area

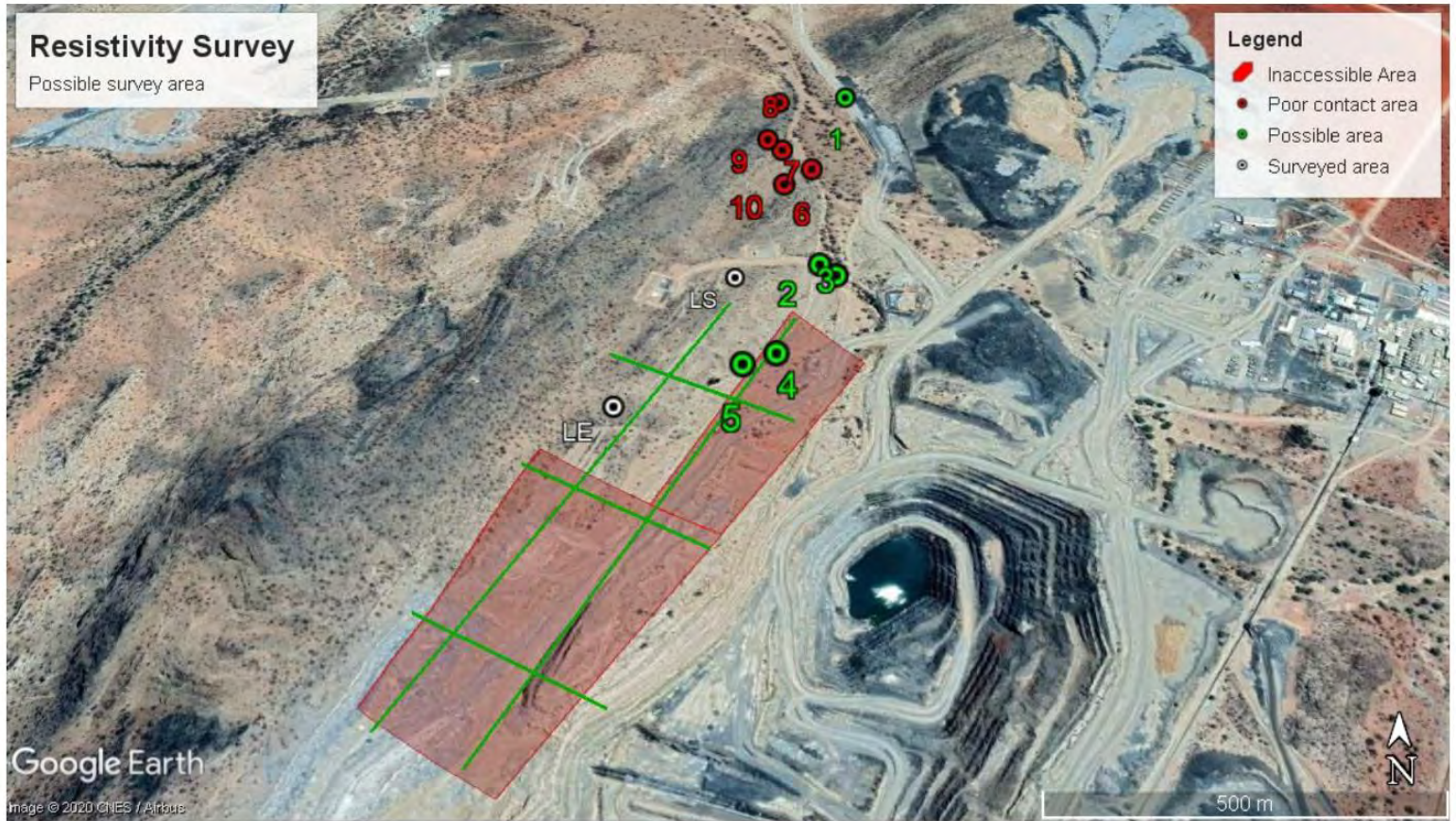


**Figure 2 : Resistivity Survey area**

## 2. Resistivity Tomography Survey

Resistivity tomography survey was carried out in the Gecko area utilizing the ABEM Terrameter LS2 with a 250W transmitter with a maximum output current of 2500 mA. Inter-electrode spacing "a" was 5m and data was acquired using the Schlumberger electrode array with "n" = 1 to 15. The software-driven field electrode switching system measures resistivities between all electrodes, which sequentially assume current and potential electrode status over the pseudo-depth interval n=1 to 15. Data acquired along a line laid out with a hand-held GPS. Total coverage was 600m of line (400m & 200m).



**Figure 3: ABEM Terrameter LS2 Resistivity system**

## 2.1 Resistivity Data Processing

The measured electrical current and potential at the receiver are related to the apparent subsurface electrical resistivity by the following expression;

$$R(\text{app}) = K \times V/I$$

Where "I" is the current measured between outer current electrodes, V is the voltage measured between the inner potential electrodes, and K is related to the electrode spacing and the array type, thus:

- The basis inter-electrode spacing "a" is multiplied by the "n" depth level factor to given an increasing inter-electrode spacings ( $n \times a$ ) as n increases (in this case) from 1 to 15
- As the electrode spacings increase so does the depth of penetration
- In this case level resistivity data sets are generated for some 15 depth levels

The basic line database comprises matching columns ranked firstly by "n" values, then station position (chainage) and apparent resistivity. "n" values are listed in ascending order. The .DAT files were imported into the RES2D\_INV software module, which inverts pseudo-section apparent resistivity data-sets to formation resistivity-depth data sets.



## **2.2 Resistivity Data Compilation**

The RESINV\_2D file carries data for the following individual line datasets:

- Measured apparent resistivity pseudo-section
- Calculated best-(model)-fitting apparent resistivity pseudo section
- Best-fitting formation resistivity-depth section.

This file was finally converted to an XYZ file for importation into Geosoft for further processing and display purposes.

## **2.3 Electrical resistivity of rocks**

The electrical resistivity of rocks is variable. Values ranging as much as 10 orders of magnitude may be encountered, and even individual rock types can vary by several orders of magnitude. The next figure is a representative chart which illustrates very generally how the resistivities of important rock groups compare to each other. This type of figure is given in most texts on applied geophysics. The resistivity of dolomite varies from 10 000 to 100 000 Ohm-m.



## Geophysics LDA

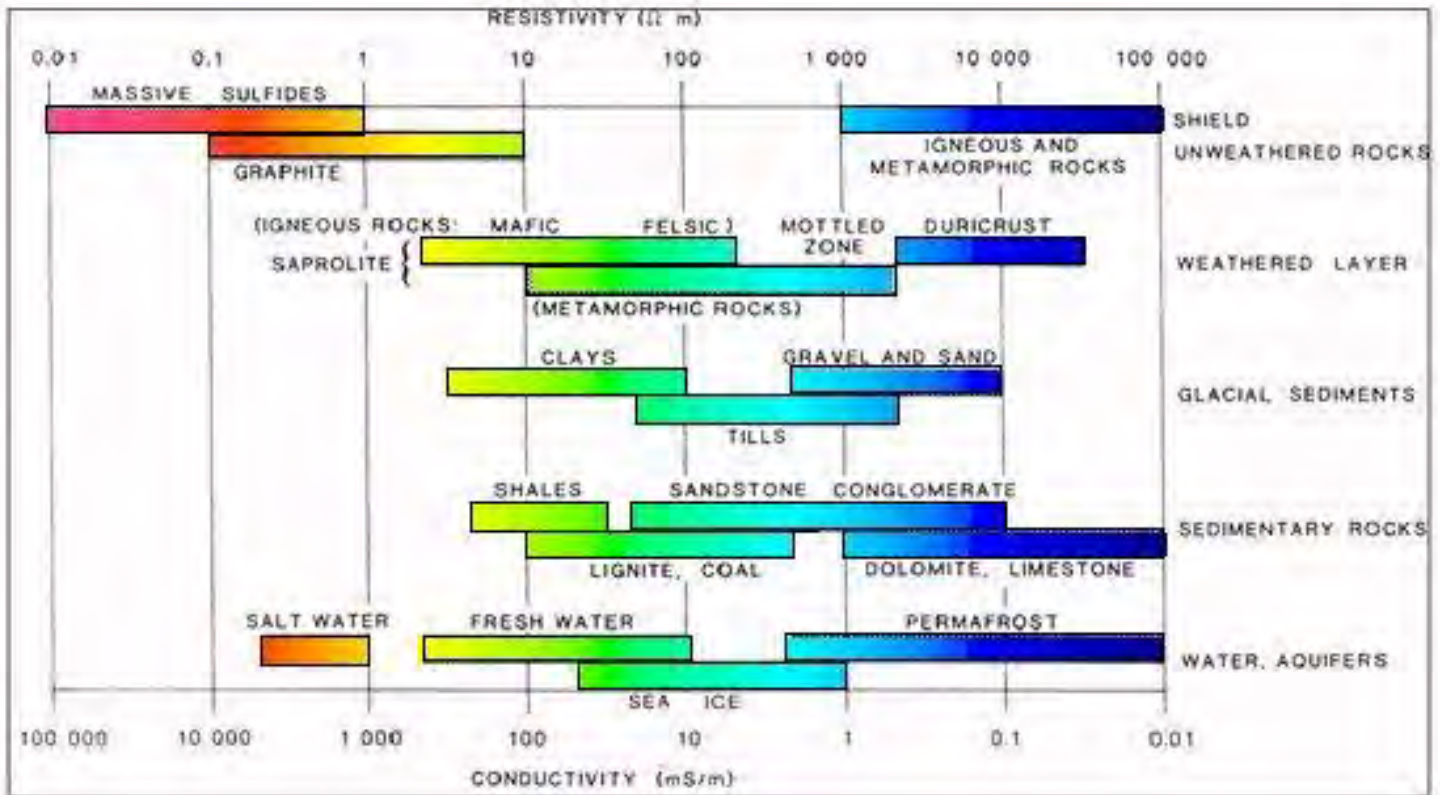


**Figure 4: Typical values for electrical resistivity of rocks (adapted from Palacky, 1987)**

### 3. Discussion of results

The aim of the survey was to delineate areas of groundwater ingress. These areas are indicated by areas of low apparent resistivity. Resistivity data is of good quality with best-model-fitting inversion errors of less than 7%. Formation resistivities are generally high in the range of 1 000 Ohm-m to 60 000 Ohm-m. The areas of possible groundwater ingress is between 80m (X = 579074, Y = 7570216) and 100m (X = 579064, Y = 7570199), and 200m (X = 579014, Y = 7570112) and 220m (X = 579004, Y = 7570094) where resistivities are relatively lower in these regions compared to other areas along the line. A resistivity basement high is 140m (X = 579044, Y = 7570164) and 180m (X = 579024, Y = 7570129) at a depth of 20m to infinity which represent areas low water ingress.

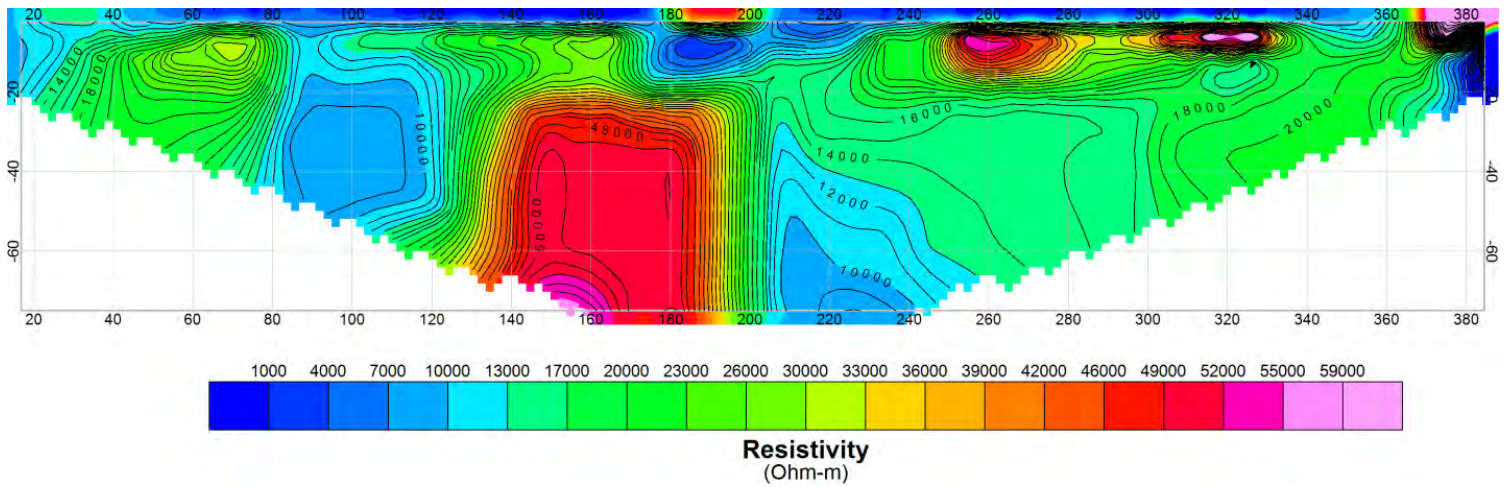


**Figure 5: Line 1 (400m) Electrical Resistivity Tomography pseudosection.**

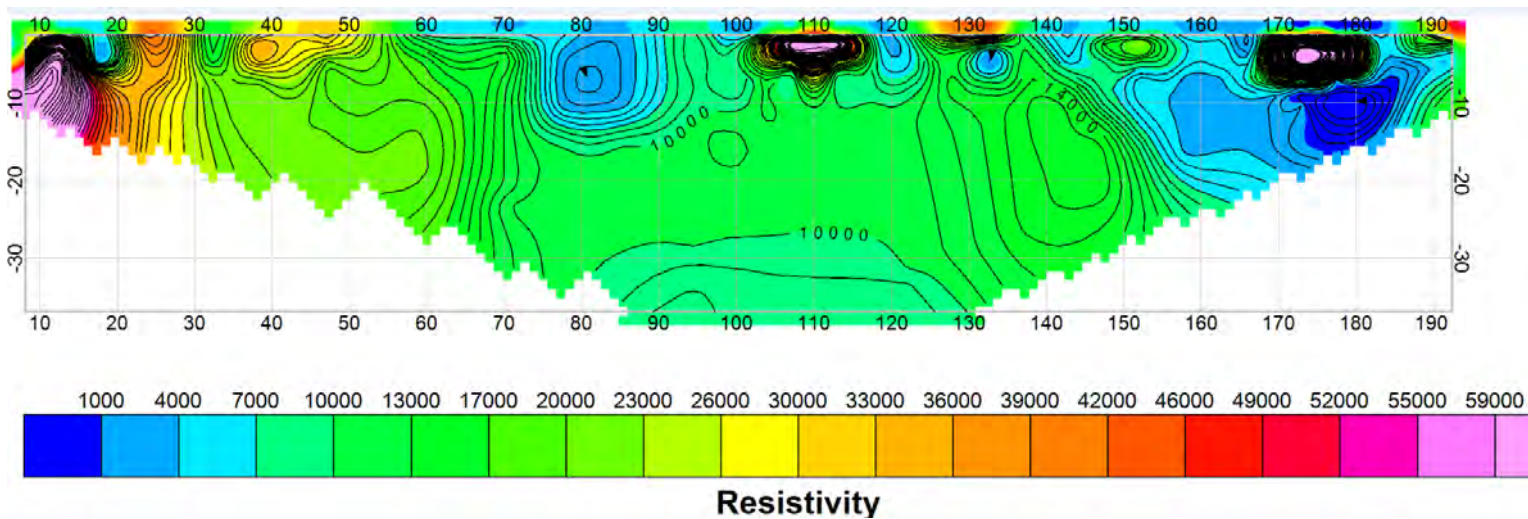


**Figure 6: Line2 (200m) Electrical Resistivity Tomography pseudosection.**

#### 4 Recommendations

Line 1 drilling of the targets at 90m (X = 579069, Y = 7570208) and 210m (X = 579009, Y = 7570103) are recommended to confirm the Resistivity results. Line 2 drilling of the targets at 80m (X = 578972, Y = 7570071) and 160m (X = 579045, Y = 7570039) are recommended to confirm the Resistivity results. A Gravity survey of the area is also recommended to check for possible sinkholes as dolomitic terrains are susceptible to sinkhole formation when acidic water runs through them.



Geophysics LDA

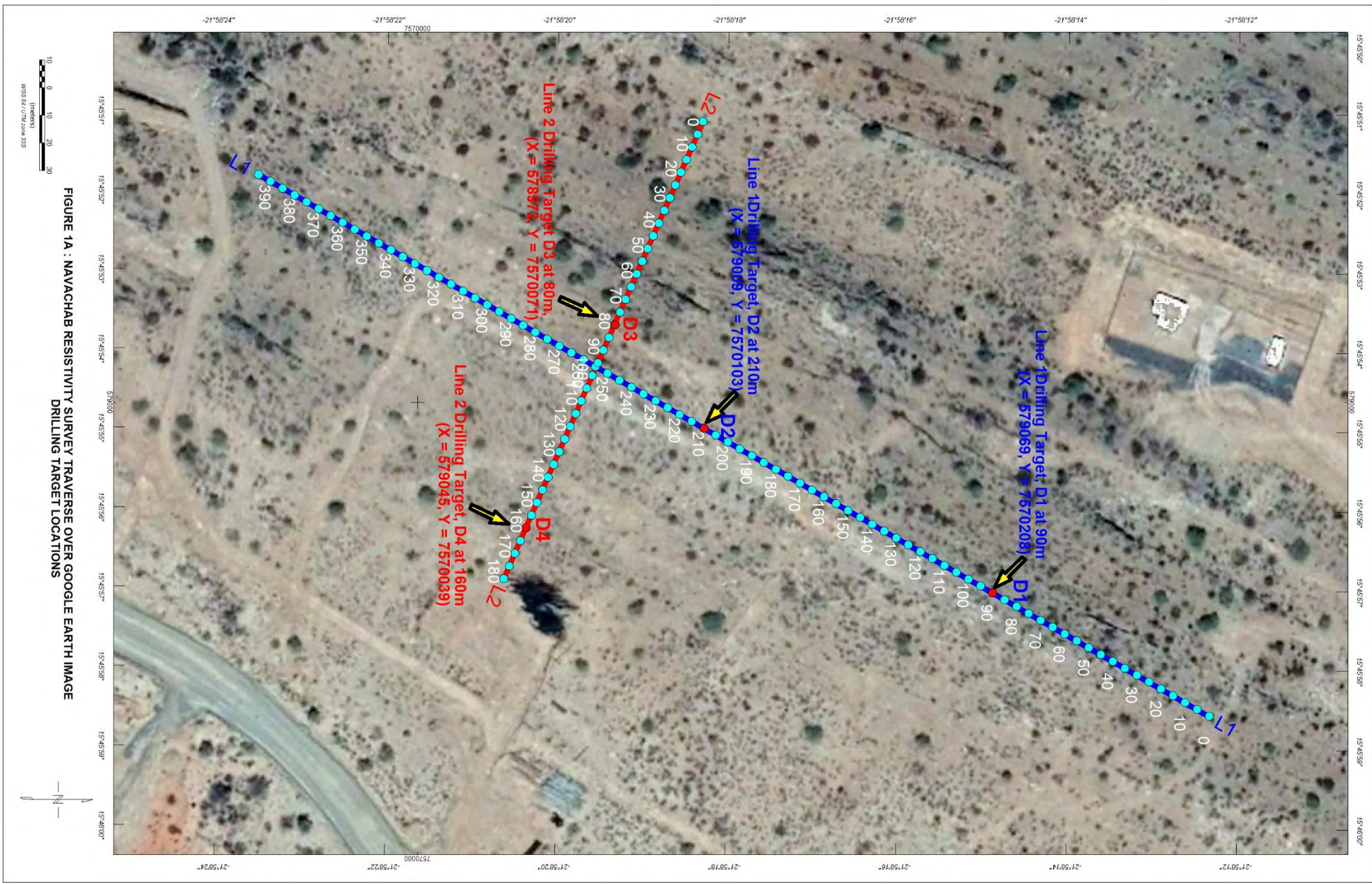


FIGURE 1A : NAVACHAB RESISTIVITY SURVEY TRAVERSE OVER GOOGLE EARTH IMAGE  
DRILLING TARGET LOCATIONS

## **Appendix B: Laboratory Certificates**

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## **Report**

Reference: SRK286

**Date:** 8<sup>th</sup> March 2021

### **Stable isotope analysis on four (4) water samples**

**submitted by Mr Ismail Mahomed**

**SRK**

**Navachab Gold Mine**

— —

M.J. Butler, O.H.T. Malinga, M. Mabitsela

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**confidential**

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## 1. General

Four water samples were submitted by Mr I. Mahomed of SRK for D/H ( $^2\text{H}/^1\text{H}$ ) and  $^{18}\text{O}/^{16}\text{O}$  analysis. The samples were received on the 4<sup>th</sup> of March 2021.

## 2. Stable Isotope Analysis

Water D/H ( $^2\text{H}/^1\text{H}$ ) and  $^{18}\text{O}/^{16}\text{O}$  ratios were analysed in the laboratory of the Environmental Isotope Laboratory (EIL) of iThemba LABS, Johannesburg.

The equipment used for stable isotope analysis consists of a Los Gatos Research (LGR) Liquid Water Isotope Analyser. Laboratory standards, calibrated against international reference materials, are analysed with each batch of samples. The analytical precision is estimated at 0.5‰ for O and 1.5‰ for H.

Analytical results are presented in the common delta-notation:

$$\delta^{18}\text{O}(\text{‰}) = \left[ \frac{(^{18}\text{O}/^{16}\text{O})_{\text{sample}}}{(^{18}\text{O}/^{16}\text{O})_{\text{standard}}} - 1 \right] \times 1000$$

which applies to D/H ( $^2\text{H}/^1\text{H}$ ), accordingly. These delta values are expressed as per mil deviation relative to a known standard, in this case standard mean ocean water (SMOW) for  $\delta^{18}\text{O}$  and  $\delta\text{D}$ .

## 3. Results

The analytical results are presented in Tables 1 and 2 and partially illustrated in Figure 1.

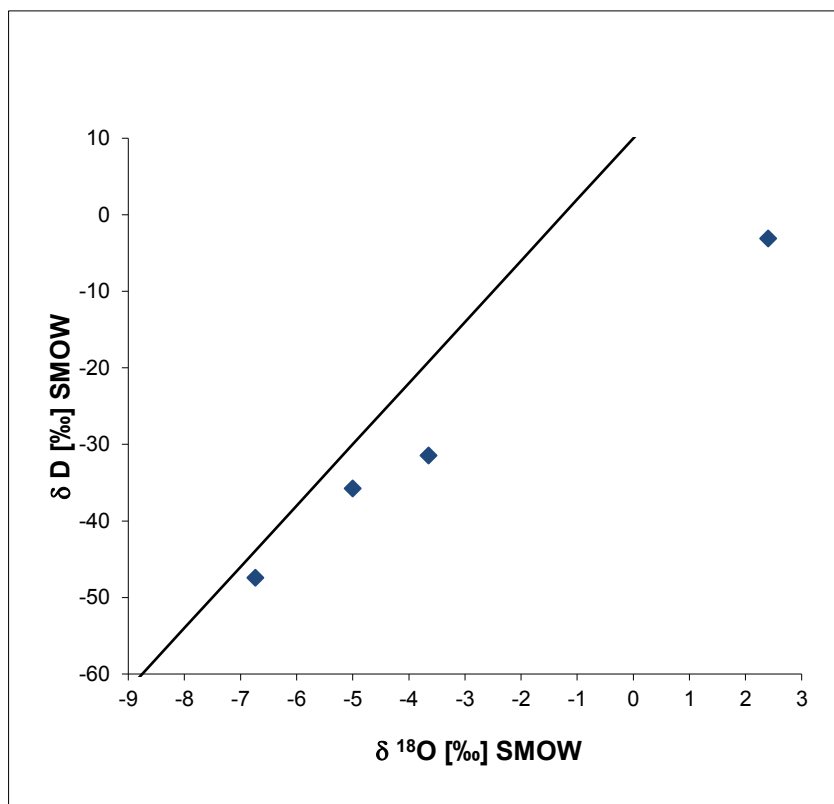


**Figure 1:** Stable isotope data relative to Global Meteoric Water Line (Craig, 1961).

The stable isotope analyses for all samples data reported could be well reproduced within the expected analytical error limits. Figure 1 shows these data in a  $\delta^{18}\text{O}$  vs.  $\delta\text{D}$  space relative to the Global Meteoric Water Line (GMWL, Craig, 1961).

## 4. References

**Craig, H.** (1961). Isotopic variations in meteoric waters. *Science*, **133**, 1702–1703.

**Table 1: Analytical Results**

| Lab No   | Field Name         | Description | Deuterium                  | Oxygen-18                      |
|----------|--------------------|-------------|----------------------------|--------------------------------|
|          |                    |             | $\delta D_{\text{‰ SMOW}}$ | $\delta^{18}O_{\text{‰ SMOW}}$ |
|          |                    |             |                            |                                |
| SRK 2582 | DW 23              | 2021/02/01  | -47.4                      | -6.74                          |
| SRK 2583 | DW 25              | 2021/02/01  | -35.8                      | -5.00                          |
| SRK 2584 | NORTH FACE SEEPAGE | 2021/02/01  | -31.4                      | -3.65                          |
| SRK 2585 | PIT WATER          | 2021/02/01  | -3.1                       | +2.40                          |

**Table 2: Stable isotope aliquot determinations**

| Lab No.  | Field Name:        | Description | Deuterium |            |                            | Oxygen-18 |            |                                |
|----------|--------------------|-------------|-----------|------------|----------------------------|-----------|------------|--------------------------------|
|          |                    |             | analysis  | Batch      | $\delta D_{\text{‰ SMOW}}$ | analysis  | Batch      | $\delta^{18}O_{\text{‰ SMOW}}$ |
| SRK 2582 | DW 23              | 2021/02/01  | a         | 2021/03/05 | -47.8                      | a         | 2021/03/05 | -6.76                          |
|          |                    |             | b         |            | -47.0                      | b         |            | -6.72                          |
|          |                    |             |           |            | <b>avg.: -47.4</b>         |           |            | <b>avg.: -6.74</b>             |
|          |                    |             |           |            | <i>diff.: 0.9</i>          |           |            | <i>diff.: 0.04</i>             |
| SRK 2583 | DW 25              | 2021/02/01  | a         | 2021/03/05 | -35.6                      | a         | 2021/03/05 | -4.96                          |
|          |                    |             | b         |            | -35.9                      | b         |            | -5.04                          |
|          |                    |             |           |            | <b>avg.: -35.8</b>         |           |            | <b>avg.: -5.00</b>             |
|          |                    |             |           |            | <i>diff.: 0.3</i>          |           |            | <i>diff.: 0.08</i>             |
| SRK 2584 | NORTH FACE SEEPAGE | 2021/02/01  | a         | 2021/03/05 | -31.5                      | a         | 2021/03/05 | -3.67                          |
|          |                    |             | b         |            | -31.4                      | b         |            | -3.63                          |
|          |                    |             |           |            | <b>avg.: -31.4</b>         |           |            | <b>avg.: -3.65</b>             |
|          |                    |             |           |            | <i>diff.: 0.1</i>          |           |            | <i>diff.: 0.03</i>             |
| SRK 2585 | PIT WATER          | 2021/02/01  | a         | 2021/03/05 | -3.4                       | a         | 2021/03/05 | 2.35                           |
|          |                    |             | b         |            | -2.8                       | b         |            | 2.45                           |
|          |                    |             |           |            | <b>avg.: -3.1</b>          |           |            | <b>avg.: 2.40</b>              |
|          |                    |             |           |            | <i>diff.: 0.5</i>          |           |            | <i>diff.: 0.10</i>             |

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## CHEMICAL WATER ANALYSIS REPORT

### DETAILS OF SAMPLE:

SAMPLE NUMBER : DS58577  
SENDER : Navachab Gold Mine  
SAMPLE POINT NAME : Navachab Gold Mine  
AREA DESCRIPTION : -  
LOCATION DESCRIPTION : Pit Water -  
COMMENTS : -  
  
DATE SAMPLE TAKEN : 01-02-21  
TIME TAKEN : -  
DATE SAMPLE RECEIVED : 03-03-21  
DATE SAMPLE ANALYSED : 05-03-21

| DETERMINANT :                                       | Value | Units | Classification |
|-----------------------------------------------------|-------|-------|----------------|
| pH                                                  | 7.9   |       | A - Excellent  |
| Conductivity mS/m                                   | 569.0 | mS/m  | D - High risk  |
| Total dissolved solids calculated from conductivity | 3812  | mg/l  |                |
| Sodium as Na                                        | 510   | mg/l  | C - Low risk   |
| Potassium as K                                      | 22    | mg/l  | A - Excellent  |
| Sulphate as SO <sub>4</sub>                         | 1430  | mg/l  | D - High risk  |
| Nitrate as N                                        | 40.1  | mg/l  | D - High risk  |
| Nitrite as N                                        | <0.1  | mg/l  |                |
| Fluoride as F                                       | 1.4   | mg/l  | A - Excellent  |
| Chloride as Cl                                      | 1069  | mg/l  | C - Low risk   |
| Total Alkalinity as CaCO <sub>3</sub>               | 104   | mg/l  |                |
| Total Hardness as CaCO <sub>3</sub>                 | 1858  | mg/l  | D - High risk  |
| Calcium as CaCO <sub>3</sub>                        | 1025  | mg/l  | D - High risk  |
| Magnesium as CaCO <sub>3</sub>                      | 833   | mg/l  | C - Low risk   |
| Iron as Fe                                          | 0.01  | mg/l  | A - Excellent  |
| Manganese as Mn                                     | <0.01 | mg/l  | A - Excellent  |
| Zinc as Zn                                          | <0.01 | mg/l  | A - Excellent  |
| Nickel as Ni                                        | <0.01 | mg/l  |                |

### REMARKS :

#### CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER IN RESPECT OF DETERMINANTS AS ABOVE :

**Class D : Unsuitable for human consumption**

**Stockwatering : Suitable**

**CONDUCTIVITY:** Conductivity is a function of the total dissolved solids in the water. A conductivity of 300 mS/m corresponds to approximately 2000 mg/l total dissolved solids.

**SODIUM:** Guideline values for sodium are based on taste considerations. High sodium levels can give high blood pressure.

**SULPHATE:** Guideline values for sulphate are based on taste considerations. Water containing high concentrations of sulphate can have a laxative effect which is enhanced when consumed in combination with magnesium. Metal corrosion and degradation of concrete and asbestos cement may be increased by high sulphate levels.

**NITRATE:** Water with more than 20 mg/l nitrate/nitrite as N, can cause methaemoglobinaemia in babies under 1 year old.

**CHLORIDE:** Guideline values for chloride are based on taste considerations. High concentrations give rise to corrosion of metals.

**TOTAL HARDNESS:** Guideline values for total hardness are based on taste and household considerations. Depending on the calcium and magnesium salt combination, high levels can cause scaling. In addition, hard water results in excessive soap consumption and subsequent scum formation.

**CALCIUM:** Guideline values for calcium are based on taste and household consideration. High calcium concentrations cause scaling problems and excessive soap consumption.

**MAGNESIUM:** Magnesium concentrations greater than 420 mg/l give rise to an unpleasant taste. Magnesium, in association with sulphate, may have laxative properties, but the human body can adapt to this effect in time.

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DS58577

**ADDITIONAL INFORMATION : DS58577**

**Stability pH : 6.93**

**Langelier Index : 0.97 - Scaling**

**Ryznar Index : 5.96 - Scaling**

**CORROSITIVITY POTENTIAL OF WATER TOWARDS STEEL : 28.69 - Corrosive**

**IRRIGATION CLASIFICATION : C4 - S3**

**VERY HIGH SALINITY WATER (C4)**

Is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected.

**SODIUM**

The classification of irrigation waters with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of Sodium-sensitives plants may, however, suffer injury as a result of sodium accumulation in plant tissues when exchangeable sodium values are lower than those effective in causing deterioration of the physical condition of the soil.

**HIGH-SODIUM WATER (S3)**

May produce harmful levels of exchangeable sodium in most soils and will require special soil management - good drainage, high leaching, and organic matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendements may be required for replacement of exchangeable sodium, except that amendements may not be feasible with waters of very high salinity.

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**CHEMICAL WATER ANALYSIS REPORT**

**DETAILS OF SAMPLE:**

SAMPLE NUMBER : DS58578  
SENDER : Navachab Gold Mine  
SAMPLE POINT NAME : Navachab Gold Mine  
AREA DESCRIPTION : -  
LOCATION DESCRIPTION : DW23 -  
COMMENTS : -

DATE SAMPLE TAKEN : 01-02-21  
TIME TAKEN : -  
DATE SAMPLE RECEIVED : 03-03-21  
DATE SAMPLE ANALYSED : 05-03-21

| DETERMINANT :                                       | Value | Units | Classification |
|-----------------------------------------------------|-------|-------|----------------|
| pH                                                  | 7.9   |       | A - Excellent  |
| Conductivity mS/m                                   | 221.0 | mS/m  | B - Good       |
| Total dissolved solids calculated from conductivity | 1481  | mg/l  |                |
| Sodium as Na                                        | 230   | mg/l  | B - Good       |
| Potassium as K                                      | 9     | mg/l  | A - Excellent  |
| Sulphate as SO <sub>4</sub>                         | 360   | mg/l  | B - Good       |
| Nitrate as N                                        | 2.0   | mg/l  | A - Excellent  |
| Nitrite as N                                        | <0.1  | mg/l  |                |
| Fluoride as F                                       | 2.1   | mg/l  | C - Low risk   |
| Chloride as Cl                                      | 399   | mg/l  | B - Good       |
| Total Alkalinity as CaCO <sub>3</sub>               | 136   | mg/l  |                |
| Total Hardness as CaCO <sub>3</sub>                 | 480   | mg/l  | B - Good       |
| Calcium as CaCO <sub>3</sub>                        | 318   | mg/l  | A - Excellent  |
| Magnesium as CaCO <sub>3</sub>                      | 163   | mg/l  | A - Excellent  |
| Iron as Fe                                          | 0.04  | mg/l  | A - Excellent  |
| Manganese as Mn                                     | 0.07  | mg/l  | B - Good       |
| Zinc as Zn                                          | <0.01 | mg/l  | A - Excellent  |
| Nickel as Ni                                        | <0.01 | mg/l  |                |

**REMARKS :**

**CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER IN RESPECT OF DETERMINANTS AS ABOVE :**

**Class C : Low risk water**

**Stockwatering : Suitable**

**FLUORIDE:** Protracted intake of water with fluoride concentrations greater than 2.0 mg/l causes mottling of teeth and from 3-6 mg/l skeletal fluorosis can occur.

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**ADDITIONAL INFORMATION : DS58578**

**Stability pH : 7.28**

**Langelier Index : 0.62 - Scaling**

**Ryznar Index : 6.66 - Stable**

**CORROSITIVITY POTENTIAL OF WATER TOWARDS STEEL : 6.86 - Corrosive**

**IRRIGATION CLASIFICATION : C3 - S3**

**HIGH-SALINITY WATER (C3)**

Cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

**SODIUM**

The classification of irrigation waters with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of Sodium-sensitives plants may, however, suffer injury as a result of sodium accumulation in plant tissues when exchangeable sodium values are lower than those effective in causing deterioration of the physical condition of the soil.

**HIGH-SODIUM WATER (S3)**

May produce harmful levels of exchangeable sodium in most soils and will require special soil management - good drainage, high leaching, and organic matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendements may be required for replacement of exchangeable sodium, except that amendements may not be feasible with waters of very high salinity.

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**CHEMICAL WATER ANALYSIS REPORT**

**DETAILS OF SAMPLE:**

SAMPLE NUMBER : DS58579  
SENDER : Navachab Gold Mine  
SAMPLE POINT NAME : Navachab Gold Mine  
AREA DESCRIPTION : -  
LOCATION DESCRIPTION : DW25 -  
COMMENTS : -  
  
DATE SAMPLE TAKEN : 01-02-21  
TIME TAKEN : -  
DATE SAMPLE RECEIVED : 03-03-21  
DATE SAMPLE ANALYSED : 05-03-21

| DETERMINANT :                                       | Value | Units | Classification |
|-----------------------------------------------------|-------|-------|----------------|
| pH                                                  | 7.7   |       | A - Excellent  |
| Conductivity mS/m                                   | 182.4 | mS/m  | B - Good       |
| Total dissolved solids calculated from conductivity | 1222  | mg/l  |                |
| Sodium as Na                                        | 74    | mg/l  | A - Excellent  |
| Potassium as K                                      | 7     | mg/l  | A - Excellent  |
| Sulphate as SO <sub>4</sub>                         | 335   | mg/l  | B - Good       |
| Nitrate as N                                        | 62.7  | mg/l  | D - High risk  |
| Nitrite as N                                        | <0.1  | mg/l  |                |
| Fluoride as F                                       | 1.5   | mg/l  | A - Excellent  |
| Chloride as Cl                                      | 115   | mg/l  | A - Excellent  |
| Total Alkalinity as CaCO <sub>3</sub>               | 238   | mg/l  |                |
| Total Hardness as CaCO <sub>3</sub>                 | 750   | mg/l  | C - Low risk   |
| Calcium as CaCO <sub>3</sub>                        | 613   | mg/l  | C - Low risk   |
| Magnesium as CaCO <sub>3</sub>                      | 138   | mg/l  | A - Excellent  |
| Iron as Fe                                          | 0.02  | mg/l  | A - Excellent  |
| Manganese as Mn                                     | 0.08  | mg/l  | B - Good       |
| Zinc as Zn                                          | <0.01 | mg/l  | A - Excellent  |
| Nickel as Ni                                        | <0.01 | mg/l  |                |

**REMARKS :**

**CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER IN RESPECT OF DETERMINANTS AS ABOVE :**

**Class D : Unsuitable for human consumption**

**Stockwatering : Suitable**

**NITRATE:** Water with more than 20 mg/l nitrate/nitrite as N, can cause methaemoglobinaemia in babies under 1 year old.

**TOTAL HARDNESS:** Guideline values for total hardness are based on taste and household considerations. Depending on the calcium and magnesium salt combination, high levels can cause scaling. In addition, hard water results in excessive soap consumption and subsequent scum formation.

**CALCIUM:** Guideline values for calcium are based on taste and household consideration. High calcium concentrations cause scaling problems and excessive soap consumption.

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**ADDITIONAL INFORMATION : DS58579**

**Stability pH : 6.74**

**Langelier Index : 0.96 - Scaling**

**Ryznar Index : 5.79 - Scaling**

**CORROSITIVITY POTENTIAL OF WATER TOWARDS STEEL : 2.14 - Corrosive**

**IRRIGATION CLASIFICATION : C3 - S1**

**HIGH-SALINITY WATER (C3)**

Cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

**SODIUM**

The classification of irrigation waters with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of Sodium-sensitives plants may, however, suffer injury as a result of sodium accumulation in plant tissues when exchangeable sodium values are lower than those effective in causing deterioration of the physical condition of the soil.

**LOW-SODIUM WATER (S1)**

Can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stone-fruit trees and advocados may accumulate injurious concentrations of sodium.

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**CHEMICAL WATER ANALYSIS REPORT**

**DETAILS OF SAMPLE:**

SAMPLE NUMBER : DS58580  
SENDER : Navachab Gold Mine  
SAMPLE POINT NAME : Navachab Gold Mine  
AREA DESCRIPTION : -  
LOCATION DESCRIPTION : North Face Seepage -  
COMMENTS : -  
  
DATE SAMPLE TAKEN : 01-02-21  
TIME TAKEN : -  
DATE SAMPLE RECEIVED : 03-03-21  
DATE SAMPLE ANALYSED : 05-03-21

| DETERMINANT :                                       | Value | Units | Classification |
|-----------------------------------------------------|-------|-------|----------------|
| pH                                                  | 8.3   |       | A - Excellent  |
| Conductivity mS/m                                   | 314.0 | mS/m  | C - Low risk   |
| Total dissolved solids calculated from conductivity | 2104  | mg/l  |                |
| Sodium as Na                                        | 230   | mg/l  | B - Good       |
| Potassium as K                                      | 14    | mg/l  | A - Excellent  |
| Sulphate as SO <sub>4</sub>                         | 350   | mg/l  | B - Good       |
| Nitrate as N                                        | 17.6  | mg/l  | B - Good       |
| Nitrite as N                                        | <0.1  | mg/l  |                |
| Fluoride as F                                       | 0.6   | mg/l  | A - Excellent  |
| Chloride as Cl                                      | 687   | mg/l  | C - Low risk   |
| Total Alkalinity as CaCO <sub>3</sub>               | 148   | mg/l  |                |
| Total Hardness as CaCO <sub>3</sub>                 | 1010  | mg/l  | C - Low risk   |
| Calcium as CaCO <sub>3</sub>                        | 323   | mg/l  | A - Excellent  |
| Magnesium as CaCO <sub>3</sub>                      | 688   | mg/l  | C - Low risk   |
| Iron as Fe                                          | <0.01 | mg/l  | A - Excellent  |
| Manganese as Mn                                     | 0.01  | mg/l  | A - Excellent  |
| Zinc as Zn                                          | <0.01 | mg/l  | A - Excellent  |
| Nickel as Ni                                        | <0.01 | mg/l  |                |

**REMARKS :**

**CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER IN RESPECT OF DETERMINANTS AS ABOVE :**

**Class C : Low risk water**

**Stockwatering : Suitable**

**CONDUCTIVITY:** Conductivity is a function of the total dissolved solids in the water. A conductivity of 300 mS/m corresponds to approximately 2000 mg/l total dissolved solids.

**CHLORIDE:** Guideline values for chloride are based on taste considerations. High concentrations give rise to corrosion of metals.

**TOTAL HARDNESS:** Guideline values for total hardness are based on taste and household considerations. Depending on the calcium and magnesium salt combination, high levels can cause scaling. In addition, hard water results in excessive soap consumption and subsequent scum formation.

**MAGNESIUM:** Magnesium concentrations greater than 420 mg/l give rise to an unpleasant taste. Magnesium, in association with sulphate, may have laxative properties, but the human body can adapt to this effect in time.

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**ADDITIONAL INFORMATION : DS58580**

**Stability pH : 7.25**

**Langelier Index : 1.05 - Scaling**

**Ryznar Index : 6.21 - Scaling**

**CORROSITIVITY POTENTIAL OF WATER TOWARDS STEEL : 8.96 - Corrosive**

**IRRIGATION CLASIFICATION : C4 - S2**

**VERY HIGH SALINITY WATER (C4)**

Is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected.

**SODIUM**

The classification of irrigation waters with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of Sodium-sensitives plants may, however, suffer injury as a result of sodium accumulation in plant tissues when exchangeable sodium values are lower than those effective in causing deterioration of the physical condition of the soil.

**MEDIUM-SODIUM WATER (S2)**

Will present an appreciable sodium hazard in fine-textured soils having high cation-exchange capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils with good permeability.

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