APPENDIX D3:

HYDROPEDOLOGY IMPACT ASSESSMENT
HYDROPEDOLOGICAL SURVEY OF THE UMSIMBITHI EMHAKHAZENI MINING PROJECT SITES NEAR, BELFAST, MPUMALANGA

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LIST OF ACRONYMS

DEM - Digital Elevation Model
DSA - Digital Soils Africa
EIA - Environmental Impact Assessment
gh - G horizon
gs - E horizon
HP - Soil observations made during hydropedological survey
HRU - Hydrological Response Unit
OC - Open pit mine
R - Rock layer/horizon
sp - soft plinthic horizon
TBC - The Biodiversity Company
UG - Underground mine
1. **Background to the study**

The Biodiversity Company (Pty) Ltd (TBC), requested Digital Soils Africa (Pty) Ltd (DSA) to assist with a hydropedological survey for six potential mining sites near Belfast in the Mpumalanga Province (Figure 1) for the Umsimbithi eMakhzeni Mining Project (the Project). The hydropedological survey forms part of the studies being conducted by TBC for the Project. As detailed site descriptions of geology, land-use and agricultural potential are being done by TBC, it was therefore not deemed necessary to include them in this report.

![Figure 1: Layout of the six potential mining sites; OC – open pit and UG – underground.](image)

Since hydropedology is a relatively new field, it was however considered important to include background information on this interdisciplinary research field. The following section is an extract from a document by Van Tol, Le Roux and Lorentz which appeared in the May/June 2017 issue of *Water Wheel*.

2. **Hydropedology and the value of hydropedological surveys**

2.1 **Hydropedology: linking soil morphology with hydrological processes**

Hydropedology is the relatively new, interdisciplinary research field which focuses on the interactive relationship between soils and water (Figure 2). Soil physical properties, such as the hydraulic conductivity and porosity, have an important impact on the occurrence and rates of hydrological processes. In turn, hydrological processes play an important role on the formation of soil morphological properties such as colour, mottles, macropores and carbonate accumulations. Accurate mapping and the interpretation of these soil morphological properties can thus be used to conceptualise and characterise hydrological processes including water flowpaths, storage...
mechanisms and the connectivity between different flowpaths. Most of these hydrological mechanisms and processes are very difficult to observe (let alone measure!) in the field because they are dynamic in nature with strong temporal and spatial variation. Nevertheless, soil morphological properties are not dynamic in nature and their spatial variation is not random – making soil properties the ideal vehicle for predicting and conceptualising hydrological processes. One of the major contributions of hydropedology is the ability to conceptualise hydrological processes spatially i.e. not only 1-D mechanisms, but a more holistic understanding of the hydrological functioning of landscapes (catchments or hillslopes).

Hydropedological information is used in process based landscape water resource management. This includes, for example:

- configuration and parameterisation of distributed hydrological models;
- effective wetland delineation, protection and rehabilitation;
- understanding and controlling the fate of pollution in the subsurface;
- determining the impact of land use change (e.g. open pit mining) on water resources and
- characterising groundwater/surface-water interactions, including the important mechanism of low-flow generation.

In general, hydropedological information assists with effective water resource management, as required by the National Water Act (1998), through improved understanding and characterisation of hydrological processes.

Figure 2: Hydropedology and some of the applications of hydropedological surveys.
2.2 **Hydropedology of Soil Types**

The hydropedological behaviour of different soils can differ significantly. For example in Figure 3a, the red colours of the top and subsoils of are typically associated with freely drained soils. Vertical flow into, through and out of the profile are the dominant hydrological pathway. These soils are termed **recharge soils**, as they are likely to recharge groundwater, or lower lying positions in the regolith, via the bedrock.

In the second example (Figure 3b), lateral flow is likely to be dominant. These soils are termed **interflow soils**. Lateral flow occurs due to differences in the conductivity of horizons. In Figure 3b the ‘sp’ is restricting downward movement and lateral flow occurs at the A/B horizon interface. The lighter colour of the ‘gs’ horizon is further support that lateral flow dominates. Lateral flow frequently occurs on soil/bedrock interfaces due to the permeability of the rock. Mottles (red, yellow and grey colours) in the ‘sp’ horizon (magnified in Figure 3b-i) are the result of a fluctuating water table.

In Figure 3c the grey colours of the ‘gh’ horizon and the dark colours of the topsoil horizon are indications that this profile is saturated for long periods of time. Because these soils are close to saturation, especially during peak rainy seasons, additional rainfall is unlikely to infiltrate the soils but will flow as overland flow (or surface runoff) downslope. These soils are termed **responsive soils** due to their rapid response to rain events. The same type of response can be expected on very shallow soils i.e. a small amount of rain can saturate the soil and additional rain will drain away as overland flow.

![Figure 3: Different hydropedological soil types](image)

Figure 3: Different hydropedological soil types a) recharge soil, b) interflow soil and c) responsive soil.
2.3 HYDROPEDOLOGY OF HILLSLOPES

For effective water resource management it is important to gain a holistic understanding of hydrological processes. Figure 4 presents a typical example of the hydropedological response of a hillslope. In the recharge zone, the dominant flow direction is vertical through the soil and into the fractured rock, from where it can recharge groundwater levels or downslope positions in the hillslope soils. Lateral flow at the A/B horizon interface or soil/bedrock interface dominates in the interflow zone. The responsive zone is fed by lateral flowing water from the interflow zone as well as via the bedrock from the recharge zone.

![Figure 4: Typical example of hydrological flowpaths on different hydropedological soil types-hillslope hydropedological behaviour.](image)

Although Figure 4 represents an oversimplification of a fraction of the complex hydrological cycle, the application of this information can make important contributions to effective management. Four scenarios are presented to support this statement.

1. **Pollution**: The fate of pollution will differ depending whether it was spilled on recharge, interflow or responsive soils. A spill on recharge soils is likely to end up in the groundwater or might arrive in the stream several months after the spill via flow through the fractured rock. Pollutants spilled on interflow zones will migrate downslope through the soil. Because this downslope migration will be in contact with the soil, and hence abundance of microorganisms. It is possible that it may be transformed into non-toxic forms (depending on the pollutant). If a pollutant is spilled on the responsive zone it may travel quickly and unaltered to streams and other surface water bodies.

2. **Conserving wetlands**: Hydropedological information can aid in identifying the sources of water to preserve wetlands. If the recharge zone is the major source of water to the wetland i.e. the recharge zone is the hydrological driver of the wetland, care should be taken to restrict surface sealing (paving) of the recharge zone. If the wetland’s water comes from an interflow zone, care should be taken to prevent obstruction of subsurface lateral flowpaths.
3. **Hydrological modelling:** Hydropedological information can assist in the correct configuration of distributed hydrological models. In many landscapes different landscape elements (or Hydrological Response Units – HRU’s) are not connected in a simple cascading downslope way to one another. There might be areas which are disconnected from the stream or groundwater stores. In addition, deep infiltration from recharge soils at the crest of a hillslope, may re-appear as lateral flow water further down the slope. Hydropedological information can thus be used to ensure that the model configuration properly reflects the hydrological processes. This can be critical in simulating low flows, where vegetation may have access to near-surface water and thus limit contributions to streamflow.

4. **Land-use change:** Hydropedological information can support the understanding of the impact of land-use change on water resources. If, for example, the interflow zone is urbanised it may result in a build-up of water against foundations and the generation of return flow to the surface and overland flow which may cause erosion. Open pit mining close to responsive zones is likely to result in a draw-down of water levels and drying of wetlands. If such an open-pit intersects lateral flowpaths it will break the connectivity of flowpaths and cut the source of water to wetlands. Although the impact of land-use change cannot always be avoided, hydropedological information might aid in managing and protecting the hydrologic drivers of the ecosystem and thereby minimise negative impacts.

2.4 **HYDROPEDOLOGICAL SURVEYS**

A hydropedological survey (in the context discussed above) is different from a conventional soil survey in the following aspects:

- **Observation depth:** the depth of observation in a conventional survey is 1.5 m, whereas the observation depth for the hydropedological survey is the depth to the soil bedrock interface.
- **Classification:** conventional soil surveys aim to classify soils in accordance with a specific classification system. In hydropedological surveys all morphological properties and all soil horizons are described, recorded and interpreted, with particular emphasis on the ambient and connected soil water environment. This includes saprolitic (weathering rock) horizons and horizons which are not necessarily included in the hierarchy of the classification system.
- **Observation density:** Conventional soil surveys aim to capture the distribution of different soils in a particular landscape. Hydropedological surveys focus on the hydrological response of dominant hillslopes/transects.

Important to note is that hydropedological surveys cannot be used as a surrogate for mapping the agricultural potential (as required during most EIA’s) of an area. Conventional soil surveys (or other existing soil information) can also not always be used to infer the hydropedological response of an area, due to the differences between conventional and hydropedological surveys highlighted above.

Hydropedological surveys do not replace detailed soil physical or hydrometric measurements but rather serves as a vehicle to identify representative sites for such measurements and to extrapolate these measurements to larger areas. Hydropedological surveys are also not a surrogate for hydrological modelling, but can contribute to the efficiency and accuracy of modelling exercises. Hydropedological surveys and the interpretation and application of hydropedological information can be a cost -and time effective approach to conceptualise and characterise hydrological behaviour of landscapes.
3. METHODOLOGY AND FIELD VISITS

3.1 DESKTOP SURVEY

As a first methodological step, land type information was obtained for the various sites (Land Type Survey Staff, 1972 – 2002) (Figure 5). A land type is an area with similar climate, geology and soil distribution patterns and therefore gives a good catenal (hillslope) spatial representation of soils in these homogenous areas.

![Figure 5: Land types of the various potential mining sites.](image)

Secondly for an improved data set on the distribution of soils, a desktop study was conducted to identify dominant, representative hillslopes for the various sites. The identification of representative hillslopes is important to determine the location of field observations. Representative hillslopes were identified was done through generation of streams and water sheds, using flow accumulation data. The latter was determined from a Digital Elevation Model (DEM) which was derived from 5 m contours of the study site in ArcGIS 10. Representative
hillslopes were then manually identified in ArcGis (Figure 6). These hillslopes represent typical topography (slope, planform - and profile curvature) of the various land types covering the different sites. For a complete data set of hillslopes the data may stretch beyond the site boundaries to the stream or crest.

3.2 FIELD PROCEDURE

The sites were visited between the 12th and 15th of November 2017. Since open pit mining is likely to have a much bigger influence on hydropedological behaviour of landscapes as opposed to underground mining, focus was placed on the open pit sites i.e. BE, BF and BA (Figure 1).
The representative slopes identified during the desktop phase were used to guide the location of the transect surveys. The locations of the transects were however altered in the field depending on factors such as accessibility and uniformity or heterogeneity of the landscape.

A total of 74 soil auger observations were made during the hydropedological survey. The observation depth was up to refusal and all features related to the hydromorphology were recorded (see section 2.4). The soils were first classified in accordance with the South African soil classification (Soil Classification Working Group, 1991) and were then regrouped into hydropedological soil types in accordance with van Tol et al. (2013) (Table 1).

Table 1: Regrouping of soil forms into hydropedological soil types

<table>
<thead>
<tr>
<th>Soil forms (Soil Classification Working Group, 1991)</th>
<th>Hydropedological soil type (van Tol et al., 2013)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kroonstad; Longlands; Wasbank</td>
<td>Interflow (A/B)</td>
</tr>
<tr>
<td>Avalon; Bainsvlei; Glencoe; Pinedene; Sepane; Tukulu</td>
<td>Interflow (soil/bedrock)</td>
</tr>
<tr>
<td>Clovelly; Hutton; Oakleaf; Swartland</td>
<td>Recharge (deep)</td>
</tr>
<tr>
<td>Glenrosa; Mispah*; R*</td>
<td>Recharge (shallow)</td>
</tr>
<tr>
<td>Dresden; Mispah*; R*</td>
<td>Responsive (shallow)</td>
</tr>
<tr>
<td>Champagne; Katspruit; Westleigh</td>
<td>Responsive (wet)</td>
</tr>
</tbody>
</table>

* Mispah soils in can occur in both recharge (shallow) and responsive (shallow) hydropedological soil types depending on the nature of the underlying rock (these differences are again highlighted in the conceptual representation).
The hydropedological survey was supplemented by soil observations made for agricultural potential determinations (458 observations). These observations were made using conventional survey techniques and the resulting descriptions had to be interpreted with care. Due to the depth criteria (1.5 m), hydromorphic properties at the soil/bedrock interface are often not observed. Clovelly and Hutton soils, which are considered to be ‘recharge’ soils, can therefore have plinthic or gleyic horizons at the soil/bedrock interface and are therefore ‘interflow’ soils. A distinction is made in the data derived from the two surveys.

The hydropedological soil type distribution pattern and the relative coverage of various soil types on representative hillslopes were used to conceptualise the hydrological response of the different sites. Conceptual models depicting the dominant flowpaths were constructed and were the basis for discussing the potential impact of the planned mining on the hydropedological response.

Each of the sites are discussed separately, and since some of the sites are hydropedologically similar there might be repetition in the following sections.

### 3.3  Rating Significance of the Impacts

The impact significance rating system is presented in Error! Reference source not found. and involves three parts:

- **Part A**: Define impact consequence using the three primary impact characteristics of magnitude, spatial scale/population and duration;
- **Part B**: Use the matrix to determine a rating for impact consequence based on the definitions identified in Part A; and
- **Part C**: Use the matrix to determine the impact significance rating, which is a function of the impact consequence rating (from Part B) and the probability of occurrence.

#### Table 2: Significance Rating Methodology

<table>
<thead>
<tr>
<th>Impact characteristics</th>
<th>Definition</th>
<th>Criteria</th>
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</thead>
<tbody>
<tr>
<td><strong>MAGNITUDE</strong></td>
<td><strong>Major -</strong></td>
<td>Substantial deterioration or harm to receptors; receiving environment has an inherent value to stakeholders; receptors of impact are of conservation importance; or identified threshold often exceeded</td>
</tr>
<tr>
<td></td>
<td><strong>Moderate -</strong></td>
<td>Moderate/measurable deterioration or harm to receptors; receiving environment moderately sensitive; or identified threshold occasionally exceeded</td>
</tr>
</tbody>
</table>

Hydropedological Assessment – Umsimbithi eMhakhazeni Mining Project
### Hydropedological Assessment – Umsimbithi eMhakhazeni Mining Project

#### Minor -
- Minor deterioration (nuisance or minor deterioration) or harm to receptors; change to receiving environment not measurable; or identified threshold never exceeded

#### Minor +
- Minor improvement; change not measurable; or threshold never exceeded

#### Moderate +
- Moderate improvement; within or better than the threshold; or no observed reaction

#### Major +
- Substantial improvement; within or better than the threshold; or favourable publicity

### SPATIAL SCALE OR POPULATION

<table>
<thead>
<tr>
<th></th>
<th>Site or local</th>
<th>Regional</th>
<th>National/International</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Specific</td>
<td>Site specific or confined to the immediate project area</td>
<td>May be defined in various ways, e.g. cadastral, catchment, topographic</td>
<td>Nationally or beyond</td>
</tr>
</tbody>
</table>

### DURATION

<table>
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<th></th>
<th>Short term</th>
<th>Medium term</th>
<th>Long term</th>
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<tbody>
<tr>
<td>Up to 18 months</td>
<td>18 months to 5 years</td>
<td>Longer than 5 years</td>
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</table>

### PART B: DETERMINING CONSEQUENCE RATING

*Rate consequence based on definition of magnitude, spatial extent and duration*

<table>
<thead>
<tr>
<th>MAGNITUDE</th>
<th>SPATIAL SCALE/ POPULATION</th>
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<tr>
<td>Minor</td>
<td>Site or Local</td>
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<td></td>
<td>Long term</td>
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<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Short</td>
<td>Low</td>
</tr>
<tr>
<td>Moderate</td>
<td>Long term</td>
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</table>

Hydropedological Assessment – Umsimbithi eMhakhazeni Mining Project
<table>
<thead>
<tr>
<th>Major</th>
<th>DURATION</th>
<th>Medium term</th>
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<th>High</th>
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</thead>
<tbody>
<tr>
<td>Short term</td>
<td></td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
</tr>
</tbody>
</table>

**PART C: DETERMINING SIGNIFICANCE RATING**

*Rate significance based on consequence and probability*

<table>
<thead>
<tr>
<th>PROBABILITY (of exposure to impacts)</th>
<th>CONSEQUENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Definite</td>
<td>Medium</td>
</tr>
<tr>
<td>Possible</td>
<td>Low</td>
</tr>
<tr>
<td>Unlikely</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
</tr>
</tbody>
</table>
4. HYDROPEDOLOGY OF SITE BE

4.1 HYDROPEDOLOGICAL SOIL TYPES

Site BE is earmarked for open pit mining and falls almost entirely within land type Ba20 (Figure 7). The geology is mainly sandstone and siltstone from the Ecca Group. Although the land type inventory indicates that recharge soils dominate on crest and mid-slope positions, the results from the hydropedological survey shows that interflow (soil/bedrock) and interflow (A/B) soils are dominant on these terrain positions (Figure 8 & Figure 9). Responsive (wet) soils occur in the valley bottom as well as on concave positions in upper slope positions. Responsive (shallow) soils are typically found on convex positions of higher lying areas.

![Figure 7: Land types, hydropedological observations (HP) and conventional soil observations for site BE.](image-url)
Figure 8: Location of hydropedological soil types on site BE.

Figure 9: Plinthic horizons dominating in site BE. These plinthic horizons occurred under yellow-brown apedal B horizons (Avalon – as in the example above); red apedal B horizons (Bainsvlei) or E horizons (Longlands).
4.2 Hillslope Hydrology of Site BE

The hydropedological behaviour of the dominant hillslopes is presented in a conceptual hydrological response model (Figure 10). The hydrological processes are discussed in relation to the numbered arrows (Figure 10):

1) The crest positions are dominated by plinthic soils, evidence of periodic saturation at the soil/bedrock interface – Interflow (soil/bedrock). The horizons are indicative that the underlying bedrock is slowly permeable and periodic saturation in the rainy season is likely, which may lead to lateral flow at the soil bedrock interface. The drainage may be restricted by a shallow impermeable rock layer.

2) In the concave positions of the upper slopes, accumulation of lateral flowing water (overland flow and sub-surface flow) cause long periods of saturation and leads to gleying – Responsive (wet). These soils are saturated or close to saturation during the rainy season and often until the next rainy season. Precipitation are unlikely to infiltrate but will flow overland due to saturation excess. Since the slope curvature is concave, slow flow limits overland flow and these soils will contribute dominantly to both evaporation from a wet soil surface and transpiration. It is a local accumulation of water from flowpaths 1 and 3 from the crest and ridges.

3) Shallow soils are dominant on convex positions of the upper slopes – Responsive (shallow). The combination of relatively impermeable bedrock and shallow soil depth implies that these soils have a low storage capacity. They will saturate quickly following a rain event and contribute mostly to overland flow.

4) The upper midslope positions are dominated by interflow (soil/bedrock) soils, mostly from the Avalon and Bainsvlei form. Lateral flow at the soil/bedrock interface is the dominant hydropedological process in these soils. Wetness and flow may be enhanced from upslope in the subsoil and return flow from the fractured rock system.

5) On the lower midslope positions, besides rain, soils indicate periodic saturation at the A/B horizon interface (typically expressed as E horizons) dominate. On site BE the interflow (A/B) were of the Longlands and Kroonstad forms. Saturation occurs at the soil/bedrock interface and can result in lateral flow. When the water level reaches the more permeable surface horizons lateral flow occurs at much faster rates at the A/B horizon interface.
6) The accumulation of lateral discharging water from upslope positions can cause long periods of saturation in the valley bottom. *Responsive (wet)* soils of the Katspruit and Westleigh forms dominate on these positions. The gleyic and plinthic horizons occurring close to the surface are indicators that water levels are shallow. During the rainy season precipitation will likely result in overlandflow towards the stream as the soils are saturated.

7) Although the plinthic and gleyic layers, which occur all over the site, are good indicators of relatively impermeable bedrock, some infiltration into the fractured rock might occur. These sub-dominant bedrock flowpaths can then either recharge groundwater or return to the soil or stream in lower lying positions.

4.3 POTENTIAL IMPACT AND ITS SIGNIFICANCE ON SITE BE

The potential impact of open pit mining on site BE is presented in Figure 11. Mining activities will be conducted pre-dominantly on the crest and upper midslope positions (see Figure 7). This will result in (numbering below coincide with numbering in Figure 11):

1) The area of interflow (*soil/bedrock*) will be smaller in the upper midslope positions and contributions from the crest to interflow will be effectively eliminated.

2) The reduction in upslope lateral contributions will impact the water regimes of interflow (*A/B*) soils in the lower midslope positions. These soils are likely to dry out and water flow restricted to the soil/bedrock interface i.e. quickflow at A/B horizon interface will be eliminated.

3) Due to the smaller contributions from upslope, the water regime of wetland soils in the valley bottom will also be altered. It is expected that the soils will not be saturated for prolonged periods and only supply minimal lateral contributions to the stream.

4) Infiltration in the mine floor into the fractured rock can recharge groundwater and/or interflow to return to the soil and soil surface in lower lying positions.
Wetland health depends on vadose zone water – infiltration to interflow to return flow. A fractured mine floor higher than the valley bottom wetland may still feed the wetland. The possibility depends on the fracture system.

Based on these alterations in the dominant flowpaths of site BE, it is clear that open pit mining will have a high significance on the hydropedological behaviour of hillslopes feeding wetlands.
Table 3).

4.4 CONCLUSIONS AND RECOMMENDATIONS FOR SITE BE

Site BE is dominated by soils which show evidence of significant interflow in the subsoil and/or shallow bedrock fractures. However, the wetland indicates a post seasonal contribution from the hillslopes indicating the presence of deep flowpaths, in spite of shallow interflow dominating.

Open pit mining of the crest and upper midslope positions will result in a reduction of interflow to lower slopes, valley bottom wetland soils and streams. This will likely result in a complete alteration of water regimes; a potentially large negative impact especially terrestrial soil based ecosystems. Wetland based ecosystems will be affected where deeper flowpaths are affected.

Mitigation is possible. A supply of water to the subsurface by irrigation is required to create interflow (soil/bedrock) in soils of midslope positions. Dams, furrows, etc may be successful if the quantity varying in different hillslopes, are known. Such interventions can only be justified following detailed investigations into water fluxes and water quality of the landscape. Special efforts may be successful in storing water and feeding wetlands through the original flowpaths.

Figure 11: Potential impact of open pit mining on site BE.
## Table 3: Impact significance summary of site BE

<table>
<thead>
<tr>
<th>Affected Environment</th>
<th>Activity</th>
<th>Impact Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction</strong></td>
<td>Site clearance and topsoil removal prior to the commencement of physical construction activities.</td>
<td>Reduced infiltration due to compaction and exposing B horizons which will lead to a change in hydropedological flowpaths, enhanced overland flow and erosion</td>
</tr>
<tr>
<td>Hydropedology</td>
<td>Construction of surface infrastructure: workshop, wash bay, change house, offices, ablution facilities, parking area/carport, power lines, substation, security room, gate, light mast, Pollution Control Dam (PCD), access, mine roads and an incline shaft.</td>
<td>Reduced infiltration and enhanced overland flow and potentially more erosion due to surface sealing</td>
</tr>
<tr>
<td>Operation</td>
<td>Open pit mining</td>
<td>Alteration of hydropedological flowpaths on which can negatively impact terrestrial soil based ecosystems as well as degradation of wetland ecosystems</td>
</tr>
<tr>
<td>Hydropedology</td>
<td>Rehabilitation of the Project area will be undertaken. Rehabilitation activities will cover the extent of the infrastructure footprint areas and will include the ripping of the compacted soil surfaces, spreading of topsoil and establishment of vegetation.</td>
<td>Alteration of hydropedological flowpaths</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SIGNIFICANCE Pre-Mitigation</th>
<th>Mitigation measures / Recommendations</th>
<th>SIGNIFICANCE Post-Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>■ Ensure proper storm water management designs are in place; ■ Storm water management should allow for artificial recharge on recharge soils; ■ Water harvested from buildings and parking areas should be artificially recharged to reflect natural flowpaths.</td>
<td>Medium</td>
</tr>
<tr>
<td>High</td>
<td>■ If any erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place; ■ If erosion has occurred, topsoil should be sourced and replaced and shaped to reduce the recurrence of erosion; ■ Only the designated access routes are to be used to reduce any unnecessary compaction; ■ Compacted areas are to be ripped to loosen the soil structure; ■ Only the designated access routes are to be used to reduce any unnecessary compaction.</td>
<td>Medium</td>
</tr>
<tr>
<td>High</td>
<td>■ Mitigation should aim to re-establish flowpaths which are impacted by the development and should be guided by the hydropedological responses as depicted in Figure 10. ■ Artificially supply water through irrigation to recreate interflow at upper midslope landscape positions; ■ Storm water management should allow for recharge to the groundwater or to the soil/bedrock interface to ensure that natural flowpaths are reflected as accurately as possible; ■ Ensure proper storm water management designs are in place; ■ If any erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place</td>
<td>High</td>
</tr>
<tr>
<td>Low</td>
<td>■ Rehabilitation activities should aim to re-establish flowpaths which are impacted by the development and should be guided by the hydropedological responses as depicted in Figure 10. ■ Artificially supply water through irrigation to recreate interflow at upper midslope landscape positions; ■ Storm water management should allow for recharge to the groundwater or to the soil/bedrock interface to ensure that natural flowpaths are reflected as accurately as possible; ■ Ensure proper storm water management designs are in place; ■ If any erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place</td>
<td>Low</td>
</tr>
</tbody>
</table>

Hydropedological Assessment – Umsimbithi eMhakhzeni Mining Project
Post-closure monitoring and rehabilitation will determine the level of success of the rehabilitation, as well as to identify any additional measures that have to be undertaken to ensure that the mining area is restored to an adequate state. Monitoring will include soil water and wetland regimes and quality.

<table>
<thead>
<tr>
<th>Hydropedology</th>
<th>Alteration of hydrological flowpaths</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soil water and wetland regimes must be assessed by a soil specialist on a seasonal basis and compared with that of an undisturbed soils/wetlands to determine if the hydropedological flowpaths have been restored; Only the designated access routes are to be used to reduce any unnecessary compaction; and Areas of subsidence must be reported and remediated as soon as possible with the best practices at the time of occurrence.</td>
<td></td>
</tr>
</tbody>
</table>
5. HYDROPEDOLOGY OF SITE BF

5.1 HYDROPEDOLOGICAL SOIL TYPES

Site BF is earmarked for open pit mining (but underground mining is also proposed) and falls almost entirely within land type Ba21 Figure 12. The geology is mainly sandstone and siltstone from the Ecca Group and quartzite and shale from the Steenkampsberg formation, Pretoria Group. Although the land type inventory indicate that recharge soils dominate on crest and mid-slope positions, the results from the hydropedological survey shows that interflow (soil/bedrock) soils are dominant on these terrain positions (Figure 13).

The soil/bedrock interface are often very deep (e.g. at 3.8 m in Figure 14). This explains the discrepancy in hydrological soil types between the hydropedological survey and the conventional survey (Figure 12 & Figure 13). The depth criteria used in the latter limits the observation depth to 1.5 m and the soil/bedrock interface with indications of saturation and hence lateral flow was not described.

Interflow (A/B) dominates on the lower midslope positions while responsive (wet) soils occur in the valley bottom, as well as on concave positions in upper slope positions (Figure 15).

![Figure 12: Land types, hydropedological observations (HP) and conventional soil observations for site BF.](image-url)
Figure 13: Location of hydropedological soil types on site BF.

Figure 14: Auguring 3.8 m to reach soil/bedrock interface of interflow (soil/bedrock) – Bainsvlei soil on midslope positions of site BF.
5.2 HILLSLOPE HYDROLOGY OF SITE BF

The hydropedological behaviour of the dominant hillslopes is presented in Figure 16. The hydrological processes are discussed in relation to the numbered arrows in Figure 16:

1) The crest and upper midslope positions are dominated by soils with evidence of periodic saturation at the soil/bedrock interface – Interflow (soil/bedrock). The plinthic horizons (mostly very deep Bainsvlei soil forms) are indicative that the ET excess is dominating and underlying bedrock is slowly permeable and saturation is likely, which may lead to lateral flow at the soil bedrock interface.

2) On the lower midslope positions, soils with indications of periodic saturation at the A/B horizon interface (typically expressed as E horizons) dominate. Bedrock returnflow may contribute largely to the water content especially wetness after the event and after the season. On site BE the interflow (A/B) were of the Longlands and Kroonstad forms. Saturation occurs at the soil/bedrock interface and can result in lateral flow. When the water level reaches the more permeable surface horizons lateral flow occurs at much faster rates at the A/B horizon interface.

3) The accumulation of lateral discharging water from upslope positions cause long periods of saturation in the valley bottom. Responsive (wet) soils of the Westleigh and Katspruit forms dominate on these positions. The gleic and plinthic horizons occurring close to the surface are indicators that water levels are shallow and that additional precipitation will likely result in overlandflow towards the stream. Wetness depends on the deep interflow paths linking the crest to the valley bottom.

4) Although the plinthic layers, which occur all over the site, are good indicators of relatively impermeable bedrock, some infiltration into the fractured rock might occur. These sub-dominant bedrock flowpaths play an important role in the wetland and river ecosystems. They can then either recharge groundwater or return to the soil or stream in lower lying positions.
Figure 16: Hillslope hydropedological behaviour of site BF.

5.3 Potential Impact and Its Significance on Site BF

The potential impact of open pit mining on site BF is presented in Figure 17. Mining activities will be conducted predominantly on the crest and upper midslope positions (see Figure 12). This will result in (numbering below coincides with numbering in Figure 17):

1) The area of interflow (soil/bedrock) will be smaller in the upper midslope positions and contributions from the crest will be effectively eliminated.

2) The reduction in upslope lateral contributions will impact the water regimes of interflow (A/B) soils in the lower midslope positions. These soils are likely to dry out and water flow restricted to the soil/bedrock interface i.e. quickflow at A/B horizon interface will be eliminated.

3) Due to the smaller contributions from upslope, the water regime of wetland soils in the valley bottom will also be altered. It is expected that the soils will not be saturated for prolonged periods and only supply minimal lateral contributions to the stream.

4) Infiltration from the mining area into the fractured rock is still possible, which can recharge groundwater or return to lower lying positions.

Based on these alterations in the dominant flowpaths of site BF, it is clear that open pit mining will have a high significance on the hydropedological behaviour (}
Table 4).

Figure 17: Potential impact of open pit mining on site BF.

5.4 CONCLUSIONS AND RECOMMENDATIONS FOR SITE BF
Site by soils which BF is dominated show morphological evidence of significant lateral flow in the deep subsoil and possibly some return-flow rock to soil. Open pit mining of the crest and upper midslope positions will result in a reduction of lateral contributions to lower slopes, valley bottom wetland soils and streams. This will likely result in a complete alteration of water regimes; a potentially large negative impact. A wet wetland is linked to the long deep crest to midslope interflow.

Management interventions can potentially reduce the negative impacts; for example subsurface irrigation of interflow (soil/bedrock) soils of midslope positions. Such interventions can only be justified following detailed investigations into water fluxes and water quality of the landscape.
Table 4: Impact significance summary of site BF

<table>
<thead>
<tr>
<th>Affected Environment</th>
<th>Activity</th>
<th>Impact Description</th>
<th>SIGNIFICANCE Pre-Mitigation</th>
<th>Mitigation measures / Recommendations</th>
<th>SIGNIFICANCE Post-Mitigation</th>
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<tbody>
<tr>
<td>Construction</td>
<td>Site clearance and topsoil removal prior to the commencement of physical construction activities.</td>
<td>Reduced infiltration due to compaction and exposing B horizons which will lead to a change in hydropedological flowpaths, enhanced overland flow and erosion</td>
<td>High</td>
<td>▪ Ensure proper storm water management designs are in place;</td>
<td>Medium</td>
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<td></td>
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<td></td>
<td></td>
<td>▪ Storm water management should allow for artificial recharge on recharge soils;</td>
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<td>▪ Water harvested from buildings and parking areas should be artificially recharged to reflect natural flowpaths.</td>
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<td>▪ If any erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place;</td>
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<td>▪ If erosion has occurred, topsoil should be sourced and replaced and shaped to reduce the recurrence of erosion;</td>
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<td>▪ Only the designated access routes are to be used to reduce any unnecessary compaction;</td>
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<td>▪ Compacted areas are to be ripped to loosen the soil structure;</td>
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<td>▪ Only the designated access routes are to be used to reduce any unnecessary compaction.</td>
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<tr>
<td>Hydropedology</td>
<td>Construction of surface infrastructure: workshop, wash bay, change house, offices, ablution facilities, parking area/carport, power lines, substation, security room, gate, light mast, Pollution Control Dam (PCD), access, mine roads and an incline shaft.</td>
<td>Reduced infiltration and enhanced overland flow and potentially more erosion due to surface sealing</td>
<td>High</td>
<td>▪ Mitigation should aim to re-establish flowpaths which are impacted by the development and should be guided by the hydropedological responses as depicted in Figure 16.</td>
<td>Medium</td>
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<td></td>
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<td></td>
<td>▪ Artificially supply water through irrigation to recreate interflow at upper midslope landscape positions;</td>
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<td></td>
<td>▪ Storm water management should allow for recharge to the groundwater or to the soil/bedrock interface to ensure that natural flowpaths are reflected as accurately as possible;</td>
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<td></td>
<td></td>
<td>▪ Ensure proper storm water management designs are in place;</td>
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<td></td>
<td></td>
<td>▪ If any erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place</td>
<td>Medium</td>
</tr>
<tr>
<td>Operation</td>
<td>Open pit mining</td>
<td>Alteration of hydropedological flowpaths which can negatively impact terrestrial soil based ecosystems as well as degradation of wetland ecosystems</td>
<td>High</td>
<td>▪ Mitigation should aim to re-establish flowpaths which are impacted by the development and should be guided by the hydropedological responses as depicted in Figure 16.</td>
<td>High</td>
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<td>▪ Artificially supply water through irrigation to recreate interflow at appropriate landscape positions;</td>
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<td></td>
<td>▪ Storm water management should allow for recharge to the groundwater or to the soil/bedrock interface to ensure that natural flowpaths are reflected as accurately as possible;</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Hydropedology</td>
<td>Underground mining</td>
<td>Alteration of hydropedological flowpaths which can negatively impact terrestrial soil based ecosystems as well as degradation of wetland ecosystems</td>
<td>Low</td>
<td>▪ Mitigation should aim to re-establish flowpaths which are impacted by the development and should be guided by the hydropedological responses as depicted in Figure 16.</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>▪ Artificially supply water through irrigation to recreate interflow at appropriate landscape positions;</td>
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<td></td>
<td>▪ Storm water management should allow for recharge to the groundwater or to the soil/bedrock interface to ensure that natural flowpaths are reflected as accurately as possible;</td>
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<td>▪ If any erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place</td>
<td></td>
</tr>
</tbody>
</table>
## Decommissioning and Closure

| Hydropedology | Rehabilitation of the Project area will be undertaken. Rehabilitation activities will cover the extent of the infrastructure footprint areas and will include the ripping of the compacted soil surfaces, spreading of topsoil and establishment of vegetation. | Alteration of hydropedological flowpaths | Low | • Rehabilitation activities should aim to re-establish flowpaths which are impacted by the development and should be guided by the hydropedological responses as depicted in Figure 16.  
• Artificially supply water through irrigation to recreate interflow at upper midslope landscape positions;  
• Storm water management should allow for recharge to the groundwater or to the soil/bedrock interface to ensure that natural flowpaths are reflected as accurately as possible;  
• Ensure proper storm water management designs are in place;  
• If any erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place | Low |

## Post-Closure

| Hydropedology | Post-closure monitoring and rehabilitation will determine the level of success of the rehabilitation, as well as to identify any additional measures that have to be undertaken to ensure that the mining area is restored to an adequate state. Monitoring will include soil water and wetland regimes and quality. | Alteration of hydrological flowpaths | Low | • Soil water and wetland regimes must be assessment by a soil specialist on a seasonal basis and compared with that of an undisturbed soils/wetlands to determine if the hydropedological flowpaths have been restored;  
• Only the designated access routes are to be used to reduce any unnecessary compaction; and  
• Areas of subsidence must be reported and remediated as soon as possible with the best practices at the time of occurrence. | Low |
6. HYDROPEDOLOGY OF SITE BA

6.1 HYDROPEDOLOGICAL SOIL TYPES

Site BA is earmarked for open pit mining and underground mining and lies within land type Ac2 in the west and Ad1 in the east (Figure 18). The geology of Ac2 is very complex and consists of Quartzite, shale, hornfels, limestone, andesite, tuff and conglomerate of Pretoria Group, tillite, sandstone and shale of the Dwyka Formation and sandstone of the Ecca Group (Land Type Survey Staff, 1972 – 2006). The geology of Ad1 is mainly sandstone and shale from the Ecca Group.

The different land types dominated by different hydropedological soil types (Figure 19) and it was therefore deemed necessary to divide the site into two zones. Zone A is dominated by Ac2 and Zone B by Ad1 (Figure 19).

SOIL TYPES OF ZONE A

Responsive (shallow) soils occur predominantly on the crest positions mostly from the Dresden and Mispah forms. In concave areas on the crest interflow (soil/bedrock) soils do occur – typically shallow Glencoe soils. Large areas of the crest are also covered by exposed hard plinthis layers. Rock outcrops (sandstone shelves) occur at the transition between the crest and the midslope (Figure 20). On the relatively steep midslopes responsive (shallow) soils are dominant – mostly of the Mispah form. These soils probably act as shallow recharge soils (the absence of bleached A horizons support this suggestion) with a shallow fractured rock flowpath dominating and ending in rock outcrops (Figure 19). Responsive (wet) soils cover the incised valley bottom.

Figure 18: Land types, hydropedological observations (HP) and conventional soil observations for site BA.
Figure 19: Location of hydropedological soil types on site BA.

Figure 20: Sandstone shelves between crest and midslope positions of Zone A in site BA.
SOIL TYPES OF ZONE B:
Concave and linear positions on the upper slopes are covered by interflow (soil/bedrock) soils, mostly from the Avalon and Glencoe forms. Convex positions are dominated by responsive (shallow) soils (Dresden and Mispah forms). Recharge (shallow) soils are prominent in the northern part of this zone (Figure 21). The bleached colour of the A horizon of the Glenrosa, typically a recharge soil, suggests however that these soils has a shallow drainage limitation and saturate during high rainfall events and that they will then act as responsive (shallow) soils. Responsive (wet) soils cover the valley bottom positions.

Figure 21: Recharge (shallow) – Glenrosa soil form in Zone B of site BA.

6.2 HILLSLOPE HYDROLOGY OF SITE BA

The hydropedological behaviour of the dominant hillslopes of zone A is presented in Figure 22. The hydrological processes are discussed in relation to the numbered arrows in Figure 22:

1) Shallow soils are dominant on the crest positions – responsive (shallow). The combination of relatively impermeable bedrock and shallow soil depth implies that these soils have a low storage capacity. They will saturate quickly following a rain event and contribute to the generation of overlandflow. Lateral flow at the soil bedrock interface is also possible on the crest positions.

2) A prominent shelf exists on the transition between the crest and midslope. The shelve is impermeable and lateral contributions will return to the surface and flow as overlandflow towards lower lying positions.

3) Below the shelf, fractured rock and shallow soils dominate – recharge (shallow). Infiltration into the fractured rock will therefore be the dominant process on the midslope positions.
4) It is expected that another slowly permeable layer occur at the same elevation as the streambed in the valley bottom. Water which did infiltrate in 3) is likely to contribute laterally to the stream.

5) The incised valley bottoms are indicative of the relatively fast hydrological response of this landscape (high erosion energy due to the dominance of overlandflow). Responsive (wet) soils dominate and promote overlandflow due to saturation excess.

Figure 22: Hillslope hydropedological behaviour of Zone A of site BA.

**HILLSLOPE HYDROLOGY OF ZONE B:**

The hydropedological behaviour of the dominant hillslopes of zone B is presented in Figure 22. The hydrological processes are discussed in relation to the numbered arrows in Figure 22:

1) Shallow soils are dominant on the convex areas of crest and midslope positions – responsive (shallow). The combination of relatively impermeable bedrock and shallow soil depth implies that these soils have a low storage capacity. They will saturate quickly following a rain event and contribute to the generation of overlandflow.

2) Concave and linear areas of the crest and upper midslope positions are dominated by soils with evidence of periodic saturation at the soil/bedrock interface – Interflow (soil/bedrock). The plinthic horizons (mostly in Avalon soil forms) are indicative that the underlying bedrock is slowly permeable and saturation is likely, which may lead to lateral flow at the soil bedrock interface.

3) Although the plinthic layers are indicative of slowly permeable bedrock there might be infiltration into fractures in the bedrock. This water can either recharge groundwater or return to the soils in the valley bottom position.

4) The accumulation of lateral discharging water from upslope positions cause long periods of saturation in the valley bottom. Responsive (wet) soils of the Katspruit and Westleigh forms
dominate on these positions. The gleyic and plinthic horizons occurring close to the surface are indicators that water levels are shallow and that additional precipitation will likely result in overlandflow towards the stream.

![Figure 23: Hillslope hydropedological behaviour of Zone B of site BA.](image)

6.3 POTENTIAL IMPACT AND ITS SIGNIFICANCE ON SITE BA

ZONE A:
The potential impact of open pit mining on Zone A of site BA is presented in Figure 24. Mining activities will be conducted pre-dominantly on the crest and upper midslope positions (see Figure 18). This will result in (numbering below coincide with numbering in Figure 24):

1) Infiltration of water into the fractured rock will still be dominant on midslope positions.
2) This infiltrated water can still flow through fractures in the bedrock and return to the stream via bedrock flowpaths.
3) It is expected that the ‘average/long-term’ supply of water to the wetland via bedrock flowpaths will not be altered drastically.

Based on the conceptual hydropedological understanding of zone A of site BA it is clear that this is a very responsive landscape; with overlandflow dominating. The longer term water regimes of soils below the mining activity will only be affected moderately (Error! Reference source not found.).
ZONE B
The potential impact of open pit mining on Zone B of site BA is presented in Figure 25. Mining activities will be conducted pre-dominantly on the crest and upper midslope positions (see Figure 18). This will result in (numbering below coincide with numbering in Figure 25):

1) The area of interflow (soil/bedrock) will be smaller in the upper midslope positions and contributions from the crest will be effectively eliminated.
2) Infiltration from the mining area into the fractured rock is still possible, which can recharge groundwater or return to lower lying positions.
3) Due to the smaller contributions from upslope, the water regime of wetland soils in the valley bottom will also be altered. It is expected that the soils will not be saturated for prolonged periods and only supply minimal lateral contributions to the stream.

Based on these alterations in the dominant flowpaths of zone B of site BA, it is clear that open pit mining will have a high significance on the hydropedological behaviour (}
Table 5).

Figure 25: Potential impact of open pit mining on Zone B of site BA.

6.4 CONCLUSIONS AND RECOMMENDATIONS FOR SITE BA

Site BA is comprised of two zones which have a different hydrological behaviour. In zone A, responsive (shallow) soils dominate the upper slopes and overlandflow is the dominant hydrological process. Below a prominent sandstone shelve, infiltration into fractured rock is dominant which then feeds valley bottom wetlands. The elimination of overlandflow through open pit mining on the crest position is unlikely to have a significant impact on the water regimes of soils downslope.

In zone B soils which show morphological evidence of significant lateral flow occur frequently. Open pit mining of the crest and upper midslope positions will result in a reduction of lateral contributions to lower slopes, valley bottom wetland soils and streams. This will likely result in a complete alteration of water regimes; a potentially large negative impact. Management interventions can potentially reduce the negative impacts; for example subsurface irrigation of interflow (soil/bedrock) soils of
midslope positions. Such interventions can only be justified following detailed investigations into water fluxes and water quality of the landscape.
### Table 5: Impact significance summary of site BA

<table>
<thead>
<tr>
<th>Affected Environment</th>
<th>Activity</th>
<th>Impact Description</th>
<th>SIGNIFICANCE Pre-Mitigation</th>
<th>Mitigation measures / Recommendations</th>
<th>SIGNIFICANCE Post-Mitigation</th>
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<tbody>
<tr>
<td><strong>Construction</strong></td>
<td></td>
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</tbody>
</table>
| Hydopedology         | Site clearance and topsoil removal prior to the commencement of physical construction activities. | Reduced infiltration due to compaction and exposing B horizons which will lead to a change in hydropedological flowpaths, enhanced overland flow and erosion | High | ■ Ensure proper storm water management designs are in place;  
■ Storm water management should allow for artificial recharge on recharge soils (see midslope positions of zone A in Figure 22);  
■ Water harvested from buildings and parking areas should on recharge areas should be artificially recharged to reflect natural flowpaths. | Medium |
|                       | Construction of surface infrastructure: workshop, wash bay, change house, offices, ablation facilities, parking area/carport, power lines, substation, security room, gate, light mast, Pollution Control Dam (PCD), access, mine roads and an incline shaft. | Reduced infiltration and enhanced overland flow and potentially more erosion due to surface sealing | High | ■ If any erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place;  
■ If erosion has occurred, topsoil should be sourced and replaced and shaped to reduce the recurrence of erosion;  
■ Only the designated access routes are to be used to reduce any unnecessary compaction;  
■ Compacted areas are to be ripped to loosen the soil structure;  
■ Only the designated access routes are to be used to reduce any unnecessary compaction. | Medium |
| **Operation**        |          |                     |                              |                                        |                             |
| Hydopedology         | Open pit mining | Alteration of hydropedological flowpaths which can negatively impact terrestrial soil based ecosystems as well as degradation of wetland ecosystems | High | ■ Mitigation should aim to re-establish flowpaths which are impacted by the development and should be guided by the hydropedological responses as depicted in Figure 22 & 23.  
■ Artificially supply water through irrigation to recreate interflow at upper midslope landscape positions;  
■ Storm water management should allow for recharge to the groundwater or to the soil/bedrock interface to ensure that natural flowpaths are reflected as accurately as possible;  
■ Ensure proper storm water management designs are in place;  
■ If any erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place | High |
| Hydopedology         | Underground mining | Alteration of hydropedological flowpaths which can negatively impact terrestrial soil based ecosystems as well as degradation of wetland ecosystems | Low | ■ Mitigation should aim to re-establish flowpaths which are impacted by the development and should be guided by the hydropedological responses as depicted in Figure 22 & 23.  
■ Artificially supply water through irrigation to recreate interflow at appropriate landscape positions;  
■ Storm water management should allow for recharge to the groundwater or to the soil/bedrock interface to ensure that natural flowpaths are reflected as accurately as possible;  
■ Ensure proper storm water management designs are in place;  
■ If any erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place | Low |
### Decommissioning and Closure

| Hydropedology | Rehabilitation of the Project area will be undertaken. Rehabilitation activities will cover the extent of the infrastructure footprint areas and will include the ripping of the compacted soil surfaces, spreading of topsoil and establishment of vegetation. | Alteration of hydropedological flowpaths | Low | ■ Rehabilitation activities should aim to re-establish flowpaths which are impacted by the development and should be guided by the hydropedological responses as depicted in Figure 22 & 23.  
■ Artificially supply water through irrigation to recreate interflow at upper midslope landscape positions;  
■ Storm water management should allow for recharge to the groundwater or to the soil/bedrock interface to ensure that natural flowpaths are reflected as accurately as possible;  
■ Ensure proper storm water management designs are in place;  
■ If any erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place. |

### Post-Closure

| Hydropedology | Post-closure monitoring and rehabilitation will determine the level of success of the rehabilitation, as well as to identify any additional measures that have to be undertaken to ensure that the mining area is restored to an adequate state. Monitoring will include soil water and wetland regimes and quality. | Alteration of hydrological flowpaths | Low | ■ Soil water and wetland regimes must be assessment by a soil specialist on a seasonal basis and compared with that of an undisturbed soils/wetlands to determine if the hydropedological flowpaths have been restored;  
■ Only the designated access routes are to be used to reduce any unnecessary compaction; and  
■ Areas of subsidence must be reported and remediated as soon as possible with the best practices at the time of occurrence. |
7. HYDROPEDOLOGY OF SITE AA

7.1 HYDROPEDOLOGICAL SOIL TYPES

Site AA is earmarked for underground mining and lies almost entirely in land type Ad1. The geology is mainly sandstone and shale from the Ecca Group (Land Type Survey Staff, 1972 – 2006). Concave and linear positions on the upper slopes are covered by interflow (soil/bedrock) soils, mostly from the Avalon and Glencoe forms (Figure 26). Convex positions are dominated by responsive (shallow) soils (Dresden and Mispah forms). Interflow (A/B) soils occur on the lower parts of the footslope and responsive (wet) soils in the valley bottom.

![Figure 26: Land types and location of hydropedological soil types on site AA.](image)

7.2 HILLSLOPE HYDROLOGY OF SITE AA

The hydropedological behaviour of the dominant hillslopes is presented in Figure 27. The hydrological processes are discussed in relation to the numbered arrows in Figure 27:

1) Shallow soils are dominant on the convex areas of crest and midslope positions – responsive (shallow). The combination of relatively impermeable bedrock and shallow soil depth implies that these soils have a low storage capacity. They will saturate quickly following a rain event and contribute to the generation of overlandflow.

2) Concave and linear areas of the crest and upper midslope positions are dominated by soils with evidence of periodic saturation at the soil/bedrock interface – interflow (soil/bedrock). The plinthic horizons (mostly in Avalon soil forms) are indicative that the underlying bedrock
is slowly permeable and saturation is likely, which may lead to lateral flow at the soil bedrock interface.

3) Although the plinthic layers are indicative of slowly permeable bedrock there might be infiltration into fractures in the bedrock. This water can either recharge groundwater or return to the soils in the valley bottom position.

4) The accumulation of lateral discharging water from upslope positions cause long periods of saturation in the valley bottom. Responsive (wet) soils of the Katspruit and Westleigh forms dominate on these positions. The gleyic and plinthic horizons occurring close to the surface are indicators that water levels are shallow and that additional precipitation will likely result in overlandflow towards the stream.

Figure 27: Hillslope hydropedological behaviour of site AA.

7.3 POTENTIAL IMPACT AND ITS SIGNIFICANCE ON SITE AA

The potential impact of underground mining on AA is presented in Figure 28. The underground mining activities are unlikely to have a significant effect on the hydrological behaviour of this site. Because of the relative impermeability of the bedrock, infiltration into fractures are only sub-dominant. The contribution of bedrock flowpaths to valley bottom wetlands and streams are therefore expected to be minimal. The significance rating of the impact is presented in
Table 6.

![Diagram of underground mining impact on hydrological behaviour]

**Legend**
- Responsive (shallow)
- Interflow (soil/bedrock)
- Responsive (wet)
- Slowly permeable bedrock
- Stream
- Dominant flowpath
- Sub-dominant flowpath

**Figure 28**: Potential impact of underground mining on the hydrological behaviour of site AA.

### 7.4 CONCLUSIONS AND RECOMMENDATIONS FOR SITE AA

Site AA is covered with soils which indicate that the underlying bedrock is relatively impermeable, which promotes lateral flow. In this case underground mining activities are unlikely to impact the hydrological behaviour significantly. Care must however be taken to ensure that the impact of access points and other infrastructure are limited.
<table>
<thead>
<tr>
<th>Affected Environment</th>
<th>Activity</th>
<th>Impact Description</th>
<th>SIGNIFICANCE Pre- Mitigation</th>
<th>Mitigation measures / Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>Site clearance and topsoil removal prior to the commencement of physical construction activities.</td>
<td>Reduced infiltration due to compaction and exposing B horizons which will lead to a change in hydropedological flowpaths, enhanced overland flow and erosion</td>
<td>High</td>
<td>■ Ensure proper storm water management on recharge soils; ■ Storm water management should allow for recharge areas to be artificially recharged.</td>
</tr>
</tbody>
</table>
Post-closure monitoring and rehabilitation will determine the level of success of the rehabilitation, as well as to identify any additional measures that have to be undertaken to ensure that the mining area is restored to an adequate state. Monitoring will include soil water and wetland regimes and quality.

<table>
<thead>
<tr>
<th>Post-Closure</th>
<th>Hydropedology</th>
<th>Alteration of hydrological flowpaths</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Post-closure monitoring and rehabilitation will determine the level of success of the rehabilitation, as well as to identify any additional measures that have to be undertaken to ensure that the mining area is restored to an adequate state. Monitoring will include soil water and wetland regimes and quality.</td>
<td>Soil water and wetland regimes must be assessment by a soil specialist on a seasonal basis and compared with that of an undisturbed soils/wetlands to determine if the hydropedological flowpaths have been restored; Only the designated access routes are to be used to reduce any unnecessary compaction; and Areas of subsidence must be reported and remediated as soon as possible with the best practices at the time of occurrence.</td>
<td>Low</td>
</tr>
</tbody>
</table>
8. HYDROPEDOLOGY OF SITE BD

8.1 HYDROPEDOLOGICAL SOIL TYPES

Site BD is earmarked for **underground mining** and lies within land type Ad1 in the south and land type Ib34 in the north. The geology of Ad1 consists of mainly sandstone and shale from the Ecca Group and that of Ib34 quartzite and shales of the Steenkampsberg formation, Pretoria Group (Land Type Survey Staff, 1972 – 2006). In land type Ad1, concave and linear positions of the upper slopes are covered by *interflow* (**soil/bedrock**) soils, mostly from the Avalon and Glencoe forms (Figure 32). Convex positions are dominated by responsive (**shallow**) soils (Dresden and Mispah forms). *Interflow (A/B)* soils occur on the lower parts of the footslope and responsive (**wet**) soils in the valley bottom. Land type Ib34 is mostly covered by shallow Mispah and Glenrosa soil forms (**shallow responsive and shallow recharge**).

![Figure 29: Land types and location of hydropedological soil types on site BD.](image)

8.2 HILLSLOPE HYDROLOGY OF SITE BD

The hydropedological behaviour of the dominant hillslopes of land type Ad1 is presented in Figure 33. The expected behaviour of Ib34 is included in this conceptual model. The hydrological processes are discussed in relation to the numbered arrows in Figure 33:

1) Shallow soils are dominant on the convex areas of crest and midslope positions – responsive (**shallow**). The combination of relatively impermeable bedrock and shallow soil depth implies that these soils have a low storage capacity. They will saturate quickly following a rain event.
and contribute to the generation of overlandflow. This is also the dominant behaviour expected the northern parts of the site – under land type lb34.

2) Concave and linear areas of the crest and upper midslope positions are dominated by soils with evidence of periodic saturation at the soil/bedrock interface – Interflow (soil/bedrock). The plinthic horizons (mostly in Avalon soil forms) are indicative that the underlying bedrock is slowly permeable and saturation is likely, which may lead to lateral flow at the soil bedrock interface.

3) Although the plinthic layers are indicative of slowly permeable bedrock there might be infiltration into fractures in the bedrock. This water can either recharge groundwater or return to the soils in the valley bottom position.

4) The accumulation of lateral discharging water from upslope positions cause long periods of saturation in the valley bottom. Responsive (wet) soils of the Katspruit and Westleigh forms dominate on these positions. The gleyic and plinthic horizons occurring close to the surface are indicators that water levels are shallow and that additional precipitation will likely result in overlandflow towards the stream.

### Figure 30: Hillslope hydropedological behaviour of site BG.

8.3 **Potential impact and its significance on Site BD**

The potential impact of underground mining on BD is presented in Figure 34. The underground mining activities are unlikely to have a significant effect on the hydrological behaviour of this site. Because of the relative impermeability of the bedrock, infiltration into fractures is only sub-dominant. The contribution of bedrock flowpaths to valley bottom wetlands and streams are therefore expected to be minimal. The significance rating of the impact is presented in
8.4 CONCLUSIONS AND RECOMMENDATIONS FOR SITE BD

Site BD is covered with soils which indicate that the underlying bedrock is relatively impermeable, which promotes lateral flow. In this case underground mining activities are unlikely to impact the hydrological behaviour significantly. Care must however be taken to ensure that the impact of access points and other infrastructure are limited.
### Table 7: Impact significance summary of site BD

<table>
<thead>
<tr>
<th>Affected Environment</th>
<th>Activity</th>
<th>Impact Description</th>
<th>SIGNIFICANCE Pre-Mitigation</th>
<th>Mitigation measures / Recommendations</th>
<th>SIGNIFICANCE Post-Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydropedology</td>
<td>Site clearance and topsoil removal prior to the commencement of physical construction activities.</td>
<td>Reduced infiltration due to compaction and exposing B horizons which will lead to a change in hydropedological flowpaths, enhanced overland flow and erosion</td>
<td>High</td>
<td>■ Ensure proper storm water management designs are in place; ■ Storm water management should allow for artificial recharge on recharge soils; ■ Water harvested from buildings and parking areas should be artificially recharged to reflect natural flowpaths.</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>Construction of surface infrastructure: workshop, wash bay, change house, offices, ablution facilities, parking area/carport, power lines, substation, security room, gate, light mast, Pollution Control Dam (PCD), access, mine roads and an incline shaft.</td>
<td>Reduced infiltration and enhanced overland flow and potentially more erosion due to surface sealing</td>
<td>High</td>
<td>■ If any erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place; ■ If erosion has occurred, topsoil should be sourced and replaced and shaped to reduce the recurrence of erosion; ■ Only the designated access routes are to be used to reduce any unnecessary compaction; ■ Compacted areas are to be ripped to loosen the soil structure; ■ Only the designated access routes are to be used to reduce any unnecessary compaction.</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Operation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydropedology</td>
<td>Underground mining</td>
<td>Alteration of hydropedological flowpaths which can negatively impact terrestrial soil based ecosystems as well as degradation of wetland ecosystems</td>
<td>Low</td>
<td>■ Mitigation should aim to re-establish flowpaths which are impacted by the development and should be guided by the hydropedological responses as depicted in Figure 30. ■ Artificially supply water through irrigation to recreate interflow at appropriate landscape positions; ■ Storm water management should allow for recharge to the groundwater or to the soil/bedrock interface to ensure that natural flowpaths are reflected as accurately as possible; ■ Ensure proper storm water management designs are in place; ■ If any erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place.</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Decommissioning and Closure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydropedology</td>
<td>Rehabilitation of the Project area will be undertaken. Rehabilitation activities will cover the extent of the infrastructure footprint areas and will include the ripping of the compacted soil surfaces, spreading of topsoil and establishment of vegetation.</td>
<td>Alteration of hydropedological flowpaths</td>
<td>Low</td>
<td>■ Rehabilitation activities should aim to re-establish flowpaths which are impacted by the development and should be guided by the hydropedological responses as depicted in Figure 30. ■ Artificially supply water through irrigation to recreate interflow at upper midslope landscape positions; ■ Storm water management should allow for recharge to the groundwater or to the soil/bedrock interface to ensure that natural flowpaths are reflected as accurately as possible; ■ Ensure proper storm water management designs are in place; ■ If any erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place.</td>
<td>Low</td>
</tr>
<tr>
<td>Post-Closure</td>
<td>Hydropedology</td>
<td>Post-closure monitoring and rehabilitation will determine the level of success of the rehabilitation, as well as to identify any additional measures that have to be undertaken to ensure that the mining area is restored to an adequate state. Monitoring will include soil water and wetland regimes and quality.</td>
<td>Alteration of hydrological flowpaths</td>
<td>Low</td>
<td>■ Soil water and wetland regimes must be assessed by a soil specialist on a seasonal basis and compared with that of an undisturbed soils/wetlands to determine if the hydropedological flowpaths have been restored; ■ Only the designated access routes are to be used to reduce any unnecessary compaction; and ■ Areas of subsidence must be reported and remediated as soon as possible with the best practices at the time of occurrence.</td>
</tr>
</tbody>
</table>
9. HYDROPEDOLOGY OF SITE BG

9.1 HYDROPEDOLOGICAL SOIL TYPES

Site BG is earmarked for underground mining and lies mostly in land type Ad1 with a small section in the south-western corner in land type Ba21. The geology is mainly sandstone and shale from the Ecca Group (Land Type Survey Staff, 1972 – 2006). Concave and linear positions on the upper slopes are covered by interflow (soil/bedrock) soils, mostly from the Avalon and Glencoe forms (Figure 32). Convex positions are dominated by responsive (shallow) soils (Dresden and Mispah forms). Interflow (A/B) soils occur on the lower parts of the footslope and responsive (wet) soils in the valley bottom.

![Figure 32: Land types and location of hydropedological soil types on site BG.](image)

9.2 HILLSLOPE HYDROLOGY OF SITE BG

The hydropedological behaviour of the dominant hillslopes is presented in Figure 33. The hydrological processes are discussed in relation to the numbered arrows in Figure 33:

5) Shallow soils are dominant on the convex areas of crest and midslope positions – responsive (shallow). The combination of relatively impermeable bedrock and shallow soil depth implies that these soils have a low storage capacity. They will saturate quickly following a rain event and contribute to the generation of overlandflow.

6) Concave and linear areas of the crest and upper midslope positions are dominated by soils with evidence of periodic saturation at the soil/bedrock interface – Interflow (soil/bedrock). The plinthic horizons (mostly in Avalon soil forms) are indicative that the underlying bedrock
is slowly permeable and saturation is likely, which may lead to lateral flow at the soil bedrock interface.

7) Although the plinthic layers are indicative of slowly permeable bedrock there might be infiltration into fractures in the bedrock. This water can either recharge groundwater or return to the soils in the valley bottom position.

8) The accumulation of lateral discharging water from upslope positions cause long periods of saturation in the valley bottom. Responsive (wet) soils of the Katspruit and Westleigh forms dominate on these positions. The gleyic and plinthic horizons occurring close to the surface are indicators that water levels are shallow and that additional precipitation will likely result in overlandflow towards the stream.

Figure 33: Hillslope hydropedological behaviour of site BG.

9.3 POTENTIAL IMPACT AND ITS SIGNIFICANCE ON SITE BG

The potential impact of underground mining on BG is presented in Figure 34. The underground mining activities are unlikely to have a significant effect on the hydrological behaviour of this site. Because of the relative impermeability of the bedrock, infiltration into fractures is only sub-dominant. The contribution of bedrock flowpaths to valley bottom wetlands and streams are therefore expected to be minimal. The significance rating of the impact is presented in (
Table 8).

9.4 CONCLUSIONS AND RECOMMENDATIONS FOR SITE BG
Site BG is covered with thick soils on the crest and midslope. Water passing the rootzone causes saturation in the deep subsoil which indicates that the underlying bedrock is relatively impermeable or the depth to the permeable rock is near the subsoil, which promotes lateral flow underneath and in the subsoil causing a fluctuating water table. In this case underground mining activities are unlikely to impact the hydrological behaviour significantly. Care must however be taken to ensure that the impacts of access points and other infrastructure are limited.
### Table 8: Impact significance summary of site BG

<table>
<thead>
<tr>
<th>Affected Environment</th>
<th>Activity</th>
<th>Impact Description</th>
<th>SIGNIFICANCE Pre-Mitigation</th>
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<tbody>
<tr>
<td><strong>Construction</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydropedology</td>
<td>Site clearance and topsoil removal prior to the commencement of physical construction activities.</td>
<td>Reduced infiltration due to compaction and exposing B horizons which will lead to a change in hydropedological flowpaths, enhanced overland flow and erosion</td>
<td>High</td>
<td>■ Ensure proper storm water management designs are in place; ■ Storm water management should allow for artificial recharge on recharge soils; ■ Water harvested from buildings and parking areas should on recharge areas should be artificially recharged to reflect natural flowpaths.</td>
<td>Medium</td>
</tr>
<tr>
<td>Hydropedology</td>
<td>Construction of surface infrastructure: workshop, wash bay, change house, offices, ablution facilities, parking area/carport, power lines, substation, security room, gate, light mast, Pollution Control Dam (PCD), access, mine roads and an incline shaft.</td>
<td>Reduced infiltration and enhanced overland flow and potentially more erosion due to surface sealing</td>
<td>High</td>
<td>■ If any erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place; ■ If erosion has occurred, topsoil should be sourced and replaced and shaped to reduce the recurrence of erosion; ■ Only the designated access routes are to be used to reduce any unnecessary compaction; ■ Compacted areas are to be ripped to loosen the soil structure; ■ Only the designated access routes are to be used to reduce any unnecessary compaction.</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Operation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydropedology</td>
<td>Underground mining</td>
<td>Alteration of hydropedological flowpaths which can negatively impact terrestrial soil based ecosystems as well as degradation of wetland ecosystems</td>
<td>Low</td>
<td>■ Mitigation should aim to re-establish flowpaths which are impacted by the development and should be guided by the hydropedological responses as depicted in Figure 30; ■ Artificially supply water through irrigation to recreate interflow at appropriate landscape positions; ■ Storm water management should allow for recharge to the groundwater or to the soil/bedrock interface to ensure that natural flowpaths are reflected as accurately as possible; ■ Ensure proper storm water management designs are in place; ■ If any erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place.</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Decommissioning and Closure</strong></td>
<td></td>
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<tr>
<td>Hydropedology</td>
<td>Rehabilitation of the Project area will be undertaken. Rehabilitation activities will cover the extent of the infrastructure footprint areas and will include the ripping of the compacted soil surfaces, spreading of topsoil and establishment of vegetation.</td>
<td>Alteration of hydropedological flowpaths</td>
<td>Low</td>
<td>■ Rehabilitation activities should aim to re-establish flowpaths which are impacted by the development and should be guided by the hydropedological responses as depicted in Figure 30; ■ Artificially supply water through irrigation to recreate interflow at upper mid-slope landscape positions; ■ Storm water management should allow for recharge to the groundwater or to the soil/bedrock interface to ensure that natural flowpaths are reflected as accurately as possible; ■ Ensure proper storm water management designs are in place; ■ If any erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place.</td>
<td>Low</td>
</tr>
<tr>
<td>Post-Closure</td>
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<tr>
<td><strong>Hydropedology</strong></td>
<td>Post-closure monitoring and rehabilitation will determine the level of success of the rehabilitation, as well as to identify any additional measures that have to be undertaken to ensure that the mining area is restored to an adequate state. Monitoring will include soil water and wetland regimes and quality.</td>
<td><strong>Low</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Alteration of hydrological flowpaths | | ■ Soil water and wetland regimes must be assessment by a soil specialist on a seasonal basis and compared with that of an undisturbed soils/wetlands to determine if the hydropedological flowpaths have been restored;  
■ Only the designated access routes are to be used to reduce any unnecessary compaction; and  
■ Areas of subsidence must be reported and remediated as soon as possible with the best practices at the time of occurrence. | **Low** |
10. **ASSUMPTIONS, LIMITATIONS AND GAPS IN KNOWLEDGE**

Hydropedological assessments and interpretations are based on the assumption that the soil morphology is in phase with the current soil water regime. Soil morphology changes slowly to alterations in soil water regimes (for example due to land-use and climate change). Another assumption is that the surveyed hillslopes are representative of the entire site. Terrain analyses were performed to identify dominant hillslopes reflective of typical terrain forms, but there might be areas which are not represented by these hillslopes and might respond hydropedologically different. This is one of the limitations of the study. In addition, hydropedological interpretations provide only qualitative descriptions of dominant flowpaths. To quantify fluxes of water in the landscape, detailed mechanistic modelling, supplemented with measured hydraulic properties are required. Hydropedology is still a relatively new discipline and there might therefore be unknown gaps in the knowledge. The authors are however the leading hydropedological researchers in South Africa and continuously address knowledge gaps through peer reviewed scientific publications.

11. **GENERAL CONCLUSIONS AND RECOMMENDATIONS**

Although interflow in soils and shallow bedrock dominates, indicating that a large part of rainfall serves terrestrial ecosystems, the wetlands in valley bottoms indicate that a significant amount of water is supplied during the rainy season and post seasonal, to the wetlands. It implies that the hills in most sites (as indicated) primarily partition the rainfall in shallow interflow, yet leaks water to the deep fractured rock system, stores and release it slowly long after the rain, keeping wetlands wet. Wetland controls contribute well to keep water in the wetland longer. These flowpaths serving recharge/interflow/release of water to wetlands and storing it in the wetland, must be preserved.

Mining is predicted to have a high impact on site BE. The site is dominated by redistribution in the crest and upper midslope by shallow interflow. The midslope has deeper flowpaths and footslope shallow flow and wetland indicates the presence of distributed deep flowpaths in the higher lying areas. Open pit mining of the crest and upper midslope positions will change terrestrial soil ecosystems. Wetland ecosystems will be affected where deeper flowpaths are affected. Mitigation should be considered.

Mining will have a high impact on the ecosystems of site BF. Storage and lateral flow in the deep subsoil and possibly some returnflow from rock to the deep subsoil is a vadose zone recharge area. Open pit mining of the crest and upper midslope positions will result in a pro rata reduction of contributions to lower slopes, valley bottom wetland soils and streams. This will likely result in a complete alteration of the water regimes of wetlands. Mitigation should be considered.

In site BA zone A is responsive (shallow) soils and a prominent sandstone shelve. Infiltration into fractured rock (as well as from the shelves), feeds valley bottom wetlands. The elimination of overland flow through open pit mining on the crest position is unlikely to have a significant impact on the water regimes of soils downslope.

In zone B of BA significant lateral flow can occur frequently. Open pit mining of the crest and upper midslope positions will impact on valley bottom wetlands and streams. This will likely result in a complete alteration of water regimes; a potentially large negative impact on ecosystems. Mitigation should be considered.
Site AA’s bedrock promotes lateral flow. In this case underground mining activities are unlikely to impact the hydrological behaviour significantly. Care must however be taken to ensure that the impact of access points and other infrastructure are limited.

Site BD promotes lateral flow. Most rain water support the terrestrial ecosystem. In this case underground mining activities are unlikely to impact the hydrological behaviour significantly. Care must however be taken to ensure that the impact of access points and other infrastructure are limited.

In site BG water passing the root zone causes saturation in the deep subsoil which indicate that the underlying bedrock is relatively impermeable or the depth to the permeable rock is near the subsoil, which promotes lateral flow underneath and in the subsoil causing a fluctuating water table. In this case underground mining activities are unlikely to impact the hydrological behaviour significantly. Care must however be taken to ensure that the impact of access points and other infrastructure are limited.

**Impact**

The operational impact of open pit mining on the three sites is ‘high’ (The impact of underground mining is ‘low’. Shallow flow paths dominate the hillslopes, yet all have flow and storage mechanisms maintaining wetlands. Shallow interflow down to the midslope, feed terrestrial ecosystems and disturbance of these flowpaths will not significantly affect wetlands. A lack of shallow flow paths in this area, however, indicates deep flowpaths. All flowpaths may meet in the valley bottom. These flowpaths feed wetlands and should be protected. Water stored for the wetlands are typical in the deep rock fractures.

**Mitigation**

The role of the vadose zone (unsaturated) in hillslope hydrology has been neglected. The result is deteriorated wetlands related to mining. The role of the vadose zone should be supported by identifying flow paths feeding wetlands. Water following recharge, deep flow and controlled release to wetlands to keep it wet, needs to be quantified. Surface and subsurface water application to recharge areas of the landscape should be developed.
REFERENCES


LAND TYPE SURVEY STAFF (1972-2006). 1:250 000 scale Land Type Survey of South Africa. ARC-Institute for Soil, Climate and Water, Pretoria.


<table>
<thead>
<tr>
<th>Affected Environment</th>
<th>Activity</th>
<th>Impact Description</th>
<th>Magnitude</th>
<th>Duration</th>
<th>Spatial Scale</th>
<th>Consequence</th>
<th>Probability</th>
<th>Mitigation Measure</th>
<th>Recovery Period</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydropedology</td>
<td>Open pit mining</td>
<td>Alteration of hydrogeological flowpaths which can negatively impact terrestrial soil based ecosystems as well as plant populations or animal interactions</td>
<td>Major - Long Term &gt; 5 years Regional</td>
<td>High</td>
<td>Definite</td>
<td>Yes</td>
<td>Low</td>
<td>Whitewash</td>
<td>Long Term &gt; 5 years</td>
<td>Site or Local</td>
</tr>
<tr>
<td>Hydropedology</td>
<td>Underground mining</td>
<td>Alteration of hydrogeological flowpaths which can negatively impact terrestrial soil based ecosystems as well as plant populations or animal interactions</td>
<td>Minor - Long Term &gt; 5 years Local</td>
<td>High</td>
<td>Definite</td>
<td>Yes</td>
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<td>Whitewash</td>
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<td>Minor - Long Term &gt; 5 years Regional</td>
<td>High</td>
<td>Definite</td>
<td>Yes</td>
<td>Low</td>
<td>Whitewash</td>
<td>Long Term &gt; 5 years</td>
<td>Site or Local</td>
</tr>
</tbody>
</table>

**Mitigation Measures / Recovery Periods**

- Whitewash - Long Term > 5 years, Site or Local
- Whitewash - Long Term > 5 years, Site or Local
- Whitewash - Long Term > 5 years, Site or Local

**Verification**

- Site or Local
- Site or Local
- Site or Local

**Environment**

- Site or Local
- Site or Local
- Site or Local

**Probability**

- Low
- Low
- Low

**Consequence**

- Site or Local
- Site or Local
- Site or Local

**Magnitude**

- High
- High
- High

**Duration**

- Long Term > 5 years
- Long Term > 5 years
- Long Term > 5 years

**Spatial Scale**

- Regional
- Regional
- Regional

**Activity**

- Open pit mining
- Underground mining