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**30 October 2013**

**SPECIALIST STUDY: SOIL CLASSIFICATION AND LAND CAPABILITY: ENVIRONMENTAL STUDY FOR THE GREATER SOUTPANSBERG PROJECT: MOPANE - RFQ NO: GSP-RFQ-004**

Attached please find the final Soil and land capability report for the Mopane Project.

Yours sincerely

………………………………
**Setenane Nkopane**
**For Gudani/Eco Soil Consortium**

…………………………………………
**Francois Botha**
**for Gudani/Eco Soil Consortium**

# Final Soil Specialist Report on the Environmental Study for the Greater Soutpansberg Project: MOPANE

## RFQ No: GSP-RFQ-004

**Compiled**

**By**


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**Report by F. Botha and A. M. Hattingh**
**Report Reviewed by: S. Nkopane**


**October 2013**

**STATEMENT OF INDEPENDANCE AND PROFESSIONAL AFFILIATION**

We, the undersigned, hereby declare that we are not involved in any way with Coal of Africa Limited.

We conducted this survey in a scientific and impartial manner and declare that the findings of this report is free from influence or prejudice.

………………………………

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Date: 2013/10/28

# EXECUTIVE SUMMARY

Coal of Africa Limited (CoAL) requested a detailed EIA study for the proposed opencast mining operations at the Greater Soutpansberg: MOPANE.

According to the parent material map the study area has Amphibolite, Serpentine, Granulite, Siliciclastic rocks, Marble and calc-silicate rocks as parent material (Figure 1) which has an influence on soil properties of the area. According to the 1:250 000 land types map the seven specific ecotopes for the area under investigation are mainly red to yellow apedal soils, as well as shallow Glenrosa/Mispah soils and Rocky areas (Figure 2).

The topography of the area varies between level plains to a rolling landscape with slopes of 2-3% (largest parts of the area), open high hills or ridges, as well as high hills and ridges (Small areas in the south western parts of the area).

The climate of the area is typified by warm to hot summers with low rainfall and high evaporation and dry warm winters. An assessment of the long-term rainfall records, indicate a mean annual rainfall of between 259-364mm within the study area.

- A number of farms were not surveyed due to accessibility problems. The Land Capability of areas not surveyed in this study, were extrapolated from previous land type and land capability data obtained from Dept Agriculture and Fisheries (2013) and presented in Figure 6. The information in Figure 6 can be used for areas not surveyed during this survey. The accuracy of these extrapolations is, however, questionable considering the scale at which the data was generated.

- The soil investigation on the proposed area was done with a soil auger on a grid system (1observation/9ha for the footprint and 1observation/25ha for the mining right area). The soils were classified according to the SA Taxonomic system. Soils were then grouped into soil associations with the same physical characteristics e.g. colour, texture, and depth.

- A combination of variables, which include topography, climate and water quality were then used to obtain land capability for the surveyed area according the Chamber of Mines Classification (Table 3). The results are illustrated in Figure 13.

- The agricultural potential of the soils were classified according to Klingebiel and Montgomery (1961) (Table 4a and 4b).

- From Table 10 it can be concluded that most of the farms are largely covered by grazing and wilderness areas (total 16605 of the approximate 21246ha) according to the Mining classification.

    - Less than 4000ha is classified as arable soils according to the mining classification. These soils are therefore classified as low agricultural potential soils and are recommended for grazing and pasture purposes. Footprint areas are generally covered by soils with a wilderness and grazing classification. The farms Voorburg, Cohen, Pretorius and Banff have significant areas of arable soils. However, the potential of these arable soils are classified as class IV to Vll as discussed in point 8.4.1.4 and 8.4.2.
    - Although there are areas of deep soils, these soils are sub optimal for crop production due to climatic and erosion restrictions. As a result of low rainfall, high temperatures (high evapotranspiration), susceptibility to soil compaction, present erosion and erodibility potential, the soils in the area study are not recommended for rain fed crop production.
    - Fields presently used for irrigation are susceptible to salinity and sodicity due to poor water quality with high chloride values. If a water source with high quality can be used for irrigation, the 4000ha classified as arable land can be utilised for crop production under irrigation.
    - Water quality of this area is presently poor for irrigation purposes. However, water samples were taken during the winter and it is recommended to make a continual assessment during the year. Only after a continual assessment a final decision could be made for the evaluation of the quality of water for irrigation.

- Shallow soils and surface rock are dominant in very large areas. Areas classified for grazing have presently low basal grass cover and are dominated by Mopane shrub field and will be discussed in detail by the biodiversity report. Present land use of these shallow soils is cattle and game farming, but carrying capacity is questionable due to poor physical soil quality (erosion susceptibility, shallow soils, surface rock and poor climatic conditions).

- Approximately 706ha was identified as wetland and should be evaluated separately. In this study area the following criteria was used:

    - Riparian zones were not delineated, and only wetland soil parameters per definition were used.
    - Based on the grid during the soil survey not all small farm dams and pans that fell between two observation points were mapped.
    - Many of the drainage lines are actually erosion dongas and gullies with Oakleaf, Augrabies, Glenrosa and Coega soil forms and cannot be regarded as wetlands soils per definition.
    - Only large water bodies on Jutland and Verdun were found.

- Overall these soils have a low agricultural potential and any disturbance of such a magnitude will have a long term to permanent impact on the land capability and agricultural soil potential (Special measures must be implemented in the soil stripping and rehabilitation process to restore the soils to an arable and grazing potential (see Appendix). Specialist consultation is needed for the severe erosion potential of the area during stock piling and the soil stripping process.

- If mining should be allowed in the area the following is recommended:
    - Specialist consultation is needed for the severe erosion potential and other possible impacts of the area during stock piling and the soil stripping process.
    - Limit impacts to footprint areas to keep physical impacts as small as possible.
    - Specific control measures are needed to control erosion and water run-off to prevent excessive surface run-off from the site.
    - Areas for road and site lay-out should be minimized.
    - Dust generation and vehicle associated pollution must be minimized.

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## GLOSSARY OF TERMINOLOGY

- **A-Horizon (30)**. The depth of the topsoil horizon.
- **B-Horizon (100)**. The bottom end of the sub-soil horizon.
- **W** - Wetness in the soil. This is an indication of drainage problems.
- **W1** – Temporary wetness in the sub-soil. Slight mottling occurs in the sub-soil.
- **W2** – Soil has a bleached / greyish colour with stronger mottling. Indication of serious water logging for longer periods of the year.
- **W3** – Permanent water logging for most parts of the year. Dark grey soil matrix with serious mottling. Free water visible in profile pit.
- **G** – The percentage (G3 = 30%) of gravel soil (>2mm) in the total soil profile. This portion has a huge influence on the water holding capacity and water movement (permeability) in the soil.
- **R** – The percentage of rocks in the profile. This has an influence on land preparation as well as the water holding capacity of the soil.
- **Limiting layer:** It can be rock fragments, soil structure or hydromorphic soil conditions that can limit root development.
- **Total available moisture (TAM)** – It is a calculation between the AWC multiplied with the effective rooting depth (ERD). TAM values are therefore the most important value to determine from an irrigation design and scheduling perspective. It is also mentioned as profile available water (PAW)
- **Effective rooting depth (ERD)**. This is the average depth that roots will develop under irrigation or where they are limited by an impeding layer. The effective rooting depth is the most important from a management perspective, which includes irrigation design, water holding capacity, drainage and nutrition.
- **Topsoil**: Is defined as the A Horizon and a portion of the red and yellow apedal B Horizon where microbial activity takes place and the majority of the plants hair roots occur.
- **Soil Forms:** Soil Forms are identified according to the SA Taxonomic Soil Classification system
- **Kriging or kriged:** A group of geostatistical techniques to interpolate the value of

a random attribute (e.g., depth or clay content, of the landscape as a function of the geographic location) at an unobserved location from observations of its value at nearby locations.

## 1. TERMS OF REFERENCE (ToR)

The ToR for the soil assessment is outlined as follows:

To perform the necessary soil impact assessment required to support the applications. It should include (as a minimum):

- Detail soil, land use and land capability mapping
- Potential impact and quantification thereof (as far as possible) on soils, land use and land capability
- Recommendations for mitigation measures to reduce the identified impacts
- Conceptual rehabilitation plan based on soil types - no soil utilisation plan required at this stage due to limited information on infrastructure and mining footprints

The following sampling intensity to be used:

- Larger MRA area - Broad Reconnaissance (500m grid, 1 observation per 25 ha)
- Resource footprint - Intensified Reconnaissance (300m grid, 1 observation per 9 ha).

## 2. INTRODUCTION

A broad soil classification, chemical composition and agricultural potential were done on approximately 21246ha (4600ha footprint area) to get baseline information regarding soil potential, land use and land capability.

Profile pits could not be opened due to limitations with access and time constraints, as land owners are hosting hunters in the peak hunting season.

The soil investigation on the proposed area was done with a soil auger on a grid system. Applying these criteria where possible to soils that were mapped based on the limitations of the soils' chemical and physical characteristics and site constraints. A combination of these variables was then used to obtain the land capability and agricultural potential of the soils.

Soils were classified in terms of the Taxonomic System for South Africa. Land capability of the study area was classified into four classes (wetland, arable land, grazing land and wilderness) according to Coaltech 2020/ Chamber of Mines of SA 2007 and Chamber of Mines Guidelines (1991).

The following farms were fully surveyed on the recommended grid:

Ancaster
BANFF
Cavan
Cohen
Delft
Du Toit
Faure
Hermanus
Honeymoon
Jutland
Pretorius
Vd Byl
Vera Small holdings
Verdun
Voorburg
Vrienden

The following farms were partly surveyed:

Vera

Ancaster

No soil surveys were done on the following farms:

- Ancaster (North of Sand River)
- Krige
- Bierman
- Mons
- Schalk
- Stubbs
- Ursa Minor
- Scheveningen

## 3. GENERAL BACKGROUND INVESTIGATION

### 3.1 PARENT MATERIALS

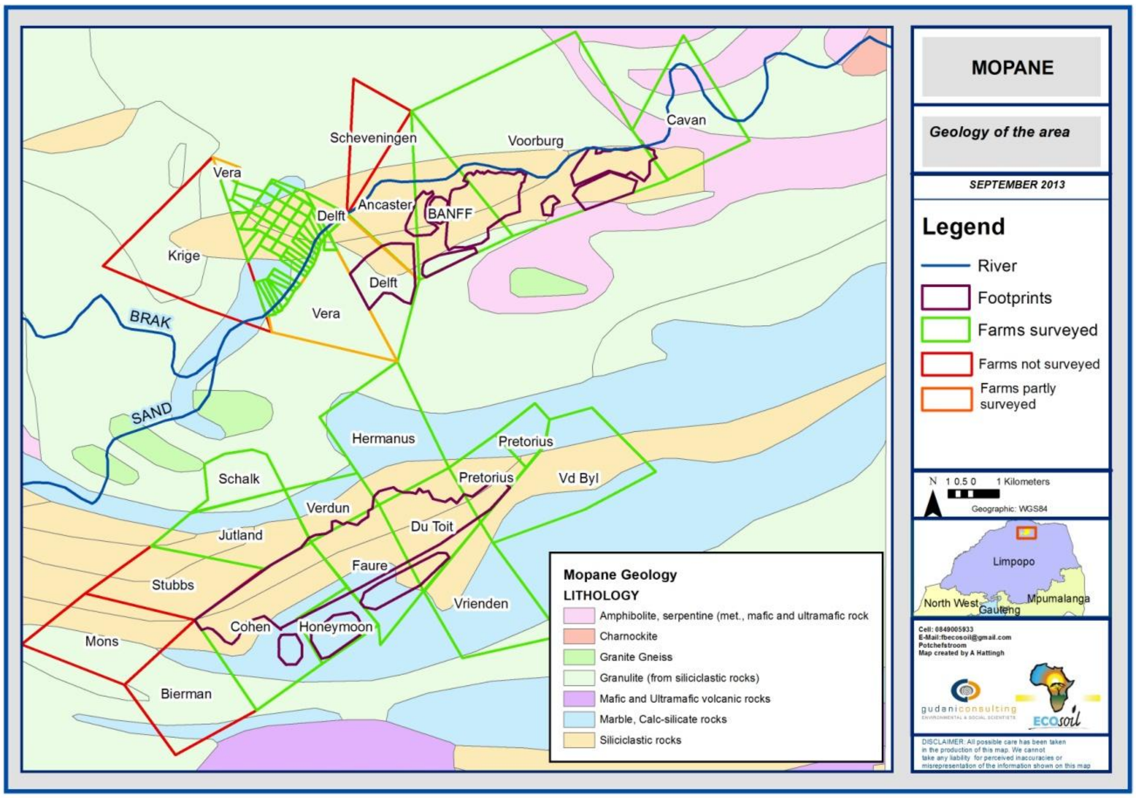
The regional parent materials of the area are illustrated in Figure 1. The following materials are found in the area and may have an influence on the soil properties.

- Amphibolite, serpentine (mafic and ultramafic rock) of the Messina stratification, Beit Bridge Complex. It is igneous rock with polycyclic deformation.
- Granulite (from siliciclastic rock) is metamorphic rock from the Malala Drift or Mount Dowe Group, Beit Bridge Complex with polycyclic deformation.
- Marble, calc-silicate rocks are metamorphic rocks of the Gumbu Group, Beit Bridge Complex with polycyclic deformation
- Siliciclastic rocks are sedimentary rocks of the Solitude or Clarens Formation, Karoo supergroup.
- Chamokite - found in the area but not present on the farms under investigation
- Granite Gneiss- found in the area but not present on the farms under investigation

- Mafic and ultramafic volcanic rocks- found in the area but not present on the farms under investigation

Footprints are mainly on Siliciclastic rocks and the southern footprints are on marble, calc-silicate rocks.

**Figure 1: Parent materials of the study area**




## 3.2 LANDTYPES

Seven land types are found in the study area (Figure 2). Land types found in the study area, in the ranking order of area covered, are:

### 3.2.1 Ah89:

- Red-yellow apedal, freely drained soils. Red and yellow colours, high base status, usually < 15% clay.

- The majority of the area namely 15058ha falls within this class.
- Parent material is: Beit bridge complex, Malala drift formation; leucogneiss, metaquartzite, and amphibolite; gumbu gneiss, marble, gneiss; metaquartzite and amphibolite.
- Soil depth:  450mm - 750mm.
- Profile available water (PAW) content is between 41 - 60 mm, indicating low potential soils.

### 3.2.2 Ae266:

- Red-yellow apedal, freely drained soils. High base status > 300 mm deep (no dunes).
- 1378ha.
- Parent material is: Bulai gneiss and metaquartzite, gneiss and amphibolite of the Beit Bridge complex.
- Soil depth:  450mm - 750mm.
- Profile available water (PAW) content is between 41 - 60 mm, indicating low potential soils.

### 3.2.3 Fc483:

- Glenrosa and/or Mispah forms (other soils may occur). Lime generally present in the entire landscape.
- 1277ha.
- Parent material is: metaquartzite, magnetite quartzite, amphibolite and metapelite of the Mount dowe group, Beit Bridge complex; migmatite grey and leucocratic pyroxene-bearing gneiss of the Sand river gneiss.
- Soil depth:  450mm - 750mm.
- Profile available water (PAW) content is between 21 - 40 mm indicating very low potential soils.

### 3.2.4 Fc574:

- Glenrosa and/or Mispah forms (other soils may occur). Lime generally present in the entire landscape.

- 948ha.
- Parent material is: basalt of the Letaba formation in the Lebombo group - Karoo sequence. leucogneiss, amphibolite, metapelite of the Malala drift group.
- Soil depth: 450mm - 750mm.
- Profile available water (PAW) content is between 21 - 40 mm indicating very low potential soils.

### 3.2.5 IB312:

- Rocky areas with miscellaneous soils.
- 804ha.
- Parent material is: quartzite, conglomerate, sandstone and shale of the Stayt formation, Soutpansberg group; argillaceous sandstone of the Clarens formation, Karoo sequence.
- Soil depth: < 450mm.
- Profile available water (PAW) content is between 21 - 40 mm indicating very low potential soils.

### 3.2.6 Fa 646:

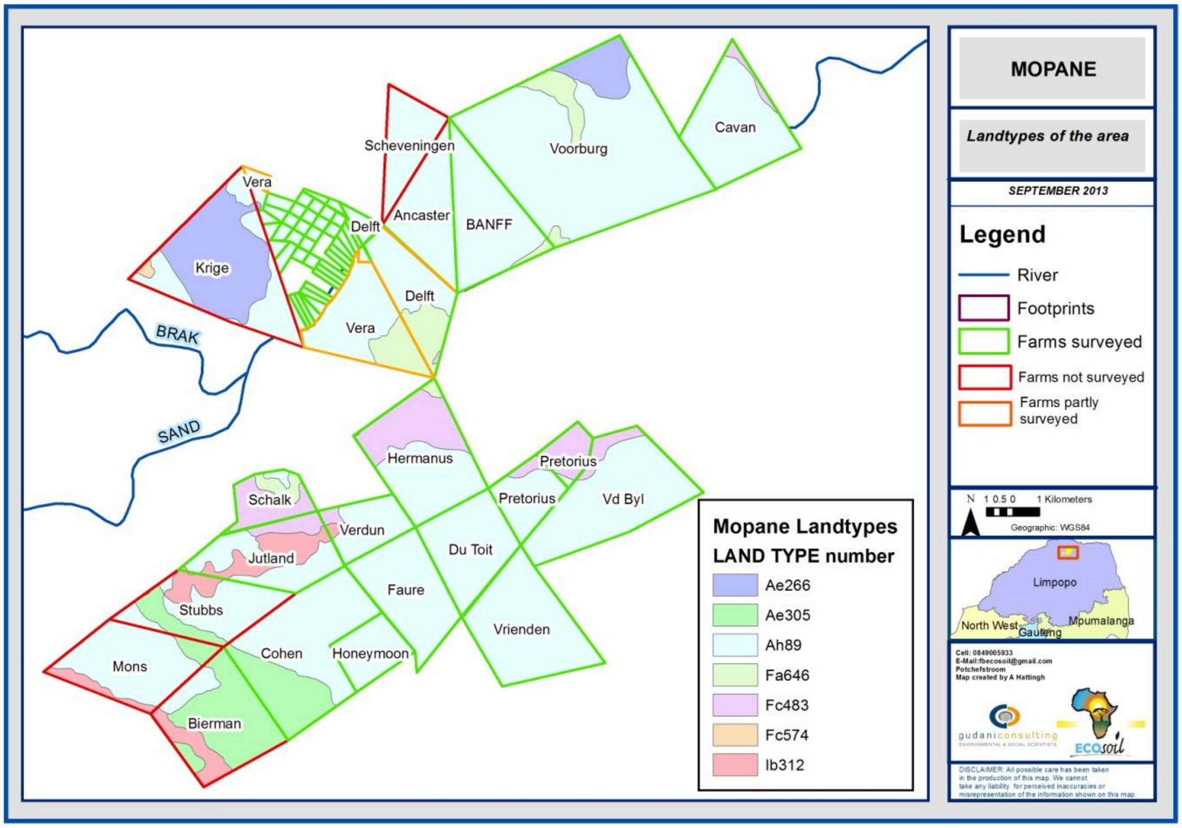
- Glenrosa and/or Mispah forms (other soils may occur). Lime rare or absent in the entire landscape.
- 602Ha.
- Parent material is: metaquartzite, leucogneiss and pink gneiss of the Mount Dowe group and Beit Bridge complex.
- Soil depth: < 450mm.
- Profile available water (PAW) content is between 21 - 40 mm indicating very low potential soils.

### 3.2.7 Ae305:

- Red-yellow apedal, freely drained soils. red, high base status > 300 mm deep (no dunes).
- 587ha.

- Parent material is: mainly sand of the quaternary system.
- Soil depth: >750mm.
- Profile available water (PAW) content is between 41 - 60 mm, indicating low potential soils.

**Figure 2: Land-types of the study area**




## 3.3 TOPOGRAPHY

Topography of the area is illustrated in Figure 3. Terrain types are illustrated in Figure 4.

The demarcated study exists of four terrain types:

- Rolling or irregular plains with some relief (largest parts of the area)
- Open high hills or ridges (mainly in the central parts of the study area)
- Level plains with some relief
- High hills or ridges (Small areas in the south western parts of the area)

**Figure 3: Topography of the demarcated study area**

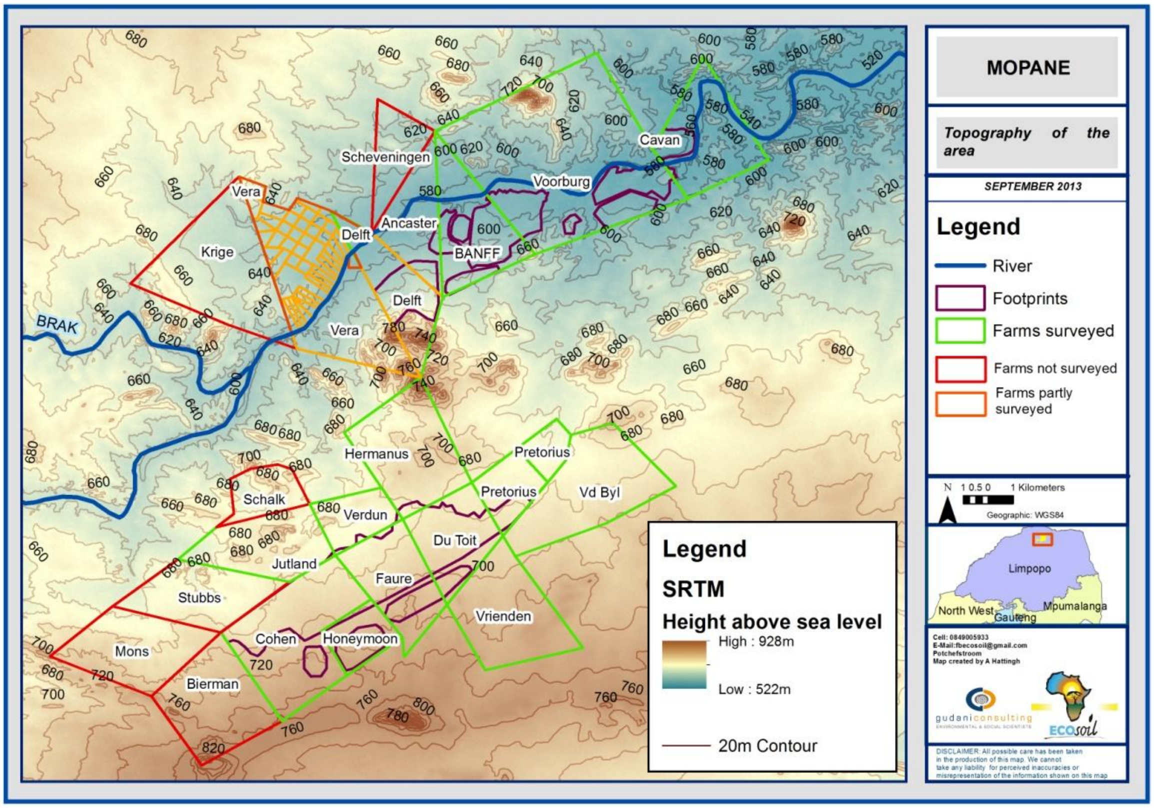
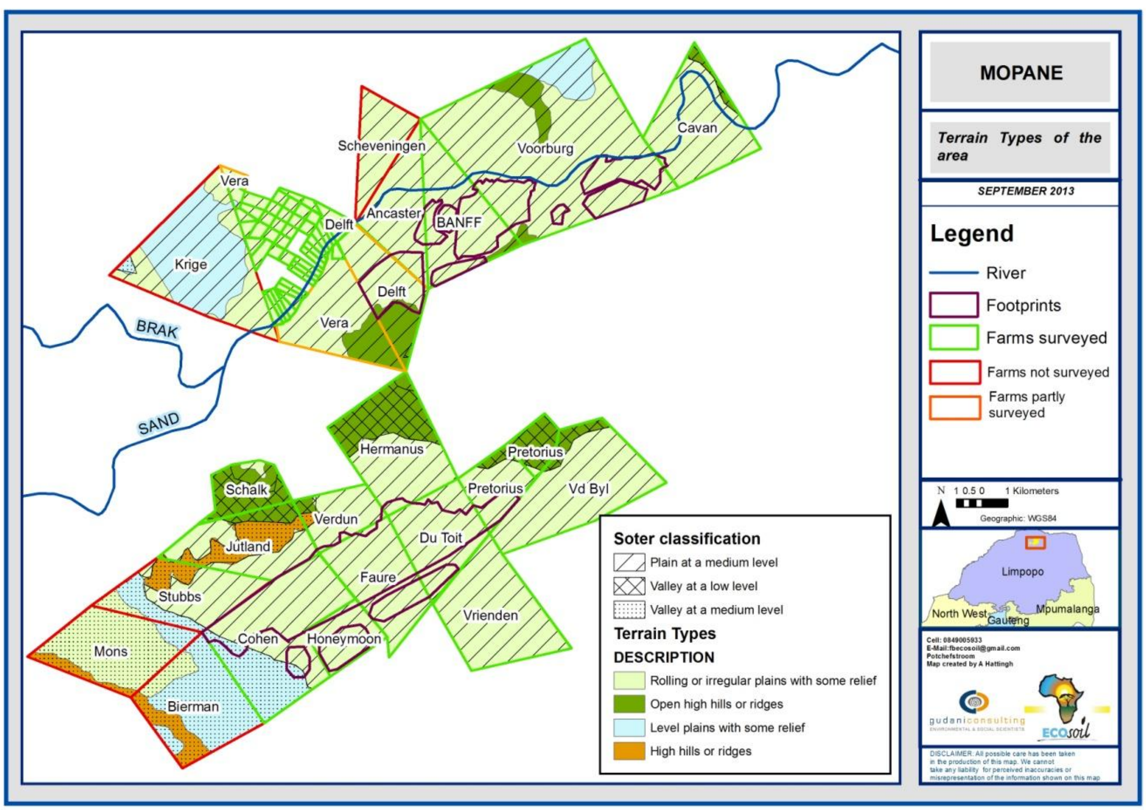



**Figure 4: Terrain types of the demarcated study area**



## 3.4 CLIMATE

The climate of the area is typified by warm to hot summers with low rainfall and high evaporation and dry warm winters.

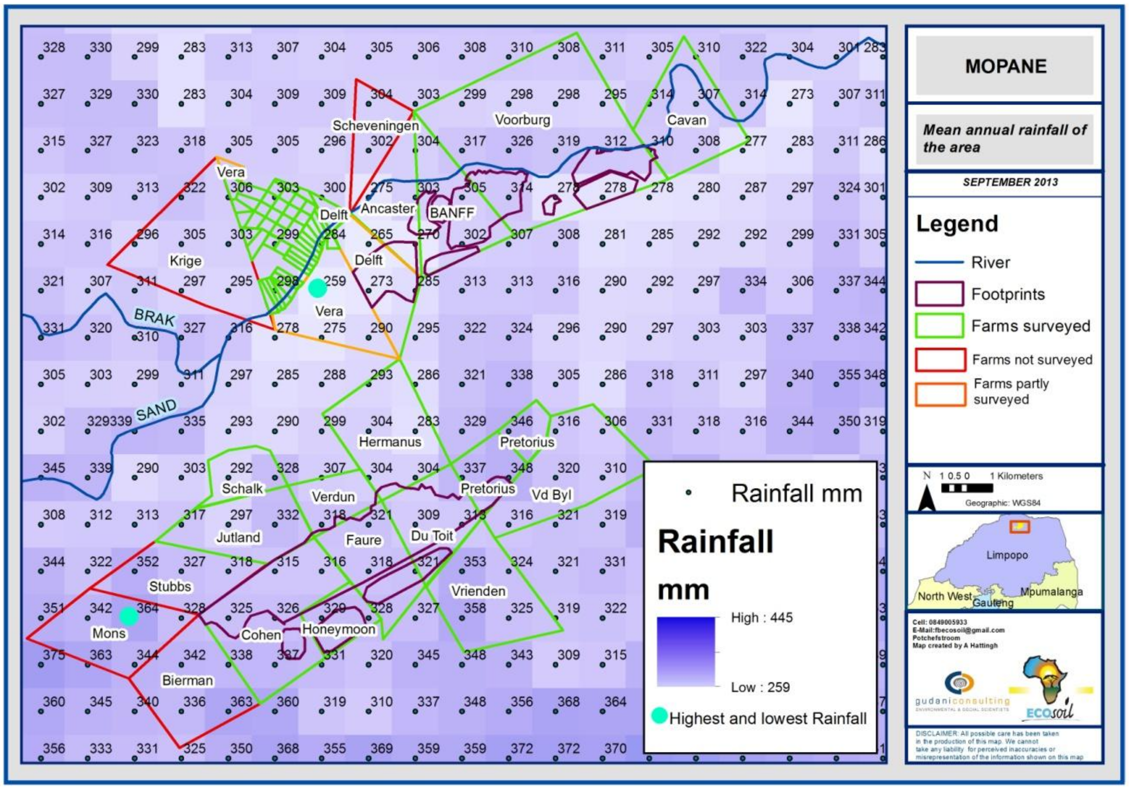
An assessment of the long-term rainfall records, indicate a mean annual rainfall of between 259-364mm within the study area. Highest mean annual rainfall and lowest temperatures are found in the area of the farm Mons and Bierman in the western part and lowest rainfall and highest temperatures in the area of Vera in the central parts of the study area. Precipitation is strongly seasonal with about 85% of the yearly rainfall falling in the summer months (October to March). Monthly statistics are given in Table 1.

**Table 1: Mean monthly rainfall, maximum and minimum temperatures**

| Month | Mean Rainfall mm | Mean Maximum Temperatures C$^o$ | Mean Minimum Temperatures C$^o$ |
|---|---|---|---|
| **January** | 43-62 | 30.4-32.4 | 19.0-20.4 |
| **February** | 36-49 | 29.8-31.6 | 18.8-20.2 |
| **March** | 18-29 | 29.1-30.7 | 17.6-18.9 |
| **April** | 10-16 | 27.3-29.0 | 14.7-15.7 |
| **May** | 0-2 | 25.3-27.0 | 10.3-11.3 |
| **June** | 0 | 22.7-24.2 | 6.9-8.1 |
| **July** | 0 | 22.7-24.2 | 6.7-7.9 |
| **August** | 0 | 24.8-26.3 | 8.9-9.9 |
| **September** | 0-2 | 27.0-28.6 | 12.5-13.5 |
| **October** | 11-17 | 28.7-30.2 | 15.7-16.7 |
| **November** | 29-43 | 29.8-31.5 | 17.4-18.8 |
| **December** | 37-51 | 30.1-31.8 | 18.5-19.9 |

The Area falls mainly in two Quaternary Water Catchment areas. The eastern and north eastern parts fall in A71K and the south-western parts in A71J.

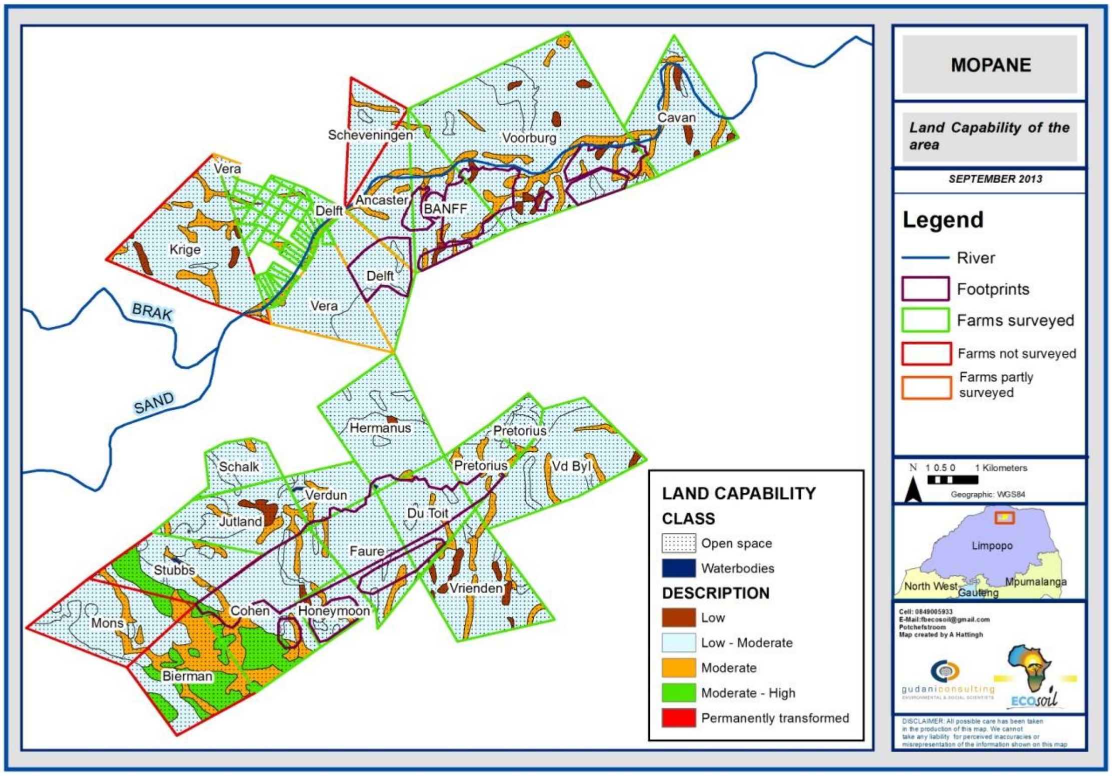
**Figure 5: Mean annual rainfall of the demarcated study area**




## 3.5 LAND CAPABILITY

Historic land capability was derived from the ENPAT data base and the Dept. of Agriculture and Fisheries data (2013). Land capability for areas not surveyed during this study can be derived from Figure 6. The accuracy of these extrapolations is questionable considering the scale at which the data was generated and should only be used in areas not surveyed.

**Figure 6: Land capability as per historic data**

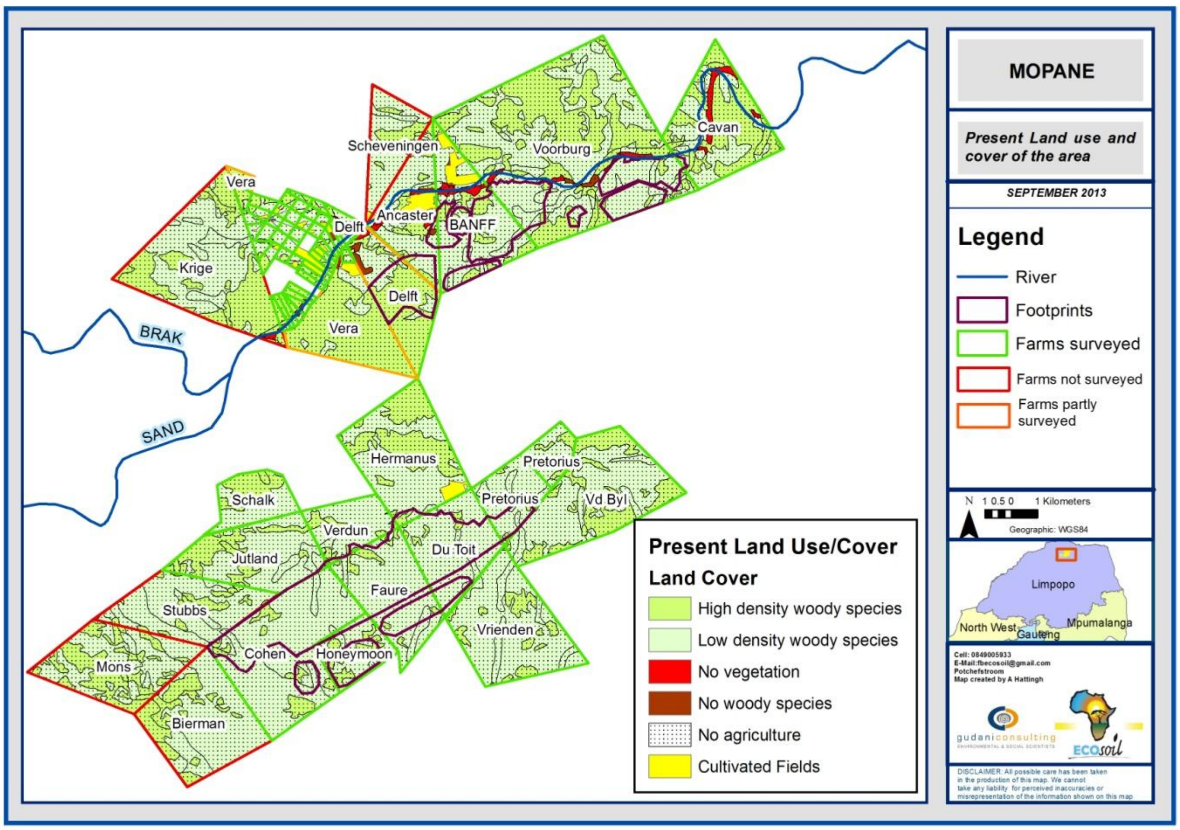



## 3.6 PRESENT LAND USE AND POTENTIAL

- There is arable crop production (predominantly vegetables) under irrigation taking place in small areas along the floodplains of the Sand River as indicated in yellow in Figure 7.
- The majority of area is presently covered with low density woody species and used for grazing purposes for either cattle or game farming.
- In the higher lying areas large areas are largely covered with high density woody species, especially on the farms Vera, Delft, northern Hermanus, Voorburg and Cavan. However, these high density woody species are present on almost all farms.
- There are significant areas on Banff, Voorburg, Delft, Cavan, Verdun, Jutland and Cohen that has no or very scarce basal cover. This leads to severe rill and sheet erosion.

- Approximately 360ha are presently under crop production. The majority of the fields are on the flood plains of the Sand River.
- According to previous studies the following land use of the total study area (including the non-surveyed areas) were found:
    - Commercial (or cleared) land: 360ha. (289 ha irrigated and 71ha dry land)
    - Degraded: Thicket and Bushland: 155ha.
    - Thicket and Bushland: 25340 ha (Vacant or unspecified)
    - Woodlands:  755ha

**Figure 7: Present land cover of the demarcated study area**



## 4. PROBLEM STATEMENT AND STUDY OBJECTIVE

The soils occurring on the proposed development area will be disturbed during the mining operation. Any medium to long-term impacts after mining needs to be limited. The purpose of this study is to identify the present soil quality in terms of soil forms, as well as their physical and chemical characteristics and how they will react to any disturbance.

## 5. PROJECT TEAM

**Table 2: List of the team members**

| SPECIALISTS | FUNCTION | QUALIFICATION |
|---|---|---|
| S. Nkopane | Project Management, Liaison and communication | M.Sc, Environmental Management |
| F Botha | Soils project leader | B.Sc (Honn) |
| A.M. Hattingh | Pedologist, GIS Specialist | M.Sc (Soil Science) |
| J.M. Hattingh | Pedologist, Soil Chemist | M.Sc (Engineering geology) |
| J.L. Pauer | Pedologist | B.Sc (Honn) |
| JHA Thiart | Pedologist | Soil Pedology Technician |
| MJ Botha | Pedologist | Soil Pedology Technician |

## 6. IDENTIFICATION OF RELEVANT LEGAL REQUIREMENTS AND GUIDELINES

A soil classification and agricultural potential study is required with every EIA where agricultural land is concerned.

## 7. INVESTIGATIVE METHODOLOGY AND TECHNIQUES

The investigation commenced conducting the following actions:

- The collation and evaluation of available information.
- A soil survey was conducted on a total area of approximately 21 246ha during this study.
- The soil survey involved the traversing of the area on a grid base using a conventional bucket hand auger (1.5 m in length) to investigate and log the soil

depths. More than 1200 points were logged (Figure 8). Selected terrain information, topography and any other infield data of significance, and of relevance to the investigation, was used.

- The land capability of the study area was classified according to soil depth and PAW, as well as the elevation of the area. Observation point data was transformed with a process called kriging to a 100 by 100meter grid. On this grid basis it was decided upon the 4 represented land use groups: arable land, grazing, wilderness or wetland. Wetlands were first delineated and polygons for the other groupings were then drawn from the kriged data. Detached areas smaller than one hectare was ignored.
- PAW was calculated by using soil form, soil depth and clay content.
- The data was recorded and stored in an electronic format (data base), and the information was then mapped with the ArcGIS program (See Figures 1 to Figure 13). Figures were created based on GPS information (Geographic: WGS 84). The field information was used to determine the Land Potential.
- Forty six soil samples (Figure 8) were taken for chemical analysis.
- At each sampling point three soil samples were taken to a depth of 30cm. These three samples were then mixed thoroughly to get a composite representative sample for the area.
- The soil samples were sent to NVirotek Laboratory at Brits (South Africa) for analyses.
- pH (KCl), P (Bray 1), K, Ca, Mg Na and S (ammonium acetate) were determined. Ratios, CEC and percentages were calculated from the soil analyses.
- The chemical results were recorded and stored in an electronic format (data base). The information was then summarized in Table 6.
- Three water samples were analysed at Eco Analitica laboratory (Potchefstroom) for irrigation purposes. Results are summarized in Table 7.

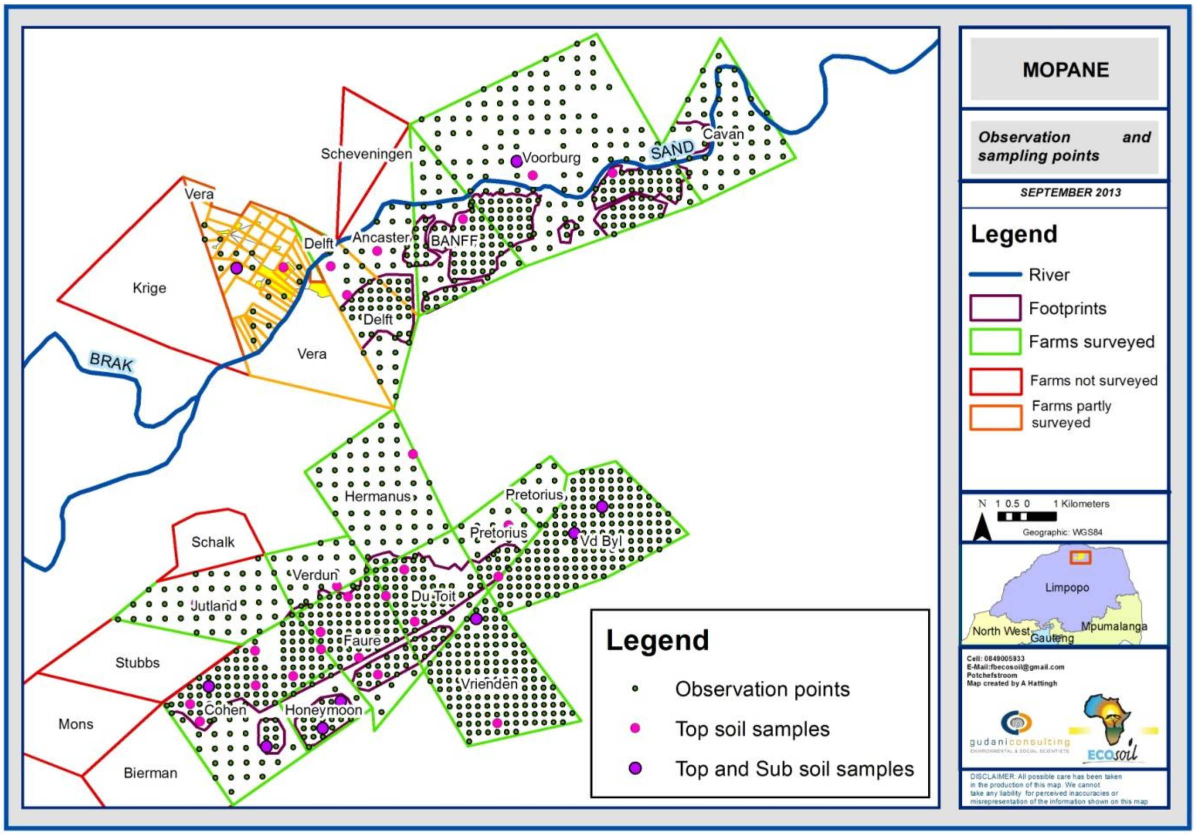
## 7.1 SOIL CLASSIFICATION

The investigation of the soils involved the traversing of the area on a grid base where possible, using a conventional bucket auger to investigate and log the soil characteristics. The following sampling intensity was used:

- Larger MRA area - Broad Reconnaissance (500m grid, 1 observation per 25 ha).
- Resource footprint - Intensified Reconnaissance (300m grid, 1 observation per 9 ha).

It was not possible to open profile pits due to restraints in terms of accessibility and time. Selected terrain information, topography and other infield data of significance, and of relevance to the soil investigation, was also recorded and stored in an electronic format (data base), and the information mapped on a recognised GIS system. Soil samples were taken for chemical analysis (Figure 8).

**Figure 8: Observation and soil sampling points**




The identification and classification of the soil profiles was carried out using the TAXONOMIC SYSTEM FOR SOUTH AFRICA (*Soil Classification working group, 1991*). The land capability of the study area was classified into four classes (wetland, arable land, grazing land and wilderness) according to Coaltech 2020/Chamber of Mines of SA (2007) and Chamber of Mines Guidelines (1991).

In this way, standardised soil identification and communication is allowed by use of the names and numbers given to the soils classified. The procedure adopted when classifying the soil profiles is as follows:

a. Demarcate master horizons
b. Identify applicable diagnostic horizons by visually noting the physical characteristics such as:
   - Depth
   - Texture
   - Structure
   - Mottling

- Visible pores
- Concretions

c. Determine from a. and b. the appropriate Soil Form

## 7.2 INFORMATION SYSTEMS

The following sources of information were utilized:

- Initial maps supplied by Jacana
- Preliminary site layout plans
- ENPAT: Geology, Land use land capability, Land use, Land types
- Topo maps:
  - 2229DA Bandur,
  - 2229DB Mopane
- Climate: Rasters University of Natal
- Remote sensing information:
  - SRTM data
  - *Google Earth*™ image; digital image - Background and cultivated fields
- Esri shapefile information, ArcGIS.
- The Dept of Agriculture's website (Agis) was used to determine the land types.
- The Taxonomic system for South Africa was used to identify the soil forms on the proposed site.
- Land Capability Classification Coaltech 2020/ Chamber of Mines of SA (2007) and Chamber of Mines Guidelines (1991).

## 7.3 LAND CAPABILITY AND AGRICULTURAL RATING

The land capability of the study area was classified into four classes (wetland, arable land, grazing land and wilderness) according to the Chamber of Mines Guidelines (1991).

**Table 3: Criteria for Pre-Development Land Capability**

**Criteria for Wetland**

- Land with organic soils or supporting hygrophilous vegetation where soil and vegetation processes are water determined.

**Criteria for Arable land**

- Land, which does not qualify as a wetland.
- The soil is readily permeable to a depth of 750 mm.
- The soil has a pH value of between 4.0 and 8.4.
- The soil has a low salinity and SAR
- The soil has less than 10% (by volume) rocks or pedocrete fragments larger than 100 mm in the upper 750 mm.
- Has a slope (in %) and erodibility factor (K) such that their product is <2.0
- Occurs under a climate of crop yields that are at least equal to the current national average for these crops.

**Criteria for Grazing land**

- Land, which does not qualify as wetland or arable land.
- Has soil, or soil-like material, permeable to roots of native plants, that is more than 250 mm thick and contains less than 50 % by volume of rocks or pedocrete fragments larger than 100 mm.
- Supports, or is capable of supporting, a stand of native or introduced grass species, or other forage plants utilisable by domesticated livestock or game animals on a commercial basis.

**Criteria for Wilderness land**

- Land, which does not qualify as wetland, arable land or grazing land.

## 7.4 LAND USE AND AGRICULTURAL POTENTIAL FORMS

The original concepts (Klingebiel & Montgomery, 1961) are as follows:

**Table 4a: Land use classes suited for cultivation**

| **Land suited for cultivation** | |
|---|---|
| **Class I** | Land in Class I has few limitations that restrict its use. |
| | It may be used safely and profitably for cultivated crops. |
| | The soils are nearly level and deep. |
| | They hold water well and are generally well drained. |
| | They are easily worked, and are either fairly well supplied with plant nutrients or are highly responsive to inputs of fertilizer. |
| | When used for crops, the soils need ordinary management practices to maintain productivity. |
| | The climate is favourable for growing many of the common field crops. |
| **Class II** | Land in Class II have some limitations that reduce the choice of plants or require moderate conservation practices. |
| | It may be used for cultivated crops, but with less latitude in the choice of crops or management practices than Class I. |
| | The limitations are few and the practices are easy to apply. |
| | Limitations may include singly or in combination the effects of: |
| | *Gentle slopes. |
| | *Moderate susceptibility to wind and water erosion. |
| | *Less than ideal soil depth. |
| | *Somewhat unfavourable soil structure and workability. |
| | *Slight to moderate salinity or sodicity easily corrected but likely to recur. |
| | *Occasional damaging flooding. |
| | *Wetness correctable by drainage but existing permanently as a moderate limitation. |
| | *Slight climatic limitations on soil use and management. |
| | Limitations may cause special soil-conserving cropping systems, soil conservation practices, water-control devices or tillage methods to be required when used for cultivated crops. |
| | Note: "Slight to moderate salinity or sodicity, easily corrected, but likely to recur" is taken to imply that strong subsoil acidity, costly to correct and likely to recur, would disqualify land from Class II. |
| **Class III** | High susceptibility to water or wind erosion or severe adverse effects of past erosion. |
| | It may be used for cultivated crops, but has more restrictions than Class II. When used for cultivated crops, the conservation practices are usually more difficult to apply and to maintain. |
| | Limitations restrict, singly or in combination, the amount of clean cultivation, time of planting, tillage, harvesting, choice of crops. |
| | Limitations may result from the effects of one or more of the following: |
| | The number of practical alternatives for average farmers is less than that for soils in Class II. |
| | *Moderately steep slopes. |
| | *Frequent flooding accompanied by some crop damage. |
| | *Very slow permeability of the subsoil. |
| | *Wetness or some continuing waterlogging after drainage. |
| | *Shallow soil depth to bedrock, hardpan, fragipan or claypan that limit the rooting zone and the water storage. |
| | *Low water-holding capacity. |
| | *Low fertility not easily corrected. |
| | *Moderate salinity or sodicity. |
| | *Moderate climatic limitations. |
| | Note: "Severe limitations" and "Low fertility not easily corrected" are taken to imply that land dominated by soils with severe subsoil acidity belongs in Class III. |
| **Class IV** | Land in Class IV has very severe limitations that restrict the choice of plants, require very careful management, or both. |
| | It may be used for cultivated crops, but more careful management is required than for Class III and conservation practices are more difficult to apply and maintain. |
| | Restrictions to land use are greater than those in Class III and the choice of plants is more limited. |
| | It may be well suited to only two or three of the common crops or the harvest produced may be low in relation to inputs over long period of time. |
| | In sub-humid and semi-arid areas, land in Class IV may produce good yields of adapted cultivated crops during years of above average rainfall and failures during years of below average rainfall. |
| | Use for cultivated crops is limited as a result of the effects of one or more permanent features such as: |
| | *Steep slopes. |
| | *Severe susceptibility to water or wind erosion or severe effects of past erosion. |
| | *Shallow soils. |
| | *Low water-holding capacity. |
| | *Frequent flooding accompanied by severe crop damage |
| | *Excessive wetness with continuing hazard of waterlogging after drainage. |
| | *Severe salinity or sodicity. |
| | *Moderately adverse climate. |

## Table 4b: Land use classes not-suited for cultivation

| Land with limited use - generally not suited to cultivation | |
|---|---|
| **Class V** | Land in Class V has little or no erosion hazard but have other limitations impractical to remove that limit its use largely to pasture, range, woodland or wildlife food and cover. These limitations restrict the kind of plants that can be grown and prevent normal tillage of cultivated crops. Pastures can be improved and benefits from proper management can be expected. |
| | It is nearly level. Some occurrences are wet or frequently flooded. Other are stony, have climatic limitations, or have some combination of these limitations. |
| | *Bottomlands subject to frequent flooding that prevents the normal production of cultivated crops. |
| | *Nearly level land with a growing season that prevents the normal production of cultivated crops. |
| | *Level or nearly level stony or rocky land. |
| | *Ponded areas where drainage for cultivated crops is not feasible but is suitable for grasses or trees. |
| **Class VI** | Land in Class VI has severe limitations that make it generally unsuited to cultivation and limit its use largely to pasture and range, woodland or wildlife. |
| | Land in Class VI has continuing limitations that cannot be corrected, such as: |
| | *Steep slope. |
| | *Severe erosion hazard. |
| | *Effects of past erosion. |
| | *Stoniness. |
| | *Shallow rooting zone. |
| | *Excessive wetness or flooding. |
| | *Low water-holding capacity. |
| | *Salinity or sodicity. |
| | *Severe climate. |
| | Physical conditions are such that it is practical to apply range or pasture improvements, if needed, such as seeding, liming and fertilizing. |
| | Some occurrences can be safely used for the common crops, provided unusually intensive management is used. Some occurrences are adapted to special crops. |
| | Depending on soil features and climate, land in Class VI may be well to poorly suited to woodlands. |
| **Class VII** | Land in Class VII has very severe limitations that makes it unsuited to cultivation and that restrict its use largely to grazing, woodland or wildlife. |
| | Restrictions are more severe than those for Class VI because of one or more continuing limitations that cannot be corrected, such as: |
| | *Very steep slopes. |
| | *Erosion. |
| | *Shallow soil. |
| | *Stones. |
| | *Wet soil. |
| | *Salts or sodicity. |
| | *Unfavourable climate. |
| | Physical conditions are such that it is impractical to apply such pasture or range improvements as seeding, liming and fertilizing. |
| | Depending on soil characteristics and climate, land in Class VII may be well or poorly suited to woodland. |
| | In unusual instances some occurrences may be used for special crops under unusual management practices. |
| **Class VIII** | Land in Class VIII have limitations that preclude its use for commercial plant production and restrict its use to recreation, wildlife, water supply or aesthetic purposes |
| | Limitations that cannot be corrected may result from the effects of one or more of: |
| | *Erosion or erosion hazard. |
| | *Severe climate. |
| | *Wet soil. |
| | *Stones. |
| | *Low water-holding capacity. |
| | *Salinity or sodicity. |
| | Land in Class VIII cannot be expected to return significant on-site benefits from management for crops, grasses or trees, although benefits from wildlife use, watershed protection or recreation may be possible. |
| | Badlands, rock outcrop, sandy beaches, river wash, mine tailings and other nearly barren lands are included in Class VIII. |

**Table 5: Land capability classes to establish land use**

| LAND CAPABILITY CLASS | LAND USE OPTIONS | LAND CAPABILITY GROUPS |
|---|---|---|
| Class I | W F LG MG IG LC MC IC VIC | Arable land |
| Class II | W F LG MG IG LC MC IC | Arable land |
| Class III | W F LG MG IG LC MC | Arable land |
| Class IV | W F LG MG IG LC | Arable land |
| Class V | W F LG MG | Grazing |
| Class VI | W F LG MG | Grazing |
| Class VII | W F LG MG | Grazing |
| Class VIII | W | Wildlife |
| W - Wildlife LC - Poorly adapted cultivation | | |
| F - Forestry MC - Moderately well adapted cultivation | | |
| LG - Light grazing IC - Intensive, well adapted cultivation | | |
| MG - Moderate grazing VIC - Very intensive, well adapted cultivation | | |
| IG - Intensive grazing | | |
| IG - Intensive grazing | | |

# 8. FAO IRRIGATION WATER QUALITY GUIDELINES

**Table 6: Water quality guidelines used in this study**

| Potential irrigation problems | Units | Degree of restriction on use | | |
|---|---|---|---|---|
| | | None | Slight to moderate | Severe |
| **Salinity** (affects crop water availibility) | | | | |
| $EC_w$ | dS $m^{-1}$ | <0.7 | 0.7-3.0 | >3.0 |
| or TDS | mg $l^{-1}$ | <450 | 450-2000 | >2000 |
| **Infiltration** (affects infiltration rate of water into the soil; evaluate using Ecw and SAR together) | | | | |
| SAR 0-3 and ECw= | | >0.7 | 0.7-0.2 | <0.2 |
| SAR 3-6 and ECw= | | >1.2 | 1.2 -0.3 | <0.3 |
| SAR 6-12 and ECw= | | >1.9 | 1.9-0.5 | <0.5 |
| SAR 12-20 and ECw= | | >2.9 | 2.9-1.3 | <1.3 |
| SAR 20-40 and ECw= | | >5.0 | 5.0-2.9 | <2.9 |
| **Spesific ion toxicity** (effects sensitive crops) | | | | |
| **Sodium (Na)** | | | | |
| Surface irrigation | SAR | <3 | 3-9 | >9 |
| Sprinkler irrigation | meq $l^{-1}$ | <3 | >3 | |
| **Chloride (Cl)** | | | | |
| Surface irrigation | meq $l^{-1}$ | <4 | 4-10 | >10 |
| Sprinkler irrigation | meq $l^{-1}$ | <3 | >3 | |
| **Boron (B)** | mg $l^{-1}$ | <0.7 | 0.7-3.0 | >3.0 |
| **Miscellaneous effects** (on susceptible crops) | | | | |
| Nitrate $NO_3$-N | mg $l^{-1}$ | <5 | 5-30 | >30 |
| Bicarbonate $HCO_3^-$ (overhead sprinkling only) | meq $l^{-1}$ | <1.5 | 1.5-8.5 | >8.5 |
| pH | | Normal range 6.5 -8.4 | | |

# 9. OBSERVATIONS

## 9.1 SOIL FORMS

The soils vary significantly in physical and chemical composition over the different areas. They are strongly influenced by the underlying rocks (geology) from which they are derived, as well as by their position in the landscape and the origin of the parent material (*in-situ* versus colluvium derived).

The major soil forms that have generally the same characteristics were grouped together in soil associations. The associations occurring on the proposed development and the number of soil form occurrences (in brackets), are as follow:

### 9.1.1 RED APEDAL SOILS

- **Hutton (Hu) [327] soils:** Have an Orthic A-Horizon over a Red Apedal B

Horizon over unspecified materials, like hard or weathered rock, or gravel.

- **Plooysburg (Py) [9] and Kimberley Ky [4] soils:** Have an Orthic A-Horizon over a Red Apedal B Horizon over a hardpan- or soft carbonate horizon respectively.
- **Bloemdal (Bd) [1] soils:** Is similar to the Hutton soils from, but has signs of wetness in the subsoil.

The depth of the apedal red soils in this study area ranges between 50cm to deeper than 150cm (average 75cm). Clay content of the top soil is between 3 and 35% (mean 15%), and at 50cm the clay content varies between 3 and 45% (mean 22%).

### 9.1.2 YELLOW-BROWN APEDAL SOILS

- **Clovelly (Cv) [22] soils**: Have an Orthic A Horizon over a Yellow Brown Apedal B Horizon over unspecified materials, like hard or weathered rock, or gravel.
- **Askham (Ak) [1] soils: H**ave an Orthic A Horizon over a Yellow Brown Apedal B Horizon over hardpan carbonate.

The average depth of the apedal yellow soils in this study area ranges from 10-120cm with a mean of 62cm. They have a mean clay content of 14% (ranging between 5 and 30) in the top soil and 23% at 50cm depth (ranging from 5 to 50%) They are present on the mid- and foot-slopes.

### 9.1.3 NEOCUTANIC SOILS

- **Oakleaf (Oa) [105] soils:** Have an Orthic A Horizon over a Neocutanic B-Horizon over unspecified materials, without signs of wetness in the subsoil.
- **Gamoep (Gm) [3]** and **Etosha (Et) [7] soils:** Have an Orthic A Horizon over a Neocutanic B-Horizon over a hardpan- or soft carbonate horizon respectively.

In this study area the average depth of the neocutanic soils range from 40-150cm (mean 88cm). Clay content in the top soils of these soils varies between 9 and 35% (mean 18%) and between 11 and 45% at 50cm depth (mean 26%).

### 9.1.4 CARBONATE SOILS

- **Coega (Cg) [133] and Brandvlei Br [7] soils**: Have an Orthic A Horizon over a hardpan- or soft carbonate horizon respectively.

The depth ranges from 5-45cm (mean 17cm). The clay content in the top soil ranges between 8 and 35% (mean 17%). These soils were seldom deeper than 45cm in this study area.

### 9.1.5 NEOCARBONATE SOILS

- **Augrabies (Ag) [66] soils:** Have an Orthic A-Horizon over a Neocarbonate B on unspecified materials.
- **Prieska (Pr) [18] and Addo (Ad) [2] soils:** Have an Orthic A Horizon over a Neocutanic B on a Hardpan- or Soft carbonate horizon respectively.

The depth ranges from 35cm to deeper than 150cm (mean 85cm). The clay content in the top soil ranges between 8 and 35% (mean 17%) and at 50cm depth it is between 18 and 35% (mean 31%).

### 9.1.6 PEDOCUTANIC SOILS

- **Swartland (Sw) [27] soils:** Have an Orthic A-Horizon over a Pedocutanic B-horizon on Weathered rock (saprolite).
- **Valsrivier (Va) [14] soils:** Have an Orthic A-Horizon over a Pedocutanic B-Horizon without signs of wetness in the sub-soil.

The depth ranges between 40—110cm (mean 66cm). The clay content in the top soil is between 13 and 50% (mean 29%) and at 50cm depth it is between 30 and 60% (mean 37%).

### 9.1.7 SHALLOW ROCKY SOILS

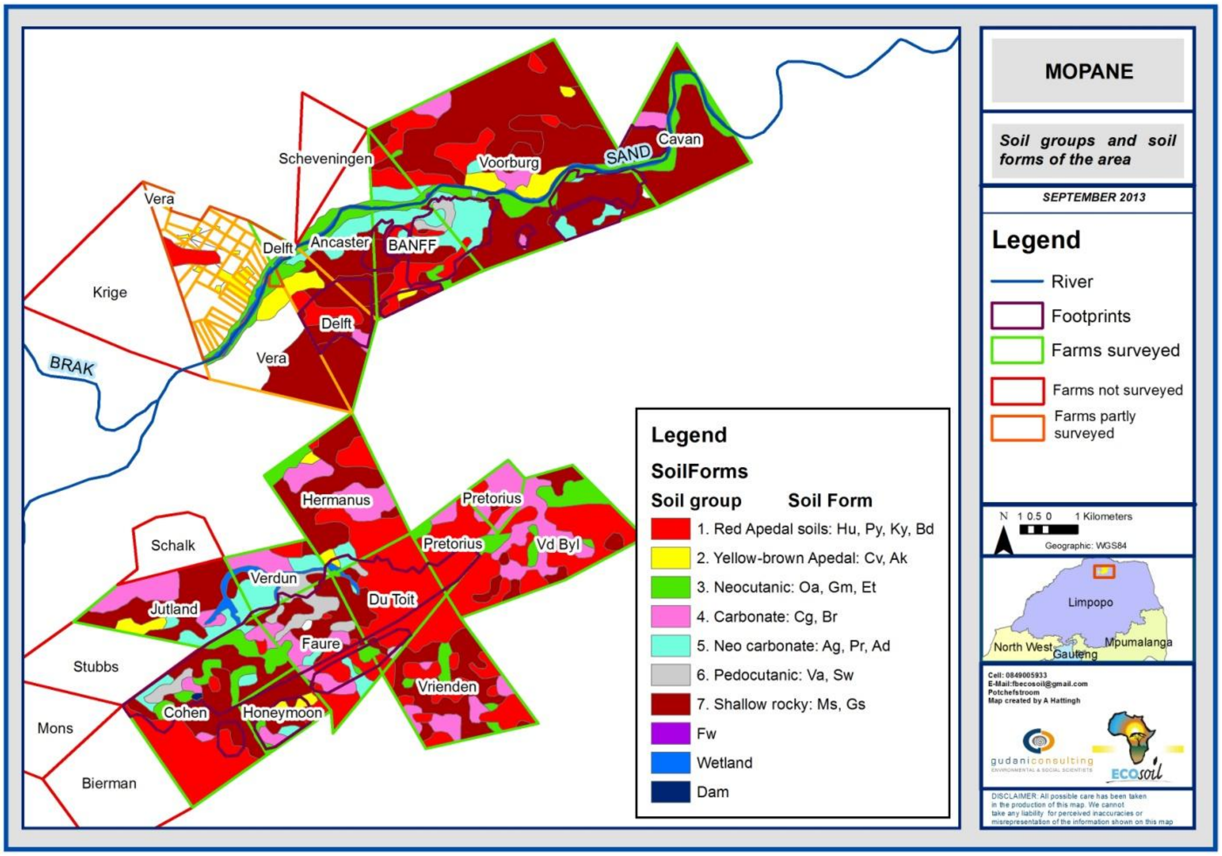
- **Mispah (Ms) [263] soils:** Have an Orthic A-Horizon over hard rock.
- **Glenrosa (Gs) [189] soils:** Have an Orthic A-Horizon on a Lithocutanic B-Horizon.

The average depth of these soils ranges from 0 to 65cm (mean 21cm). The clay content in the A-Horizon varies between 5 and 55% (mean 15%) and at 50cm depth it varies between 25 and 55% (mean 53%).

### 9.1.8 FERNWOOD SOILS

- **Fernwood (Fw) [2] soils:** Have an Orthic A-Horizon over an E-Horizon on unspecified material.

**Figure 9: Soil groups (associations) and forms of the study area**




Although soil forms can give a slight indication of soil capability, it cannot give an indication of agricultural potential. Soil forms give an indication of expected soil colour, properties and soil forming processes.

Large areas of the farms Vd Byl, Pretorius, Du Toit, Hermanus, Cohen, Vrienden and Faure are covered with Hutton soil forms. When deep and when climate permits these soils can be considered as high potential. However this is not the case in the project area and the potential of these soils are degraded to Class IV, as will be discussed in point 10.4.1 (due to climatic constraints).

Relatively small areas of Yellow Apedal soils are found on localized areas on the farms Voorburg, Honeymoon and Jutland as well as on Vera and Delft. Only a small area of the footprint of Honeymoon is covered by yellow apedal soils. These soils are generally considered as having high agricultural potential where climatic conditions (e.g. rainfall) are favourable. Unfortunately this is not the case at Mopane. The agricultural potential is therefore downgraded.

Neocutanic soils are mainly found on the floodplains along the river banks.

Shallow rocky soils are dominant in the farms Voorburg, Cavan, BANFF, and the southern parts of the farms Vera, Delft and Ancaster.

Neo Carbonate soils are found in significant areas around the Sand River on the farms Voorburg, Banff and Ancaster.

**Table 7: Summary of different soil physical properties of the soil groups**

| Properties | Soil Group 1 | Soil Group 2 | Soil Group 3 | Soil Group 4 | Soil Group 5 | Soil Group 6 | Soil Group 7 |
|---|---|---|---|---|---|---|---|
| **Soil association** | Red Apedal | Yellow - brown Apedal | Neo cutanic | Carbo-nate | Neo-carbonate | Pedo-cutanic | Shallow, rocky |
| **Soil forms** | Hu, Py, Ky, Bd | Cv, Ak | Oa, Gm, Et | Cg, Br | Ag, Pr, Ad | Sw, Va | Ms, Gs |
| **Dominant soil** | Hutton | Clovelly | Oakleaf | Coega | Augrabies | Swartland | Mispah |
| **Soil family** | 1200 | 1200 | 1120 | 1000 | 1120 | 1122 | 1100 |
| **Soil Depth cm** | 50-150 | 10-120 | 40-150 | 5-40 | 35-120 | 40-110 | 0-40 |
| **Mean rooting depth cm** | 75 | 62 | 88 | 17 | 85 | 66 | 21 |
| **Infiltration rate** | Moderate 10-15mm/h | Fast 15-20mm/h | Slow 5-10mm/h | Very Slow <5mm/h | Slow 5-10mm/h | Very Slow <5mm/h | Slow 5-10mm/h |
| **Consistency** | Loose | Loose | Friable | Soft | Soft | Hard | Loose |
| **Structure** | Apedal | Apedal | Weak blocky | Weak blocky | Weak blocky | Strong blocky | |
| **Clay % A (mean)** | 3-28(15) | 5-30 (14) | 9-35(18) | 8-35(17) | 3-50(19) | 13-50(29) | 5-55(53) |
| **Clay % 50cm** | 3-45 (22) | 5-31 (23) | 11-45 (26) | Soil not 50cm | 18-50 (31) | 18-60 (34) | Soil not 50cm |
| **PAW mm/profile** | 29-184 (82) | 12-134 (78) | 42-203 (112) | 4-98 (19) | 49-197 (110) | 54-149 (93) | 0-140 (25) |
| **Field capacity mm** | 49-338 (146) | 22-237 (136) | 71-396 (208) | 7-171 (33) | 90-383 (207) | 104-290 (182) | 0-267 (44) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Wilting point mm** | 20-126 (64) | 10-107 (58) | 30-139 (96) | 3-79 (14) | 38-1390 (98) | 49-141 (89) | 0-128 (19) |
| **Drainage** | Fast | Fast | Poor | Poor | | | |
| **Gravel/Rocks A Horizon** | - | - | - | R1 | - | - | R5 |
| **Gravel/rocks B1 Horizon** | G1 | G1 | G3 | R6 | G3 | - | R |
| **Gravel/rocks B2 Horizon** | G1 | G1 | G3 | - | G3 | G3 | - |
| **Wetness** | 0 | 0 | 0 | 0 | 0 | W1 | 0 |
| **Compactability** | High | High | High | Moderat e | High | Moderate | Low |
| **Erodibility** | Very High | Very High | High | Very High | Very High | Very High | Very High |
| **Potential Nematode Infestation** | High | High | Moderate | Low | Low | Low | High |
| **Irrigation classification** | 3 | 3 | 4 | 5 | 5 | 4 | 5 |
| **Agricultural potential** | Low to Medium | Low to medium | Medium | Marginal | Low | Low | Marginal |

## 9.2 SOIL PHYSICAL PROPERTIES

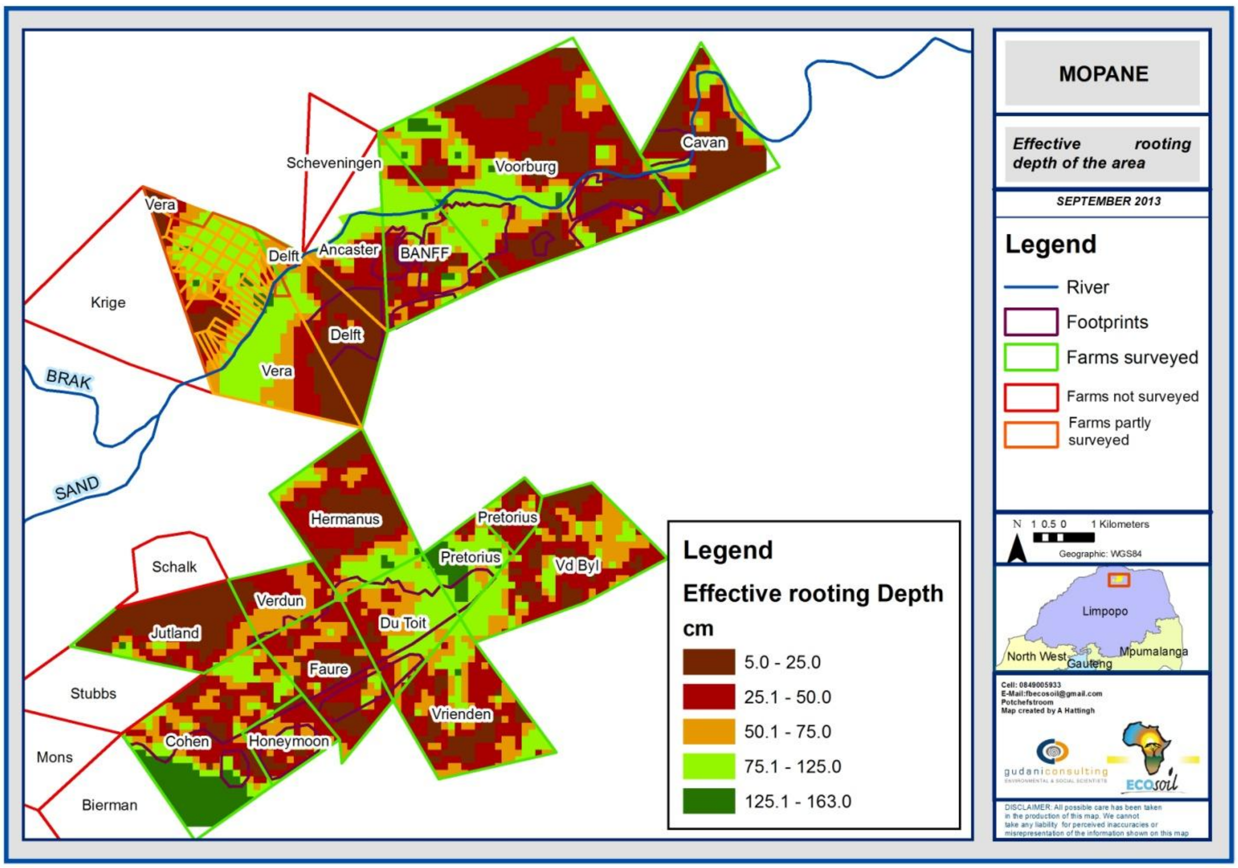
Figures 10-12 shows the effective rooting depth, Clay content of the A- Horizon and Profile Available Water capacity (PAWC) respectively.

- Deep soils (>125cm) are found in the south western parts of Cohen, as well as on localised areas in the western parts of the Farm Pretorius. Soils between 75 and 125cm are generally found on the western parts of Voorburg, and Vera, as well as on Banff (north), Du Toit and on significant areas of the farm Pretorius. According to the Chamber of Mines (1991) classification (Table 3) these deep soils can be regarded as arable. But according the agricultural classification (Klingebiel & Montgomery, 1961) these soils are classified as **classes IV to VII** as is outlined in Table 4a and 4b.

Soils on Cavan, eastern parts of Voorburg, southern parts of Ancaster and almost the entire farms of Delft, Hermanus, Jutland, Faure, as well as localized areas on Pretorius are shallower than 50cm.

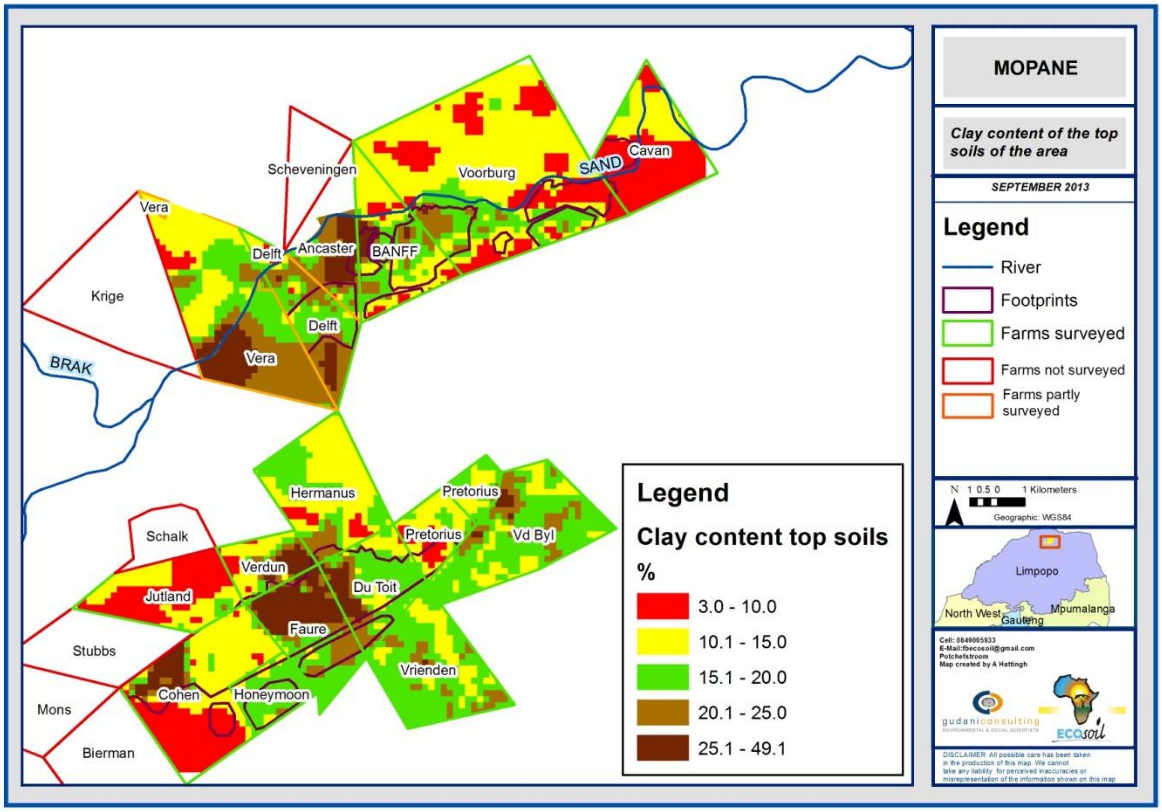
The depth of the soils on the farms Pretorius north, Vrienden, Vd Byl, Honeymoon, central parts of Cohen varies considerably between shallow and deep.

**Figure 10: Effective rooting depth of the study area**




Clay contents of the top soils are illustrated in Figure 11. Clay content of the top soil gives an indication of the susceptibility to soil erosion. Clay contents of top soils on the farms Cohen, Jutland, Cavan and smaller areas on Voorburg are generally lower than 10%. These soils can be considered as prone to wind erosion. Footprints on the eastern parts of Voorburg have such low clay contents. It will be necessary to protect these soils from wind erosion if it is to be considered for moving soils during the mining process. Special attention is needed for this operation and specialist should be consulted. High clay contents (>25%) can give rise to water erosion, especially during intensive rainstorms that occasionally may occur.

**Figure 11: Clay content (%) of A Horizons**

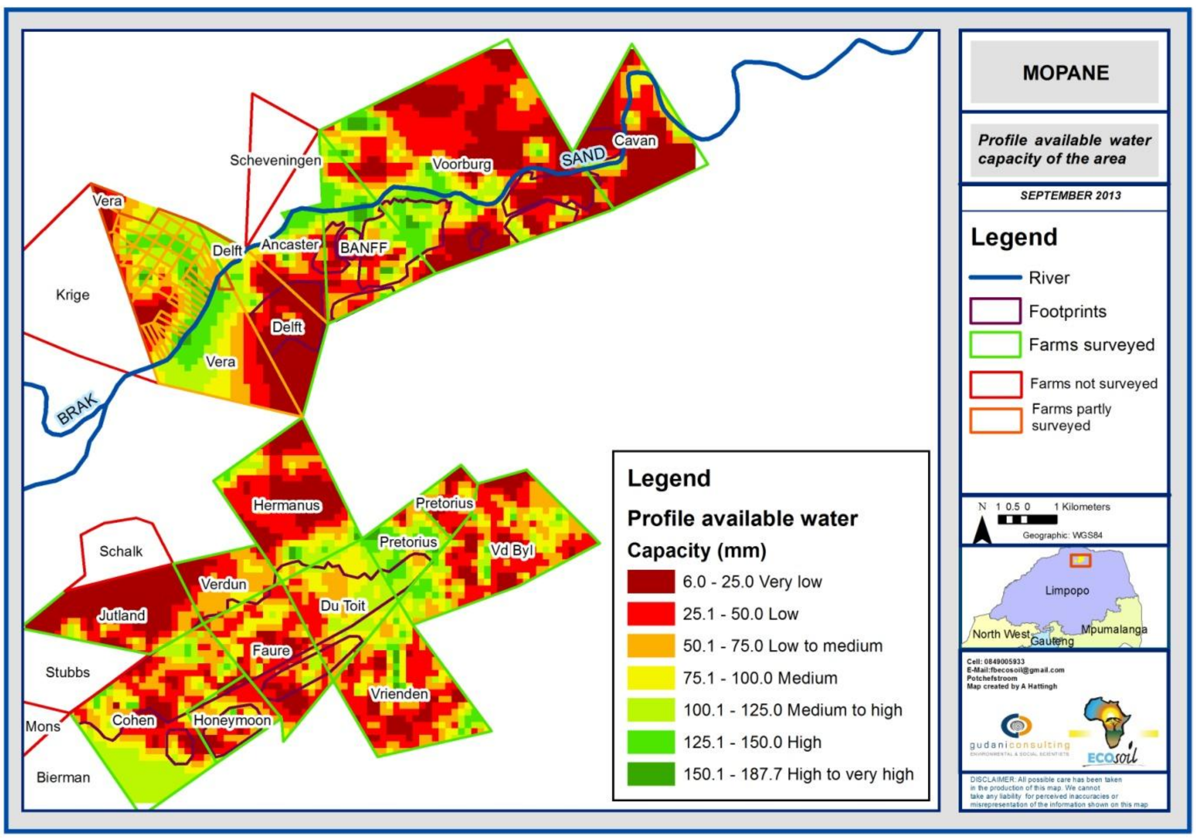



Profile available water capacity (PAWC) is illustrated in Figure 12. PAWC is the capacity of soil to keep a certain amount of water in the profile that can be used by a plant. The values are calculated from soil depth, soil texture (clay content) and soil forms. These combined factors give an indication of the potential of the soil for dry land crop production, as well as the amount of water that will be needed to fill the profile in the case of irrigation.

PAWC of the majority of the area is very low and ranges between 6 and 100mm (illustrated in brown, red, orange and yellow in Figure 12), which can be considered as sub-optimum for crop production purposes. Only relatively small areas along the Sand River can be considered as having high water holding water capacities of higher than 120mm (darkest two green hues in Figure 12). However, the rainfall of the area is too low to regard these areas of value for crop production, unless irrigated with **good** quality water.

On the footprint areas only Voorburg has a small area with a high profile available water capacity, which can be considered as of potential value for irrigation purposes if good quality irrigation water was available.

**Figure 12: Profile available water capacity of the study area**



## 9.3 SOIL CHEMICAL PROPERTIES

**Table 7** is a copy of the soil analysis and co-ordinates of sample sites.

- The pH of most soil samples are close to neutral. This is an indication of the influence of the free lime in the soil profile.
- The phosphate (P) levels are generally extremely low and are generally below 10mg $kg^{-1}$, except for observation points 635 (Farm Hermanus), 835, 856 (Farm Pretorius) as well as 411 (Delft), which have higher than normal values. These high values cannot be explained, but has no implications for the mining process.
- K contents are generally high, except for observation points 221, 227 and 1128, with low clay contents and it can therefore be expected (Table 7).
- Ca and Mg contents are normal. The Ca and S values of observation point 98 on the footprint of BANFF is extremely high.
- There is no indication of any salinity or sodicity in any of the soil samples.
- Cation ratios are within acceptable ranges.

**Table 8: Soil analysis Report**

**SOILANALYSIS REPORT**

086 683 7781

**F M B Management Services**
**12 Olienhout Str**
**Potchefstroom**
**2531**

**NAME:** **Francois Botha**
**FARM:**
**EMAIL:** fbecosoil@gmail.com
**FAX:**
**ORDER N**

| Obs No | Longs | Lats | Ref No | pH (KCl) | PBray1 | K | Na | Ca | Mg | %Ca | %Mg | %K | %Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | % | % | % | % |
| 689 | 29.7333291 | -22.6679104 | M1 | 6.26 | 22 | 223 | 3 | 908 | 161 | 70.48 | 20.43 | 8.87 | 0.23 |
| 1128 | 29.83264355 | -22.5307927 | M2A | 6.04 | 2 | 66 | 94 | 1492 | 365 | 67.65 | 27.10 | 1.54 | 3.71 |
| 1128 | | | M2B | 6.16 | 1 | 64 | 47 | 2813 | 378 | 80.25 | 17.65 | 0.93 | 1.17 |
| 1035 | 29.74585137 | -22.563891 | M3A | 6.09 | 13 | 498 | 5 | 811 | 219 | 56.73 | 25.16 | 17.80 | 0.31 |
| 1035 | | | M3B | 6.79 | 3 | 993 | 11 | 1217 | 291 | 55.05 | 21.55 | 22.98 | 0.41 |
| 1558 | 29.82009 | -22.67272 | M4A | 4.55 | 5 | 158 | 4 | 266 | 88 | 53.79 | 29.14 | 16.31 | 0.76 |
| 1558 | | | M4B | 4.10 | 2 | 137 | 7 | 281 | 129 | 45.50 | 34.07 | 11.31 | 1.03 |
| 1539 | 29.82659 | -22.70510 | M5 | 4.88 | 6 | 174 | 4 | 628 | 280 | 53.25 | 38.92 | 7.53 | 0.30 |
| 1397 | 29.85907776 | -22.6378447 | M6A | 5.88 | 55 | 424 | 2 | 1415 | 208 | 71.63 | 17.28 | 10.99 | 0.11 |
| 1397 | | | M6B | 6.06 | 3 | 245 | 5 | 1081 | 179 | 71.88 | 19.48 | 8.35 | 0.29 |
| 1438 | 29.85049748 | -22.6461209 | M7A | 6.54 | 48 | 375 | 4 | 1422 | 238 | 70.83 | 19.42 | 9.56 | 0.19 |
| 1438 | | | M7B | 5.84 | 2 | 170 | 17 | 1380 | 479 | 60.85 | 34.64 | 3.84 | 0.67 |
| 13 | 29.78948013 | -22.5586262 | M8 | 6.49 | 8 | 608 | 28 | 3526 | 449 | 76.69 | 16.02 | 6.76 | 0.53 |
| 575 | 29.78044342 | -22.665836 | M9 | 6.63 | 1 | 419 | 45 | 3813 | 576 | 76.08 | 18.86 | 4.27 | 0.79 |
| 1093 | 29.77699116 | -22.6626457 | M10 | 6.52 | 1 | 245 | 44 | 3107 | 457 | 77.28 | 18.65 | 3.12 | 0.95 |
| 98 | 29.81598922 | -22.5487772 | M11 | 6.39 | 1 | 443 | 52 | 6710 | 412 | 87.63 | 8.83 | 2.96 | 0.59 |
| 662 | 29.77818163 | -22.6983699 | M12A | 6.12 | 4 | 276 | 7 | 1202 | 282 | 66.38 | 25.49 | 7.80 | 0.33 |
| 662 | | | M12B | 5.82 | 1 | 248 | 15 | 1524 | 340 | 68.61 | 25.09 | 5.72 | 0.57 |
| 647 | 29.77251029 | -22.706592 | M13A | 5.74 | 4 | 250 | 6 | 951 | 250 | 63.63 | 27.43 | 8.57 | 0.38 |
| 647 | | | M13B | 5.84 | 1 | 106 | 15 | 1270 | 317 | 68.39 | 27.98 | 2.91 | 0.72 |
| 1048 | 29.76042476 | -22.5636413 | M14 | 6.51 | 23 | 161 | 76 | 804 | 486 | 45.97 | 45.57 | 4.71 | 3.76 |
| 432 | 29.80102556 | -22.6736007 | M15 | 5.28 | 9 | 109 | 6 | 309 | 90 | 59.80 | 28.47 | 10.76 | 0.97 |
| 1219 | 29.83759209 | -22.5352185 | M16 | 6.60 | 2 | 487 | 11 | 1287 | 228 | 67.06 | 19.47 | 12.97 | 0.50 |
| 1182 | 29.8623362 | -22.5344196 | M17 | 6.99 | 7 | 204 | 22 | 2719 | 519 | 73.64 | 23.02 | 2.83 | 0.51 |
| 407 | 29.78003669 | -22.5723295 | M18 | 6.70 | 38 | 210 | 52 | 588 | 346 | 44.97 | 43.37 | 8.21 | 3.46 |
| 502 | 29.78968685 | -22.690046 | M19 | 5.89 | 6 | 415 | 12 | 861 | 310 | 54.08 | 31.93 | 13.35 | 0.64 |
| 513 | 29.78374291 | -22.6847338 | M20 | 4.95 | 6 | 170 | 10 | 563 | 143 | 63.03 | 26.31 | 9.72 | 0.94 |
| 447 | 29.79211041 | -22.6656329 | M21 | 5.41 | 3 | 172 | 10 | 545 | 143 | 62.19 | 26.71 | 10.08 | 1.03 |
| 411 | 29.77499795 | -22.5633902 | M22 | 7.08 | 49 | 1113 | 418 | 1744 | 797 | 43.79 | 32.79 | 14.29 | 9.13 |
| 481 | 29.7977791 | -22.6574103 | M23 | 6.65 | 1 | 175 | 21 | 3195 | 619 | 74.00 | 23.50 | 2.07 | 0.43 |
| 535 | 29.77191083 | -22.6768156 | M24 | 6.60 | 1 | 169 | 21 | 3356 | 629 | 74.72 | 22.95 | 1.93 | 0.41 |
| 531 | 29.78946758 | -22.6792184 | M25 | 5.53 | 4 | 240 | 3 | 451 | 113 | 59.23 | 24.28 | 16.13 | 0.37 |
| 635 | 29.80047286 | -22.6216188 | M26 | 7.24 | 91 | 350 | 9 | 1391 | 161 | 75.55 | 14.30 | 9.73 | 0.41 |
| 835 | 29.82699958 | -22.6596049 | M27 | 7.27 | 101 | 417 | 7 | 1613 | 186 | 75.45 | 14.27 | 9.98 | 0.30 |
| 856 | 29.83009247 | -22.6436638 | M28 | 7.18 | 97 | 378 | 6 | 1487 | 173 | 75.52 | 14.37 | 9.83 | 0.28 |
| 258 | 29.73722877 | -22.6936603 | M29A | 6.44 | 3 | 469 | 25 | 1408 | 309 | 64.71 | 23.27 | 11.03 | 0.99 |
| 258 | | | M29B | 6.92 | 1 | 406 | 18 | 2067 | 436 | 68.81 | 23.77 | 6.91 | 0.51 |
| 315 | 29.77201975 | -22.6822295 | M30 | 5.73 | 1 | 410 | 8 | 1494 | 317 | 66.99 | 23.29 | 9.41 | 0.31 |
| 237 | 29.73150125 | -22.6991742 | M31 | 7.20 | 1 | 357 | 11 | 2667 | 286 | 80.16 | 14.07 | 5.49 | 0.28 |
| 227 | 29.7345264 | -22.7045384 | M32A | 6.37 | 1 | 66 | 5 | 337 | 41 | 76.24 | 15.07 | 7.64 | 1.05 |
| 227 | | | M32B | 6.27 | 3 | 87 | 3 | 355 | 28 | 79.24 | 10.30 | 9.95 | 0.51 |
| 263 | 29.75181596 | -22.69341 | M33 | 6.19 | 1 | 139 | 9 | 530 | 136 | 63.73 | 26.78 | 8.53 | 0.95 |
| 308 | 29.75159963 | -22.682582 | M34 | 6.20 | 4 | 406 | 7 | 1674 | 266 | 72.06 | 18.74 | 8.95 | 0.26 |
| 279 | 29.76343124 | -22.6905018 | M35 | 5.54 | 1 | 254 | 6 | 721 | 309 | 52.89 | 37.17 | 9.54 | 0.40 |
| 221 | 29.75511268 | -22.7123087 | M36A | 5.21 | 1 | 35 | 3 | 244 | 29 | 78.28 | 15.06 | 5.70 | 0.96 |
| 221 | | | M36B | 5.72 | 1 | 25 | 4 | 198 | 26 | 77.12 | 16.66 | 5.03 | 1.19 |

(Continues)

| Obs | Ca:Mg | (Ca+Mg)/K | Mg:K | S-Value | Na:K | T | Density | S AmAc | Clay | Silt | Sand | EC | Ca | Mg | Na | SAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No | 1.5-4.5 | 10.0-20.0 | 3.0-4.0 | cmol(+)/kg | cmol(c)/kg | | /cm3 | mg/kg | % | % | % | ms/m | me/l | me/l | me/l | |
| 689 | 3.45 | 10.25 | 2.30 | 6.44 | 0.03 | 6.44 | 1.55 | 0.74 | 13 | 2 | 85 | | | | | |
| 1128 | 2.50 | 61.46 | 17.58 | 11.03 | 2.41 | 11.03 | 1.25 | 12.71 | 21 | 7 | 72 | | | | | |
| 1128 | 4.55 | 105.55 | 19.03 | 17.53 | 1.26 | 17.53 | 1.17 | 0.53 | 23 | 12 | 65 | 22.8 | 1.21 | 0.79 | 1.07 | 1.07 |
| 1035 | 2.26 | 4.60 | 1.41 | 7.15 | 0.02 | 7.15 | 1.49 | 0.67 | 15 | 5 | 80 | | | | | |
| 1035 | 2.55 | 3.33 | 0.94 | 11.05 | 0.02 | 11.05 | 1.43 | 0.35 | 21 | 4 | 75 | 49.9 | 1.69 | 1.00 | 0.47 | 0.41 |
| 1558 | 1.85 | 5.08 | 1.79 | 2.47 | 0.05 | 2.47 | 1.51 | 1.31 | 15 | 3 | 82 | | | | | |
| 1558 | 1.34 | 7.03 | 3.01 | 2.84 | 0.09 | 3.09 | 1.43 | 4.37 | 21 | 2 | 77 | 16.7 | 0.65 | 0.69 | 0.44 | 0.53 |
| 1539 | 1.37 | 12.24 | 5.17 | 5.90 | 0.04 | 5.90 | 1.52 | 0.61 | 19 | 4 | 77 | | | | | |
| 1397 | 4.14 | 8.09 | 1.57 | 9.88 | 0.01 | 9.88 | 1.44 | 2.35 | 17 | 10 | 73 | | | | | |
| 1397 | 3.69 | 10.94 | 2.33 | 7.52 | 0.04 | 7.52 | 1.37 | 1.88 | 29 | 7 | 64 | 28.3 | 1.95 | 0.98 | 0.45 | 0.37 |
| 1438 | 3.65 | 9.44 | 2.03 | 10.04 | 0.02 | 10.04 | 1.50 | 3.40 | 15 | 8 | 77 | | | | | |
| 1438 | 1.76 | 24.87 | 9.02 | 11.34 | 0.17 | 11.34 | 1.29 | 1.29 | 31 | 12 | 57 | 18.5 | 1.10 | 1.17 | 0.47 | 0.44 |
| 13 | 4.79 | 13.70 | 2.37 | 22.99 | 0.08 | 22.99 | 1.29 | 7.49 | 31 | 14 | 55 | | | | | |
| 575 | 4.04 | 22.22 | 4.41 | 25.05 | 0.18 | 25.05 | 1.15 | 16.47 | 35 | 17 | 48 | | | | | |
| 1093 | 4.14 | 30.74 | 5.98 | 20.10 | 0.30 | 20.10 | 1.42 | 8.04 | 27 | 13 | 60 | | | | | |
| 98 | 9.93 | 32.60 | 2.98 | 38.28 | 0.20 | 38.28 | 1.39 | 3318.40 | 27 | 26 | 47 | | | | | |
| 662 | 2.60 | 11.77 | 3.27 | 9.06 | 0.04 | 9.06 | 1.54 | 52.81 | 17 | 4 | 79 | | | | | |
| 662 | 2.73 | 16.38 | 4.39 | 11.11 | 0.10 | 11.11 | 1.40 | 1.98 | 23 | 4 | 73 | 27.1 | 1.93 | 1.12 | 0.38 | 0.31 |
| 647 | 2.32 | 10.62 | 3.20 | 7.47 | 0.04 | 7.47 | 1.58 | 2.31 | 17 | 6 | 77 | | | | | |
| 647 | 2.44 | 33.12 | 9.62 | 9.29 | 0.25 | 9.29 | 1.49 | 0.13 | 21 | 4 | 75 | 14.3 | 0.97 | 0.82 | 0.34 | 0.36 |
| 1048 | 1.01 | 19.45 | 9.68 | 8.74 | 0.80 | 8.74 | 1.36 | 10.98 | 15 | 4 | 81 | | | | | |
| 432 | 2.10 | 8.20 | 2.65 | 2.58 | 0.09 | 2.58 | 1.60 | 1.46 | 15 | 3 | 82 | | | | | |
| 1219 | 3.44 | 6.67 | 1.50 | 9.60 | 0.04 | 9.60 | 1.55 | 0.02 | 19 | 14 | 67 | | | | | |
| 1182 | 3.20 | 34.21 | 8.15 | 18.46 | 0.18 | 18.46 | 1.41 | 3.09 | 23 | 13 | 64 | | | | | |
| 407 | 1.04 | 10.76 | 5.28 | 6.54 | 0.42 | 6.54 | 1.28 | 5.28 | 17 | 1 | 82 | | | | | |
| 502 | 1.69 | 6.44 | 2.39 | 7.96 | 0.05 | 7.96 | 1.53 | 1.41 | 21 | 9 | 70 | | | | | |
| 513 | 2.40 | 9.20 | 2.71 | 4.47 | 0.10 | 4.47 | 1.56 | 0.90 | 19 | 5 | 76 | | | | | |
| 447 | 2.33 | 8.82 | 2.65 | 4.38 | 0.10 | 4.38 | 1.60 | 1.82 | 19 | 7 | 74 | | | | | |
| 411 | 1.34 | 5.36 | 2.29 | 19.91 | 0.64 | 19.91 | 1.30 | 73.03 | 33 | 18 | 49 | | | | | |
| 481 | 3.15 | 47.11 | 11.36 | 21.59 | 0.21 | 21.59 | 1.36 | 0.32 | 35 | 19 | 46 | | | | | |
| 535 | 3.26 | 50.69 | 11.91 | 22.46 | 0.21 | 22.46 | 1.35 | 26.34 | 36 | 18 | 46 | | | | | |
| 531 | 2.44 | 5.18 | 1.51 | 3.81 | 0.02 | 3.81 | 1.62 | 0.75 | 17 | 5 | 78 | | | | | |
| 635 | 5.28 | 9.24 | 1.47 | 9.20 | 0.04 | 9.20 | 1.56 | 3.59 | 15 | 8 | 77 | | | | | |
| 835 | 5.29 | 8.99 | 1.43 | 10.69 | 0.03 | 10.69 | 1.57 | 4.49 | 13 | 9 | 78 | | | | | |
| 856 | 5.25 | 9.15 | 1.46 | 9.85 | 0.03 | 9.85 | 1.59 | 4.08 | 13 | 9 | 78 | | | | | |
| 258 | 2.78 | 7.97 | 2.11 | 10.88 | 0.09 | 10.88 | 1.53 | 8.17 | 25 | 15 | 60 | | | | | |
| 258 | 2.90 | 13.39 | 3.44 | 15.02 | 0.07 | 15.02 | 1.46 | 3.45 | 37 | 16 | 47 | 13.8 | 9.89 | 3.79 | 0.56 | 0.21 |
| 315 | 2.88 | 9.60 | 2.48 | 11.15 | 0.03 | 11.15 | 1.44 | 0.84 | 25 | 8 | 67 | | | | | |
| 237 | 5.70 | 17.15 | 2.56 | 16.64 | 0.05 | 16.64 | 1.50 | 1.51 | 27 | 18 | 55 | | | | | |
| 227 | 5.06 | 11.95 | 1.97 | 2.21 | 0.14 | 2.21 | 1.72 | 0.39 | 10 | 1 | 89 | | | | | |
| 227 | 7.69 | 9.00 | 1.03 | 2.24 | 0.05 | 2.24 | 1.71 | 2.45 | 10 | 1 | 89 | | | | | |
| 263 | 2.38 | 10.61 | 3.14 | 4.16 | 0.11 | 4.16 | 1.66 | 0.61 | 21 | 4 | 75 | | | | | |
| 308 | 3.85 | 10.15 | 2.09 | 11.62 | 0.03 | 11.62 | 1.48 | 0.64 | 22 | 13 | 65 | | | | | |
| 279 | 1.42 | 9.44 | 3.90 | 6.81 | 0.04 | 6.81 | 1.56 | 0.42 | 17 | 7 | 76 | | | | | |
| 221 | 5.20 | 16.36 | 2.64 | 1.56 | 0.17 | 1.56 | 1.74 | 0.63 | 10 | 1 | 89 | | | | | |
| 221 | 4.63 | 18.65 | 3.31 | 1.28 | 0.24 | 1.28 | 1.75 | 0.18 | 11 | 1 | 88 | 9.6 | 0.72 | 0.37 | 0.20 | 0.27 |

## 9.4 WATER SAMPLE ANALYSIS

Three borehole water samples were taken for analysis from Vera, Du Toit and Honeymoon respectively. **Table 8** is a copy of the water analysis results, analysed for agricultural and irrigation purposes only.

Soils will be maintained in a good condition (non-saline, non sodic) when good quality irrigation water and adequate leaching is used. The criteria of quality are low salinity, low ratio of $Na^+$ to ($Ca^{2+}$ + $Mg^{2+}$) to prevent sodicity, and small concentrations of those ions which may have specific toxic effects. High salinity water has a direct effect on sensitive crops. At lower salinities, salts may accumulate leading to crop damage.

**SALINITY:**

**EC (dS/m)**: Sample M3 has no restriction (<0.7)
Sample du Toit has slight to moderate restriction (0.7 to 3.0)
Sample Vera has severe restriction (>3.0)

The major hazard is a reduction in infiltration rate due to structural damage caused by exchangeable $Na^+$. The extent of structural damage at a given sodicity depends on the salinity of the water.

**SODICITY:**

**SAR:** 0-3 AND EC: 0.7 -0.2 M3 has slight to moderate restriction
3.0 - 6.0 AND EC :> 0.7 Du Toit and Vera has no restriction

Remark: These are broad guidelines and the effects will depend on crop sensitivity
Use of irrigation water may cause crusting and run-off under rainy conditions on Du Toit and Vera due to dispersion.

**SPECIFIC ION TOXICITY:**

Na+ (SAR): Vera and M3 has no restriction (<3)
Du Toit has slight to moderate restriction (3.0-9.0)

Cl+ (mmol/l): M3 has no restriction (<4)
Du Toit and Vera have severe restriction (>10)

Boron (mg/l): M3 and du Toit have no restriction (<0.7)
Vera has slight to moderate restriction (0.7-3.0)

- The Chloride (Cl) content of both Vera and Du Toit samples are extremely high and will have a negative impact on Chloride sensitive crops.

- The Sodium (Na) content of both the Vera and Du Toit samples are high and could lead to the potential build-up of sodicity on poorly drained soils.

**Table 9: Water analysis report**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **NOORDWES UNIVERSITEIT** | | | | | Eco Analytica | | | | |
| **ECO ANALYTICA** | | | | | Posbus 19140 | | | | |
| | | | | | NOORDBRUG 2522 | | | | |
| | | | | | Tel: 018-293 3900 | | | | |
| **FRANCOIS BOTHA** | | | | | | | | | |
| 27/9/2013 | | | **$H_20$-ANALISE** | | | | | | |

| **Makro-elemente** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Monster** | Ca | Mg | K | Na | $PO_4$ | $SO_4$ | $NO_3$ | $NH_4$ | Cl | $HCO_3$ |
| **nommer** | *Millimol per liter* | | | | | | | | | |
| **DU TOIT** | 3.04 | 4.07 | 0.56 | 9.77 | 0.01 | 1.55 | 0.52 | 0.02 | 12.05 | 8.90 |
| **HONEYMOON** | 0.62 | 0.43 | 0.02 | 0.56 | 0.01 | 0.21 | 0.08 | 0.02 | 0.62 | 1.55 |
| **VERA** | 4.06 | 12.89 | 0.70 | 12.05 | <0.01 | 4.78 | 3.45 | 0.01 | 24.76 | 8.90 |

| **Mikro-elemente en ander data** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Monster** | Fe | Mn | Cu | Zn | B | pH | EG | P-BRAY 1 |
| **nommer** | *Mikromol per liter* | | | | | | *(mS/cm)* | *dpm* |
| **DU TOIT** | 0.84 | 0.36 | 0.02 | 0.38 | 39 | 7.01 | 2.46 | |
| **HONEYMOON** | 0.03 | 0.02 | 0.02 | 0.18 | 5 | 6.58 | 0.27 | |
| **VERA** | 0.66 | 0.05 | 0.05 | 0.17 | 85 | 6.96 | 4.67 | |

Ten einde betroubaarheid van analises te verseker, neem Eco Analytica deel aan die volgende instansies se kontroleskemas:

1. Agri-Laboratorium Assosiasie van Suidelike Afrika
2. International Soil Analytical Exchange (ISE), Wageningen, Nederland

Geen verantwoordelikheid word egter deur Noordwes Universiteit aanvaar vir enige verliese wat uit die gebruik van hierdie data mag spruit nie

### 9.4.1 LAND CAPABILITY ASSESSMENT

The land capability of the area (according to the Chamber of Mines 1991) classification is presented in Figure 13 and is summarised per farm in Table 10.

- Wetlands are defined as: "Land with organic soils or supporting hygrophilous vegetation where soil and vegetation processes are water determined". In this study area the following criteria was used:
    - Riparian zones were not delineated, and only wetland soil parameters per definition were used.
    - Small farm dams and pans that fell between two observation points (based on the grid size in the ToR's) were not mapped.
    - Many of the drainage lines are actually erosion dongas and gullies with Oakleaf, Augrabies, Glenrosa and Coega soils and cannot be regarded as wetlands soils per definition.
    - Only large water bodies on Jutland and Verdun were found.

- Footprint areas are generally covered by soils classified with a wilderness and grazing capability. The farms Cohen and Pretorius have significant areas of arable soils. The farms Banff and Cohen have small areas of arable soils. However, the potential of these arable soils are classified as class IV soils (as discussed in point 8.4.1.4 and 8.4.2).

**Figure 13: Land capability of the surveyed area**

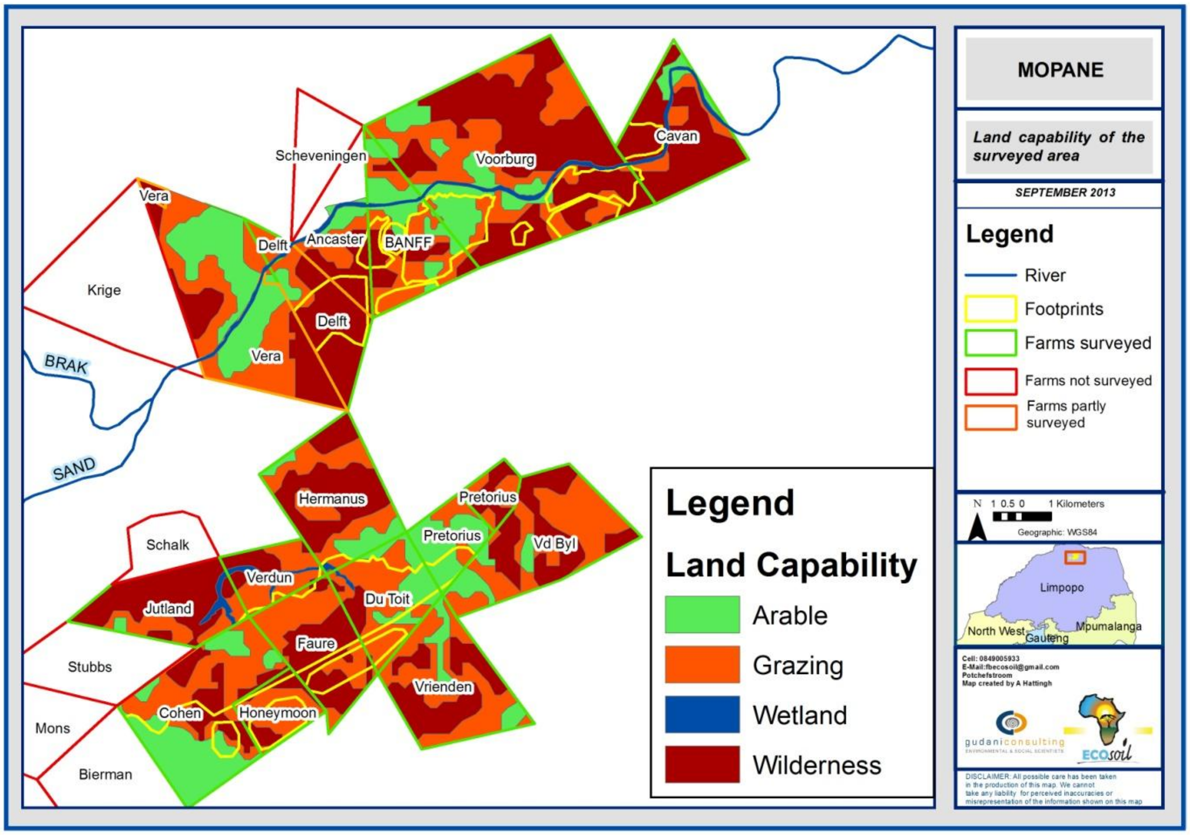


**Table 10: Areas of Land capability classes on respective farms in the study area**

| Farm name | Total area (ha) | Arable | Grazing | Wetland | Wilderness |
|---|---|---|---|---|---|
| Ancaster | 552 | 93 | 144 | 40 | 275 |
| BANFF | 1157 | 341 | 516 | 17 | 283 |
| Cavan | 1248 | 110 | 149 | 77 | 912 |
| Cohen | 1808 | 761 | 652 | 0 | 395 |
| Delft | 887 | 49 | 187 | 11 | 640 |
| Du Toit | 935 | 268 | 563 | 11 | 93 |
| Faure | 1106 | 0 | 469 | 0 | 638 |
| Hermanus | 1398 | 167 | 498 | 10 | 723 |
| Honeymoon | 467 | 0 | 323 | 0 | 144 |
| Jutland | 1371 | 23 | 240 | 371 | 737 |
| Pretorius | 761 | 371 | 250 | 0 | 140 |
| Vd Byl | 1588 | 170 | 797 | 0 | 621 |
| Vera | 1056 | 307 | 408 | 21 | 320 |
| Vera Small holdings | 988 | 489 | 372 | 7 | 120 |
| Verdun | 516 | 0 | 314 | 53 | 149 |
| Voorburg | 4024 | 612 | 1216 | 88 | 2108 |
| Vrienden | 1384 | 175 | 656 | 0 | 553 |
| **Total** | 21246 | 3936 | 7754 | 706 | 8851 |

#### 9.4.2 AGRICULTURAL POTENTIAL ASSESMENT

For purposes of international and national technology transfer and simplicity, the methodology was aimed at reflecting the classic concepts of land capability, as established by Klingebiel and Montgomery (1961) as far as possible. These concepts were to be brought under parameters suited to South African conditions and the local availability of data.

External factors like climate, topography, erosion factors, surface rock and water quality parameters are brought in consideration to determine the present agricultural potential.

**Table 11: Agricultural Potential Classification of land capability classes according to agricultural classification system**

| Soil Management Unit | Soil Group 1 | Soil Group 2 | Soil Group 3 | Soil Group 4 | Soil Group 5 | Soil Group 6 | Soil Group 7 | Soil Group 8 |
|---|---|---|---|---|---|---|---|---|
| **Soil Types** | Red Apedal | Yellow Apedal | Neo Cutanic | Carbonate | Neo Carbonate | Pedo cutanic | Shallow rocky | Wetland |
| **Soil depths cm** | 50->150 | 10-120 | 40->150 | 5-45 | 35->150 | 40-110 | 0-65 | - |
| **Average soil depth cm** | 75 | 69 | 88 | 17 | 87 | 70 | 21 | - |
| **Limiting Factors** | Texture, Water-holding capacity | Texture, Water-holding capacity | Erosion, Depth, Surface rock | Surface Rock, Erosion, | Surface Rock, Erosion, | Structure, Erosion | Rock, Depth | Water-logging |
| **External Factors** | Climate, Water Quality | Climate, Water Quality | Climate, Water Quality | Climate, Water Quality | Climate, Water Quality | Climate, Water Quality | Climate, Water Quality | Climate, Water Quality |
| **Land capability** | Arable, crop production | Arable crop production | Grazing | Grazing / Wilderness | Wilderness / Grazing | Grazing | Wilderness | Wetland |
| **Agricultural potential** | Low | Low | Low | Marginal | Marginal | Low | Marginal | Marginal |
| **Agricultural Classification** | 4 | 4 | 4 | 5-6 | 6 | 4 | 6 | 8 |
| **Area %** | 5237ha 24.6% | 565ha 2.7% | 1610ha 7.6% | 2116ha 10.0% | 1363ha 6.4% | 430ha 2.0% | 9219ha 43.4ha | 706ha 3.3% |

## 10. SUMMARY OF THE IMPACT OF THE MINING DEVELOPMENT ON AGRICULTURAL POTENTIAL AND LAND CAPABILITY

**Table 12: Summary of the impact of mining on agricultural potential and land capability**

| Impact | Loss of agricultural potential and land capability | |
|---|---|---|
| | Without mitigation | With mitigation |
| Extent | Low | Low |
| Duration | Permanent | Permanent |
| Magnitude | Low | Low |
| Probability | Highly probable | Highly probable |
| Significance | Low | Low |
| Status (positive or negative) | Negative | Negative |
| Reversibility | Medium | Medium |
| Irreplaceable loss of resources | No | No |
| Can impacts be mitigated | No | No |
| * The agricultural potential of the area is low, but the loss of agricultural land stretches far beyond the operational mining processes. | | |
| * Soil erosion is a strong possibility due to increased surface run-off and occasional high intensity rain occurrences. Erosion control and adequate management is needed. | | |
| * Loss of agricultural land is a long term loss. There are no mitigation measures that can combat this type of loss. | | |

## 11. CONCLUSIONS OF SOILS ASSESSMENT

- Generally the soils are heavily degraded through erosion and top soil loss.
- Although there are large areas of deep soils, these areas are sub optimal due to low clay contents. As a result of low rainfall, high temperatures (high evapotranspiration), susceptibility to compaction, present erosion and erodibility the soils in the area is study is not recommended for rain fed crop production.
- Fields presently used for irrigation are susceptible to salinity and sodicity due to poor water quality with high chloride values. The relatively high salt contents currently prevents dispersion, however rain water can cause dispersion and enhance crust formation on the soils.
- Water quality for irrigation purposes is of low quality with restriction to sensitive crops. Water samples were taken during the winter and it is recommended to make a continual assessment of water quality during the year, since it can change significantly during the year.
- Shallow soils and surface rock are dominant in large areas. Areas classified for grazing have presently low basal grass cover and are dominated by Mopane shrub field and will be discussed in detail by the biodiversity report.
- Present land use is cattle and game farming, but carrying capacity is questionable due to poor physical soil quality (erosion susceptibility, shallow soils, surface rock and poor climatic conditions).
- Approximately 706ha was identified as wetland and should be evaluated separately.
- Land capability per farm is summarized in Table 10. From this Table it can be concluded that most of the farms are largely covered by grazing and wilderness areas (total 16605 of the approximate 21246ha) according to the Mining classification.
- Less than 4000ha is classified as arable soils according to the mining classification. However, these soils fall into classes 4 to 7 according to the agricultural classification system, which recommends these soils for grazing purposes.

- The same restrictions and limitations discussed above apply for the footprint areas. The footprint on the Jutland Portion overlies some of the deep soils, previously mentioned.
- Stripping and rehabilitation for the proposed mining operation will be discussed separately under point 15 and onwards.

## 12. RECOMMENDATIONS OF SOILS ASSESSMENT

Impacts on the environment must be minimized or limited on construction sites.

The following is recommended:

- Specialists should be used to evaluate the erosion and other possible impacts during the entire mining process
- Limit impacts to the footprints to keep physical impacts as small as possible
- Specific control measures are needed to control erosion and water run-off to prevent excessive surface run-off from the site
- Areas for road and site lay-out should be minimized.
- Dust generation and vehicle associated pollution must be minimized.

## 13. METHODOLOGY USED FOR IMPACT RATING

The methodology includes the following:

- Descriptions of all methods, measures and instruments adopted during the undertaking of the applicable specialist study; and
- Impact rating method used, which is provided below.

## 13.1 NATURE OF IMPACT

The nature of the impact refers to whether an impact is positive or negative

**Table 13: Nature of impact**

| Status | Description | Rating |
|---|---|---|
| Positive | Benefit to the environment | +'ve' |
| Negative | Detriment to the environment | -'ve' |

## 13.2 IMPACT TYPE

Each impact needs to be classified as a direct, indirect or cumulative impact. (Centre for Environmental Excellence, 2008) (Council on Environmental Quality, 2008)

**Table 14: Impact type**

| Type | Description | Rating |
|---|---|---|
| Direct Impact | Is a reaction that is caused by the direct interaction of a planned action or activity on the receiving environment, e.g. the discharge of water into a water stream, the discharge of pollutions through a stack. Usually in close proximity to the action or activity. | Direct |
| Indirect Impact | Is a reasonably foreseeable reaction that is indirectly caused as a result of a planned action or activity, the effects/ impacts are usually later in time and farther removed from the action or activity, e.g. growth inducing effects, changes in patterns of land use, population density or growth rate and related effects on air, water, ground and ecosystems. | Indirect |
| Cumulative Impact | Is the impact on the environment, which results from the incremental impact of the action when added to other past, present and reasonably foreseeable future actions, regardless of undertakings by other industries, mines, developments or persons? Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. | Cumulative |

## 13.3 GROUPING OF IMPACT

The grouping of the impact refers to whether the impact will be a result of a planned project activities or unplanned project activities.

**Table 15: Grouping of impact**

| Grouping | Description | Rating |
|---|---|---|
| Routine | Impact that occurs as a result of expected and planned project activities. | 'R' |
| Non-Routine | Impact that occurs as a result of an unexpected and unplanned project activity. Usually occurs in emergency events. | 'NR' |

## 13.4 CERTAINTY (PROPABILITY) OF IMPACT

The certainty of the impact describes the likelihood of the impact occurring.

**Table 16: Certainty of impact**

| Certainty | Description | Rating |
|---|---|---|
| Unlikely | Less than 40% sure that the impact or benefit will occur. | 1 |
| Possibility | Between 40% and 70% sure that the impact or benefit will occur. | 2 |
| Probable | Between 70% and 90% sure that the impact or benefit will occur. | 3 |
| Definite | Over 90% sure that the impact or benefit will occur. | 4 |

## 13.5 SPATIAL EXTENT OF IMPACT

The extent of the impact refers to the spatial scale of the impact or benefit of the proposed project and the area over which it extends.

**Table 17: Spatial extent of impact**

| Spatial Extent | Description | Rating |
|---|---|---|
| Site specific | Effects felt within the site boundary area. | 1 |
| Local | Effects are felt within 5 km radius from the site boundary area. | 2 |
| Regional | Effects are felt within a 50 km radius from the site boundary area. | 3 |
| National | Effects are felt beyond a 50 km radius from the site boundary area within South Africa. | 4 |

## 13.6 DURATION OF IMPACT

The duration refers to the time scale of the impact or benefit in terms of the period of time that the surrounding environment will be affected or altered by the proposed project.

**Table 18: Duration of impact**

| Duration | Description | Rating |
|---|---|---|
| Short term | Less than 5 years | 1 |
| Medium term | Between 5 and 20 years | 2 |
| Long term | Between 21 and 40 years | 3 |
| Permanent | Permanent impact | 4 |

## 13.7 REVERSIBILITY OF IMPACT

Reversibility refers to the time it would take to reverse or undo the impact under discussion.

**Table 19: Reversibility of impact**

| Reversibility | Description | Rating |
|---|---|---|
| Short term | Less than 5 years | 1 |
| Medium term | Between 5 and 20 years | 2 |
| Long term | Between 21 and 40 years | 3 |
| Permanent | Permanent impact, i.e. not reversible | 4 |

## 13.8 SEVERITY (INTENSITY) OF IMPACT

The severity is the attempt to quantify the magnitude of the impact whether positive or negative, which is associated with the proposed project. The scale therefore accounts for the extent and magnitude but is subject to the value judgement.

**Table 20: Severity of impact**

| Status of Impact | Severity | Description | Rating |
|---|---|---|---|
| Negative | Slight | • Minor deterioration;<br>• Short to medium term duration; and<br>• Mitigation is easy, cheap and quick. | 1 |
| | Moderately severe | • Moderate deterioration;<br>• Medium to long term duration; and<br>• Fairly easy to mitigate. | 2 |
| | Severe | • Marked deterioration;<br>• Long term duration;<br>• Serious and severe impact; and<br>• Mitigation is very expensive, difficult or time consuming. | 3 |
| | Very severe | • Substantial deterioration;<br>• Irreversible of permanent; and<br>• Cannot be mitigated. | 4 |
| Positive | Slightly beneficial | • Minor improvement; and<br>• Short to medium term duration. | 1 |
| | Moderately beneficial | • Moderate improvement; and<br>• Medium to long term duration. | 2 |
| | Beneficial | • Large improvement; and<br>• Long term duration. | 3 |
| | Very Beneficial | • Permanent improvement. | 4 |

## 13.9 SIGNIFICANCE OF IMPACT

The significance of a positive or negative impact describes and evaluates the importance of that impact in accordance with the scope of the project. Impacts can be described and evaluated in terms of their type, extent, complexity, intensity and duration. This evaluation criterion provides a basis for comparison and the application of judgement (Department of Environmental Affairs and Tourism, 2002). The significance of an impact is calculated as follows:

**(Severity + Reversibility + Duration + Spatial) x Certainty = Significance**

**Table 21: Significance of impact**

| Significance | | Description | Rating |
|---|---|---|---|
| Very low(1) | Negative | • Constitutes as a short term effect, which is site specific;<br>• Easily reversible by the application of easy, cheap or quick mitigation measures;<br>• Mitigation might not even be required, and<br>• Society and/or specialist view the change as negligible. | 0-4 |
| | Positive | • Slightly beneficial impact, which constitutes a minor improvement;<br>• Short term duration; and<br>• Enhancement measures to be implemented to increase the effect of the positive impact. | |
| Low (1 - 2) | Negative | • Marked deterioration;<br>• Short to medium term;<br>• Effects are not substantial.<br>• Society and/or specialists view the change as unimportant; and<br>• Mitigation is easy, cheap or quick. | 5 - 15 |
| | Positive | • Marked improvement;<br>• Short to medium term; and<br>• Enhancement measures to be implemented to increase the effect of the positive impact. | |
| Moderate (2 - 3) | Negative | • Constitutes as medium to long term effect;<br>• Effects are real but not substantial and ;<br>• Society and/or specialist do not view the impact as substantial and very important; and<br>• Mitigation is fairly easily possible. | 16 - 35 |
| | Positive | • Marked improvement;<br>• Medium to long term;<br>• Effects are real, but not substantial; and<br>• Enhancement measures to be implemented to increase the effect of the positive impact. | |
| High (3-4) | Negative | • Long term effect;<br>• Society and specialist view the change as very serious;<br>• The reversibility of the impact is long term; and<br>• Mitigation is very expensive, difficult and time consuming. | 36-63 |
| | Positive | • Long term effect;<br>• Society and specialist view the change as very positive; and<br>• Enhancement measures to be implemented to increase the effects of the positive impact. | |
| Very high (4) | Negative | • Constitutes as a permanent change to the environment;<br>• Society and/or specialist view the change as very serious;<br>• The impact cannot be reversed; and<br>• The impact cannot be mitigated. | 64 |
| | Positive | • Constitutes as a permanent change to the environment;<br>• Society and specialist view the change as very positive; and<br>• Impacts cannot be reversed. | |

## 14. IMPACT ASSESSMENT

**Table 22: Predicted impact assessment of the proposed mining activity on the soils**

| Project phase | Nature | Certainty | Extent | Duration | Reversibility | Severity | Significance |
|---|---|---|---|---|---|---|---|
| **Before Mitigation** | | | | | | | |
| Construction | **-** | 4 | 2 | 1 | 3 | 3 | **36** |
| Operation | **-** | 4 | 2 | 4 | 3 | 3 | **48** |
| Decommissioning | **-** | 2 | 2 | 2 | 3 | 3 | **20** |
| **After Mitigation** | | | | | | | |
| Construction | **-** | 4 | 1 | 1 | 3 | 2 | **28** |
| Operation | **-** | 4 | 2 | 4 | 3 | 3 | **36** |
| Decommissioning | **-** | 2 | 2 | 2 | 3 | 3 | **20** |

## 15. DUST GENERATION AND VEHICLE IMPACT ASSESSMENT

### 15.1 DUST GENERATION

During the operational time all vegetation will be removed and creates a potential for wind erosion and therefore dust generation.

- A soil with low clay contents is susceptible to wind erosion, but has a low dust generation potential.
- Soils with high clay contents have an inherent stability and have a low dust generation potential, except for Vehicle movement. Vehicles can cause powdering and breaking of the soil structure. It is recommended that all roads should be gravelled.
- Soils with clay contents between 12 and 25 percent have a high dust potential.

Three potential areas of dust formation are identified:

- Open-pit areas: Dust control can be achieved by additives like molasses or watering.
- Stockpiling areas: Rock armouring of the stock piles can reduce wind and water erosion.
- All roads: Use of gravelled roads.

## 15.2 ON SITE VEHICLE OPERATIONS

- Vehicle movement should be minimized and restricted to the construction site on gravelled roads, in order to reduce potential rill erosion and dust formation.
- Maintain vehicles and prevent and address spillages of lubricants and petroleum.

# 16. CONCLUSIONS OF IMPACT ASSESSMENT

- As mentioned previously, generally the soils are severely degraded through erosion and top soil loss. The majority of area has a poor basal cover, and it is prone to compaction and crust formation
- A large percentage of the area has very shallow and rocky soils as well as surface rock outcrops.
- The soils are not high potential arable soils and have low soil fertility. This has the implication that rehabilitation will be complex and special measures need to be implemented to prevent soil loss through wind and water erosion (see Appendix)
- Water for irrigation purposes is already of poor quality. Special measures should be put in place to protect surface and sub-surface water sources from further contamination.

# 17. RECOMMENDATIONS

## 17.1 MITIGATION MEASURES REQUIRED

### 17.1.1 SOIL STRIPPING IN CONSTRUCTION PHASE

- The Red and Yellow Apedal soil groups are suitable as growing medium; effort should therefore be made to strip the topsoil separate from the underlying material (see Appendix) for later use.
- Soils in the wetland should be kept undisturbed.
- Average soil depths range from 30-90 and are generally shallower than 70cm. If soil stripping is necessary, it is recommended to strip only 40-60cm of the soil. These estimates take into consideration a possible 10% topsoil loss through compaction and allow the rehabilitated areas to be returned to the pre-mining land capability, i.e. arable cropping and grazing land.
- Any soil that might possibly be contaminated during the construction phase should be stripped and stockpiled in advance of construction activities.
- The stripped soils should be stockpiled upslope of areas of disturbance to prevent contamination of stockpiled soils by runoff or seepage.
- All stockpiles should also be protected by a bund wall to prevent erosion of stockpiled material and deflect water runoff.
- Stockpiles should be placed where possibly on the areas covered by stony or rocky soils (Mispah, Glenrosa and Coega).
- Care should be taken that stockpiles do not to block too many drainage lines as high intensity rainfall events can occur in this area (e.g. the rainfall in January 2013 exceeds the average annual rainfall).

### 17.1.2 OPERATIONAL PHASE

- Stockpiles can be used as a barrier to screen operational activities. If stockpiles are used as screens, the same preventative measures described above should be implemented to prevent loss or contamination of soil.

- The stockpiles should not exceed a maximum height of 6m and it is recommended that the side slopes and surface areas be vegetated in order to prevent water and wind erosion and to keep the soils biologically active.
- If used to screen operations, the surface of the stockpile should not be used as roadway as this will result in excessive soil compaction.

### 17.1.3 DECOMMISIONING AND REHABILITATION

Detailed recommendations concerning a sustainable approach to soil rehabilitation of opencast mining areas are given in the appendix. The following issues need to be taken into consideration before, during mining operations, with closure and rehabilitation:

- Loss of topsoil and usable soil
  - Strip all usable soil and stockpile.
  - Vegetate long-term soil stockpiles
- Contamination of topsoil and stockpiled soil
  - Prevent contamination of topsoil and stockpiled soil.
  - Site all soil stockpiles upslope from any mining / development activities
  - Position stockpiles upslope of mining areas, or as screens to restrict visibility of the mining operation provided that in doing so, the stockpile is not exposed to the risk of seepage or dirty water contamination.
- Erosion of stockpiled soil
  - Ensure that all stockpiles have a storm water diversion berm for protection against erosion and contamination by dirty water.
- Loss of soil biodiversity
  - Most soil stockpiles become sterile as soil microbiology dies off due to long-fallow syndrome. Compost, Kraal Manure and / or humic and microbial substances can be used to restore soil biology.
- Probability of compaction

- The footprints of stockpiles on deep soils (not necessary for shallow soils) must be loosened after removal of the stockpiles, because of compaction during the stockpiling process.

### 17.1.4 MONITORING AND MEASUREMENT REQUIREMENTS

- Sampling sites need to be established down- stream on neighbouring farms.
- Regular water quality monitoring also need to take place in the Sand River to monitor any impact the proposed development might have on the regional surroundings.

## 18. MANAGEMENT RECOMMENDATIONS

The area can be converted to mining, but measures must be put in place to limit soil erosion and contamination of boreholes and surface water and the wetlands.

## 19. BIBLIOGRAPHY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## 20. APPENDIX 1

ILLUSTRATION OF SHEET EROSION DUE TO POOR BASAL COVER

# 21. APPENDIX *2:* REHABILITATION OF OPENCAST MINING SOILS

## 1. INTRODUCTION

Global agriculture is facing a trend in yield decline for most crops. This is specifically applicable to crops that are practised under a mono-cropping system. It is a well-known scientific fact that monoculture has a negative impact on soil fertility and potential.

With mono cropping and overuse of land, it has become necessary for farmers to resort to more drastic measures to maintain yields. One such practise is to increase N, P and K chemical fertilisers at ever increasing costs, because the perception is that the higher the fertiliser levels the higher the yield.

This same mind-set is prevalent with the rehabilitation of opencast mining areas. The impact of mining operations is just so much amplified as the whole soil profile with all the integrated soil physical, chemical and biological processes is destroyed. This is often the result of a lack of understanding that soil is a living eco-system and that there is a difference between soil fertility and plant nutrition. There is also a difference in understanding the term topsoil from a soil science and mining perspective.

A distinction must be made between restoring soils to previous inherent potential for crop production and sustainable rehabilitation. As previously mentioned soils form over a long period of time with various processes involved. The opencast mining operations totally disturb these process and soil forming factors.

It is not possible to restore the soil potential and initial characteristics to its original state but huge improvements can be made in the methodology of stripping and re-dressing of soil material to ensure sustainability of rehabilitation. Over time these soils can produce proper vegetation and grazing of cattle and arable crop production at lower yields then the initial soil potential.

To achieve this it is necessary to understand the soil forming factors and processes and the difference between soil fertility and plant nutrition.

## 2. DEFINITION OF SOIL

Soil is an open living ecosystem and can therefore be defined as a function of physical, chemical and biological processes.

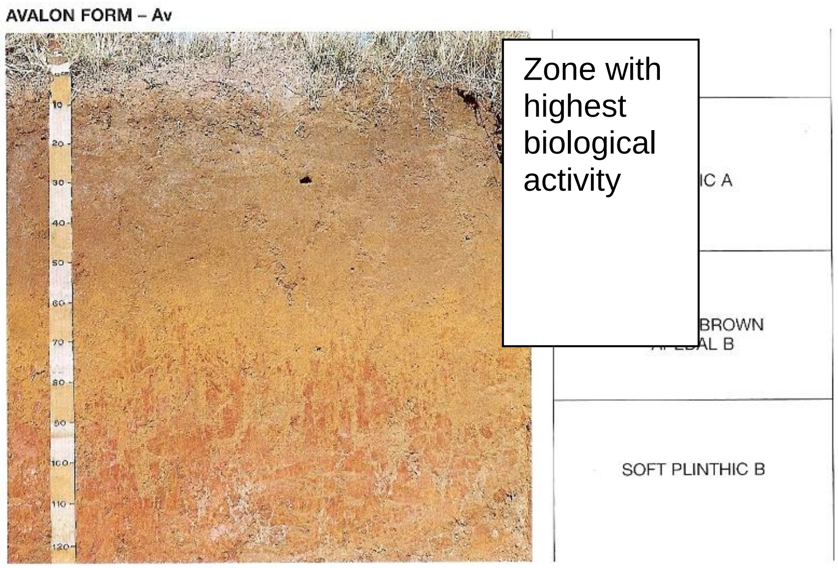
## 3. SOIL FORMING PROCESSES

The following factors are involved in soil formation:

- Parent Material (geology, e.g. sedimentary rock (sandstone), acid igneous (granite) or basic rock dolerite) etc.)
- Topography (slope of landscape)
- Climate (wind, water, temperature etc.)
- Microbial Activity  and microbial diversity
- Time (soil formation occurs over a long time period, e.g. 1cm of topsoil is formed over 100yrs)

These factors with different physical, chemical and biological processes combine under specific conditions to form specific soil diagnostic horizons with a unique character and inherent soil fertility.

**Photo 1:** Avalon soil showing different horizons (Soil classification working group, (1991)




## 4. FERTILITY / PLANT NUTRITION

Fertility refers to the inherent capacity of a soil to supply nutrients to plants in adequate amounts and in suitable proportions as well as oxygen and moisture to maintain a healthy soil bio-diversity (active micro-biology, immune system). The focus here is soil health.

Plant nutrition refers to the soils ability to supply nutrients to the plant so it can complete its reproductive cycle. The nutrient status of the soil can be manipulated by adding organic and inorganic fertilisers according to the crop's need. The focus here is on the crop's needs.

It can now be summarised that different soils have different levels of soil fertility according to the combination of the soil forming factors and soil processes involved under specific conditions. All these factors and processes are interlinked and no single soil type has all these factors in the ideal combination, therefore the yield potential and use of soils varies.

Unfortunately soil fertility and nutrition was relegated to a simple recipe of four elements provided through chemical fertilisers e.g. Nitrogen (N), Phosphorous (P), Potassium (K) and Zinc (Zn) to meet only the crop needs at the expense of soil fertility. Very little attention was given to the important role of bio-diversity and active microbiology in plant nutrition. It is only in the last couple of years that there is a serious interest on this matter.

## 5. THE ROLE OF BIODIVERSITY

Active and healthy soil microbiology is able to:

- Mineralise nitrogen, phosphorous and sulphur
- Suppress nematodes, bacterial and fungal diseases
- Actively decompose organic material
- Improve root development with the result of better nutrient and water uptake
- Recycle and keep nutrients available for plants, especially micro-nutrients
- Improve soil physical and chemical conditions by increasing the humus content
- Improve water holding capacity of soil
- Less KWa power needed for soil tillage

## 6. MINING PRACTISES THAT CONTRIBUTE TO THE DESTRUCTION OF SOIL FERTILITY AND LOSS OF BIO-DIVERSITY

- Incorrect stripping of topsoil. Various soil horizons with different properties are stripped together and stockpiled.
- Stockpiling of proper topsoil with sterile or acidic subsoil (plinthic or grey clay material)
- Long periods of stockpiling creates anaerobic conditions, resulting in a decline in microbial activity and/ or changes in bio diversity.
- Soils are nutritionally stripped and have low microbial activity

- Long fallow periods are as detrimental to soil health as no fallowing.
- Incorrect soil placement with rehabilitation (plinthic and grey clay material on the soil surface), causes slaking, increasing crust formation, and compaction resulting in poor infiltration, aeration and increased run-off and erosion. These plinthic and grey clay materials are also basically sterile in terms of microbial activity
- Poor irrigation practises. Over irrigation causes leaching of nutrients.
- Decline in water quality in major river systems is causing a gradual build-up of salinity and sodicity.

In most cases poor seed germination or die-back of seeded grass occur because of a combination of these factors mentioned.

The following can be done to improve soil bio-diversity and therefore sustainable rehabilitation:

- Crop rotation
- Fallowing and green-manuring
- If there is not sufficient time to introduce proper fallowing or green-manuring practises compost can be applied to the soil

# 7. RECOMMENDATIONS FOR PROPER REHABILITATION OF SOILS DISTURBED BY OPENCAST MINING OPERATIONS

## 7.1. STRIPPING

- Sequential stripping of soil horizons. In some cases the A and B Horizons can be stripped together. This has a huge practical, logistics and cost implication, but until such time that it is implemented, no improvement in sustainability of rehabilitation will occur
- Smaller stockpiles and seeding of stockpiles with grass

## 7.2. LANDSCAPING AND REPLACEMENT OF SOILS

- It is imperative to reshape the landscape as close as possible to its original topographic features (e.g. slope and drainage lines, wetlands). Various surveying and GIS software can be used to achieve this goal
- Where possible use the "freshest" stripped soils for redressing, as this will alleviate the soils becoming sterile or lose microbial activity
- Place the plinthic and grey clay material in the sub-soils and the original A and B horizon material on top. Create an environment where the topsoil is at least 40-60cm deep for proper aeration, water-holding capacity and drainage, resulting in proper root development

## 7.3. SEEDING WITH GRASS SPECIES AND LEGUME CROPS

- A three stage approach can be implemented where pioneer species are planted to create a soil environment for sub-climax species. After some time climax species can be introduced. There are many case studies where reseeding is necessary because the sub-climax and climax grass species die back after the first or second season
- Legume crops like soya, cow peas, Dolichos, or Lucerne can be introduced to improve the soils microbial activity and soil structure.
- Compost and other organic humic substances can be used to speed up the process of restoring soil biodiversity

# 8. THE ROLE OF COMPOST AND OTHER HUMIC SUBSTANCES IN RESTORING BIODIVERSITY IN DISTURBED SOILS

Many books have been written about the role of compost in improving soil bio-diversity as well as the making of compost. It never became a standard practise in commercial agriculture for the following reasons:

- It is bulky and transport costs did not make it viable
- Practical problems with application

- The value was always measured in terms of N, P and K content and in monetary terms.

Times have changed however and recent research across the world has shown that soil bio-diversity has great value in commercial agriculture and rehabilitation both from fertility as well as a plant nutrition perspective. Compost is a great and fairly quick way in restoring soil fertility although it must be made clear that it is a long term approach that is necessary. Organic and humic products can overcome to some degree the practical and logistical problems posed of importing large volumes of organic matter.

## 9. SUMMARY

- There is no quick fix solution to the seriously negative impact of opencast mining on high potential soils
- Proper stripping and replacement of soils is imperative for any proper redressing and seeding with grass species to take place
- A holistic long term, staged approach is necessary to restore physical, chemical and biological processes in the growth medium
- Long term monitoring and relevant adjustments must be made to restore the soils to some sort of arable crop production potential to ensure future food security problems that might loom.