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SOIL CLASSIFICATION AND LAND CAPABILITY OF THE PRIESKA COPPER MINE PROJECT AREA

Attached please find the draft report on the soil and land capability of the Prieska Copper Mine (PCM) site.

Yours sincerely

Eco Soil

Specialist Soil Report and Land Potential of the Prieska Copper Mine (PCM) Site

Compiled

By

Soil Classification and Capability Report by A. M. Hattingh and J.M. Hattingh

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EXECUTIVE SUMMARY

Repli Trading No. 27 (Pty) Ltd, a subsidiary of ORION Minerals NL, requested a soil specialist report based on information for the proposed re-establishment of the Prieska Copper Mine (PCM). The latter is a copper and zinc mine situated near the town of Prieska in the Northern Cape Province. The purpose of this study is to identify the present soil quality in terms of soils physical characteristics and to identify obvious highly sensitive areas to be avoided (based on field study and desktop available information). A total of approximately 7082 ha were studied during the desk top study. Approximately 463 ha from an old tailings pad next to the slimes dam on the mining site, plus 45 ha from the floor of a retaining dam next to the old tailings pad (Figure 1) were investigated in more detail during the field study.

The investigation of the soils involved the collation of climate, geology, topography information and determining the broad soil groups of the area as background for further interpretation. Properties of the soil types, soil depth, clay content, estimated profile available water content (PAWC), soil restrictions and strengths, as well as soil potential were determined from information obtained of a field survey. The soil investigation on the proposed area was done on the available data from the land type information of the Institute of Soil Climate and Water and other relevant information.

The present land use is severe mining operations and open field. Most soils are highly disturbed and only small patches are relatively undisturbed in the areas of the old tailings and at the retaining dam.

Properties like clay content and erosion susceptibility to erosion is highly dependent on the parent material. In the case of this site the tillite/mudstone can give rise to soils susceptible to erosion when exposed. Exposed surfaces should therefore be limited or prevented. It should be covered with any crop or rock, even for short periods.

The site is between 1042 to 1118 m above sea level. The terrain type can be described as slightly irregular plains.

The climate of the area is typified by warm to hot summers, high evaporation and dry warm winters, a mean annual rainfall of 244 mm and a large degree of variability in the monthly rainfall. Potential evaporation is extremely high. The temperatures are highest in January with an average around 26.9°C. July is the coldest month with 9.8°C on average. Frost may occur. Due to the very low rainfall the area is not suitable for dryland crop production.

Red/yellow apedal, freely drained soils with a high base status is present in the largest part of the PCM Project area. The Ah93 soil group occupies a large percentage of land in the south of the site. The soils are shallow (less than 450mm deep) and of low agricultural potential and have rock, weathered rock or calcrete as underlying material.

Clay contents are generally less than 15 % and may therefore be susceptible to wind erosion. Soils should always be kept covered with plants or crops to prevent erosion. The profile (plant) available water content of 0 and 40 mm also indicates soils of low potential in the entire Project area. The area can be classed in land capability class III: Soils not suitable for arable agriculture, but suitable for grazing. The disturbed areas have very low pH values giving rise to elevated Cu, Zn and Fe values. An application of 2 ton/ha lime is recommended in the indicated areas to avoid further built-up of micro-elements. The presence of the underlying calcrete will fortunately restrict the acid mine drainage. Without the presence of the calcrete, acid mine drainage can give rise to pollution of groundwater especially in this area with low clay contents. According to the desktop study, there is no peat or soils with a high potential agricultural value within the PCM Project area.

Contamination of presently undisturbed top soils should be prevented as far as possible. All waste products should be dumped on previously disturbed sites.
The number of roads should be restricted in order to prevent wind and/or water erosion. Position of access roads is therefore not restricted by soil properties, as long as disturbance regarding roads are kept to a minimum.

Table of contents

List of Figures

List of Tables

GLOSSARY OF TERMINOLOGY

Refer to Van der Watt H.v.H. & van Rooyen T.H. (1995)

- **A-Horizon (30)**. The depth of the topsoil horizon.
- **B-Horizon (100)**. The bottom end of the sub-soil horizon.
- **Restriction layer:** It can be rock fragments, soil structure or hydromorphic soil conditions that can limit root development.
- **Profile available water capacity (PAWC) –** It is a calculation between the AWC multiplied with the effective rooting depth (ERD). PAWC values are therefore the most important value to determine an irrigation design and scheduling perspective. It is also mentioned as total available moisture (TAM)
- **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 A-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
- **Land types:** A class of land with specified characteristics. In South Africa it has been used as a map unit denoting land, mappable at 1:250 000scale, over which there is a marked uniformity of climate, terrain form and soil pattern
- **Mesotrophi**c: Refers to soil that has suffered moderate leaching, such that the sum of the Ca, Mg, K and Na (base) cations is 5-15cmol/kg clay. Such a soil is said to have a medium base status
- **Dystrophic:** Refers to soil that has suffered marked leaching, such that the sum of the exchangeable (as opposed to soluble) Ca, Mg, K and Na (base) cations is <5cmol/Kg clay. Such a soil is said to have a low base status
- **Base status:** A qualitative expression of base saturation.
- **Base saturation**: The sum of the exchangeable Ca, mg, K and Na expressed as a percentage of the total cation exchange capacity at a specific pH
- **Plinthic**: A plinthic horizon is a subsurface horizon that consists for 10%or more of an iron-rich, humus-poor mixture of kaolinitic clay with quartz and other

diluents, which changes irreversibly to a hardpan or to irregular aggregates on exposure to repeated wetting and drying with free access to oxygen

- **Margalitic**: Refers to A-horizons with strongly developed structure that are dark coloured with a high base status, Ca and Mg being the predominant exchangeable cations
- **Melanic:** A dark coloured horizon with a high base status
- **Duplex**: A soil with a relatively permeable topsoil abruptly overlying a very slowly permeable diagnostic horizon which is not a hardpan
- **Catena**: A sequence of soils of about the same age and derived from the same parent material. These soils occur under similar macroclimatic conditions, but have different characteristics due only to variation in topography and drainage

STATEMENT OF INDEPENDANCE AND PROFESSIONAL AFFILIATION

I, the undersigned, hereby declare that we are not involved in any way with the PCM, Repli TradingNo. 27 or ORION Minerals NL.

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

DISCLAIMER:

All possible care has been taken in compiling this report. ECO SOIL and the authors of this report cannot take any liability for perceived inaccuracies, misinterpretation of the information or any decisions made as a result of the information used in this report.

…………………………………………….
Francois Botha
Eco Soil

Field of expertise: Soil Scientist

1. INTRODUCTION

A broad soil classification and agricultural potential were done on the hand of a field study (confined to the area over which they have prospecting rights) supported with a desktop study on the project area of approximately 7082 ha. An additional 463 ha at an old tailings pad next to the slimes dam on the mining site, plus 45 ha from the floor of a retaining dam next to the old tailings pad (Figure 1) were investigated in more detail during the field study. The purpose of this study was to get baseline information regarding soil potential, land use and land capability of the study area and to determine what the possible impacts of the proposed development (mining and related infrastructure) can have on the soil quality.

The desktop study of the soil quality at the Prieska Copper Mine (copper and zinc mine) in the Northern Cape Province was done during September 2017 on available data from the land type information of the Institute of Soil Climate and Water and other relevant information. A field trip to the site was done on 13 Sept 2017. Applying the obtained information, it was possible to characterize soils based on the limitations of the soils' physical characteristics and site constraints. Soils were classified in terms of the Taxonomic classification of South Africa. A combination of variables was used to obtain the land capability and agricultural potential of the soils.

2. 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):

- Site visit to the project study area and selected sampling of soils;
- Characterise and classify the soils of the prospecting right areas;
- Assess the impacts that the proposed development (mining and its related infrastructure) will have on the soils, and

- Give recommendations on possible management and mitigation measures that should be used to minimise the impacts, including input to the Closure Plan.

3. PROBLEM STATEMENT AND STUDY OBJECTIVE

Repli is interested in further mining of the Copperton Deposit and is in the process to prepare a Bankable Feasibility Study (BFS) for the proposed re-establishment of the PCM. PCM exploits the Copperton deposits. These deposits are of volcanogenic origin and includes economically important grades of sulphide copper and zinc, but also has traces of barite, lead and Pyrite (0 PEA PCM_20170421_C (2017). The purpose of this study is to identify the present soil quality in terms of soils physical characteristics and to identify obvious highly sensitive areas to be avoided.

4. PROJECT TEAM

Complete Curriculum Vitae's are summarised in Appendix 2.

Table 1: List of the team members

SPECIALISTS	FUNCTION	QUALIFICATION
F Botha	Soils project leader	B.Sc. (Hon), Pedology
A.M. Hattingh	Soil scientist, GIS Specialist	M.Sc. (Soil Science)
Johan Hattingh	Soil scientist	M.Sc. (Engineering geology)

5. IDENTIFICATION OF RELEVANT LEGAL REQUIREMENTS AND GUIDELINES

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

6. INVESTIGATIVE METHODOLOGY AND TECHNIQUES

The investigation commenced conducting the following actions:

- The collation and evaluation of available information.
- A desktop study was conducted on a total study area of approximately 7082

ha and with specific reference to the prospecting rights areas of 463 ha on an old tailings pad next to the slimes dam, plus 45 ha from the floor of a retaining dam next to the old tailings pad were investigated in more detail during the field study.

- A site visit on 13 September 2017. The site visit was only conducted on the proposedmining rights application area. Eighteen observations were made and eight samples were taken for lab analysis.
- The eight samples were submitted to Geolab (Potchefstroom) for a routine soil analysis (pH, P, K, Ca, Mg, Na) plus micro-elements (B, Cu, Mn, Zn, Fe and Al). Two samples were sent to EcoAnalitica (Potchefstroom) for a more intensive analysis of heavy metals. These results of the soil analysis should serve as baseline information for the present prospecting rights area.

6.1. SOIL CLASSIFICATION

The investigation of the soils involved the collation of following soil information:

- Information of the field visit, using the TAXONOMIC CLASSIFICATION OF SOUTH AFRICA
- Broad soil groups of the area were identified (*Soil Classification working group, 1991*) were obtained from the land type survey of the ISCW. At the time of the land type survey classification of soil profiles was carried out using the BINOMIAL SYSTEM FOR SOUTH AFRICA.
- Geology, properties of the soil types, soil depth, clay content, estimated profile available water content (PAWC), soil restrictions and favourable conditions, as well as soil potential were determined form the information.

6.2. INFORMATION SYSTEMS

The following sources of information were utilized:

- Initial Figures and shapefiles supplied by Repli
- Preliminary site layout plans supplied by Repli

- Geology gw_2922.tif Geological maps of the Republic of South Africa and the Kingdoms of Lesotho and Swaziland, 1997; scale 1: 250 000 (ENPAT shapefile (http://egis.environment.gov.za DTA) Geological map 2922, Area Prieska. Scale 1 : 250 000 (hard copy) Above mentioned map (1988) were obtained from: The Director. Department of Mineral and Energy Affairs, Geological Survey, Pretoria.

- Remote sensing information for topography:

  For background purposes the topography of the area was obtained from SRTM (1arc) information from Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global Sheets s31_e022_1arc_v3.tif and s30_e022_1arc_v3.tif, Earth Explorer: U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Centre. Slope information was calculated from the abovementioned data.

- Climate: https://en.climate-data.org/location/12734/ Website accessed 6 Sept 2017.

- Google EarthTM image; digital image - Background

  - The Dept. of Agriculture's information was used to determine land types and soil descriptions: Memoir 38: 2922 (Prieska). The land type survey information at 1:250 000 scale

7. GENERAL BACKGROUND INVESTIGATION

7.1. PRESENT LAND USE

The proposed mining rights application area is heavily disturbed (Figure 2) and only small patches of this area are relatively undisturbed. Relics of an old golf course are present in the area.

Land-use of the areas surrounding the PCM site is restricted to low intensity grazing. The natural grazing capacity of the site is approximately 35-40 hectares per large stock unit. The combination of low rainfall, high potential evaporation, high maximum and low minimum temperatures, as well as low potential shallow soils limits agricultural activities.

7.2. GEOLOGY

Geological borders generally changes gradually from one lithology to the next and are not sharp transitions as depicted on Figure 3. In geological time, several phases of uplifting, erosion and deposition have created complex landforms determined by the underlying geology. Geology may have a marked influence on soil properties and especially on topography, which in turn influences soil properties. Properties like soil depth, clay content, clay mineralogy and susceptibility to erosion is highly dependent on the parent material.

Northern parts: Migmatite, gneiss and granite are predominant. Occasional small outcrops of ultra-metamorphic rocks forms small hills. All rocks are included in Namaqualand Metamorphic Complex. Lime nodules and calcrete are abundant and dorbank is present in places.

South corner: Predominantly tillite, mudstone and shale (Dwyka Formation); occasional small inliers of granite-gneiss (Keimoes Suite). Coarse desert pavement is common on the Dwyka Formation. Calcrete and lime nodules are abundant. Occasional small pans sub parallel drainage pattern can be present.

In the case of this site the tillite/mudstone can give rise to soils severely susceptible to erosion when exposed. Exposed surfaces should therefore be limited or prevented. It should be covered with any crop, mulch or rock armour, and should not be exposed even for short periods.

7.3. TOPOGRAPHY

Topography of the area is illustrated in Figure 4. The height above sea level of the PCM area varies between 1042 to 1118 m. The north-north-eastern parts are higher lying and gradually declining to the south and south-west. Current drainage pattern is illustrated in Figure 5. The 5 m contour lines are indicted in

Figure 6. No natural steep slopes are present in the study area. Steep slopes within the site will need to be stabilized and always be protected from wind and water erosion.

7.4. TERRAIN TYPES

Terrain types of the area can be described as slightly irregular plains.

The terrain properties indicate that there is only a slight variation in properties, and that the terrain type and topography has no restrictions for development of the area.

7.5. CLIMATE

The climate of the area is typified by warm to hot summers with a low rainfall of approximately 244 mm and a large degree of variability in the monthly rainfall. Precipitation is strongly seasonal with about 85% of the yearly rainfall falling in the summer months (October to March). Monthly variations in rainfall throughout the study area are given in Table 2. The highest rainfall is found during February and March. The variation in the precipitation between the driest and wettest months is 44 mm. The variation in annual temperature is around 17.1 °C. Potential evaporation is extremely high. The area can be classified as arid (AI = 0.1). High maximum and very low minimum temperatures are typical of this environment. The temperatures are highest in January with an average around 26.9°C. July is the coldest month with 9.8°C on average.

This area with its very low rainfall is not suitable for dry land crop production.

Table 2: Mean monthly rainfall and Temperatures of Prieska

Month	Mean Rainfall mm	AveTemp °C	MinTemp °C	MaxTemp °C
January	24	26.9	19.2	34.6
February	46	26.1	18.5	33.8
March	49	23.5	16	31
April	30	19	11.3	26.8
May	10	14.1	5.9	22.3
June	8	10.1	1.5	18.8
July	6	9.8	1	18.6
August	7	12.7	3.7	21.7
September	5	16.3	7.5	25.2
October	18	20.6	12.1	29.2
November	20	23.1	15	31.3
December	21	25.9	17.8	34.1
Total ave.	244			

Agriculture of this study area is limited by climatic factors. Soils indicated as having a high erodibility potential may cause problems during construction in wet periods of the year or during thunderstorms. Soils with such properties are found, but average annual rainfall is low in this area.

8. SOIL TYPES AND PROPERTIES

Existing historic soil property information was gathered in order to determine the percentages of land suitable or not suitable for agriculture. This information was derived from previous surveys of the Institute of Soil Climate and Water (ISCW) and from the ENPAT data base. 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 during a specific targeted soil survey. It will be necessary to do a proper soil survey in follow-up-studies of this area in order to determine the actual land use potential of the area. There may possibly be highly productive patches between the generally low potential agricultural areas.

The major soil forms that generally have similar characteristics were grouped together in broad soil groups to simplify the data for interpretation purposes. Broad soil groups occurring on the proposed development site is summarised in Table 3 for the specific site. The number of hectares and percentages of each of the soil groups is summarised in Table 4. The soils vary significantly in physical composition over the different areas. They are strongly influenced by the underlying parent material (geology) from which they were derived, as well as by their position in the landscape and the origin of the parent material (*in-situ* versus colluvium/alluvium derived).

Soil groups and forms give an indication of expected soil colour, properties and soil forming processes. Although soil forms can give a slight indication of soil capability, it cannot give a real indication of agricultural potential without taking the soil depth into account.

8.1. BROAD SOIL CLASSES

Three broad soil classes were found in the PCM study area and are summarized in Table 3.

Table 3: Broad soil classes for the PCM study area

Soil Class	Position on the PCM site	Class description
Ah93	Larger southern and central parts	Red-yellow apedal, freely drained soils; red and yellow, high base status, usually < 15% clay
Ag6	Northern corner	Red-yellow apedal, freely drained soils, red, high base status, < 300 mm deep
Ag154	East to north-eastern parts	Red-yellow apedal, freely drained soils, red, high base status, < 300 mm deep

Table 4: Hectares of the soil classes in the PCM study area

Broad Soil class	PCM study area	
	Ha	%
Ah93	4758 ha	67.2
Ag6	839 ha	11.8
Ae154	1485 ha	21.0

The broad soil classes in the study area can be described as:

Class A (red-yellow apedal, freely drained soils):

Class A refers to yellow and red soils without water tables and Hutton, Clovelly, Inanda, Griffin, Kranskop soil forms are typical in this class. This unit refer to land with one or more of the above soil forms and they occupy at least 40% of the area. These soils do not have plinthite.

Soil class Ah:

Broad soil class Ah refers to areas where red soils and yellow soils occupy less than 10% of the area. The soils have a high base status.

Soil class Ag:

Broad soil class Ag indicates red soils with soil depths less than 300 mm. The soils have a high base status.

Soil class Ae154:

Broad soil class Ae is typified by red soils with a high base status, normally deeper than 300mm and no dunes are present.

The majority of soils fall in the Ae, Ag and Ah group of soils (Table 3). These soils are red and yellow freely draining soils. Although the soils are of limited use for dry land crop production, it may have restrictive properties for construction in wet periods of the year and may be erosive. The soils are shallow and of low agricultural potential and have rock, calcrete or weathered rock underlying material.

Soil description of the soils (Figure 9) observed in the footprint sites:

- Clovelly-Cv (Orthic A / yellow-brown apedal B / unspecified material without signs of wetness): The B-horizon of these soils has very poor developed structure, or is single grain or granular (apedal). The dominant profile colour is yellow brown, which is an indication that iron (Fe^{2+}) is in a reduced state (less oxygen available than in red soils). These profiles are generally freely draining and do not have water logged conditions. No mottling or signs of drainage impedance are present. The underlying material is unspecified (to be specified by the surveyor), but is usually rock or weathered rock. In the case of the observations made in this study the soil of the Clovelly form was 45 cm deep.
- Coega-Cg (Orthic A / hardpan carbonate horizon): It is a shallow soil, generally approximately 30 cm deep, on a lime-cemented calcium carbonate hard bank. In the case of the observations made in this study the soils of the Coega form were between 15 and 20 cm deep.
- Mispah-Ms (Orthic A / hard rock): The Mispah is generally a shallow soil and the underlying material in this case is a continuous hard layer of rock. It cannot be cut with a spade when wet. In the case of the

observations made in this study the soils of the Mispah form were between 10 and 25 cm deep.

- Plooysburg (Orthic A / red apedal B / hardpan carbonate): The reddish brown colour of these soils is an indication that Iron (Fe) is in an oxidised state (oxygen rich) and that soils have a slightly dryer moisture regime than yellow soils. The B-horizon of these soils does not have significant structure (apedal). The sub soil is a lime-cemented calcium carbonate hard bank. In the case of the observations made in this study the soils of the Plooysburg form were between 55 and 75 cm deep.
- Prieska (Orthic A / neocarbonate B / hardpan carbonate): This soil form has undergone pedogenesis and contains Ca or Ca-Mg carbonate in the soil matrix of the B-horizon. The sub soil is a lime-cemented calcium carbonate hard bank. In the case of the observation made in this study the soil of the Prieska form was 95 cm deep.
- The Witbank soil form is a man-made soil deposit In the case of the observations made in this study the soils of the Witbank form were 15 cm deep.

8.2. SOIL PROPERTIES OF THE SITE

Soil depth of the PCM site is usually less than 45 cm (Figure 8) and that of the proposed mining rights application area is generally less than 25 cm, although very small patches of soils deeper than 50cm were observed. Soil depth has a dominant influence on soil potential.

Shallow soils indicate soils with a low arable crop potential while deep soils are a good indication of high potential. It is not recommended that arable crops and especially trees to be cultivated on soils shallower than 60 cm. Some vegetable can be produced on these shallow soils, but success is mostly limited to small areas and farmer’s competency. Variation in soil depth indicates that there will be a variation in yield potential.

Clay content of the top soil (A-Horizon) is less than 15% in the majority of the soils.

It can be expected that soils with clay contents less than 15% may be susceptible to wind erosion if exposed and not covered with plants or crops.

A large percentage of soils in the PCM site have such low clay contents (Figure 8). Soils with such low clay contents are also susceptible to compaction.

A good relationship between profile available water holding capacity (PAWC) and yield potential exists. Yields are determined by the amount of water available for plant growth. PAWC forms the basis for calculations of yield potential and for irrigation scheduling. Profile available water capacity (PAWC), saturated water content, field capacity and wilting point are calculated from soil depth, texture, soil form and bulk density.

The PAWC of the soils are very low in the PCM area (Figure 8). It therefore indicates that the agricultural value for dry land crops and even for irrigation purposes is generally very low. However, localized patches of deep soils will a high PAWC may be present, but on the scale of this desktop study it is not possible to determine.

8.3. FAVOURABLE PROPERTIES AND LIMITATIONS OF THE BROAD SOIL CLASSES

The favourable properties and limitations of the broad soil classes have also been investigated from available land type sources (Figure 10). The soils on this site are freely drained, structureless soils and have favourable physical properties, but have restricted soil depth, excessive drainage, and high erodibility potential as well as a low natural fertility status.

The limitations of the soil can give an indication of the soil properties that may have an impact during mining operations.

8.4. SOIL POTENTIAL

According to the information obtained from the desk study the land capability is Class III: Soils not suitable for arable agriculture, but suitable for grazing.

From the above mentioned classes it can be deducted that the soils of almost the entire proposed site is of low to marginally low suitability for arable agriculture. It should be taken in mind the scale of this survey is very broad and relative small patches of deep, highly productive soils may be present in some areas. With additional irrigation, these areas can be highly productive for most crops, especially for high value vegetable crop production when good quality irrigation water is used.

External factors like climate, topography, erosion factors surface rock and water quality for irrigation need to be considered to determine the actual agricultural potential.

According to the desk study the percentage of soils not suitable for arable agriculture, but suitable for forestry or grazing. These types of soils cover the highest percentage of the proposed area.

9. PEAT

The land-type memoir information and relevant accompanied documentation has been consulted to establish the possibility of the presence of peat in the PCM Area. There is no reference to peat in the memoirs. It must be noted that the definition of peat and its role in wetlands only became an issue during the last couple of years. The scale of the land-type survey was 1:250 000 and therefore it may be possible to have missed areas covered with peat. Personal experience is that the peat soils occur more likely in cooler temperate areas on the slightly undulating areas and drier makes the development of peat highly unlikely.

10. TRACE ELEMENTS

It is important to get baseline information on the trace-element contents in the soil before starting operations for future reference, since the mine exploits copper and zinc. Guidelines on highest “allowable” values are given in Table 5. In this case only the micro element contents of Cu, Zn, B, Mn, Fe and Al were analysed.

Table 5: Maximal permissible addition (MPA) of heavy metals and metalloids by the data of Dutch ecologists in mg/kg. *(Vodyanitskii, Y. N., 2016)*

Metal/metalloid	MPA
Beryllium (Be)	0.0061
Selenium (Se)	0.11
Thallium (Tl)	0.25
Antimony (Sb)	0.53
Cadmium (Cd)	0.76
Vanadium (V)	1.1
Mercury (Hg)	1.9
Nickel (Ni)	2.6
Copper (Cu)	3.5
Chromium (Cr)	3.8
Arsenic (As)	4.5
Barium (Ba)	9.0
Zinc (Zn)	16
Cobalt (Co)	24
Tin (Sn)	34
Lead (Pb)	55
Molybdenum (Mo)	253

Table 6: Standard chemical analysis of the soils in the study area

							DTPA			
Sample no	pH(KCl)	P(Bray 1)	K	Ca	Mg	Na	Zn	Cu	Mn	Fe
		mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}
CT 1	7.6	7	204	894	187	47	4.31	1.50	1.51	3.01
CT 7	3.4	6	29	408	44	1	34.65	91.08	3.36	98.95
CT 13	6.5	21	227	891	191	2	2.06	1.71	2.26	5.20
CT 14	3.5	12	13	430	63	1	6.31	6.71	2.01	72.54
CT 15	3.9	4	20	424	18	1	6.02	9.61	1.52	104.57
CT 16	5.8	3	54	852	138	2	10.65	4.23	8.90	61.26

The chemical analysis, based on standard agricultural analysis, is summarized in Table 6. The zinc and copper values at sample point CT7 (Figure 11) is above permissible values indicated in Table 5. Since the pH (3.4) of this sample point is extremely low, some of the Cu and Zn will be fixed if the pH is higher. The pH values at sample points CT14 and CT 15 are also low (Figure 12). It is therefore recommended to apply 2 ton/ha agricultural lime to all the areas with low pH values. The reasoning about acid mine drainage and the recommendation for lime application is discussed in point 11.

11. ACID MINE DRAINAGE (AMD)

The uncontrolled release of acid mine drainage (AMD) is the most serious environmental impact of mining operations world-wide. AMD originates from the oxidation of sulphide minerals when exposed to oxygen as is discussed in the last paragraph of point 10. The AMD releases various dissolved toxic heavy metals which have the potential to contaminate groundwater and surface water beyond drinking water limits.

When acidic solutions (AMD) interact with solids in the underlying unsaturated and saturated zone which contain carbonate or hydroxide, a series of chemical neutralisation reactions occur. For example, the buffering of H^+ by the dissolution of calcite ($CaCO_3$) releases bicarbonate (HCO_3^-) favouring the precipitation of less soluble metal-containing carbonates and hydroxides. The precipitation of $Cu(OH)_2$ (malachite) on calcrete was observed in the field during the site visit.

The carbonate and hydroxide-generating reactions remove dissolved metals from the tailings and rock-dump leachate and can therefore act to mitigate groundwater contamination. The unsaturated zone is considered to be a geochemical and physical barrier between the pollution source (tailings dam and rock-dumps) and the receiving groundwater system, because fluid movement and contaminant attenuation conditions can be favourable for mitigation of groundwater pollution. It must be stressed that metals can be significantly retarded as they move through the unsaturated zone but the retention of salinity maybe low resulting in high TDS values in groundwater.

Results of a total chemical element analysis for samples taken from the old concrete drying beds (CT5) and from the area adjacent to the old concrete drying beds (CT6) are summarized in Table 7. The positions of the sample points are illustrated in Figure 13. The contamination values of the analysed soil samples in Table 7 do not exceed the contamination assessment criteria for commercial/industrial purposes. It is most likely that the values of these samples will have the highest contaminated values on the PCM site and represents the worst case scenario.

Table 7: ICP-MS analysis from the old concrete drying beds (CT5) and from the area adjacent to the old concrete drying beds (CT6)

Sample:	CT 5	CT 6	SSV2 Commercial/ Industrial
	mg/kg	*mg/kg*	*mg/kg*
Ag 107	1.49	14.72	
Al 27	15760.00	7988.00	
As 75	2.61	4.21	150
Au 197	ND	ND	
B 11	1.90	1.21	
Ba 137	605.40	1206.00	
Be 9	1.08	0.41	
Bi 209	0.46	5.45	
Ca 43	24980.00	1631.00	
Cd 111	0.79	0.64	260
Co 59	12.81	5.04	5000
Cr 53	42.74	43.84	790000
Cu 63	390.10	453.30	19000
Fe 57	17370.00	53240.00	
Hg 202	ND	ND	6.5
K 39	2353.00	2007.00	
Mg 24	3316.00	2163.00	
Mn 55	152.60	98.41	12000
Mo 95	1.02	7.57	
Na 23	276.50	274.30	
Ni 60	13.79	6.99	10000
P 31	205.00	236.10	
Pb 208	24.94	309.20	1900
Pd 105	0.18	0.11	
Pt 195	ND	ND	
Rb 85	18.69	19.14	
Sb 121	0.21	0.27	
Se 82	0.84	2.01	
Sr 88	37.67	24.39	
Th 232	3.82	6.23	
Ti 47	343.70	397.70	
Tl 205	0.16	0.32	
U 238	1.74	0.77	
V 51	37.84	48.32	2600
Zn 66	514.60	324.10	150000

Microwave digested (Ethos UP, Magna Analytical) with EPA3051A method and results were obtained by using Agilent ICP-MS - mg/kg

Trace elements occur in the soil in various sorption phases

- Easily soluble phase
- Exchangeable phase
- Bonded to organic matter and oxides of Fe and Mn
- Residual fraction

Of these phases, the residual fraction is the least mobile and does not partake in chemical reactions in soils. The easily and exchangeable fractions are the most mobile and determine the bio-availability of trace elements.

Various leaching methods are used to estimate the concentration of an element in the easily soluble and exchangeable fraction. Although there is some agreement between different simple salt solutions to estimate the bio-availability of trace elements, the threshold concentration (TC) for each trace element is not defined for each extraction salt. The trace elements were extracted using a DTPA solution but the TC values are defined for a NH_4NO_3 solution.

Because the proposed mining rights application area is within an old mining area an assessment of the current contamination impact, using the threshold exceeding ratio (TER) and the trace element mobility coefficient (MOB%), would be more appropriate than to define current background values.

The TER and MOB% are calculated as follows

TER = ExC/TC and

MOB% =ExC/TotC

Where TER is the threshold exceedance ratio for an element, ExC is the NH_4NO_3 (1M) extractable concentration of a trace element and TC is a given threshold concentration, MOB represents the percentage mobility of an element and TotC is the total concentration measure in soil.

It is not possible to evaluate TER and MOB with the available chemical analysis, but there is some contamination as indicated by low pH values and high Cu , Zn and Fe values (CT7), low pH and high Fe (CT14 and CT15). The buffer capacity of the sandy top soils is low. Fortunately, the underlying material is mostly calcrete with a high neutralisation and immobilisation capacity of metals and the danger of deep acid drainage can therefore be limited by the presence of the calcrete. The sandy nature of the top soils has the ability of acidifying, but the application of the underlying calcrete will counteract the associated problems.

12. IMPACT ASSESSMENT

Table 8 shows the predicted impact assessment of the proposed opencast mine on the soils.

Table 8: Predicted impact assessment of the proposed mining activity on the soils at the PCM

SOILS								
Project Activity		Soils	Likelihood		Consequence			Significance Rating
All construction phase activities	Phase of Project	Construction Phase	Frequency of Activity	Frequency of Impact	Severity	Spatial Scope	Duration	
	Impact Classification	Direct Impact	Significance Pre-Mitigation					
	Resulting Impact from Activity	Disturbance/Loss of Soil Resources	4	5	4	2	4	90
			Significance Post-Mitigation					
			4	5	4	2	4	90
Project Activity		Soils	Likelihood		Consequence			
Ineffective Housekeeping and Management of Stockpiles and Exposed Soils	Phase of Project	Preparation-Closure Phases	Frequency of Activity	Frequency of Impact	Severity	Spatial Scope	Duration	Significance Rating
	Impact Classification	Secondary Impact	Significance Pre-Mitigation					
	Resulting Impact from Activity	Additional Disturbances/ loses of Soil Due to Erosion as well as Contamination	3	3	3	2	3	48
			Significance Post-Mitigation					
			3	3	3	2	3	48
Project Activity		Soils	Likelihood		Consequence			
Continued Activities Including Mining and Transportation	Phase of Project	Preparation-Closure Phases	Frequency of Activity	Frequency of Impact	Severity	Spatial Scope	Duration	Significance Rating
	Impact Classification	Cumulative Impact	Significance Pre-Mitigation					
	Resulting Impact from Activity	Cumulative Disturbance, Loss and Degradation of Soils	3	3	3	2	3	48
			Significance Post-Mitigation					
			3	3	3	2	3	48
Project Activity		Soils	Likelihood		Consequence			
Continued Activities Including Mining and Transportation	Phase of Project	Exploration-Closure Phases	Frequency of Activity	Frequency of Impact	Severity	Spatial Scope	Duration	Significance Rating
	Impact Classification	Cumulative Impact	Significance Pre-Mitigation					
	Resulting Impact from Activity	Increased/ Decreased Sediment Loads On Downstream Systems	3	2	3	2	3	40
			Significance Post-Mitigation					
			3	2	3	2	3	40

Table 9 shows the predicted impact assessment of the proposed opencast mine on the land capability.

Table 9: Predicted impact assessment of the proposed mining activity on the land capability at the PCM

LAND CAPABILITY AND LAND USE								
Project Activity		Land Capability & Land Use	Likelihood		Consequence			
Stripping of Soils, Clearing of Vegetation and Stockpiling of Materials	Phase of Project	Preparation, Construction and Operational Phases	Frequency of Activity	Frequency of Impact	Severity	Spatial Scope	Duration	Significance Rating
	Impact Classification	Secondary Impact	Significance Pre-Mitigation					
	Resulting Impact from Activity	Disturbance/Loss/Sterilisation of Inherent Land Capability and Land Use	4	5	3	3	4	90
			Significance Post-Mitigation					
			4	4	3	3	4	44
Project Activity		Land Capability & Land Use	Likelihood		Consequence			
Continuous Clearing, Disturbance, Laydown, Stockpiling and Transportation	Phase of Project	Preparation - Post-Closure Phases	Frequency of Activity	Frequency of Impact	Severity	Spatial Scope	Duration	Significance Rating
	Impact Classification	Cumulative Impact	Significance Pre-Mitigation					
	Resulting Impact from Activity	Loss of Land Services, Ecosystem Support and Services	4	4	2	2	3	56
			Significance Post-Mitigation					
			4	4	2	2	3	56

13. MITIGATION MEASURES REQUIRED

13.1. DUST CONTROL

Since the clay content of the soils is below 15% it may cause wind erosion. It is recommended to restrict the number of roads on the site. Measurements should be taken to control dust, especially on unpaved roads.

Surface areas should not be left bare, but should always be vegetated or covered with suitable coverage to prevent dust formation.

13.2. SOIL STRIPPING IN CONSTRUCTION PHASE

- The soil depths range from 30-70 cm, but are generally shallower than 70 cm. 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 land.
- During the construction phase it is recommended that the topsoil be stripped and stockpiled in advance of construction activities that might contaminate the soil.
- The stripped soils should be stockpiled upslope of areas of disturbance to prevent contamination of stockpiled soils by dirty runoff or seepage.
- All stockpiles should also be protected by a bund wall to prevent erosion of stockpiled material and deflect water runoff.

13.3. 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 6 m 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.

13.4. DECOMMISIONING AND REHABILITATION

- 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.

14. CONCLUSIONS OF SOILS ASSESSMENT

According to the desk study performed on the soils of the proposed PCM site for the proposed redevelopment of mining, most of the soils are not suitable for arable agriculture, but generally suitable for grazing. Soils are generally very shallow and less than 450 mm deep and not recommended for dry land crop production. Clay contents are less than 15%. Due to the soil depth and clay content of this area the profile available water capacity is very low (less than 40mm) and gives an indication of the low agricultural potential of the area.

Soil forms are mainly in the A group of soils (shallow red-yellow apedal, freely drained soils) in the PCM site. Most soils in the area may be susceptible to wind and water erosion, especially the southern parts.

No areas with peat have been observed during the field visit and desktop study.

From the soil properties encountered in the area it can therefore be concluded that the soils does not have high agricultural value. The negative properties of the soil are manageable.

Contamination of presently undisturbed top soils should be prevented as far as possible. Since large areas on this site have already been disturbed all waste products should be dumped on previously disturbed sites of the prospecting rights areas, even though the soils on this site are of low potential.

The number of roads should be restricted in order to prevent wind and/or water erosion. Soils are shallow and any operations regarding road construction will most probably end up on hard lime or rock on most places. Position of access roads is therefore not restricted by soil properties, as long as disturbance regarding roads are kept to a minimum.

15. BIBLIOGRAPHY

Dept. of Agriculture, forestry, and fisheries (2013). Land use and land capability.

MACVICAR, C.N., et al, 1977. Soil Classification, a Binomial System for South Africa.

Soil classification working group. 1991. Soil classification. A Taxonomic system for South Africa. Department of Agricultural Development. Pretoria.

Land Type Survey Staff. 1972 – 2006. Land types of South Africa: Digital Figure (1:250 000 scale) and soil inventory datasets. ARC-Institute for Soil, Climate and Water, Pretoria

Van der Watt H.v.H. & van Rooyen T.H., 1995. A glossary of Soil Science, 2nd Edition. The Soil Science Society of South Africa, Pretoria.

Vodyanitskii, Y. N., 2016. Standards for the contents of heavy metals in soils of some states. Annals of Agrarian Science 14, p257 -263.

16. APPENDIX 1: Maps

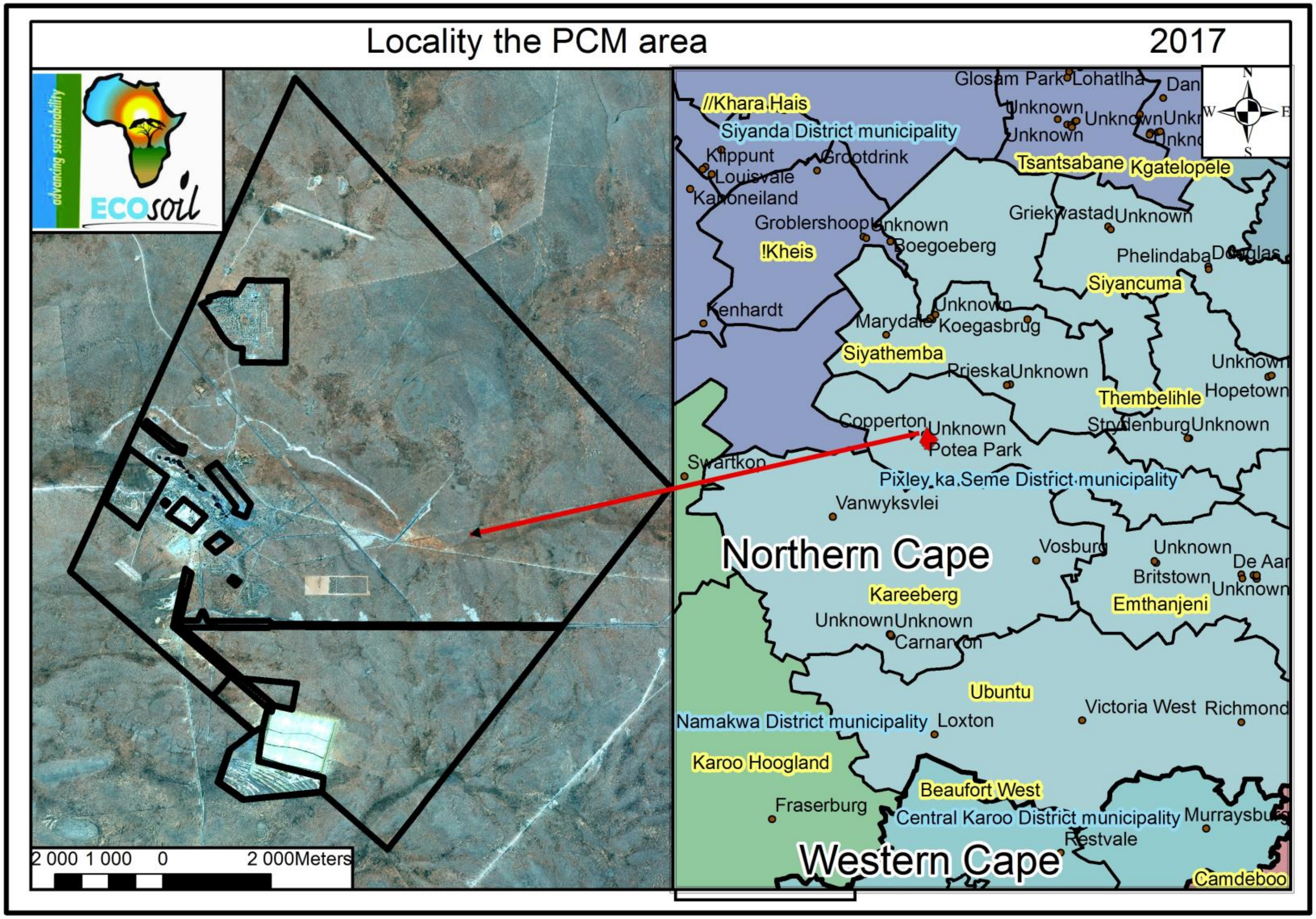

Figure 1: Locality of the study area

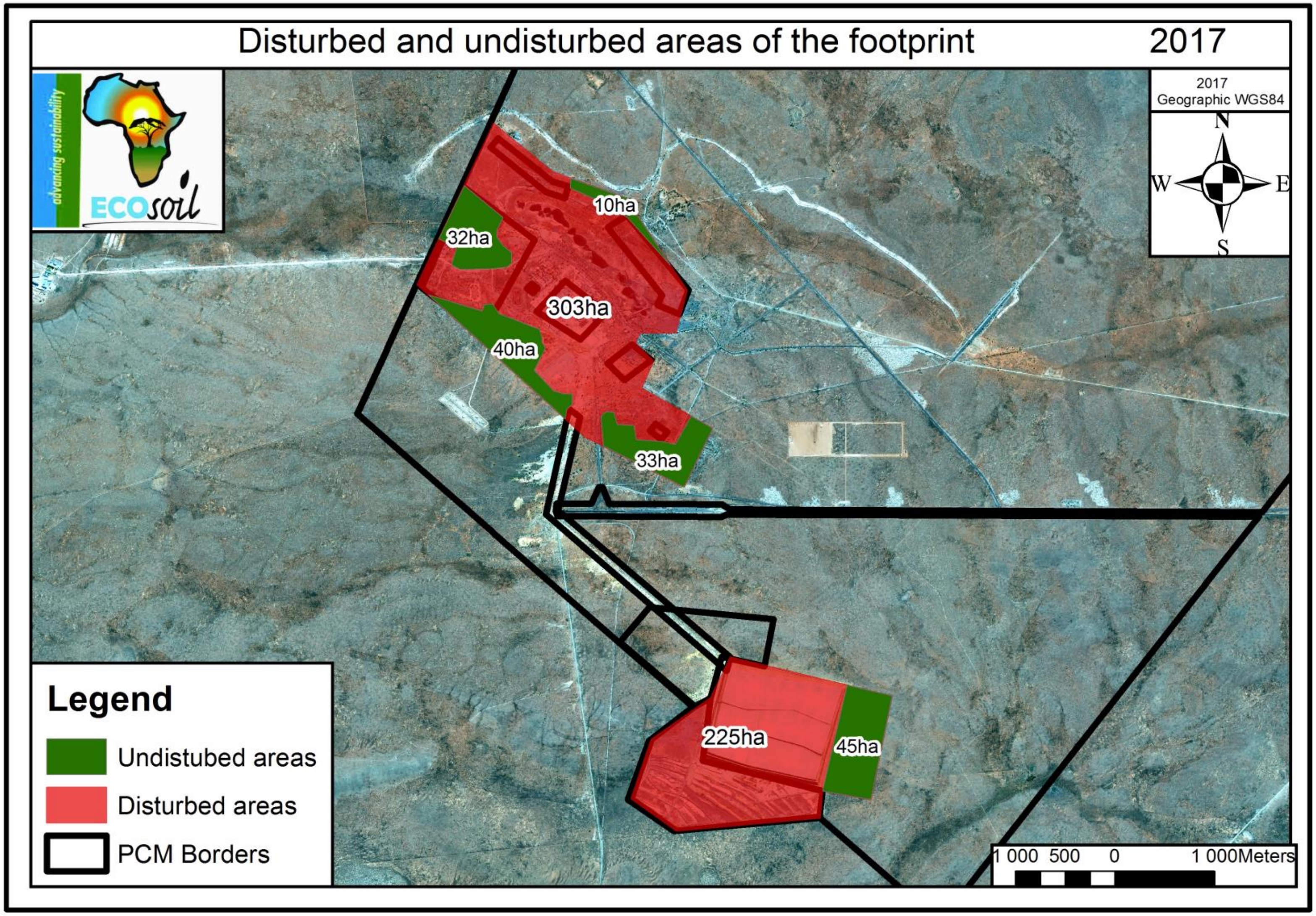

Figure 2: Disturbed and undisturbed areas on the PCM footprint site

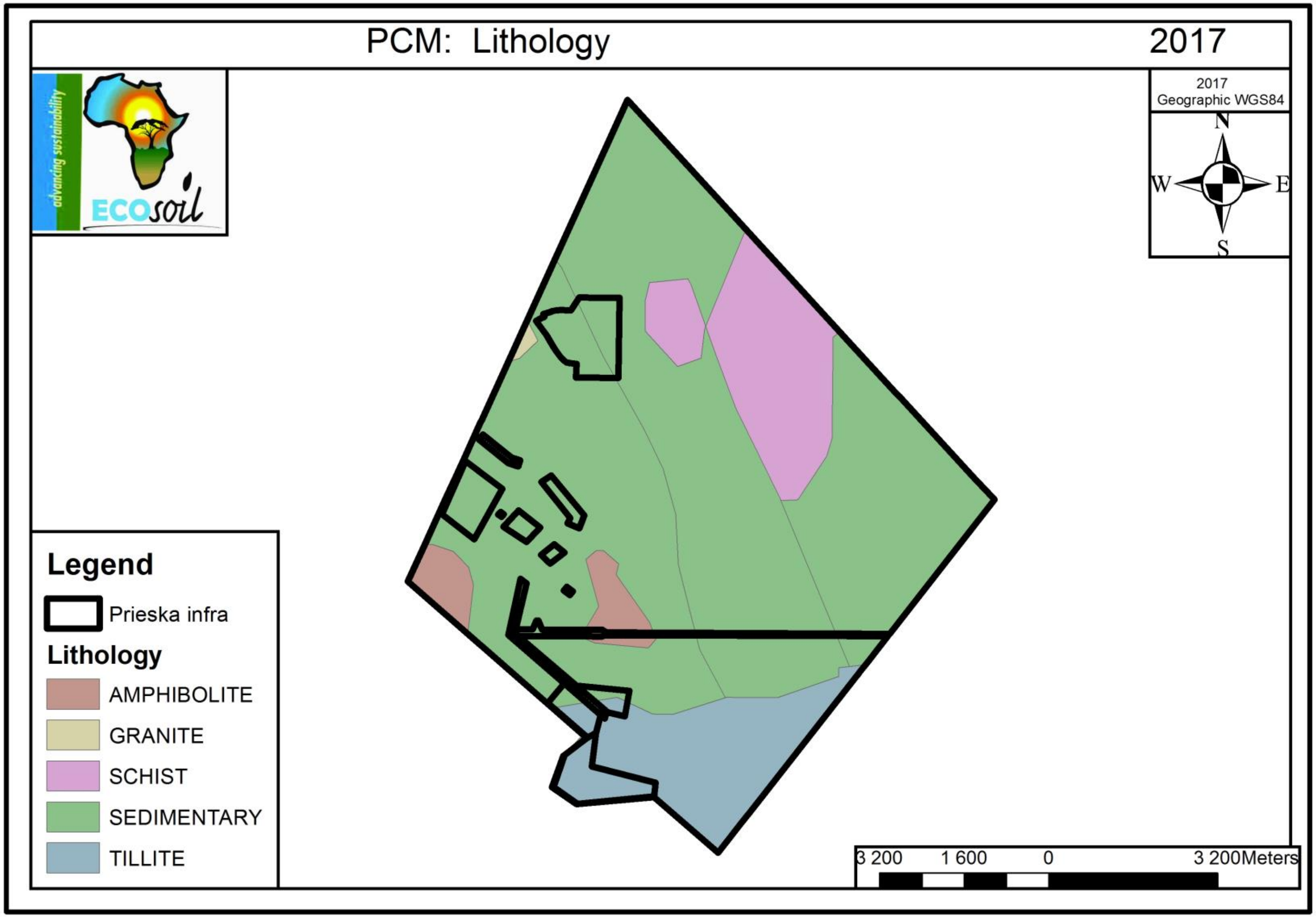

Figure 3: Geology of the study area

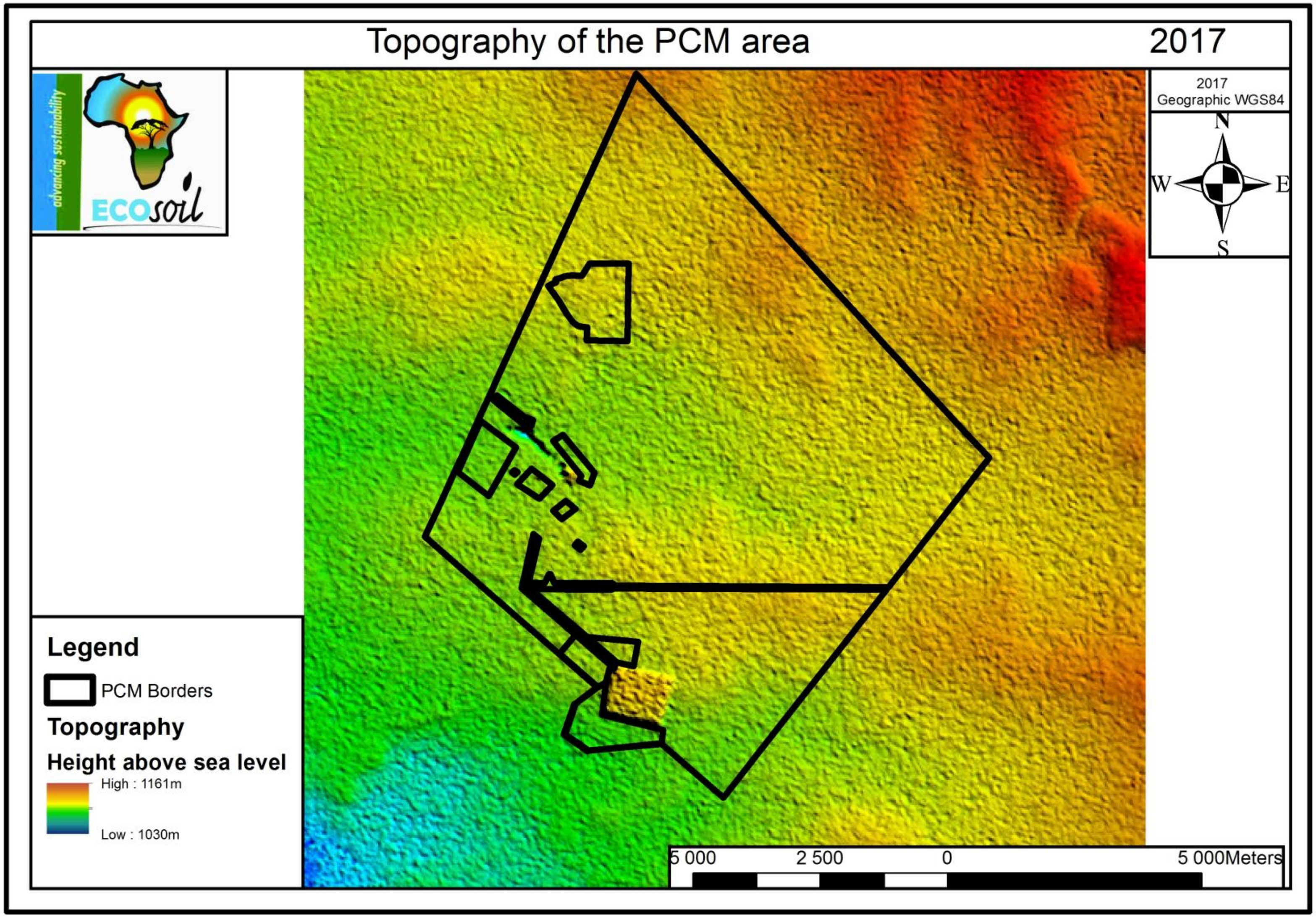

Figure 4: Topography of the study area

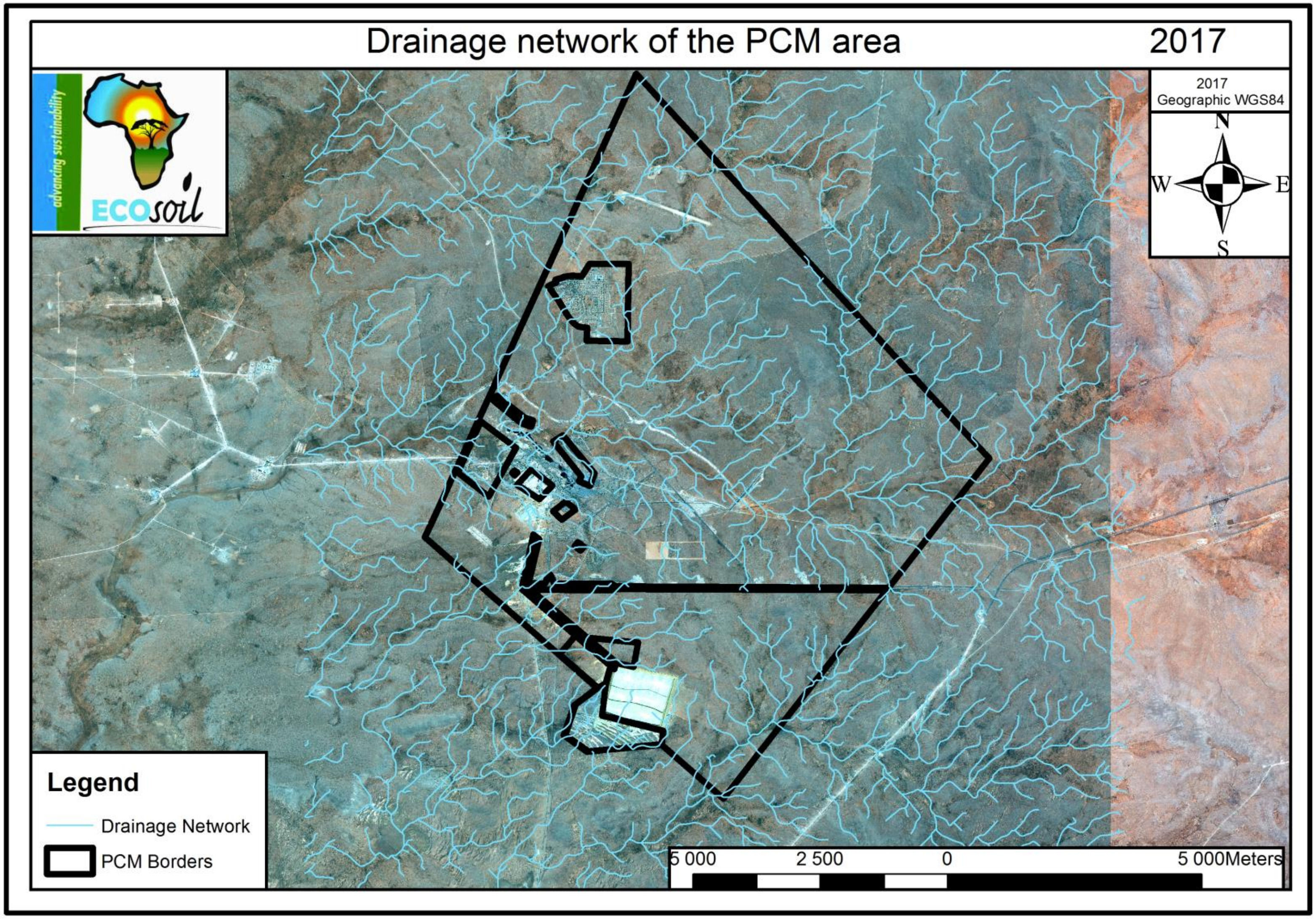

Figure 5: Drainage of the study area

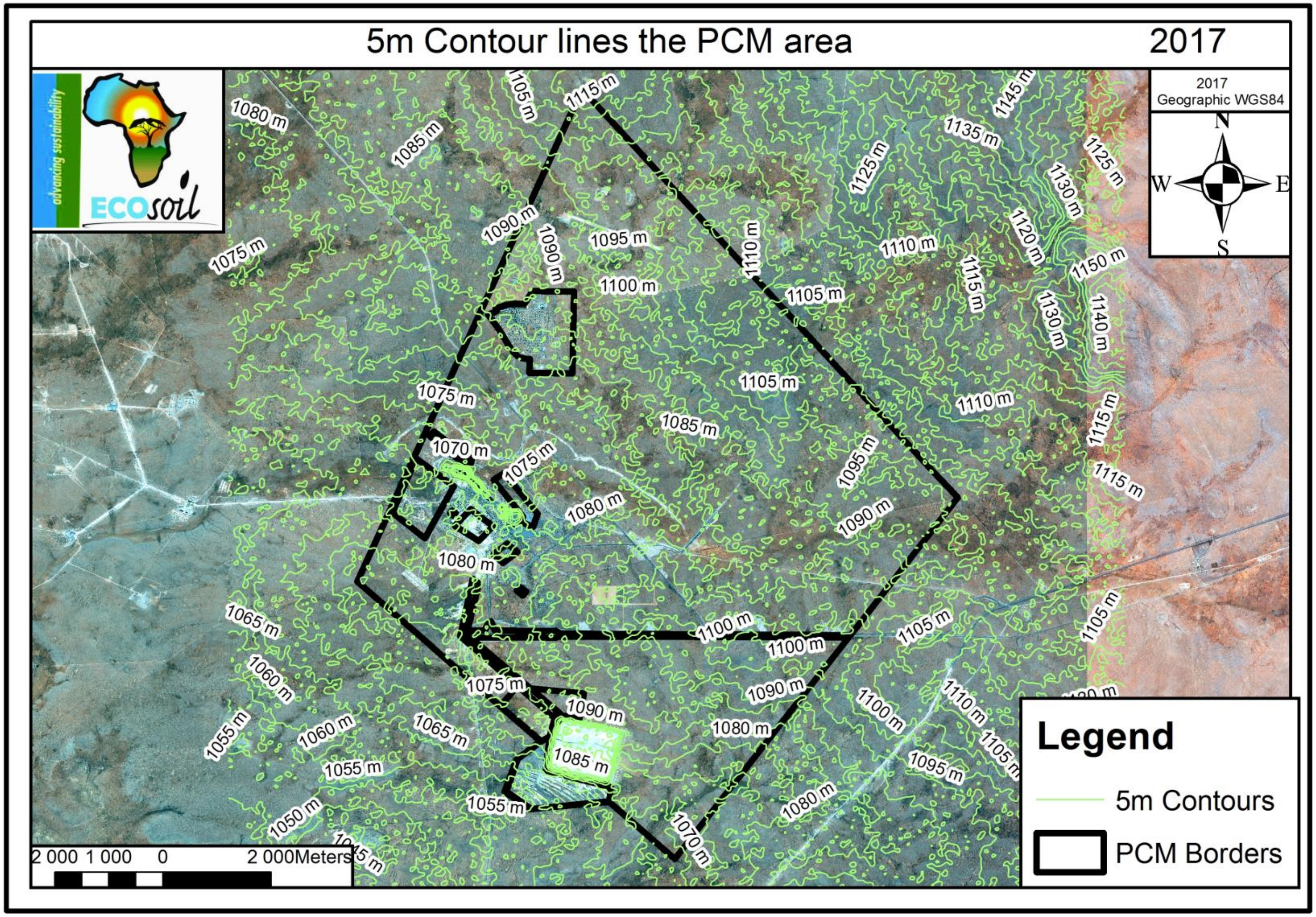

Figure 6: The 5 m contour lines of the Project area

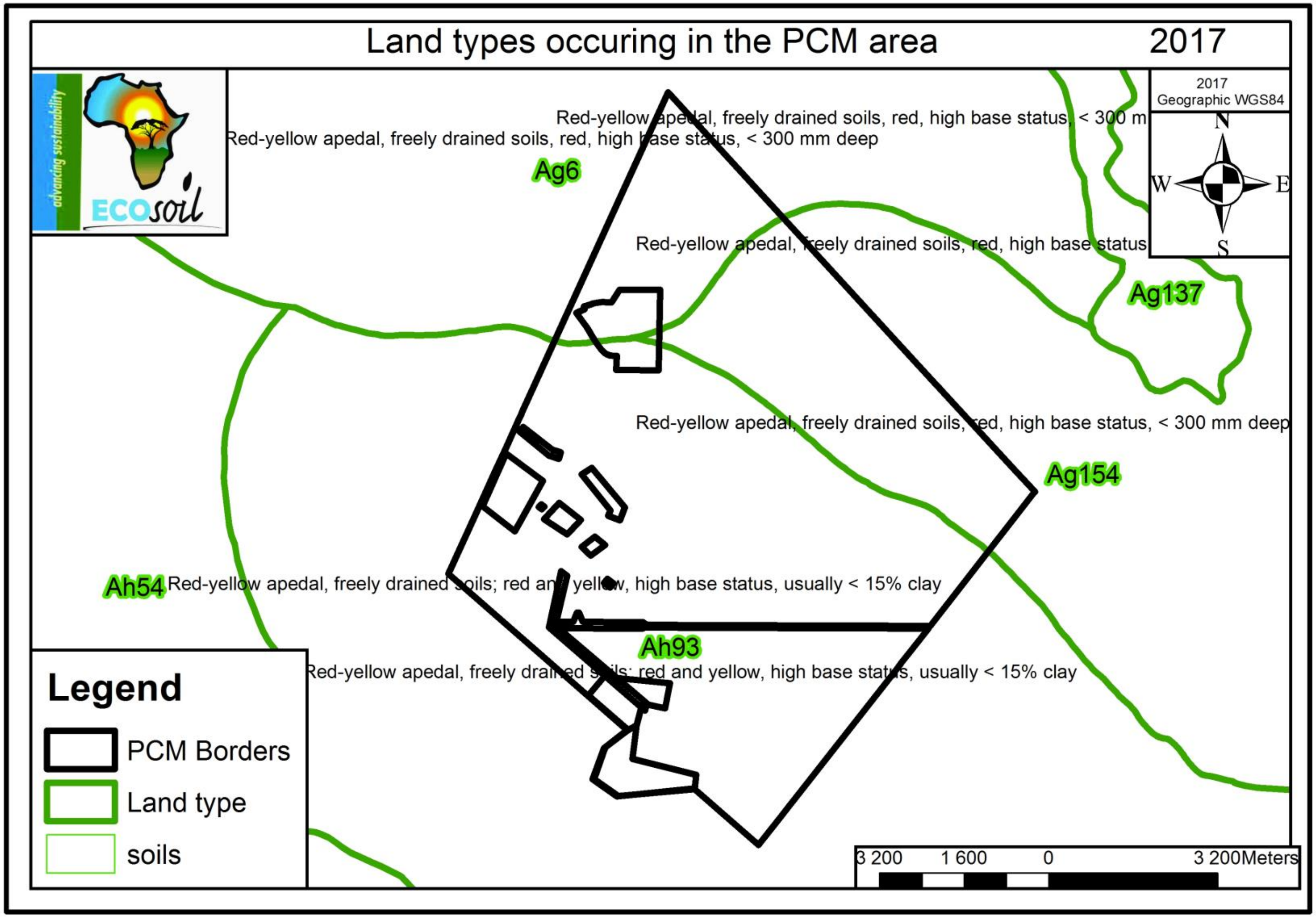

Figure 7: Broad soil classes of the study Area

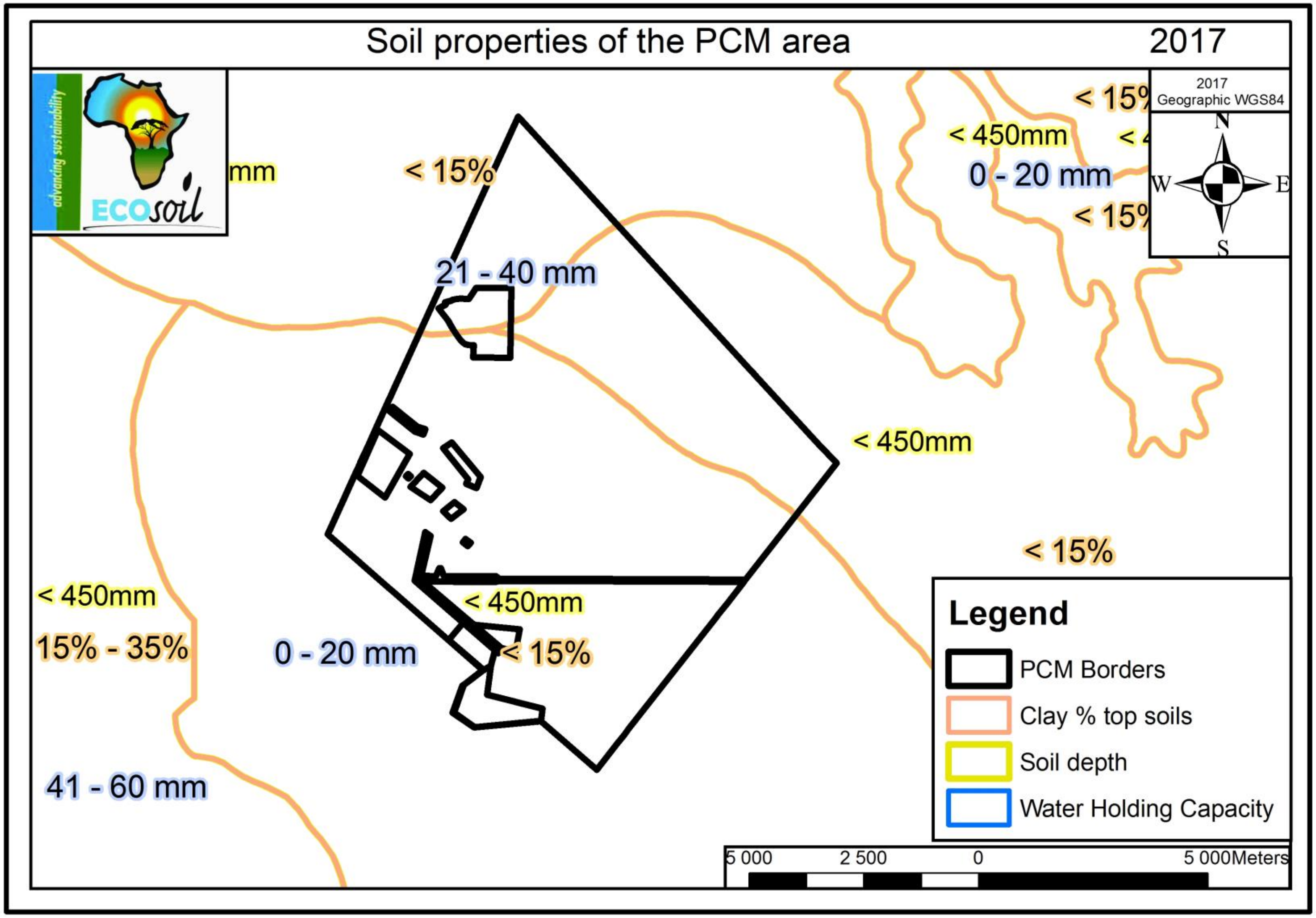

Figure 8: Soil properties of land classes in the study area

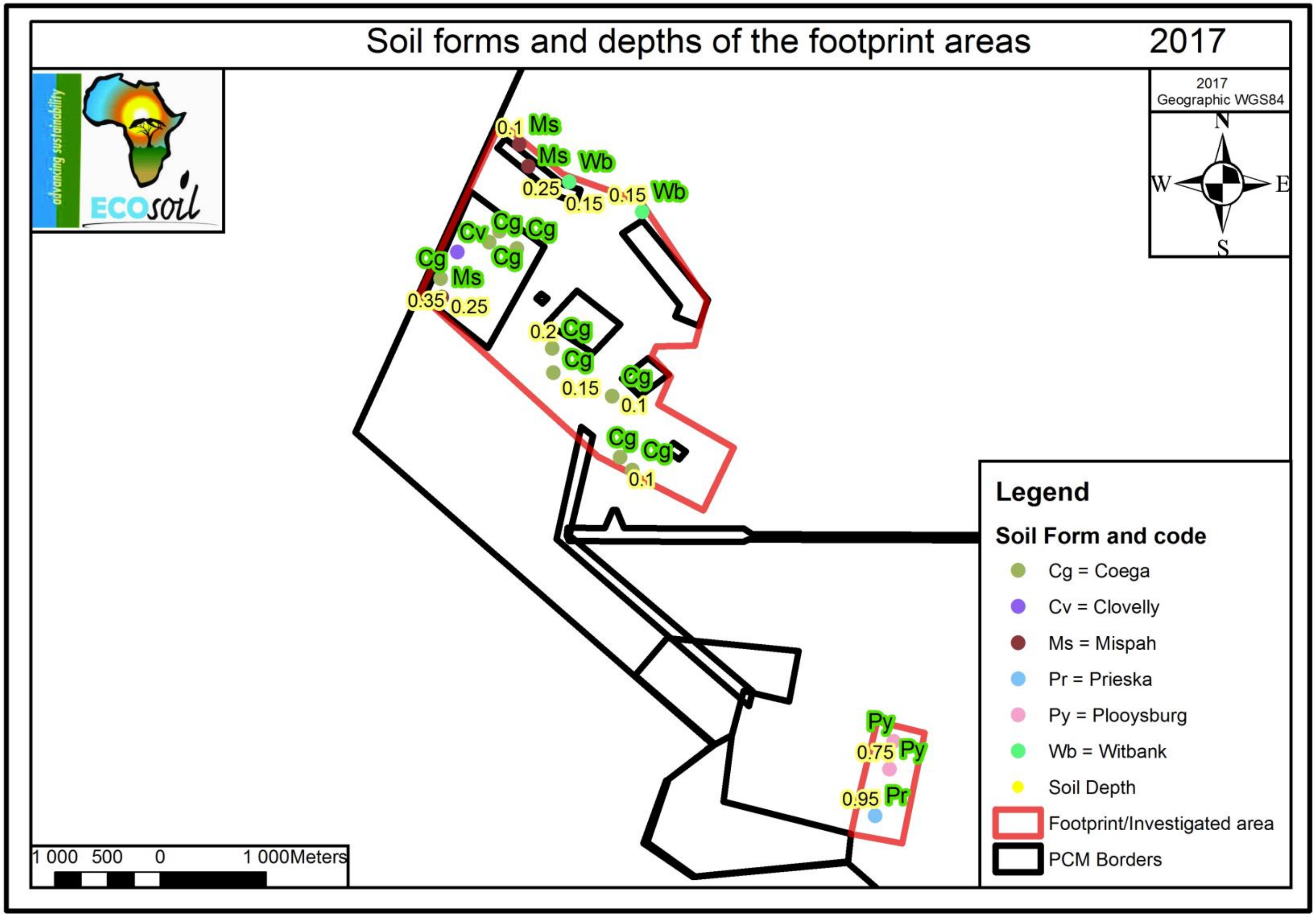

Figure 9: Soil forms and depths (m) observed in the footprint Area

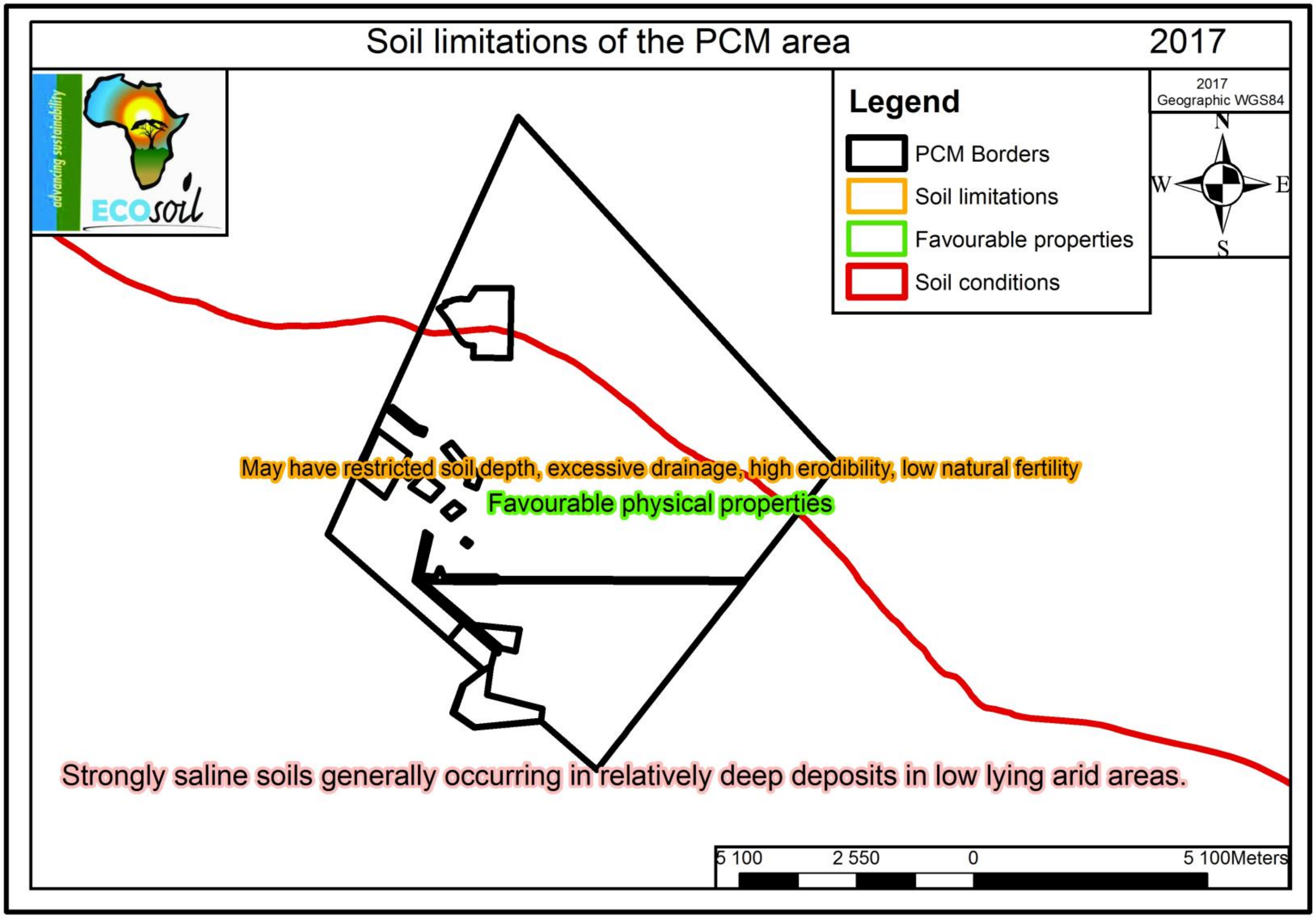

Figure 10: Soil limitations of the study area

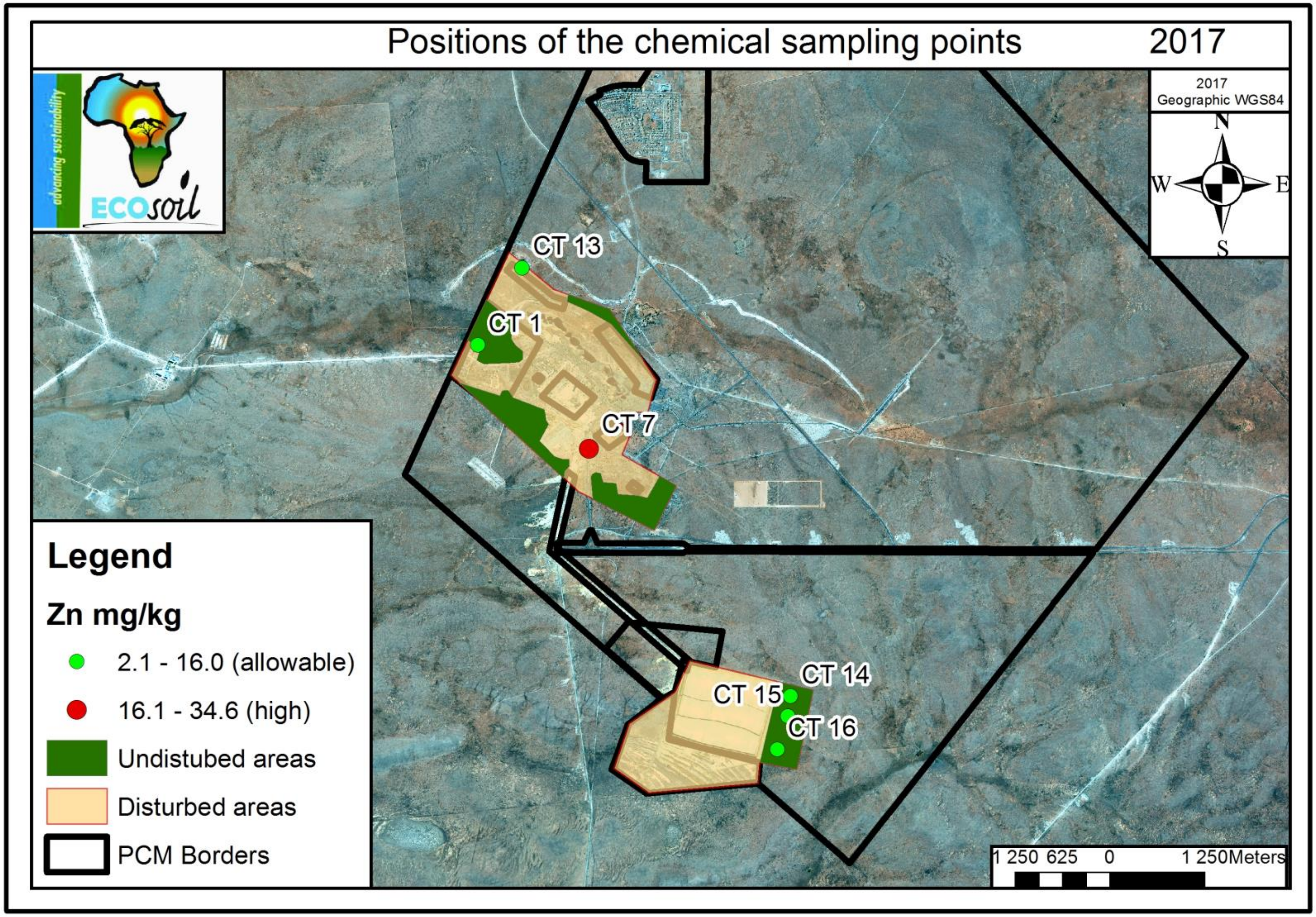

Figure 11: Position of soil chemical sampling points indicating high and allowable micro-element values

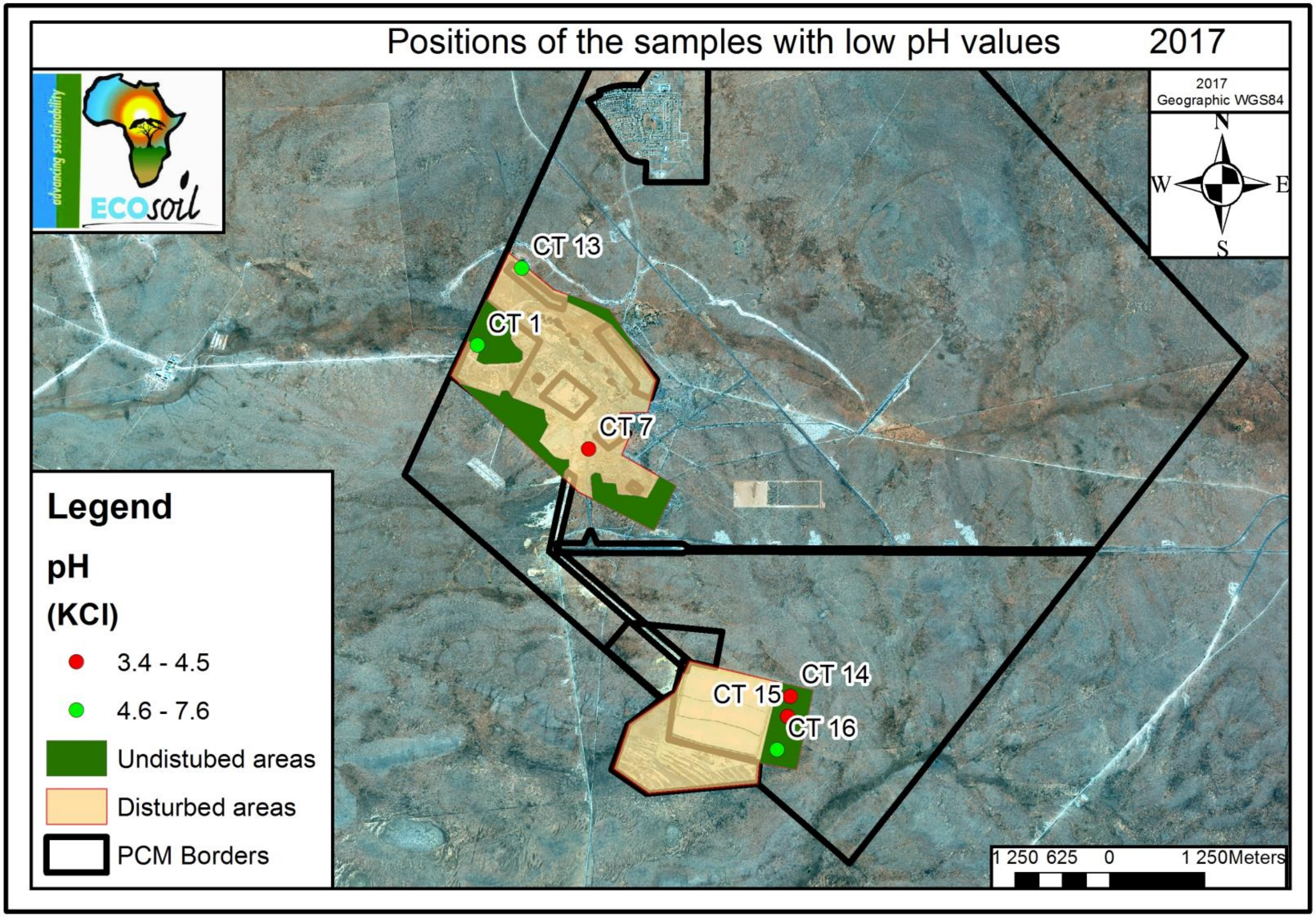

Figure 12: Position of samples with low pH values

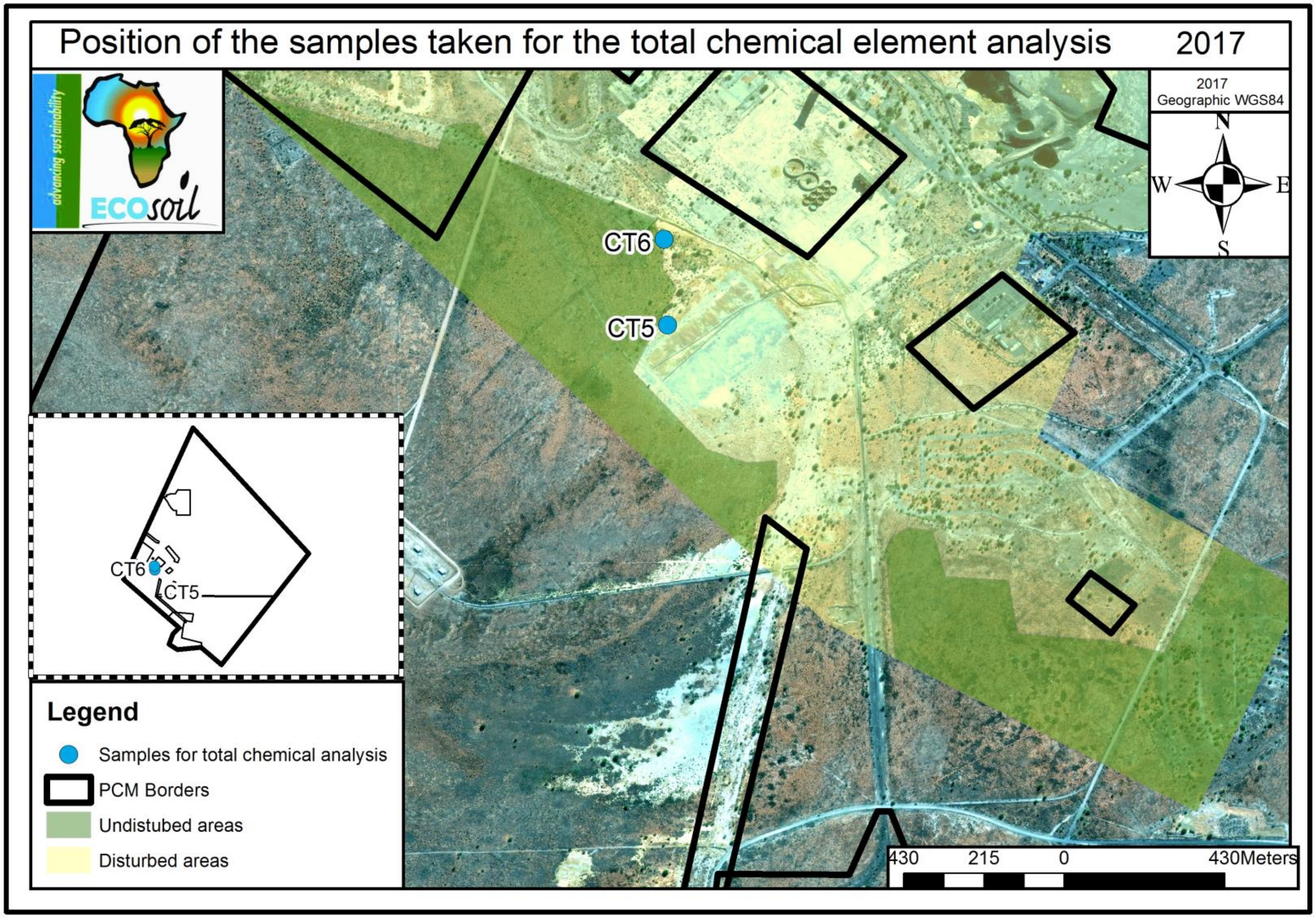

Figure 13: Position of the samples taken for the total chemical analysis

17. APPENDIX 2: CURRICULUM VITAES

CURRICULUM VITAE OF F. BOTHA

PERSONAL DETAILS

- **Name :** Botha, F
- **Date of Birth :** 9 June 1959
- **ID Number :** 59 06095074087
- **Marital Status :** Married
- **Cell:** 0849005933
- **Email address:** fbecosoil@gmail.com

FORMAL QUALIFICATIONS

- B.Sc (Pedology) from PU for CHE, 1984
- B.Sc (Hon) Pedology) from PU for CHE, 1988
- B. Comm. (Economics and Business Economics) from UNISA, 2001.

PROFFESIONAL AFFILIATIONS

- Soil Science Society of South Africa
- South African Soil Surveyors association
- Land Rehabilitation Association of SA (formation in process)
- SA Irrigation Institute

EMPLOYMENT HISTORY

- 1984-1988, Trans-Agric, College of Agriculture, Senior Lecturer in Soil Science.
- 1988-1991, ICI-Kynoch Agrochemicals, Training Co-coordinator
- 1991-1996, Lowveld College of Agriculture, Senior Lecturer in Soil Science.
- 1997-2004, SA Sugar Association, Senior Extension Officer, Malelane region.

- 2004-2007, Advanced Nutrients SA, Technical Director.
- 2007-Present, Private Consultancy and Director of Eco Soil.

WORK EXPERIENCE AND PROJECTS

- 8 years' experience as an extension officer, with the focus on sugarcane production under irrigation in the Malelane region.
- Initiated and Assisted SASRI research Dept with various trials related to sugarcane production.
- Involvement in pedological and geological surveys for Forestek (35 000ha's), ARC and private individuals for forestry, game ranching, farming enterprises and new agricultural developments (150 000ha).
- Functioned as project leader on a number of large scale soil survey projects, e.g. Donkerhoek Agricultural project, Mpumalanga
- Pedological specialist studies for environmental impact assessments (EIA's) as well as a number of economic and agronomic feasibility studies for new agricultural developments.
- 13 Years lecturing experience in soil science at agricultural colleges.
- Consultation on biological and soil health principles on various agricultural projects
- At present consulting on the following Precision farming sampling and Figureping in the maize sugar and industry
  - Feasibility studies on new sugarcane and agricultural projects under irrigation in Southern Africa
  - Environmental Impact Assessments for mining and new projects
  - Rehabilitation of opencast mining soils

CURRICULUM VITAE OF A. M. HATTINGH

PERSONAL DETAILS

- **Name :** Hattingh, A. M.
- **Date of Birth :** 9 December 1956

- **ID Number :** 5612090077089
- **Marital Status :** Married
- **Cell:** 0828536228
- **Email address:** astridhattingh@yahoo.com

FORMAL QUALIFICATIONS

- BSc Soil Science, PU for CHE, 1977
- BSc (Hon) Soil Science, PU for CHE, 1978
- MSc Soil Science, PU for CHE, 1983

MEMBERSHIP

- Soil Science Society of South Africa.
- International Soil Science Society.

EMPLOYMENT HISTORY

1979 –1993 Dept. of Agriculture (Highveld Region) as Researcher.

1993-1996 Assistant Director Soil Science.

1997-1998 Part time lecturer at PU for CHE in clay mineralogy, soil physics, irrigation, drainage, soil chemistry.

1997 Part time at REHAB. Soil consultant

1998-2002 Own business: Handrid Flora: Seedlings and vegetable production.

2002- 2003 Own Business in participation with Africa Plus Projects and Geoquip. Irrigation scheduling and soil consultant.

2004 Consultant Techniland. Precision farming.

2006 GCI- ARC. Researcher

2007 –2008 Africa Geo Environmental Services (AGES) GIS specialist, Soil Scientist

2009-2010 Part time Lecturer at Potchefstroom University and Agricultural College Potchefstroom. Private consultation.

2011-present. Own Business: Precision Farming also in Africa and mine Projects with GIS interpretation of soil and land capability studies.

WORK EXPERIENCE AND PROJECTS

Reports and GIS work for Africa (Tanzania, Mozambique) Projects: Basanza/Lugufu, Kigoma, Kilombero, Kasulu, Mopeia, Rufiji.

Management Plan for Vredefort World Heritage Site: GIS and agriculture

Geotechnical reports and GIS work.

Planning and research of various projects

Research: Water holding capacity – Influence of clay content and mineralogy

Determination of field capacity and wilting point.

Water conservation practices

Stubble mulching

Evaluation of cultivation practices

Recompaction rate of soils with different clay contents.

Cone penetrometer studies.

Water consumption of maize at different plant densities.

Calibration of neutron water meters and gamma density meters.

“Basin cultivation”

Handling of research plots: plant, herbicides and pesticides, cultivation, harvesting, soil water and compaction monitoring etc.

Nitrogen transfer

Organic growing of vegetables

Fertilisation of vegetables

Water conservation and irrigation for small-scale vegetable farming.

Soil acidity

Fertilisation of pasture

Phosphorus studies.

Head of soil analysis laboratory:

Soil, plant, water, lime, in vitro analysis --- supervisor

Interpretation and approval of results

Fertiliser recommendations- grain, pasture and vegetables.

POSITIONS HELD AND COMMITTEE PARTICIPATION

Assistant Director Soil Science. Dept. Of Agriculture Northwest Province (Administration, supervision of junior researchers, technicians and head of laboratory).

WRC steering committee projects.

1994 Secretary of SSSSA Congress organising committee.

Member of research steering committee Highveld Region.

Soil interest group of Western Transvaal: Founder member and Secretary and Chairlady-several times.

Combined Soil, Crop Science, Crop protection Congress: Organizing committee 1996 and 2012

Organizing convenor: Precision Farming Congress for 2013 and 2016

17.3. CURRICULUM VITAE OF J. M. HATTINGH

SOIL SCIENTIST AND ENGINEERING GEOLOGIST

ACADEMIC QUALIFICATIONS

University: PU for CHE (1971 to 1977) B.Sc and B.Sc (Honns) (Soil Science)

University: Purdue (Indiana USA) (1980-1982). M.Sc (Engineering Geology)

PROFESSIONAL REGISTRATION AND MEMBERSHIP

International Society for Terrain Vehicle Interaction

EMPLOYMENT HISTORY

- 1998: Lecturer in soil science at the PU for CHE.

1998 to 2003: Own business (Handrid Flora) and technical consultant for Envirogreen (Pty) Ltd.

2003 – 2005: Research and development in precision farming for Techniland (Pty) Ltd

2005 –2007: Specialist agronomist in precision agriculture for Cal Tech (Pty) Ltd

2007-present: Own business in precision agriculture

RESEARCH

Trafficability of vehicles (53 Reports)

Terrain evaluation

Dispersion of soils

Phosphate adsorption.

Soil Compaction (Forestry)

Cone penetrometer and Bevameter

Backfill material

Sustainability

Erosion

Rehabilitation of Gold tailings dams

LECTURE:

Soil Chemistry (4 years)

Clay mineralogy (5 years)

Soil Mechanics (17 years)

Soil Physics (6 years)

Irrigation (6 years)

Drainage (6 years)

Erosion (6 years)

Soil classification (7 years)

Land use planning and sustainability (5 years)

POST GRADUATE LEADER

Leader of five M.Sc dissertations

Examiner of various M.Sc dissertations.

INVESTIGATIONS AND PRECISION FARMING

Reconnaissance soil investigations (soil mapping) (Venda and Gazankulu)

Soil investigation for irrigation purposes (Taung and Klein Letaba)

Soil investigation for township development (Potchefstroom, Klerksdorp, Krugersdorp, Fochville and Nylstroom)

Soil investigation for precision farming (more than 50 000ha) (Schweizer Reneke, Hoopstad, Hertzogville, Klerksdorp, Viljoenskroon, Bothaville, Lichtenburg)

Rehabilitation of slimes dams (FS N 6, ST Helena and Beatrix slimes dams)

PRODUCTION AND MARKETING

Cultivation of vegetables (Tomato and Cucumber) under protection.

Cultivation of vegetable and flower seedlings

POSITIONS HELD AND COMMITTEE PARTICIPATION

Acting head of Department of Soil Science. PU for CHE

Administration, management, training, research and projects

Acting director of Institute for Soil Science Research. PU for CHE

Member of the Faculty Board: Natural Science. PU for CHE

Executive member of the Environmental Earth Science Group (4 years)

Member of various ARMSCOR panels

Member of various WRC panels

PUBLICATIONS:

9 Papers presented at various congresses and symposiums

3 Poster presentations at congresses

Manuals: 1) Recovery of vehicles

2) Maintenance manual for slimes dams

MODELLING:

Soil wheel interaction (Traction, drawbar pull and rolling resistance)

Trafficabilty of soils based on cone penetration resistance

Soil water balance (Modified AquaCrop)

Site specific Nutrient Management (SSNM): Based on the QUEFTS model and adapted for maize and sunflower

Water and wind erosion on tailing dams

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