DIGBY WELLS ENVIRONMENTAL

Proposed Open Pit Magnetite Mine and Concentrator Plant, Mokopane, Limpopo Province

Soils, Land Capability, Land Use and Conceptual Soil Stripping Plan

Project Number:

VMC3049

Prepared for:

Pamish Investments No. 39 (Pty) Ltd

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This document has been prepared by Digby Wells Environmental.

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Project Name:	**Proposed Open Pit Magnetite Mine and Concentrator Plant, Mokopane, Limpopo Province**
Project Code:	**VMC3049**

Name	**Responsibility**	**Signature**	**Date**
Wayne Jackson	Report Compiler		June 2015
Brett Coutts	Report reviewer		June 2015

EXECUTIVE SUMMARY

Introduction

Digby Wells Environmental (hereafter Digby Wells) was appointed by Pamish Investments No. 39 (Pty) Ltd (Pamish). This report covers the soils, land capability, and land use assessment for the open pit mining planned on the farms Vogelstruisfontein 765 LR, Vriesland 781 LR, Vleigekraal 783 LR, Schoonoord 786 LR and portions Re/1, Re/2, 3, 4, 5 and 6 of the farm Bellevue 808 LR. Soil surveys of mine impacted areas are needed to establish soil form (soil type) distribution patterns and properties, land capability (soil use potential) and land use. The relevant project components include the following:

- The delineation of soil types, including the determination of physical and chemical properties of the dominant soils indicated in the project area;
- Determining the existing land capability;
- Determining current land use;
- Develop soil stripping plan; and
- Producing a detailed soil report describing all the above.

The conservation of South Africa's limited soil resources is essential for human survival. In the past misuse of land due to not understanding soil properties, such as physical and chemical properties and their capability/potential correctly has led to loss of these resources through erosion and destabilisation of the natural systems.

In order to identify soils accurately, it is necessary to undertake a soil survey. The aim is to provide an accurate record of the soil resources of an area. Land capability and land potential is then determined from these results. The objective of determining the land capability/potential is to find and identify the most sustainable use of the soil resource without degrading the system.

Project Area

The study area is situated approximately 45 km north-west of the town of Mokopane, Limpopo Province. The site is bound to the west by the Mogalakwena River, a major watercourse for the Limpopo Province and a tributary of the Limpopo River. The study area falls within the farms: Vogelstruisfontein 765 LR, Vriesland 781 LR, Vleigekraal 783 LR, Schoonoord 786 LR and portions Re/1, Re/2, 3, 4, 5 and 6 of the farm Bellevue 808 LR. The N11 national route is situated 5 km east and the R518 regional road is situated 2.5 km south of the proposed project area respectively.

Methodology

As part of the desktop assessment, baseline soil information was obtained using published South African Land Type Data. Land type data for the site was obtained from the Institute for

Soil Climate and Water (ISCW) of the Agricultural Research Council (ARC) (Land Type Survey Staff 1972 - 2006). The land type data is presented at a scale of 1:250 000 and comprises of the division of land into land types.

A detailed study of the soils present within the project area was conducted during field visits in April 2015. The site was traversed by vehicle and on foot. A soil auger was used to determine the soil form and depth. The soil was hand augured to the first restricting layer or 1.2 m. Soil survey positions were recorded as waypoints using a handheld Samsung tablet. Soil forms (types of soil) found in the landscape was identified using the South African soil classification system. Landscape features such as existing open trenches were also helpful in determining soil types and depth.

Land capability is determined by a combination of soil, terrain and climate features. Land capability is defined by the most intensive long term sustainable use of land under rain-fed conditions. At the same time an indication is given about the permanent limitations associated with the different land use classes.

Findings

The land type data gathered during the scoping phase suggested that the dominant soils on the pit locations would be black clays and that the rock dumps would be sited on some black clays and some red soils. The land type data presents general soil types that may be found within the area and should always be confirmed by site visits as the data is at a high level and needs to be verified and fine-tuned.

The project area is dominated by the Arcadia (black clay) soil form with small portions of Oakleaf (red) soils to the west, and Shallow Glenrosa/Mispah soils on the hills towards the east

The land capability is dominated by the Class IV (moderate grazing) land capability, the Class IV land capability coincides with the Arcadia soils, and although these soils are deep their high clay percentage and shrink/swell properties make them very difficult to manage from an agricultural perspective.

The Class III (moderate cultivation/intensive grazing) land capability coincides with the Oakleaf soils, which are better drained and more easily managed in comparison with the Arcadia soil. They are situated to the west of the site and the low/lower grade stockpiles would be situated on them.

The Class VIII (wilderness) land capability can be found in the eastern portion of the project site and is linked to the shallow/steep Glenrosa/Mispah soils.

The land use that is dominant within the project area is grazing of the natural veld with a small portion in the north east being used for subsistence agriculture.

Conceptual Soil Stripping plans

There are two major soil groups in the project area and these soils will be stripped separately.

The Arcadia soils are heavy black clay soils with shrink/ swell properties. These soils are to be stripped and stockpiled as follows:

- The top 30cm of these soils are to be stripped and stockpiled in one stockpile (**S1**); and
- The remaining 90cm (up to depth 120cm) are to be stripped separately and stockpiled in another stockpile (**S2**).

The Oakleaf soils are red and somewhat freely draining. These soils are to be stripped and stockpiled as follows:

- The top 30cm of these soils are to be stripped and stockpiled in one stockpile (**S3**); and
- The remaining 90cm (up to depth 120cm) are to be stripped separately and stockpiled in another stockpile (**S4**).

The top 30cm of soil is stripped separately to conserve the natural seed bank as well as the natural fertility that has been accumulated in this layer. This layer is also to be replaced last to increase the chances of rehabilitation success.

These soils are stockpiled separately, and cannot be mixed under any circumstances. This would compromise their usefulness for rehabilitation.

These soils are to be stripped in the dry season only.

Potential Impacts

The major impacts associated with open pit mining are the disturbance of naturally occurring soil profiles. Rehabilitation of open pit areas aims to restore land capability but the experience is that post mining land capability usually decreases compared to pre-mining land capability. Soil formation is determined by a combination of five interacting main soil formation factors. These factors are time, climate, slope, organisms and parent material. Soil formation is an extremely slow process and soil can therefore be considered as a non-renewable resource.

Soil quality deteriorates during stockpiling and replacement of these soil materials into soil profiles during rehabilitation cannot imitate pre-mining soil quality properties. Depth however can be imitated but the combined soil quality deterioration and resultant compaction by the machines used in rehabilitation, leads to a net loss of land capability. A change in land capability then forces a change in land use.

The impact on soil is high because natural soil layers are stripped and stockpiled for later use in rehabilitation. Soil fertility is impacted on because stripped soil layers are usually thicker than the defined topsoil layer.

The topsoil layer is the layer where most plant roots are found and is generally 0.30 m thick. Topsoil contains organic carbon which is responsible for nutrient cycling, thereby improving soil fertility. Mixing topsoil with subsoil dilutes the soil fertility and also impacts on microbial activity leading to soil quality degradation over time in stockpiles.

The potential impacts associated with open pit mining on soils are broken up into the following:

- Loss of Topsoil;
  - Erosion;
  - Compaction; and
  - Physical & chemical alterations.
- Loss of Land Capability;
  - Replacement of topsoil not to pre-land capability specifications;
  - Low soil fertility; and
  - Slope/drainage design for rehab not done correctly.

Conclusion and Recommendation

The project area is dominated by dark shrink/swell clay soils of the Arcadia form with some portions to the west having red fairly well drained Oakleaf soils. The soil types and depths dictate the land capability which was classified as Class IV (moderate grazing) and Class III (moderate cultivation/intensive grazing) land capabilities respectively. The land uses followed similar trends and the Arcadia soils were mainly left as natural veld, whilst the Oakleaf soils were being utilised for subsistence grazing purposes.

The project area does not have a high agricultural footprint within the area due to the difficulties in cultivating the Arcadia soils.

The following recommendations are made to minimise the impact on the soils as well as things to look out for regarding these soils:

- All soils are only to be stripped during the dry season;
- The topsoil stockpiles are designed for a height of 30m this will impact the physical and chemical properties of the soils health, it Is recommended to stockpile to a maximum height of 4 m to reduce the impacts on soil physical and chemical properties;
- The Arcadia soils shrink when dry and swell when wet creating a risk to any infrastructure built on them and as a result this needs to be taken into account when designing infrastructure; and
- The soils must be stripped according to the soil stripping guideline (see Section 13).

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1 Introduction

The conservation of South Africa's limited soil resources is essential for human survival. In the past misuse of land due to not understanding soil properties, such as physical and chemical properties and their capability/potential correctly has led to loss of these resources through erosion and destabilisation of the natural systems.

Soils can be seen as the foundation for ecological function as shown in Figure 1-1. Without a healthy soil system for microbes to thrive in, the flora and fauna would be negatively impacted, which intern feeds the natural soil system with organics and nutrients.

In order to identify soils accurately, it is necessary to undertake a soil survey, in accordance with standard procedures. The aim is to provide an accurate record of the soil resources of an area. Land capability and land potential is then determined from these results. The objective of determining the land capability/potential is to find and identify the most sustainable use of the soil resource without degrading the system.

Soil mapping is essential to determine the types of soils present, their depths, their land capability and land potential. These results can then be used to give practical recommendations on preserving and managing the soil resource.

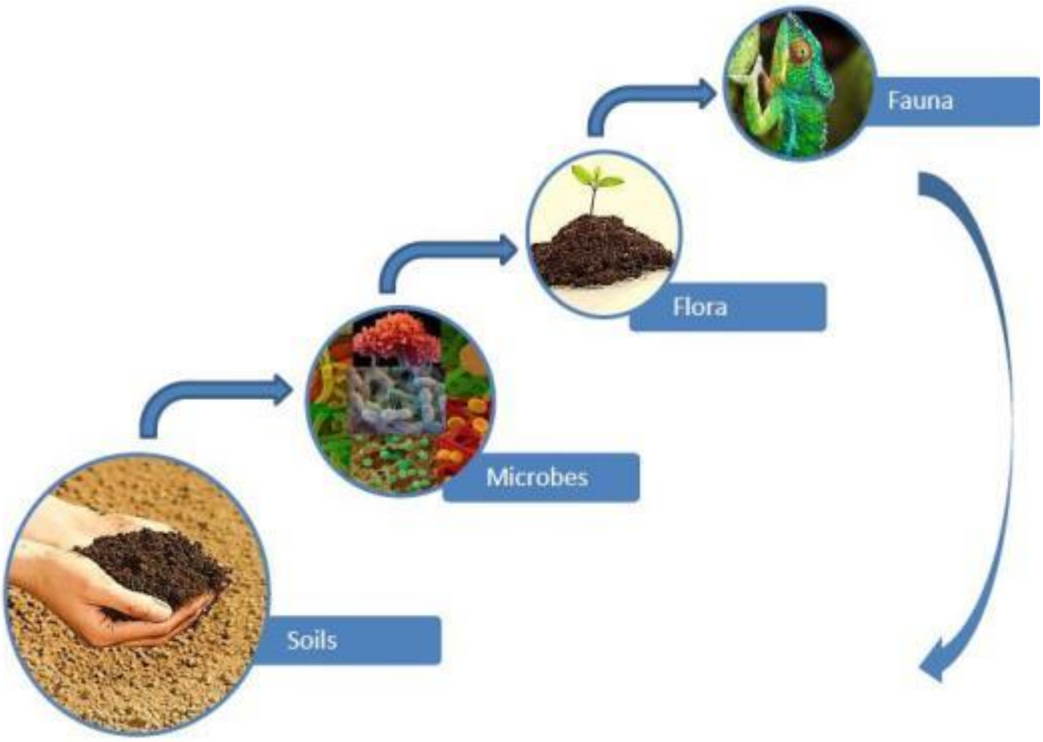


Figure 1-1: The Relationship between Soil and Above-Ground Ecological Succession

1.1 Project Area

The study area is situated approximately 45km north-west of the town of Mokopane, Limpopo Province. The site is bound to the west by the Mogalakwena River, a major watercourse for the Limpopo Province and a tributary of the Limpopo River. The study area falls within the farms: Vogelstruisfontein 765 LR, Vriesland 781 LR, Vleigekraal 783 LR, Schoonoord 786 LR and portions Re/1, Re/2, 3, 4, 5 and 6 of the farm Bellevue 808 LR. The N11 national route is situated 5 km east and the R518 regional road is situated 2.5 km south of the proposed project area respectively. The primary land-use is crop and livestock agriculture, which has contributed to some alteration of the natural landscape. The landscape is mainly natural veld as can be seen in Figure 1-2 from the top of the gabbro hill. Numerous secondary roads run through the project area as shown in Figure 1-3.

Figure 1-2: A Panoramic Image of the Project Area from the Top of the Gabbro Hill on the Eastern Portion of the Site

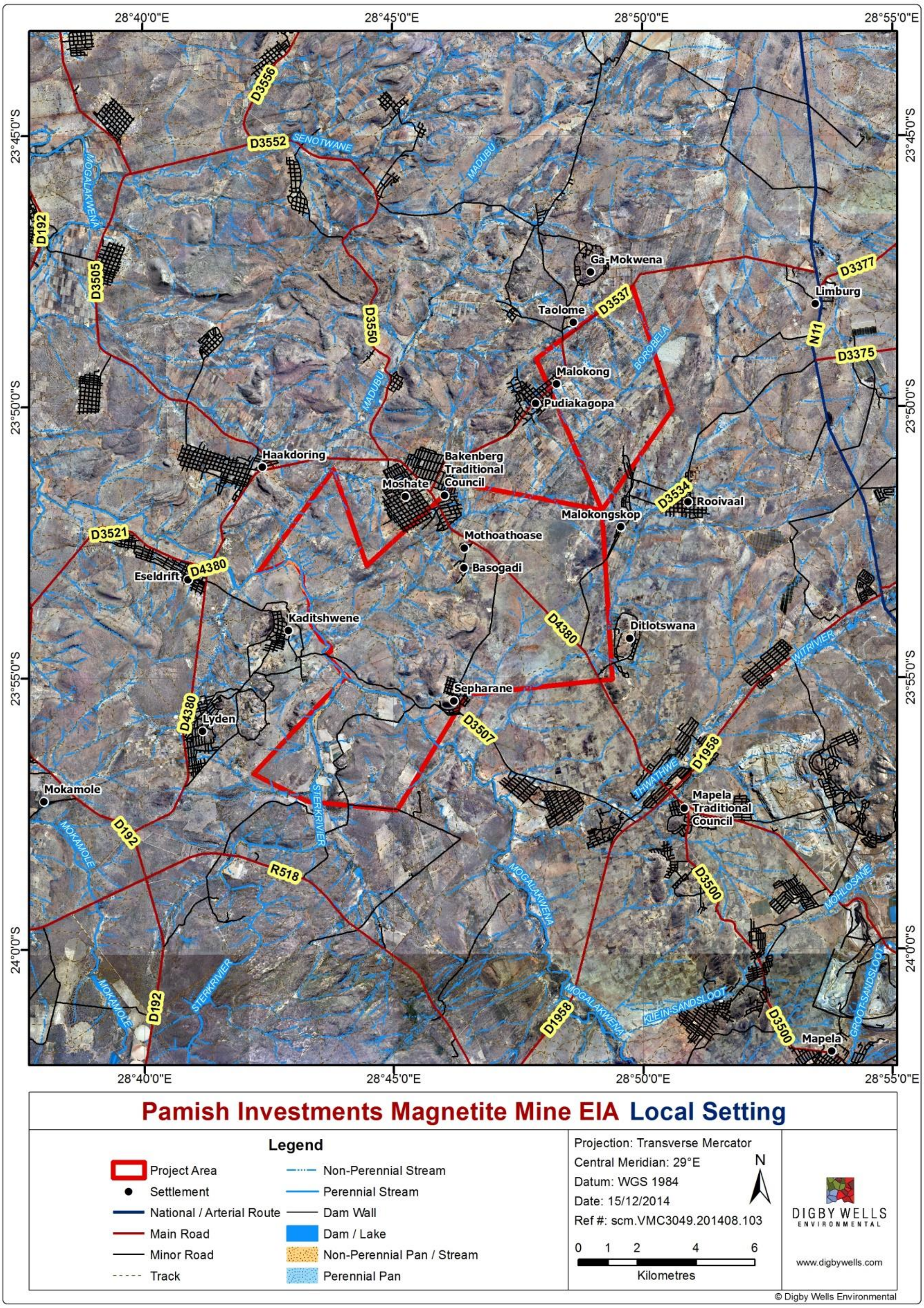


Figure 1-3: The Local Setting Map of the Magnetite Project Area

1.2 Mining Method

Open pit mining is considered the optimal mining method based on the thickness and positioning of the mineral resource.

Open pit mining is proposed to be undertaken outwards from the middle of the strike length advancing north and south to an initial depth of 20 m below the surface then to 40 m and thereafter to 60 m, and 80 m. A bench height of 10 m will be used to allow for the separate loading of the two ore layers and the parting. There are two open pits planned, which are separated by the D4380 Provincial Road, the approximate footprint of the north (Pit 1) and south (Pit 2) open pits are 129 ha and 66 ha respectively as shown in Figure 7-1.

The Life of Mine (LoM) is approximately 30 years with a Run of Mine (RoM) of up to one million tonnes per annum (tpa). The open pit mining will involve the activities as described in the sections below.

1.3 Infrastructure

The following associated surface infrastructure will be constructed in support of the mining activities proposed for the site:

- Overburden Stockpiles (Waste Rock Dumps);
- Low/Lower Grade Stockpiles;
- Tailings Dam;
- Clean and dirty water management systems, including treatment of water;
- Pollution control facilities;
- Waste management facilities;
- Power lines and associated transformers;
- Haul roads and other ancillary roads;
- Sewage treatment plant;
- Conveyors;
- Pipelines;
- Hazardous material storage area;
- Offices and workshops etc.

2 Terms of Reference

Digby Wells Environmental (hereafter Digby Wells) was appointed by Pamish Investments No. 39 (Pty) Ltd (Pamish) to undertake an specialist studies in support of the Environmental Impact Assessment that is being undertaken for the Proposed Mining Right Application. This report covers the soils, land capability, and land use assessment for the open pit mining planned on the farms Vogelstruisfontein 765 LR, Vriesland 781 LR, Vleigekraal 783 LR, Schoonoord 786 LR and portions Re/1, Re/2, 3, 4, 5 and 6 of the farm Bellevue 808 LR.

3 Expertise of the Specialist

The specialist involved in the compilation of the soils, land capability, land use, and soil stripping ratio assessment was Wayne Jackson. His curriculum vitae can be made available upon request.

4 Aims and Objectives

This reports aims to provide an accurate record of the soil resources of the study area through provision of the following data:

- The land type data describing the soil types expected in the area;
- Surveyed soils found on site;
- The land capability data which is derived from the soil survey results;
- The land use as noted in the field;
- The soil stripping guidelines; and
- The potential impacts associated with this project.

5 Assumptions and Limitations

The following assumptions and limitations have been made:

- The information provided in this report is based on information gathered from site visits undertaken on the 12th to 15th January 2015 and on the 10th to 12th June 2015;
- The information contained in this report is based on auger points taken and observations on site. There may be variations in terms of the delineation of the soil forms presented compared to when stripping of soil is undertaken. If this is encountered that soil tripping plan may need to be updated to reflect these variations in terms of how soil is stripped and stockpiled;
- The area surveyed was based on the infrastructure layout presented by the Applicant.

6 Methodology

6.1 Literature Review and Desktop Assessment

As part of the desktop assessment, baseline soil information was obtained using published South African Land Type Data. Land type data for the site was obtained from the Institute for Soil Climate and Water (ISCW) of the Agricultural Research Council (ARC) (Land Type

Survey Staff 1972 - 2006). The land type data is presented at a scale of 1:250 000 and comprises of the division of land into land types.

6.2 Soil Sampling and Classification

A study of the soils present within the project area was conducted during field visits on the 12th to 15th January 2015 and on the 10th to 12th June 2015. The site was traversed by vehicle and on foot. A soil auger was used to determine the soil form and depth. The soil was hand augured to the first restricting layer or 1.2 m. Soil survey positions were recorded as waypoints using a handheld Samsung tablet. Soil forms (types of soil) found in the landscape were identified using the South African soil classification system (Soil Classification Working Group, 1991). Landscape features such as existing open trenches were also helpful in determining soil types and depth.

6.3 Land Capability

Land capability is determined by a combination of soil, terrain and climate features. Land capability is defined by the most intensive long term sustainable use of land under rain-fed conditions. At the same time an indication is given about the permanent limitations associated with the different land use classes (Schoeman, Van der Walt, Monnik, Thackrah, Malherbe, & Le Roux, The Development and Application of a Land Capability Classification System for South Africa., 2000) (Smith, 2006).

Land capability is divided into eight classes and these may be divided into three capability groups. Table 6-1 shows how the land classes and groups are arranged in order of decreasing capability and ranges of use. The risk of use increases from class I to class VIII (Smith, 2006).

Table 6-1: Land capability class and intensity of use (Smith, 2006)

Land Capability Class	Increased Intensity of Use									Land Capability Groups
I	W	F	LG	MG	IG	LC	MC	IC	VIC	**Arable Land**
II	W	F	LG	MG	IG	LC	MC	IC		
III	W	F	LG	MG	IG	LC	MC			
IV	W	F	LG	MG	IG	LC				
V	W		LG	MG						**Grazing Land**
VI	W	F	LG	MG						
VII	W	F	LG							
VIII	W									**Wildlife**

W - Wildlife
F- Forestry
LG - Light Grazing
MG - Moderate Grazing
IG - Intensive Grazing
LC - Light Cultivation
MC - Moderate Cultivation
IC - Intensive Cultivation
VIC - Very Intensive Cultivation

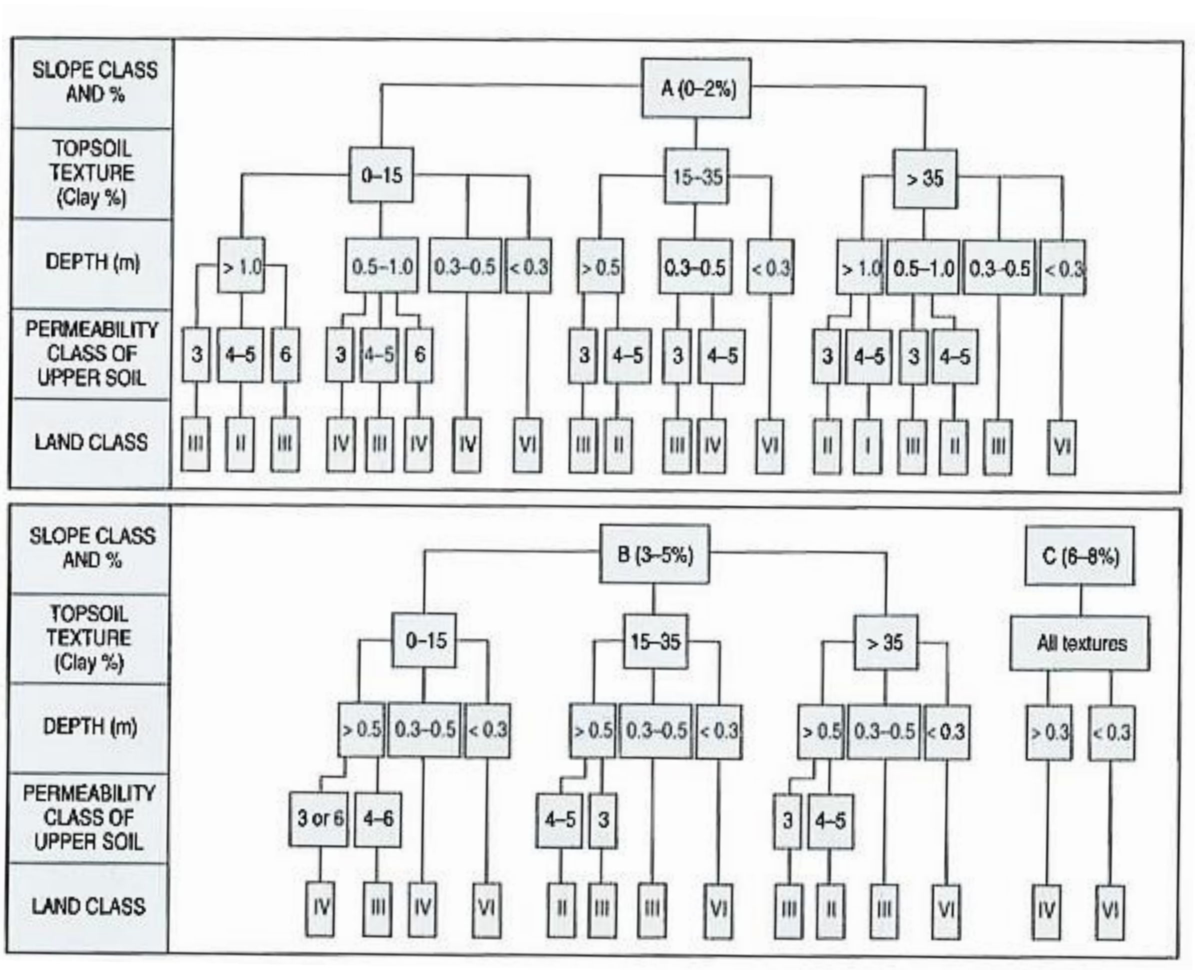
6.3.1 Land Capability Flow Chart

The land capability flow chart shown in Table 6-2 was chosen as the rainfall in the area is less than 750mm and is used to classify the land capability based on the following criteria;

- Slope (%);
- Topsoil Texture (clay %);
- Effective rooting depth; and
- Permeability class topsoil.

Once a land capability is derived from this the capability class is adjusted using the soil characteristics discussed in the sections to follow.

Table 6-2: Land capability flow chart for areas with rainfall of below 750mm and soils are eutrophic (high base status) (Smith, 2006)



6.3.2 Soil Characteristics to Determine and Adjust Land Capability

The tables below are to be used to adjust the land capability that was derived from the flow chart (Table 4-2) above.

6.3.2.1 Soil Permeability

Soil permeability is calculated using an infield test technique, by applying a couple of drops of water to the soil surface and recording the amount of seconds it takes to be absorbed into the soil. Table 6-3 shows the classification system. The permeability class is then used to adjust the value from the flow chart as per Table 6-4

Table 6-3: The Soil Permeability Classes (Smith, 2006)

Class	Rate (seconds)	Description	Texture
7	<1	Extremely Rapid	Gravel and coarse sand, 0 to 10% clay
6	1 to 3	Rapid	5 to 10% clay
5	4 to 8	Good	> 10% clay
4	9 to 20	Slightly restricted	
3	21 to 40	Restricted	Strong structure, grey colour, mottled, >35% clay
2	41 to 60	Severely restricted	Strong structure, weathered rock, >35% clay
1	>60	Impermeable	Rock and very strong structure, >35% clay

Table 6-4: The Soil Permeability Adjustment Factors (Smith, 2006)

Permeability Class	Adjustment to be made
1 to 2	If in subsoil, rooting is likely to be limited. Use the permeability of topsoil in the flow chart. If this is the permeability of the topsoil, then the topsoil is probably dark structured clay, in which case a permeability class 3 can be used in the flow chart.
3 to 5	Classify as indicated in the flow chart
6	Topsoil should have < 15% clay - use the flow chart
7	Downgrade land classes I -III to land class IV

6.3.2.2 Soil Wetness Factors

Soil wetness is divided into the five categories shown in Table 6-5; these describe varying degrees of wetness at various depths. Wetness affects plant production when the roots are wet for extended periods of time near the surface, and as a result this will downgrade a soils land capability based on the below definitions.

Table 6-5: The Soil Wetness Adjustment Factors (Smith, 2006)

Class	Definition	Land Class
W0	Well drained - no grey colour with mottling within 1,5m of the surface. Grey colour without mottling is acceptable.	No Change
W1	There is no evidence of wetness within the top 0,5m. Occasionally wet - grey colours and mottling begin between 0,5m and 1,5m from the surface	Downgrade Class I to Class II, otherwise no change
W2	Temporarily wet during the wet season. No mottling in the top 0,2m but grey colours and mottling occur between 0,2m and 0,5m from surface. Included are: soils with G horizons (highly gleyed and often clayey) at depths of more than 0,5m; soils with E horizon over G horizon where the depth to the G horizon is more than 0,5m.	Downgrade to Class IV
W3	Periodically wet. Mottling occurs in top 0,2m, and includes soils with a heavily gleyed or G horizon at a depth of less than 0,5m. Found in bottomlands.	Downgrade to Class V (a)
W4	Semi-permanently/permanently wet at or above soil surface throughout the wet season. Usually an organic topsoil or an undrained vlei. Found in bottomlands.	Downgrade to Class V (b)

6.3.2.3 Soil Rockiness Factors

Soil rockiness affects the management of a soil in a negative way. And the soils land capability will be reduced as described in Table 6-6 accordingly.

Table 6-6 : The Soil Rockiness Adjustment Factors (Smith, 2006)

Class	Definition	Land Class
R 0	No rockiness	No change
R 1	2 to 10% rockiness	Downgrade class I to class II, otherwise no change
R 2	10 to 20% rockiness	Downgrade class II to class III, otherwise no change
R 3	20 to 30% rockiness	Downgrade class I - III to class IV
R 4	>30% rockiness	Downgrade classes I, II, III, and IV to class VI

6.3.2.4 Surface Crusting

Surface crusting has an effect on initial infiltration and could cause erosion to some degree. Table 6-7 shows how to adjust the flow chart results for land capability accordingly.

Table 6-7: The Soil Crusting Adjustment Factors (Smith, 2006)

Class	Definition	Land Class
t0	No surface crusting when dry	No Change
t1	Slight surface crusting when dry	Downgrade class I to II, no Change
t2	Unfavourable surface crusting when dry	Downgrade class I to II, no Change

6.4 Current Land Use

Land use was identified using aerial imagery and then ground-truthed while out in the field.

The land use categories are split into:

- Cultivated;
- Natural;
- Mines;
- Urban Built-Up; and
- Waterbodies.

6.5 Impact Assessment Methodology

The impact rating process is designed to provide a numerical rating of the various environmental impacts identified by use of the Input-Output model.

The significance rating process follows the established impact/risk assessment formula:

Significance = CONSEQUENCE X PROBABILITY X NATURE

Where

Consequence = intensity + extent + duration

And

Probability = likelihood of an impact occurring

And

Nature = positive (+1) or negative (-1) impact

The matrix calculates the rating out of 147, whereby intensity, extent, duration and probability are each rated out of seven as indicated in Table 6-8. The weight assigned to the various parameters is then multiplied by +1 for positive and -1 for negative impacts.

Impacts are rated prior to mitigation and again after consideration of the mitigation has been applied; post-mitigation is referred to as the residual impact. The significance of an impact is determined and categorised into one of seven categories (The descriptions of the significance ratings are presented in Table 6-10.

It is important to note that the pre-mitigation rating takes into consideration the activity as proposed, (i.e., there may already be some mitigation included in the engineering design). If the specialist determines the potential impact is still too high, additional mitigation measures are proposed.

Table 6-8: Impact Assessment Parameter Ratings

<table>
<tr><th rowspan="2">Rating</th><th colspan="2">Intensity/Replace ability</th><th rowspan="2">Extent</th><th rowspan="2">Duration/Reversibility</th><th rowspan="2">Probability</th></tr>
<tr><th>Negative impacts
(Nature = -1)</th><th>Positive impacts
(Nature = +1)</th></tr>
<tr><td>7</td><td>Irreplaceable loss or damage to biological or physical resources or highly sensitive environments.
Irreplaceable damage to highly sensitive cultural/social resources.</td><td>Noticeable, on-going natural and / or social benefits which have improved the overall conditions of the baseline.</td><td><u>International</u>
The effect will occur across international borders.</td><td>Permanent: The impact is irreversible, even with management, and will remain after the life of the project.</td><td>Definite: There are sound scientific reasons to expect that the impact will definitely occur. >80% probability.</td></tr>
<tr><td>6</td><td>Irreplaceable loss or damage to biological or physical resources or moderate to highly sensitive environments.
Irreplaceable damage to cultural/social resources of moderate to highly sensitivity.</td><td>Great improvement to the overall conditions of a large percentage of the baseline.</td><td><u>National</u>
Will affect the entire country.</td><td>Beyond project life: The impact will remain for some time after the life of the project and is potentially irreversible even with management.</td><td>Almost certain / Highly probable: It is most likely that the impact will occur. <80% probability.</td></tr>
</table>

Rating	Intensity/Replace ability		Extent	Duration/Reversibility	Probability
	Negative impacts (Nature = -1)	**Positive impacts (Nature = +1)**			
5	Serious loss and/or damage to physical or biological resources or **highly** sensitive environments, limiting ecosystem function. Very serious widespread social impacts. Irreparable damage to highly valued items.	On-going and widespread benefits to local communities and natural features of the landscape.	<u>Province/ Region</u> Will affect the entire province or region.	Project Life (>15 years): The impact will cease after the operational life span of the project and can be reversed with sufficient management.	Likely: The impact may occur. <65% probability.
4	Serious loss and/or damage to physical or biological resources or **moderately** sensitive environments, limiting ecosystem function. On-going serious social issues. Significant damage to structures / items of cultural significance.	Average to intense natural and / or social benefits to some elements of the baseline.	<u>Municipal Area</u> Will affect the whole municipal area.	Long term: 6-15 years and impact can be reversed with management.	Probable: Has occurred here or elsewhere and could therefore occur. <50% probability.

Rating	Intensity/Replace ability		Extent	Duration/Reversibility	Probability
	Negative impacts (Nature = -1)	Positive impacts (Nature = +1)			
3	Moderate loss and/or damage to biological or physical resources of **low to moderately** sensitive environments and, limiting ecosystem function. On-going social issues. Damage to items of cultural significance.	Average, on-going positive benefits, not widespread but felt by some elements of the baseline.	Local Local extending only as far as the development site area.	Medium term: 1-5 years and impact can be reversed with minimal management.	Unlikely: Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur. <25% probability.
2	**Minor loss and/or effects** to biological or physical resources or low sensitive environments, not affecting ecosystem functioning. Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected.	Low positive impacts experience by a small percentage of the baseline.	Limited Limited to the site and its immediate surroundings.	Short term: Less than 1 year and is reversible.	Rare / improbable: Conceivable, but only in extreme circumstances. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures. <10% probability.

Rating	Intensity/Replace ability		Extent	Duration/Reversibility	Probability
	Negative impacts (Nature = -1)	**Positive impacts (Nature = +1)**			
1	**Minimal to no loss** and/or effect to biological or physical resources, not affecting ecosystem functioning. Minimal social impacts, low-level repairable damage to commonplace structures.	Some low-level natural and / or social benefits felt by a very small percentage of the baseline.	Very limited/Isolated Limited to specific isolated parts of the site.	Immediate: Less than 1 month and is completely reversible without management.	Highly unlikely / None: Expected never to happen. <1% probability.

Table 6-9: Probability/Consequence Matrix

Probability	Significance																																					
7	-147	-140	-133	-126	-119	-112	-105	-98	-91	-84	-77	-70	-63	-56	-49	-42	-35	-28	-21	21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	126	133	140	147
6	-126	-120	-114	-108	-102	-96	-90	-84	-78	-72	-66	-60	-54	-48	-42	-36	-30	-24	-18	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126
5	-105	-100	-95	-90	-85	-80	-75	-70	-65	-60	-55	-50	-45	-40	-35	-30	-25	-20	-15	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105
4	-84	-80	-76	-72	-68	-64	-60	-56	-52	-48	-44	-40	-36	-32	-28	-24	-20	-16	-12	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84
3	-63	-60	-57	-54	-51	-48	-45	-42	-39	-36	-33	-30	-27	-24	-21	-18	-15	-12	-9	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63
2	-42	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42
1	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Consequence	**-21**	**-20**	**-19**	**-18**	**-17**	**-16**	**-15**	**-14**	**-13**	**-12**	**-11**	**-10**	**-9**	**-8**	**-7**	**-6**	**-5**	**-4**	**-3**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**

Table 6-10: Significance Rating Description

Score	Description	Rating
109 to 147	A very beneficial impact that may be sufficient by itself to justify implementation of the project. The impact may result in permanent positive change	Major (positive) (+)
73 to 108	A beneficial impact which may help to justify the implementation of the project. These impacts would be considered by society as constituting a major and usually a long-term positive change to the (natural and / or social) environment	Moderate (positive) (+)
36 to 72	An positive impact. These impacts will usually result in positive medium to long-term effect on the natural and / or social environment	Minor (positive) (+)
3 to 35	A small positive impact. The impact will result in medium to short term effects on the natural and / or social environment	Negligible (positive) (+)
-3 to -35	An acceptable negative impact for which mitigation is desirable. The impact by itself is insufficient even in combination with other low impacts to prevent the development being approved. These impacts will result in negative medium to short term effects on the natural and / or social environment	Negligible (negative) (-)
-36 to -72	A minor negative impact requires mitigation. The impact is insufficient by itself to prevent the implementation of the project but which in conjunction with other impacts may prevent its implementation. These impacts will usually result in negative medium to long-term effect on the natural and / or social environment	Minor (negative) (-)
-73 to -108	A moderate negative impact may prevent the implementation of the project. These impacts would be considered as constituting a major and usually a long-term change to the (natural and / or social) environment and result in severe changes.	Moderate (negative) (-)
-109 to -147	A major negative impact may be sufficient by itself to prevent implementation of the project. The impact may result in permanent change. Very often these impacts are immitigable and usually result in very severe effects. The impacts are likely to be irreversible and/or irreplaceable.	Major (negative) (-)

7 Findings

The land type data gathered during the scoping phase suggested that the dominant soils on the pit locations would be black clayey and that the rock dumps would fall within red well drained soils. The land type data presents general soil types that may be found within the area and should always be confirmed by site visits as the data is at a high level and needs to be verified and fine-tuned.

The field survey confirmed these findings with the dominant soil in the area of the open pit locations were in fact the Arcadia soil form and the mixed red soils were the Oakleaf soils in the other infrastructure locations.

7.1 Land Type Data

The soils found in the project area are represented by five possible land types namely Ae227, Ae335, Ea208, Fa757 and ib447. These land types are also depicted on Figure 7-1 (Land Type Survey Staff, 1972 - 2006).

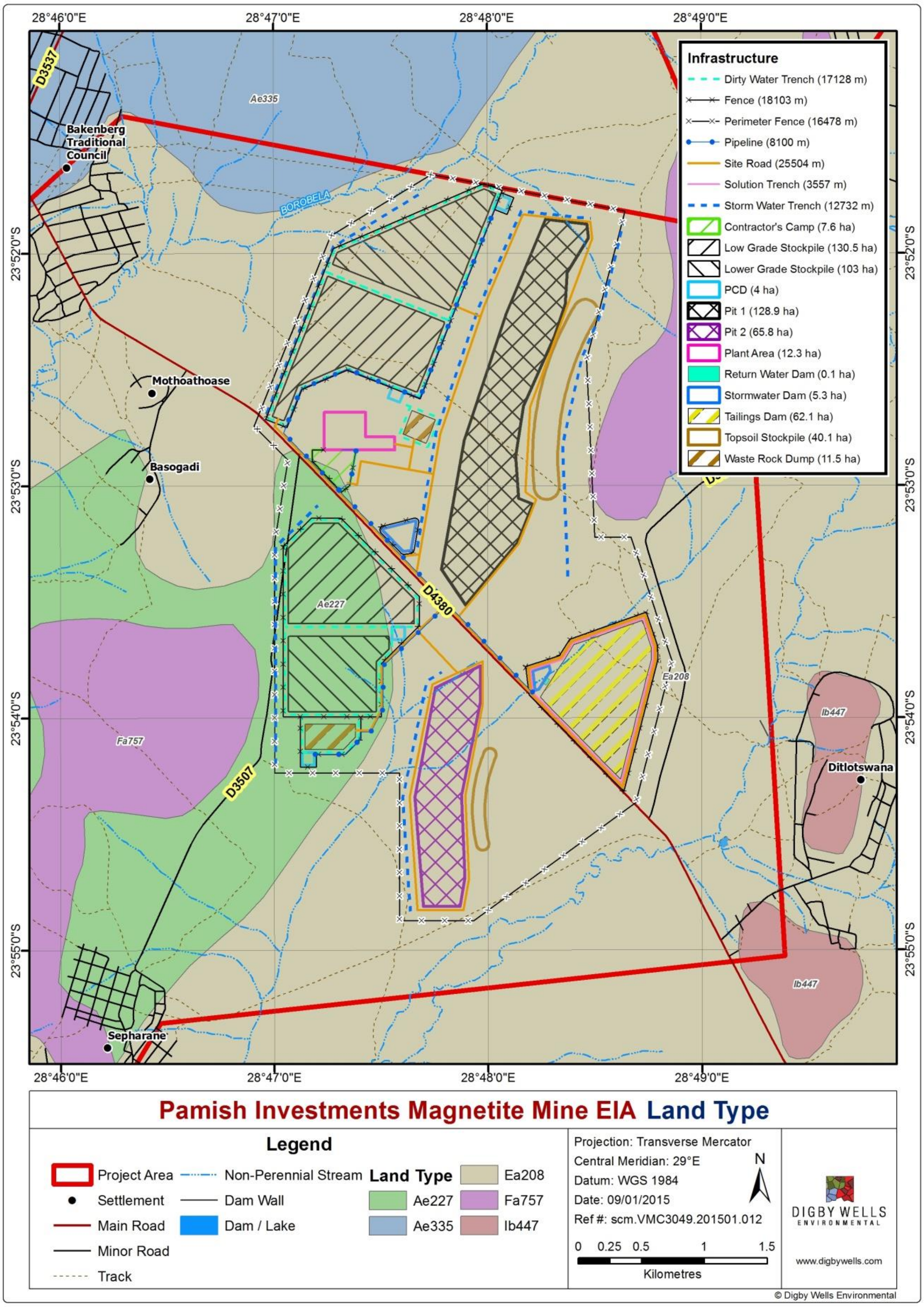


Figure 7-1: The land type data map for the magnetite project area (Land Type Survey Staff, 1972 - 2006)

7.2 Field Survey Findings

The project area is dominated by the Arcadia soil form with small portions of Oakleaf soils to the west, and Shallow Glenrosa/Mispah soils on the hills towards the east as shown in Figure 7-5.

These soils are described in more detail in the sections below and Table 7-1 shows the soil survey positions and descriptions.

7.2.1 Arcadia Soil Form

7.2.1.1 Description

The Arcadia soil form consist of deep Vertic A horizons (>1,2m). On site these soils are black in colour and are more commonly known as "Turf soils" or "Black cotton soils". They have a high clay percentage (> 55% clay).

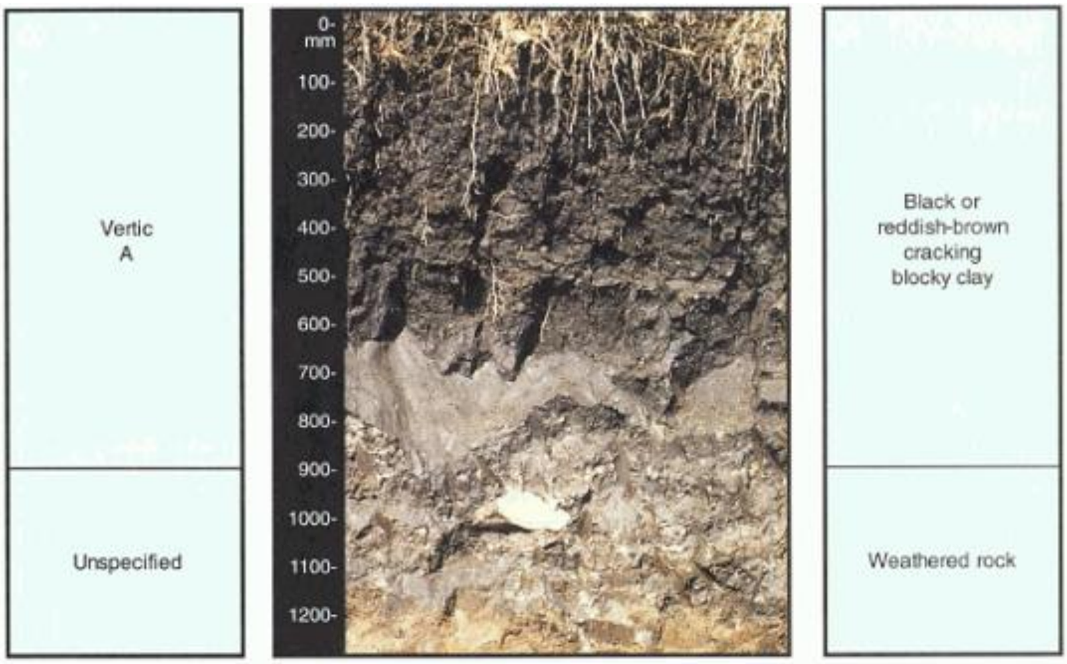


Figure 7-2: A typical cross section of the Arcadia soil form (SASA, 1999)

7.2.1.2 Behaviour

Arcadia soils are extremely physically active. They shrink when dry and swell when wet (Fey, et al. 2010). The soil moves objects to the surface know as heave and can exceed 100 mm, this upward movement can lift buried pipes and poles to the surface. With the start of the rainy season, Arcadia soils are dry and cracked and water infiltration is high bypassing the soil body and potentially recharging the groundwater or downslope soils. When it rains, the soil swells and the cracks close and infiltration rate slows (Fey, et al. 2010). Arcadias have typically inverted profiles and lack horizons due to the random mixing when wet, therefore are not sensitive to disturbance (Soil Classification Working Group 1991). Additionally, the soils store large amounts of organic carbon (Smith 2006).

7.2.1.3 Suitability

Arcadia soils hold large amounts of water which often is not available for crops. Therefore, dry climates often do not support dryland cropping on these soils. Despite this, Arcadia soils can accommodate a selected composition of vegetation such as grazing vegetation for cattle or strong rooted crops such as sorghum, cotton and sunflower.

7.2.2 Oakleaf Soil Form

7.2.2.1 Description

The Oakleaf soil form are deep (>1.2 m) soils that consist of an Orthic A horizon, overlying a Neocutanic B, overlying a subsoil with no signs of wetness due to A and B horizons having good internal drainage properties. They generally have moderate clay percentages (15 – 25% and 25 – 40% clay in A and B horizons).

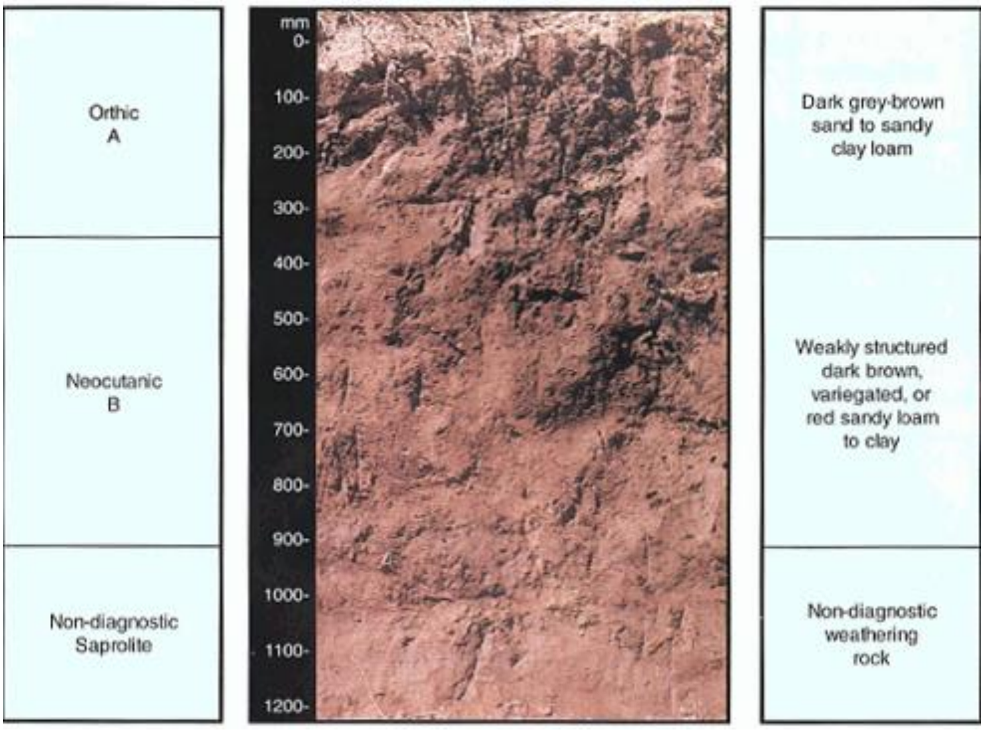


Figure 7-3: A typical cross section of the Oakleaf soil form (SASA, 1999)

7.2.2.2 Behaviour

Oakleaf soils are physically and chemically inactive. The soils are slightly sensitive to erosion. The subsoil is more sensitive to erosion and should preferably not be exposed.

7.2.2.3 Suitability

Oakleaf soils are moderately suitable for crop production but irrigation is limited by availability of water and climate.

7.2.3 Glenrosa Soil Form

7.2.3.1 Description

The Glenrosa soil form consists of an Orthic A horizon which forms on soft, thoroughly decomposed and porous rock, often rich in clay (known as saprolite) forming a lithocutanic B subsoil which merges into parent rock material. These soils are generally shallow. They are generally of clayey texture (15 - 25% and 35 - 45% clay in the A and B horizons respectively).

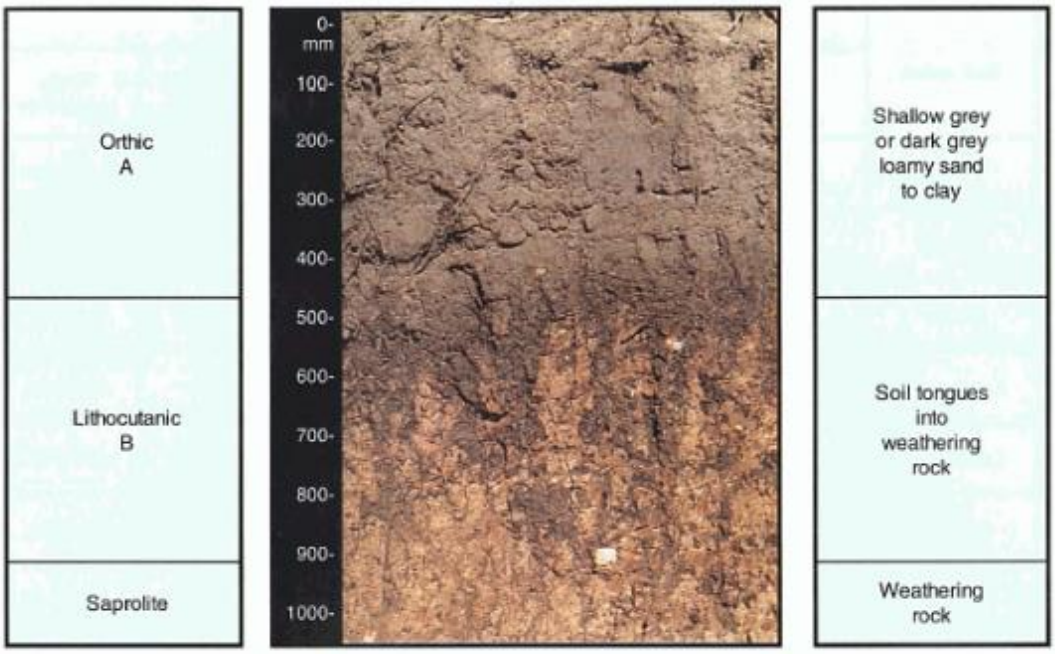


Figure 7-4: A Typical Cross Section of the Glenrosa Soil Form (SASA, 1999).

7.2.3.2 Behaviour

They are moderately physically active. The soils are moderately sensitive to erosion. The subsoil is usually sensitive to erosion.

7.2.3.3 Suitability

Glenrosa soils are generally shallow and have a low agricultural potential.

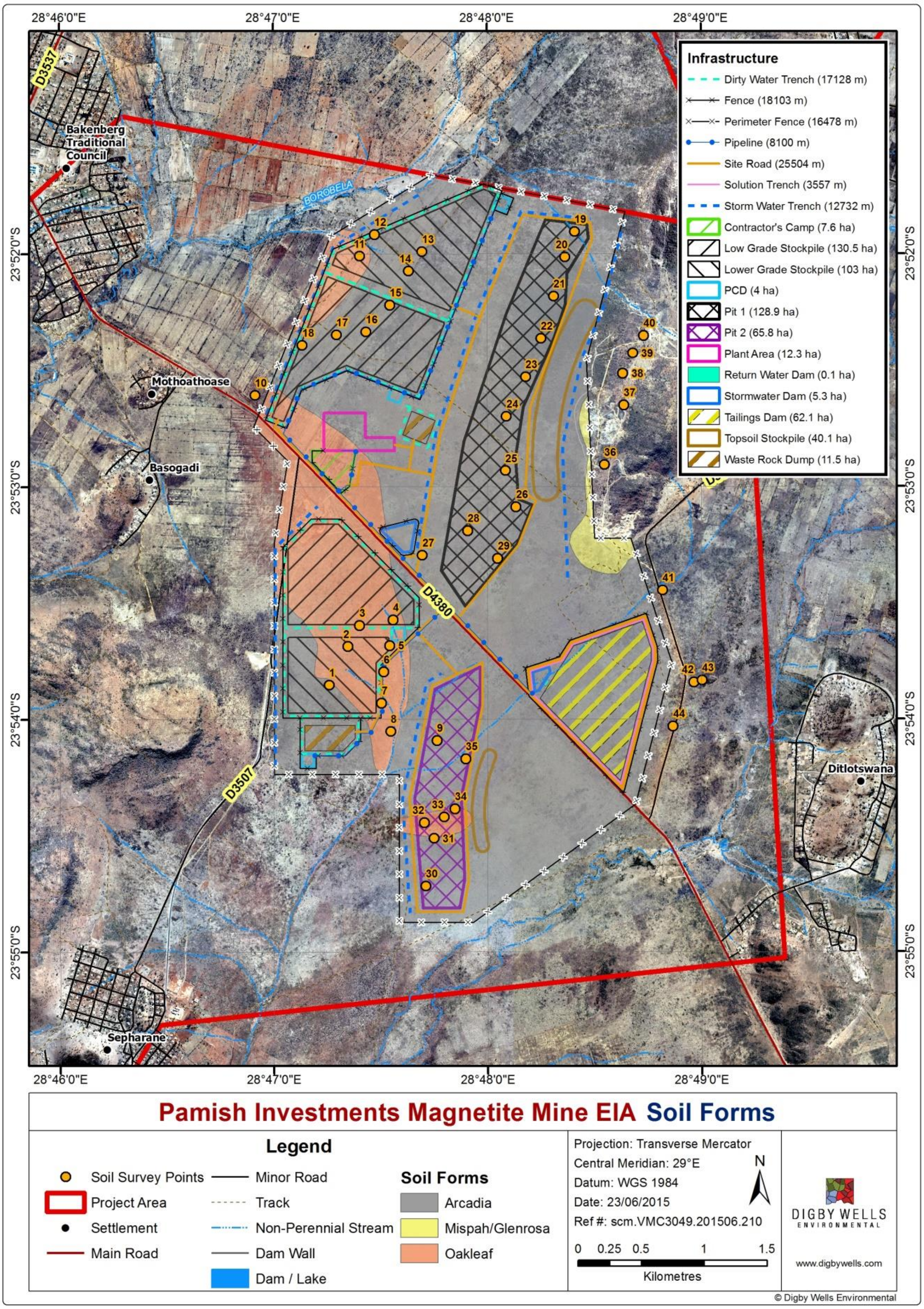


Figure 7-5: The Soil Forms Delineated as per the Field Survey Finding for the Magnetite Project Area

Table 7-1: The Soil Survey Positions and Descriptions

Survey No	Field Tag	Description	Latitude	Longitude
1	ar 12	Arcadia	-23.897561	28.787652
2	oa 12	Oakleaf	-23.894787	28.789112
3	oa 12	Oakleaf	-23.89327	28.790017
4	oa 12	Oakleaf	-23.892884	28.792637
5	oa 12	Oakleaf	-23.894712	28.792366
6	oa 12	Oakleaf	-23.89661	28.791895
7	oa 12	Oakleaf	-23.898843	28.791733
8	Oa 12	Oakleaf	-23.900874	28.792442
9	Ar 10	Arcadia	-23.901528	28.796059
10	Oa	Oakleaf	-23.876785	28.781885
11	oa 10 calc S5	Oakleaf	-23.866825	28.790059
12	ar 10	Arcadia	-23.865258	28.791223
13	Ar 10	Arcadia	-23.866507	28.794927
14	Ar 10	Arcadia	-23.867882	28.793878
15	Ar 100	Arcadia	-23.870326	28.792403
16	Ar 11	Arcadia	-23.872246	28.790532
17	Ar 12	Arcadia	-23.872461	28.788235
18	Ar 12 S4	Arcadia	-23.873201	28.785576
19	ar12	Arcadia	-23.86508	28.806818
20	Ar 10	Arcadia	-23.866885	28.806058
21	Ar 10	Arcadia	-23.869697	28.805177
22	Ar 10	Arcadia	-23.872708	28.804181
23	Ar 10	Arcadia	-23.875475	28.802995
24	ar 10	Arcadia	-23.878314	28.801484
25	ar 10	Arcadia	-23.8822	28.801403
26	ar 10	Arcadia	-23.884789	28.802229
27	ar10	Arcadia	-23.888254	28.794924
28	ar 12	Arcadia	-23.886489	28.798458
29	ar 10	Arcadia	-23.888478	28.800798
30	ar 12 calc	Arcadia	-23.911969	28.795166

Survey No	Field Tag	Description	Latitude	Longitude
31	ar 10	Arcadia	-23.908542	28.795815
32	oa 12	Oakleaf	-23.907415	28.795068
33	oa 12 S3	Oakleaf	-23.907008	28.796585
34	start		-23.906425	28.797441
35	ar 10 S2	Arcadia	-23.902837	28.798288
36	ms	Glenrosa	-23.881757	28.809114
37	ms	Glenrosa	-23.87748	28.810637
38	ms	Glenrosa	-23.875218	28.810567
39	ms	Glenrosa	-23.873781	28.811339
40	ms/gs	Glenrosa	-23.872513	28.812193
41	ar/va 12 calc	Arcadia	-23.890752	28.813642
42	ar /va 7 calc	Arcadia	-23.897356	28.816075
43	gs /ms	Glenrosa	-23.897222	28.816731
44	ar/va 10 calc S1	Arcadia	-23.900511	28.814462

7.3 Land Capability

The land capability is dominated by the Class IV (moderate grazing) land capability as shown in Figure 7-6, the Class IV land capability coincides with the Arcadia soils, and although these soils are deep their high clay percentage and shrink/swell properties make them very difficult to manage from an agricultural perspective.

The Class III (moderate cultivation/intensive grazing) land capability coincides with the Oakleaf soils, which are better drained and more easily managed in comparison with the Arcadia soil. They are situated to the west of the site and the low/lower grade stockpiles would be situated on them.

The Class VIII (wilderness) land capability can be found in the eastern portion of the project site and is linked to the shallow/steep Glenrosa/Mispah soils.

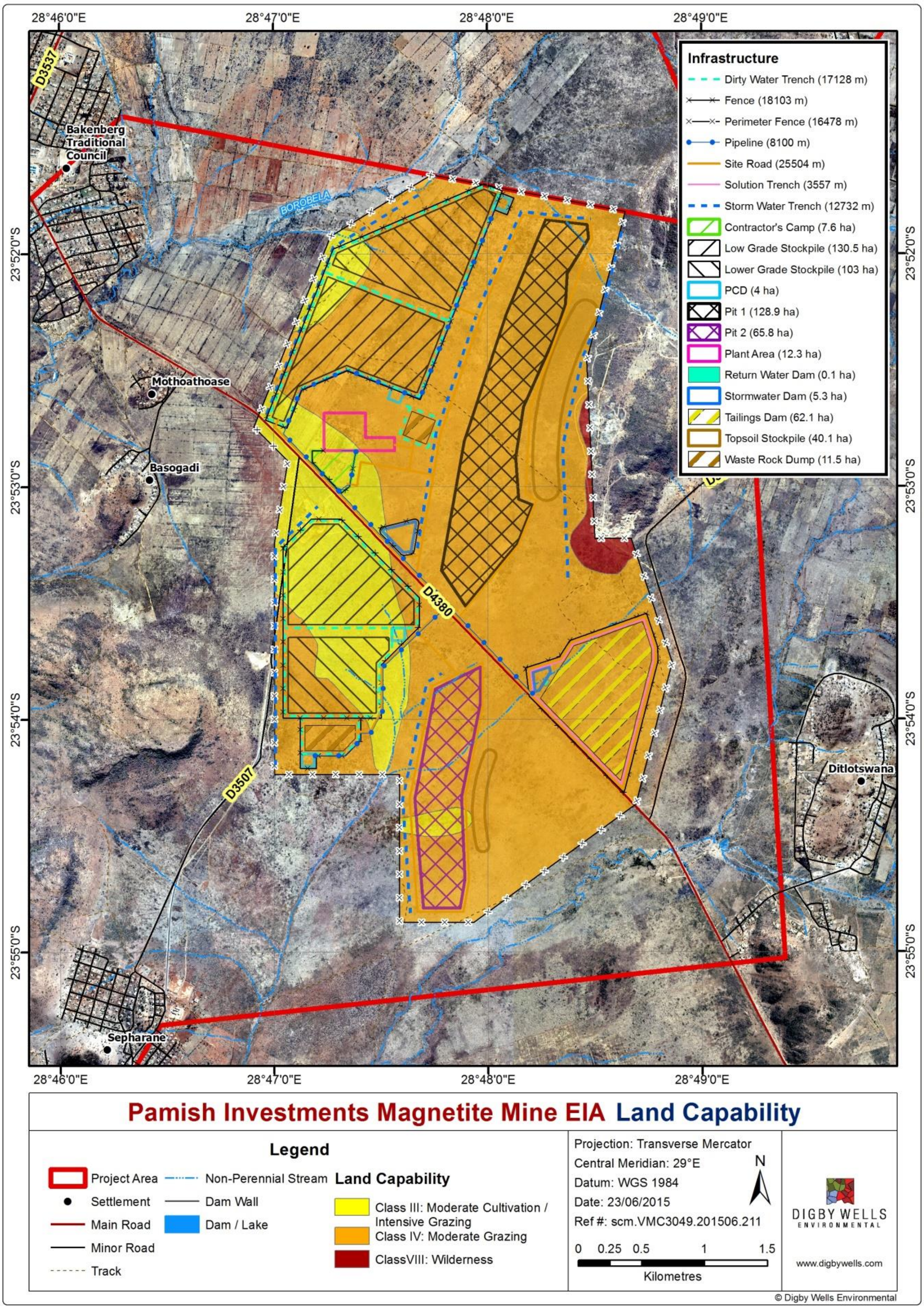


Figure 7-6: The Land Capabilities associated with the Soil Classification

7.4 Land Use

The land use that is dominant within the project area is the natural veld that is used for grazing with a small portion in the north east being used for subsistence agriculture as shown in Figure 7-7.

These land uses are driven by climate and land capability. The dominant soil in the project area is the Arcadia soil form. These soils are very difficult to cultivate and as a result have been left to natural veld. The Oakleaf soils are high in clay but do not have the same restrictions as the Arcadia soils and have therefor been used as subsistence agricultural fields.

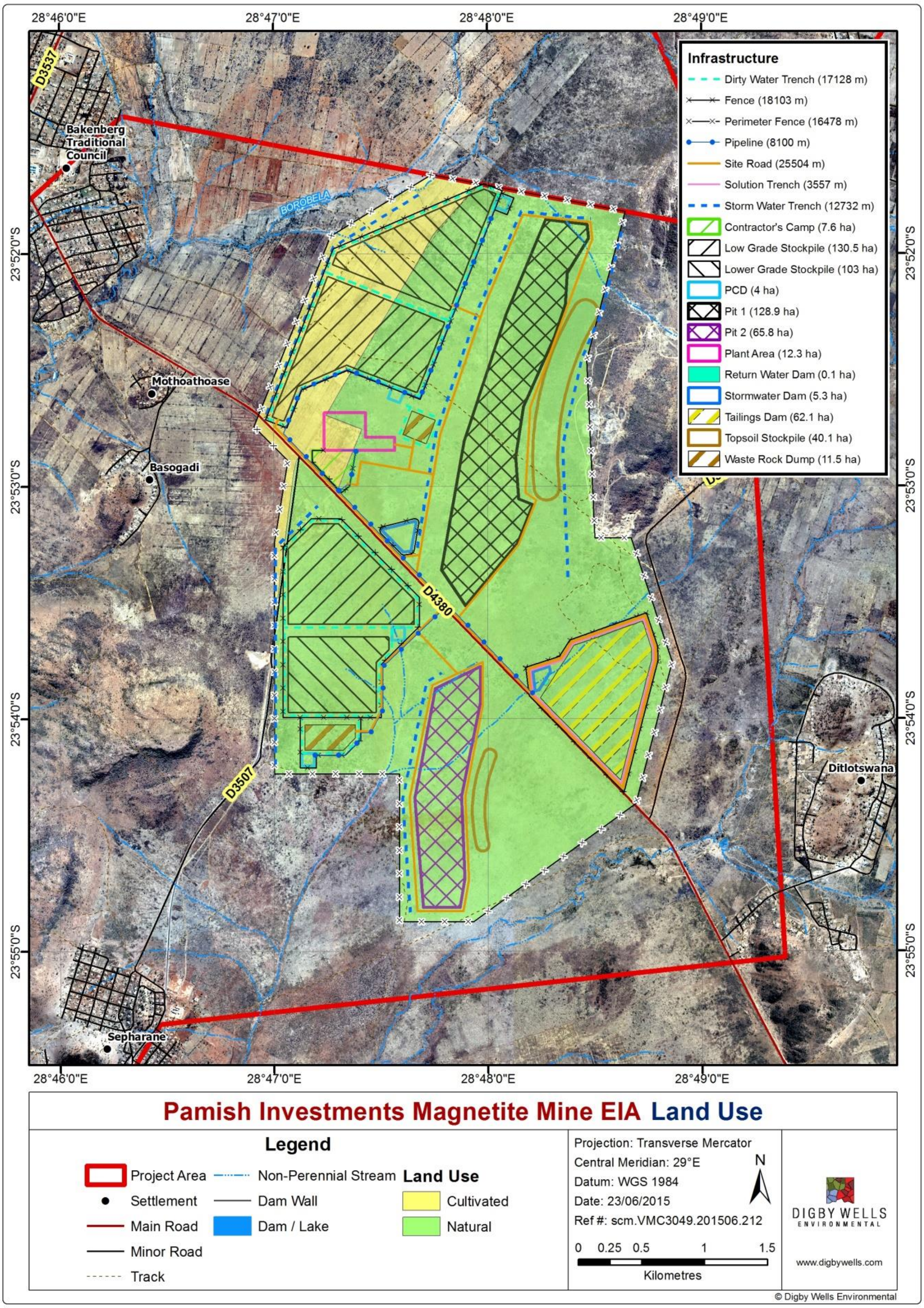


Figure 7-7: The Land Use for the Magnetite Project Area

8 Sensitivity Analysis and No-Go Areas

The Arcadia soils are sensitive from both an environmental perspective and a engineering perspective. These soils have shrink/ swell properties and if stripped during wet periods massive compaction will occur, as well as the risk of machinery getting stuck.

From an engineering perspective these soils pose a risk to the stability of infrastructure.

9 Potential Impacts

The major impacts associated with open pit mining are the disturbance of natural occurring soil profiles consisting of layers or soil horizons. Rehabilitation of open pit areas aims to restore land capability but the experience is that post mining land capability usually decreases compared to pre-mining land capability. Soil formation is determined by a combination of five interacting main soil formation factors. These factors are time, climate, slope, organisms and parent material. Soil formation is an extremely slow process and soil can therefore be considered as a non-renewable resource.

Soil quality deteriorates during stockpiling and replacement of these soil materials into soil profiles during rehabilitation cannot imitate pre-mining soil quality properties. Depth however can be imitated but the combined soil quality deterioration and resultant compaction by the machines used in rehabilitation, leads to a net loss of land capability. A change in land capability then forces a change in land use.

The impact on soil is high because natural soil layers are stripped and stockpiled for later use in rehabilitation. Soil fertility is impacted on because stripped soil layers are usually thicker than the defined topsoil layer. The topsoil layer is the layer where most plant roots are found and is generally 0.30 m thick. Topsoil contains organic carbon which is responsible for nutrient cycling, thereby improving soil fertility. Mixing topsoil with subsoil dilutes the soil fertility and also impacts on microbial activity leading to soil quality degradation over time in stockpiles.

The potential impacts associated with open pit mining on soils are broken up into the following;

- Loss of Topsoil;
  - Erosion;
  - Compaction; and
  - Physical & chemical alterations.
- Loss of Land Capability;
  - Replacement of topsoil not to pre-land capability specifications;
  - Low soil fertility; and
  - Slope/drainage design for rehab not done correctly.

10 Impact Assessment

The impact assessment is aimed at identifying impacts related to the various activities listed in Table 10-1 from a soils perspective. The activities associated with soil impacts are highlighted (in grey) below and discusses within the impact and risk sections below.

Table 10-1: Proposed Project Activities for Magnetite Mine

Construction	
1	Site clearance and vegetation removal;
2	Change of land-use from agriculture to mining;
3	Topsoil and softs removal and stockpiling;
4	Development of access and haul roads;
5	Surface infrastructure development such as stormwater channels, bridges, dams, offices and workshops.
6	Water abstraction and use;
7	Waste generation, storage and disposal (hazardous and general);
8	Use of heavy machinery (Haul Trucks, FEL, Excavators etc.)
9	Employment and capital expenditure;
Operation	
10	Development of two open pits by drilling and blasting, truck and shovel methods;
11	Development of one waste rock dump;
12	Concentrator plant including crushing, grinding and screening;
13	Conveyor belts at crushing and grinding sections and for concentrate product and tailings;
14	Hauling of waste rock;
15	Tailings Storage Facility (TSF);
16	Pollution control dam, water storage dam and associated pipelines;
17	Stormwater diversion berms and channels;

18	Storage of fuels, process concentrate, maintenance/workshop oils, and explosive storage facilities;
19	Waste generation, storage and disposal (hazardous and general);
20	Product storage (magnetite concentrate);
21	Sewerage treatment plant;
22	Use of heavy machinery (Haul trucks, FEL, Excavators etc.)
23	Employment and operational expenditure;
Closure and Rehabilitation	
24	Dismantling and removal of major equipment and infrastructure
25	Waste generation, storage and disposal
26	Rehabilitation of disturbed areas including stockpile dumps and pits etc
27	Backfilling of the open pits using waste rock only.
28	Post-closure monitoring

10.1 Construction Phase

During the construction phase the following activities will impact on the soils;

- Site clearing and vegetation removal;
- Change of land-use from agriculture to mining;
- Topsoil and softs removal and stockpiling;
- Development of access and haul roads; and
- Surface infrastructure development such as stormwater channels, bridges, dams, offices and workshops.

The impacts associated with these activities are described in the following sections

10.1.1 Impact: Loss of Topsoil as a Resource

When topsoil is removed from a soil profile, the profile loses effective rooting depth, water holding capacity and fertility. The largest volumes of topsoil will be removed in preparation for open pit mining.

The movement of heavy machinery on the soil surface causes compaction, which reduces the vegetation's ability to grow and as a result erosion could be caused.

Large areas of land will be cleared increasing the runoff potential of the area, this intern increase the erosion hazard present.

During any excavation activity the soil physical and chemical properties are impacted on.

The loss of topsoil as a resource is a serious impact as the natural regeneration of a few millimetres of topsoil takes hundreds of years.

The topsoil stockpiles are designed for a height of 30m this will impact the physical and chemical properties of the soils health.

The impacts are described in Table 10-2.

Table 10-2: Impact Rating for Loss of Topsoil as a Resource during Construction Phase

Dimension	Rating	Motivation	Significance
Activity and Interaction: ▪ **Site clearing and vegetation removal;** ▪ **Topsoil and softs removal and stockpiling;** ▪ **Development of access and haul roads; and** ▪ **Surface infrastructure development such as stormwater channels, bridges, dams, offices and workshops.**			
Impact Description: The movement of heavy machinery on the soil surface causes compaction, which reduces the vegetation's ability to grow and as a result erosion could be caused. Large areas of land will be cleared increasing the runoff potential of the area, this intern increase the erosion hazard present. During any excavation activity the soil physical and chemical properties are impacted on.			
Prior to mitigation/ management			
Duration	5 (Project Life)	The largest volumes of topsoil will be removed in preparation of open pit mining but may last after this phase.	Medium-High (negative) – 91
Extent	3 (Local)	Loss of topsoil will only occur within and immediately around the Project site.	
Intensity	Very Serious – negative (-5)	Loss of topsoil may result in loss of land capability and land use. Soil regeneration takes a very long time.	
Probability	Certain (7)	By excavating the soil it will certainly impact on the soil.	
Mitigation/ Management actions			
▪ Follow adequate stripping guidelines, as described in section 13 soil stripping guidelines. ▪ The topsoil should be stripped by means of an excavator bucket, and loaded onto dump trucks; ▪ Topsoil stockpiles are to be kept to a maximum height of 4m (the practical tipping height of dump trucks);			

<table>
<tr><th>Dimension</th><th>Rating</th><th>Motivation</th><th>Significance</th></tr>
<tr><td colspan="4">

Topsoil is to be stripped when the soil is dry, as to reduce compaction;
The topsoil 0.3 m of the soil profile should be stripped first and stockpiled separately (to be stockpile in the soils stockpile area identified on the infrastructure plan, but this must be split into the 4 stockpiles described in the soil stripping ratios section);
The subsoil approximately 0.3 – 1.2 m thick will then be stripped and stockpiled separately;
Soils to be stripped according to the soil stripping ratios and stockpiled accordingly;
Foundation excavated soil should also be stockpiled;
Stockpiles are to be maintained in a fertile and erosion free state by sampling and analysing annually for macro nutrients and pH, and vegetating the stockpiles to reduce erosion;
The handling of the stripped topsoil will be minimized to ensure the soil’s structure does not deteriorate;
Compaction of the removed topsoil must be avoided by prohibiting traffic on stockpiles;
Prevent unauthorised borrowing of stockpiled soil;
The stockpiles will be vegetated (details contained in rehabilitation plan) in order to reduce the risk of erosion, prevent weed growth and to reinstitute the ecological processes within the soil;
Ensure proper storm water management designs are in place;
Access routes are to be kept to a minimum as to reduce any unnecessary compaction from occurring;
If erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place;
Only the designated access routes are to be used; and
Implement Land rehabilitation measures as defined in rehabilitation report.

</td></tr>
<tr><td colspan="4">Post- mitigation</td></tr>
<tr><td>Duration</td><td>Project Life (5)</td><td>Loss of topsoil makes land less productive. Effects will occur long after the project life.</td><td rowspan="4">Low (negative) – 30</td></tr>
<tr><td>Extent</td><td>Limited (2)</td><td>Loss of topsoil will only occur within and immediately around the Project infrastructure area.</td></tr>
<tr><td>Intensity</td><td>Moderate - negative (-3)</td><td>Loss of topsoil may result in loss of land capability and land use.</td></tr>
<tr><td>Probability</td><td>Unlikely (3)</td><td>If the mitigation is followed then it is unlikely that the impacts will occur.</td></tr>
</table>

10.1.2 Impact: Loss of Land Capability & Land Use

When the topsoil is removed from the open pit and infrastructure areas, the land capability is reduced to nothing. The land use will change from natural and subsistence grazing to mining. The impacts are described in Table 10-3.

Table 10-3: Impact Rating for Loss of Land Capability and Land Use during Construction Phase

Dimension	Rating	Motivation	Significance

Dimension	Rating	Motivation	Significance
Activity and Interaction: ▪ **Site clearing and vegetation removal;** ▪ **Change of land-use from agriculture to mining;** ▪ **Topsoil and softs removal and stockpiling;** ▪ **Development of access and haul roads; and** ▪ **Surface infrastructure development such as stormwater channels, bridges, dams, offices and workshops.**			
Impact Description: Removal of soil layers will impact on the land capability because vegetation can no longer be supported.			
Prior to mitigation/ management			
Duration	7 (Permanent)	The removal of soil from a profile reduces the land capability from a rateable index to non-existent, this impact is permanent if not mitigated	Major negative (negative) – 112
Extent	2 (Limited)	The impact will only occur on the project infrastructure area	
Intensity	Very Serious – negative (-7)	Loss of natural soil is a very serious negative impact as it takes many hundreds of years for soil to regenerate naturally	
Probability	Certain (7)	By removing a the topsoil the impact on land capability is certain	
Mitigation/ Management actions			
▪ No land capability mitigation is possible during the construction and operational phases because the land use is changed from agriculture to open pit mining.			
Post- mitigation			
Duration	7 (Permanent)	During this phase no mitigation is possible and the impacts will be permanent if not mitigated during the rehabilitation and closure phase	Major negative (negative) – 112
Extent	2 (Limited)	The impact will only occur on the project infrastructure area	
Intensity	Very Serious – negative (-7)	Loss of natural soil is a very serious negative impact as it takes many hundreds of years for soil to regenerate naturally	
Probability	Certain (7)	By removing a the topsoil the impact on land capability is certain	

10.2 Operational Phase

During the operational phase the following activities will impact on the soils;

- Development of two open pits by drilling and blasting, truck and shovel methods (128.92 ha and 65.81 ha footprints); and
- Development of low grade stockpiles and waste rock dumps (244.97 ha footprint);

The impacts associated with these activities are described in the following sections

10.2.1 Impact: Loss of Topsoil as a Resource

During the operational phase the loss of topsoil as a resource becomes a problem in the stripping and stockpiling of the expanding open pit as well as the increasing sizes of the waste rock dumps.

Large areas of land will be cleared increasing the runoff potential of the area, this intern increase the erosion hazard present.

During any excavation activity the soil physical and chemical properties are impacted on.

The loss of topsoil as a resource is a serious impact as the natural regeneration of a few millimetres of topsoil takes hundreds of years.

The topsoil stockpiles are designed for a height of 30m this will impact the physical and chemical properties of the soils health.

The impacts are described in Table 10-4.

Table 10-4: Impact Rating for Loss of Topsoil as a Resource during Operational Phase

Dimension	Rating	Motivation	Significance
Activity and Interaction: ▪ **Development of two open pits by drilling and blasting, truck and shovel methods (128.92 ha and 65.81 ha footprints); and** ▪ **Development of one waste rock dump (244.97 ha footprint).**			
Impact Description Topsoil losses can occur during the operational phases as a result of rain water runoff and wind erosion, especially from haul roads and soil stockpiles where steep slopes are present. The expansion of the open pit areas and the waste rock dump sites will impact on the loss of topsoil as a resource			
Prior to mitigation/ management			
Duration	5 (Project Life)	The largest volumes of topsoil will be removed in preparation of open pit mining but may last after this phase.	Medium-High (negative) – 91
Extent	3 (Local)	Loss of topsoil will only occur within and immediately around the Project site.	
Intensity	Very Serious – negative (-5)	Loss of topsoil may result in loss of land capability and land use. Soil regeneration takes a very long time.	
Probability	Certain (7)	By excavating the soil it will certainly impact on the soil chemical and physical properties.	

Dimension	Rating	Motivation	Significance
Mitigation/ Management actions			
▪ Follow adequate stripping guidelines, as described in section 13 soil stripping guidelines. ▪ The topsoil should be stripped by means of an excavator bucket, and loaded onto dump trucks; ▪ Topsoil stockpiles are to be kept to a maximum height of 4m (the practical tipping height of dump trucks); ▪ Topsoil is to be stripped when the soil is dry, as to reduce compaction; ▪ The topsoil 0.3 m of the soil profile should be stripped first and stockpiled separately (to be stockpile in the soils stockpile area identified on the infrastructure plan, but this must be split into the 4 stockpiles described in the soil stripping ratios section); ▪ The subsoil approximately 0.3 – 1.2 m thick will then be stripped and stockpiled separately; ▪ Soils to be stripped according to the soil stripping ratios and stockpiled accordingly; ▪ Foundation excavated soil should also be stockpiled; ▪ Stockpiles are to be maintained in a fertile and erosion free state by sampling and analysing annually for macro nutrients and pH, and vegetating the stockpiles to reduce erosion; ▪ The handling of the stripped topsoil will be minimized to ensure the soil's structure does not deteriorate; ▪ Compaction of the removed topsoil must be avoided by prohibiting traffic on stockpiles; ▪ Prevent unauthorised borrowing of stockpiled soil; ▪ The stockpiles will be vegetated (details contained in rehabilitation plan) in order to reduce the risk of erosion, prevent weed growth and to reinstitute the ecological processes within the soil; ▪ Ensure proper storm water management designs are in place; ▪ Access routes are to be kept to a minimum as to reduce any unnecessary compaction from occurring; ▪ If erosion occurs, corrective actions (erosion berms) must be taken to minimize any further erosion from taking place; ▪ Only the designated access routes are to be used; and ▪ Implement Land rehabilitation measures as defined in rehabilitation report.			
Post- mitigation			
Duration	Project Life (5)	Loss of topsoil makes land less productive. Effects will occur long after the project life.	Low (negative) – 30
Extent	Limited (2)	Loss of topsoil will only occur within and immediately around the Project site.	
Intensity	Moderate - negative (-3)	Loss of topsoil may result in loss of land capability and land use.	
Probability	Unlikely (3)	If the mitigation is followed then it is unlikely that the impacts will occur	

10.2.2 Impact: Loss of Land Capability & Land Use

When the topsoil is removed from the open pit and waste rock areas, the land capability is reduced to nothing. The land use will change from natural and subsistence grazing to mining. The impacts are described in Table 10-5.

Table 10-5: Impact Rating for Loss of Land Capability and Land Use during Operational Phase

Dimension	Rating	Motivation	Significance
Activity and Interaction: ▪ **Development of two open pits by drilling and blasting, truck and shovel methods (128.92 ha and 65.81 ha footprints); and** ▪ **Development of one waste rock dump (244.97 ha footprint).**			
Impact Description: When the topsoil is removed from the open pit and waste rock areas, the land capability is reduced to nothing. The land use will change from natural and subsistence grazing to mining.			
Prior to mitigation/ management			
Duration	7 (Permanent)	If the expanding open pit and waste rock dumps are left then the impact will be permanent	Major negative (negative) – 112
Extent	2 (Limited)	The impact will only occur on the open pits and waste rock areas only.	
Intensity	Very Serious – negative (-7)	Loss of natural soil is a very serious negative impact as it takes many hundreds of years for soil to regenerate naturally	
Probability	Certain (7)	The impact on land capability is certain as it changes from an arable capability to no capability	
Mitigation/ Management actions			
▪ No land capability mitigation is possible during the operational phase and operational phases because the land use is changed from agriculture to open pit mining.			
Post- mitigation			
Duration	7 (Permanent)	If the expanding open pit and waste rock dumps are left then the impact will be permanent	Major negative (negative) – 112
Extent	2 (Limited)	The impact will only occur on the open pits and waste rock areas only.	
Intensity	Very Serious – negative (-7)	Loss of natural soil is a very serious negative impact as it takes many hundreds of years for soil to regenerate naturally	
Probability	Certain (7)	The impact on land capability is certain as it changes from an arable capability to no capability	

10.3 Rehabilitation and Closure Phase

During the rehabilitation and closure phase the following activities will impact on the soils;

- Dismantling and removal of major equipment and infrastructure;
- Rehabilitation of disturbed areas including stockpile dumps and pits etc;
- Partial backfilling of the open pits using waste rock only; and
- Post-closure monitoring.

The impacts associated with these activities are described in the following sections

10.3.1 Impact: Loss of Topsoil as a Resource

During the rehabilitation and closure phase topsoil will be moved from the topsoil stockpile locations and placed in the designated rehabilitation areas. The topsoil will then be spread across to surface. The soil will again be impacted physically and chemically. The spreading of topsoil will also cause compaction as heavy machinery is used to achieve this. The erosion potential will be increased as a result of the bare soil surfaces.

When topsoil is removed from a soil profile, the profile loses effective rooting depth, water holding capacity and fertility. The impacts are described in Table 10-6.

Table 10-6: Impact Rating for Loss of Topsoil as a Resource during Rehabilitation and Closure Phase

Dimension	Rating	Motivation	Significance
Activity and Interaction: ▪ **Dismantling and removal of major equipment and infrastructure;** ▪ **Rehabilitation of disturbed areas including stockpile dumps and pits etc;** ▪ **Backfilling of the open pits using waste rock only; and** ▪ **Post-closure monitoring.**			
Impact Description Topsoil losses can occur during the decommissioning/closure phases as a result of the removal of all infrastructure, particularly the loss of soil quality and the disturbance of soil surfaces.			
Prior to mitigation/ management			
Duration	5 (Project Life)	The largest volumes of topsoil will be removed in preparation of open pit mining but may last after this phase.	Medium-High (negative) – 91
Extent	3 (Local)	Loss of topsoil will only occur within and immediately around the Project site.	
Intensity	Very Serious – negative (-5)	Loss of topsoil may result in loss of land capability and land use. Soil regeneration takes a very long time.	
Probability	Certain (7)	By excavating the soil it will certainly impact on the soil.	

Dimension	Rating	Motivation	Significance
Mitigation/ Management actions			
▪ Ensure proper storm water management designs are in place; ▪ Soil are to be replaced as per soil management and rehabilitation guidelines; ▪ Access routes are to be kept to a minimum as to reduce any unnecessary compaction from occurring; ▪ Ensure proper storm water management designs are in place; ▪ Stockpiles are to be revegetated and erosion free; ▪ Access routes are to be kept to a minimum as to reduce any unnecessary compaction from occurring; and ▪ If erosion occurs, corrective actions must be taken to minimize any further erosion from taking place. ▪ If erosion occurs, corrective actions must be taken to minimize any further erosion from taking place; and ▪ Soil stockpiles are to be used for their designated uses only.			
Post- mitigation			
Duration	Project Life (5)	Loss of topsoil makes land less productive. Effects will occur long after the project life.	Low (negative) – 30
Extent	Limited (2)	Loss of topsoil will only occur within and immediately around the Project site.	
Intensity	Moderate - negative (-3)	Should adequate soil stripping not be followed, loss of topsoil may result in loss of land capability and land use.	
Probability	Unlikely (3)	It is unlikely that loss of topsoil will have an effect after adequate soil stripping and rehabilitation.	

10.3.2 Impact: Loss of Land Capability & Land Use

During the rehabilitation and closure phase, the rehabilitation studies have indicated that there will be a final void, this significantly impacts on the final land capability and land use as these cannot be returned to pre-mining conditions and an alternative land use will have to be considered. The impacts are described in Table 10-7.

The infrastructure areas can be rehabilitated though and as a result the impact will be significantly reduced. The impacts are described in Table 10-8.

Table 10-7: Impact rating for loss of land capability and land use during rehabilitation and closure phase on the open pits

Dimension	Rating	Motivation	Significance
Activity and Interaction: ▪ **Dismantling and removal of major equipment and infrastructure; and** ▪ **Rehabilitation of disturbed areas including stockpile dumps and pits etc.**			
Impact Description: The impact on the rehabilitation of soil, soil quality and land capability. Backfilling of soil layers will impact on the land capability by restoring the land capability to some however as per the materials balance (refer to rehabilitation report) there will be a large void in the open pits.			
Prior to mitigation/ management			
Duration	7 (Permanent)	The loss of land capability for the open pit area will be permanent.	Moderate negative (negative) – 105
Extent	1 (Very Limited)	The impact will only occur on the project infrastructure area	
Intensity	Very Serious – negative (-7)	Loss of natural soil is a very serious negative impact as it takes many hundreds of years for soil to regenerate naturally	
Probability	Certain (7)	There will not be enough material to fill the void and therefor the impact is certain.	
Mitigation/ Management actions			
▪ Mitigation is not possible on the pit areas due to the size of the void that will be left after mining.			
Post- mitigation			
Duration	7 (Permanent)	The loss of land capability for the open pit area will be permanent.	Moderate negative (negative) – 105
Extent	1 (Very Limited)	The impact will only occur on the project infrastructure area	
Intensity	Very Serious – negative (-7)	Loss of natural soil is a very serious negative impact as it takes many hundreds of years for soil to regenerate naturally	
Probability	Certain (7)	There will not be enough material to fill the void and therefor the impact is certain.	

Table 10-8: Impact Rating for Loss of Land Capability and Land Use during Rehabilitation and Closure Phase on the remaining Infrastructure Areas

Dimension	Rating	Motivation	Significance
Activity and Interaction: ▪ **Backfilling of the open pits using waste rock only; and** ▪ **Post-closure monitoring.**			
Impact Description: the infrastructure area will be rehabilitated and the land capability will be restored to the original land capability.			
Prior to mitigation/ management			
Duration	6 (Beyond Project Life)	If no mitigation is taken into consideration the loss of land capability will be	Moderate negative (negative) – 105
Extent	2 (Limited)	The impact will only occur on the project infrastructure area	
Intensity	Very Serious – negative (-7)	Loss of natural soil is a very serious negative impact as it takes many hundreds of years for soil to regenerate naturally	
Probability	Certain (7)	Due to the void being left land capability will be impacted.	
Mitigation/ Management actions			
▪ The soil should be shaped taking the pre-mining landscape into consideration; ▪ The designed post mining landforms should be modelled to establish the post mining landscape stability by using a combination of GIS and erosion modelling techniques by a suitably qualified expert using site specific soil quality data; ▪ The soil layers should be put back in the reverse order of stripping namely subsoil first then topsoil; ▪ The yellow and red soils should be replaced in upland landscape positions (upper part of the landscape); ▪ Wetland soils should be put back in the reverse order of stripping; ▪ Wetland soils should be placed in lower landscape positions (foot slopes and valley bottoms); ▪ The soil cover should be at least 0.8 m in depth consisting of at least 0.5 m subsoil and 0.3 m topsoil on top of the reconstructed profile. Rehabilitation should strive to rehabilitate the soil and land capability back to emulate pre-mining land capability; ▪ The soil quality should be investigated prior to establishing vegetation on the rehabilitated soil through representative sampling and laboratory analysis; ▪ The analytical data should be evaluated by a suitably qualified expert and vegetation fertility and or soil acidity problems should be corrected prior to vegetation establishment; ▪ Clear targets incorporating medium to long term post mining land capability influencing land use, should be part of a potentially successful closure plan; ▪ Soil fertility is to be monitored to ensure vegetation succession; and ▪ Post mining land capability assessment is to be undertaken to assess rehabilitation success.			
Post- mitigation			
Duration	5 (Permanent)	When the area has been rehabilitated the	Minor negative

Dimension	Rating	Motivation	Significance
		impacts will be reduced to	(negative) – 40
Extent	1 (Very Limited)	The impact will only occur on the infrastructure area	
Intensity	Serious – negative (-4)	Loss of natural soil is a very serious negative impact as it takes many hundreds of years for soil to regenerate naturally	
Probability	Propable (4)	If rehabilitation is completed as per recommendations then the impacts will be reduced to	

11 Cumulative Impacts

The Arcadia soils have high clay contents, with a grazing land capability. The agricultural potential of these soil are low compared to their possible natural fertility due to the difficulty in managing these soils. The clays are expected to be shrink/swell clays which shear roots when they dry out. These could also provide difficulty in the rehabilitation of these areas or the availability of cover material for the waste rock dumps. In all likelihood topsoil might need to be imported to improve rehabilitation efforts and reduce any long term negative effects such as erosion, loss of topsoil, and loss of land capability.

Post mining land capability depends to a large extent on the rehabilitation efforts by the mining company. The mining of this Magnetite Project site therefore presents a low risk to food security in area. The project has a relatively small regional agricultural impact.

12 Unplanned Events and Low Risks

Low risks can be monitored to gauge if the baseline changes and mitigation is required. Table 12-1 shows the risk of hydrocarbon spills of occurring as well as mitigation measures to reduce this risk and to manage the risk.

Table 12-1: The Risk of Hydrocarbon Spills of occurring as well as Mitigation Measures to Reduce / Manage the Risk

Unplanned event	Potential impact	Mitigation/ Management/ Monitoring
Hazardous substances spillage	Soil contamination	▪ Prevent any spills from occurring. Machines must be parked within hardpark areas and must be checked daily for fluid leaks; ▪ If a spill occurs it is to be cleaned up immediately and reported to the appropriate authorities; ▪ All vehicles are to be serviced in a correctly banded area or at an off-site location; and; ▪ Leaking vehicles will have drip trays place under them where the leak is occurring

13 Soil Stripping

There are two major soil groups in the project area and these soils will be stripped separately as shown in Figure 13-1.

The Arcadia soils are heavy black clay soils with shrink swell properties. The top 30cm of these soils are to be stripped and stockpiled in one stockpile (**S1**). The remaining 90cm (up to depth 120cm) are to be stripped separately and stockpiled in another stockpile (**S2**).

The Oakleaf soils are red and somewhat freely draining. The top 30cm of these soils are to be stripped and stockpiled in one stockpile (**S3**). The remaining 90cm (up to depth 120cm) are to be stripped separately and stockpiled in another stockpile (**S4**).

The top 30cm of soil is stripped separately to conserve the natural seed bank as well as the natural fertility that has been accumulated in this layer. This layer is also to be replaced last to increase the chances of rehabilitation success.

These soils are stockpiled separately as to maintain their natural structures, and cannot be mixed under any circumstances. This would compromise their ability to rehabilitate.

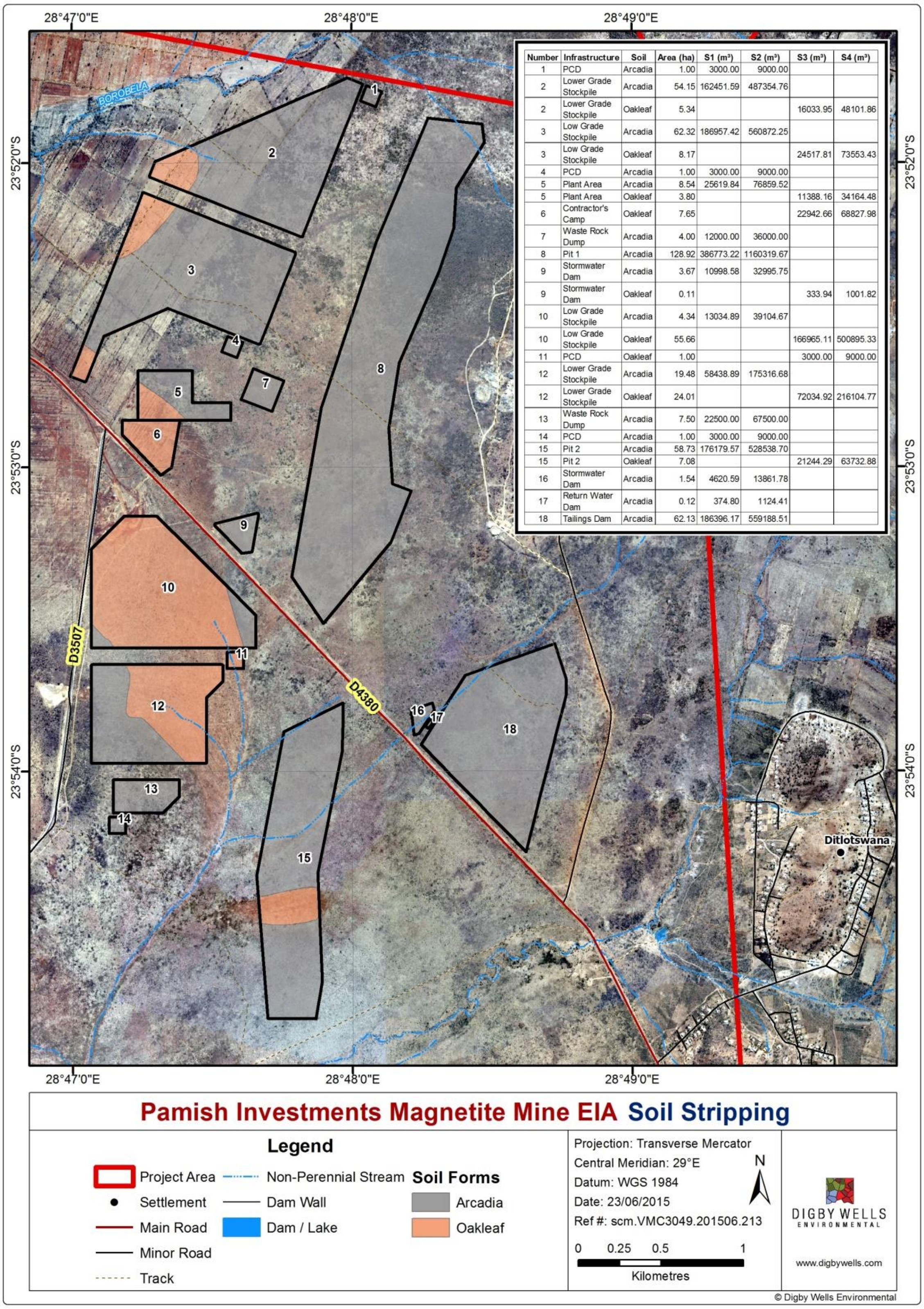
These soils are to be stripped in the dry season only.

Table 13-1 shows the infrastructure within the project site and which soils are to be stripped and to which stockpile they should be assigned too. All S1 stripped soils are to be placed together and the same with S2 through to S4. The volumes of these have been tabulated for closure and rehabilitation purposes.

Table 13-1: Soil Stripping Areas and Volumes for the Various Infrastructures/Activities as well as the Soils to be Stripped and which Stockpiles they are to be assigned to

Number	Infrastructure	Soil	Area (ha)	S1 (m^3)	S2 (m^3)	S3 (m^3)	S4 (m^3)
1	PCD	Arcadia	1.00	3000.00	9000.00		
2	Lower Grade Stockpile	Arcadia	54.15	162451.59	487354.76		
2	Lower Grade Stockpile	Oakleaf	5.34			16033.95	48101.86
3	Low Grade Stockpile	Arcadia	62.32	186957.42	560872.25		
3	Low Grade Stockpile	Oakleaf	8.17			24517.81	73553.43
4	PCD	Arcadia	1.00	3000.00	9000.00		
5	Plant Area	Arcadia	8.54	25619.84	76859.52		
5	Plant Area	Oakleaf	3.80			11388.16	34164.48
6	Contractor's Camp	Oakleaf	7.65			22942.66	68827.98

Number	Infrastructure	Soil	Area (ha)	S1 (m³)	S2 (m³)	S3 (m³)	S4 (m³)
7	Waste Rock Dump	Arcadia	4.00	12000.00	36000.00		
8	Pit 1	Arcadia	128.92	386773.22	1160319.67		
9	Stormwater Dam	Arcadia	3.67	10998.58	32995.75		
9	Stormwater Dam	Oakleaf	0.11			333.94	1001.82
10	Low Grade Stockpile	Arcadia	4.34	13034.89	39104.67		
10	Low Grade Stockpile	Oakleaf	55.66			166965.11	500895.33
11	PCD	Oakleaf	1.00			3000.00	9000.00
12	Lower Grade Stockpile	Arcadia	19.48	58438.89	175316.68		
12	Lower Grade Stockpile	Oakleaf	24.01			72034.92	216104.77
13	Waste Rock Dump	Arcadia	7.50	22500.00	67500.00		
14	PCD	Arcadia	1.00	3000.00	9000.00		
15	Pit 2	Arcadia	58.73	176179.57	528538.70		
15	Pit 2	Oakleaf	7.08			21244.29	63732.88
16	Stormwater Dam	Arcadia	1.54	4620.59	13861.78		
17	Return Water Dam	Arcadia	0.12	374.80	1124.41		
18	Tailings Dam	Arcadia	62.13	186396.17	559188.51		
Totals			**531.26**	**1 255 345.56**	**3 766 036.68**	**338 460.84**	**1 015 382.52**



Number	Infrastructure	Soil	Area (ha)	S1 (m³)	S2 (m³)	S3 (m³)	S4 (m³)
1	PCD	Arcadia	1.00	3000.00	9000.00		
2	Lower Grade Stockpile	Arcadia	54.15	162451.59	487354.76		
2	Lower Grade Stockpile	Oakleaf	5.34			16033.95	48101.86
3	Low Grade Stockpile	Arcadia	62.32	186957.42	560872.25		
3	Low Grade Stockpile	Oakleaf	8.17			24517.81	73553.43
4	PCD	Arcadia	1.00	3000.00	9000.00		
5	Plant Area	Arcadia	8.54	25619.84	76859.52		
5	Plant Area	Oakleaf	3.80			11388.16	34164.48
6	Contractor's Camp	Oakleaf	7.65			22942.66	68827.98
7	Waste Rock Dump	Arcadia	4.00	12000.00	36000.00		
8	Pit 1	Arcadia	128.92	386773.22	1160319.67		
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9	Stormwater Dam	Oakleaf	0.11			333.94	1001.82
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15	Pit 2	Oakleaf	7.08			21244.29	63732.88
16	Stormwater Dam	Arcadia	1.54	4620.59	13861.78		
17	Return Water Dam	Arcadia	0.12	374.80	1124.41		
18	Tailings Dam	Arcadia	62.13	186396.17	559188.51		

Figure 13-1: Soil Stripping Areas and Volumes for the Various Infrastructures/Activities as well as the Soils to be Stripped and which Stockpiles they are to be assigned to

13.1 Stripping Guideline

This section explains the correct measures that should be followed during the stripping of soil. This is a key rehabilitation activity because soils lost cannot be regenerated in the lifetime of the mine.

Correct stripping of soils will firstly ensure that enough soils are available for rehabilitation and secondly, that the soils are of adequate quality to support vegetation growth and thus ensure successful rehabilitation.

The steps that should be taken during soil stripping are as follows:

- A soil plan of the mining area is compiled and soils should be stripped making use of this;
- Determine stripping depths, which is dependent on the type of soil identified in the area to be cleared;
- Ensure that mining operations do not impact on soil that is stripped or going to be stripped;
- Demarcate the boundaries of the different soil types;
- Define the cut-off horizons in simple terms so that they are clear to the stripping operator;
- Stripping should be supervised to ensure that the various soils are not mixed;
- Soils should only be stripped when the moisture content will minimise the compaction risk (i.e. when they are dry);
- The subsoil clay layers which can be found under certain hydromorphic soils need to be stripped and stockpiled separately. This clay material can be used as a compacted clay cap over rehabilitated pit areas that will become wetlands post-rehabilitation (stripping of wetland soils should be avoided, however if stripping does occur the above is recommended for stripping and stockpiling);
- Where possible, soils should be stripped and replaced in one action i.e. soils should only be handled once instead of moving it around two or more times.
- Truck and shovel should preferably be used as a means of moving soil, instead of bowlscrapers.

13.1.1 Supervision

A very important aspect is the supervision and monitoring during the stripping process. Close supervision will ensure that soils are being stripped from the correct areas and to the correct depths, and placed on the correct stockpiles with a minimum of compaction. Monitoring requires an assessment of the depth of the soil, the degree of mixing of soil materials and the volumes of soils that are being replaced directly or being placed on stockpiles.

Contracts for the stripping of soils should not only be awarded on the volumes being stripped but also on the capability to strip and place soil accurately.

13.1.2 Stripping Method

Soils should be stripped and replaced using the truck and shovel method as far as possible. This method will limit the compaction of soils. If bowl scrapers are used then the soils must be dry during stripping to minimise compaction.

13.1.3 Stockpiling

This section explains the correct measures to be followed during the stockpiling of soil. Stockpiling should be minimised as far as possible since it increases compaction and decreases the viability of the seed bank. Stripped soil should not be stockpiled but placed directly wherever possible.

The steps that should be taken during soil stockpiling are as follows:

- Mark stockpile locations accurately on a plan to ensure that re-handling is minimised (i.e. soils will not have to be moved a second or third time);
- Ensure that the location is free draining to minimise erosion loss and waterlogging;
- Minimise compaction during stockpile formation. The soils should be kept loose by, preferably, tipping at the edge of the stockpile not driving over the stockpile (avoid end-tipping as this causes compaction);
- Re-vegetate with a native seed mixture (stockpiles that will remain standing for several years); and
- Ensure that the stockpiled soil is only used for the intended purposes.

14 Monitoring Plan

The soils monitoring plan guidelines should be put in place to ensure the best chances of rehabilitative success from a soils perspective.

The monitoring plan for soils must contain the following:

- The location of soil types that can be stripped and stockpiled together;
- Stripping depths of different soil types;
- The location, dimensions and volume of planned stockpiles for different soil types;

Progressive monitoring must take place on at least a quarterly basis and should involve the following:

- Inspection of stripping depths;
- Inspection of stockpiles to check degradation and or pollution;

- Inspection of soil surfaces before replacing soil to ensure that pre mined topography is emulated;
- Random inspection of soil thickness on rehabilitated sections;
- Fertility analysis and amelioration procedures prior to re-vegetation; and
- Evaluating and readjusting the rehabilitation plan.

A final post-mining rehabilitation performance assessment must be completed with information that is adequate for closure applications. This involves:

- Assessment of rehabilitated soil thickness and soil characteristics by means of auger observations using a detailed grid;
- A post-mining land capability map based on soil thickness and characteristics;
- A proposed post-mining land use map;
- Erosion occurrences;
- Soil acidity and salt pollution analyses (pH, electrical conductivity and sulphate) at 0-250 mm soil depth every 4 ha (200m x 200m);
- Fertility analysis (exchangeable cations K, Ca, Mg and Na and phosphorus) every 16 ha (400x400m); and
- Bulk density analysis every 4 ha (200m x 200m).

15 Consultation Undertaken

No consultations were undertaken by the soil specialists.

16 Comments and Responses

No comments were received on the Soils Impact Assessment

17 Conclusion and Recommendation

The project area is dominated by dark shrink/swell clay soils in the Arcadia form with some portions to the west having red fairly well drained Oakleaf soils. The soil types and depths dictate the land capability which was classified as Class IV (moderate grazing) and Class III (moderate cultivation/intensive grazing) land capabilities respectability. The land uses followed similar trends and the Arcadia soils were mainly left as natural veld, whilst the Oakleaf soils were being utilised for subsistence grazing purposes.

The project area does not have a high agricultural footprint within the area due to the difficulties in cultivating the Arcadia soils.

The following recommendations are made to minimise the impact on the soils as well as things to look out for regarding these soils:

- All soils are only to be stripped during the dry season;
- The topsoil stockpiles are designed for a height of 30m this will impact the physical and chemical properties of the soils health, it Is recommended to stockpile to a maximum height of 4 m to reduce the impacts on soil physical and chemical properties;
- The Arcadia soils shrink when dry and swell when wet creating a risk to any infrastructure built on them and as a result this needs to be taken into account when designing infrastructure; and
- The Soils must be stripped according to the soil stripping guideline.

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Appendix A: Declaration of Independence

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I, Wayne Jackson as duly authorised representative of Digby Wells and Associates (South Africa) (Pty) Ltd., hereby confirm my independence (as well as that of Digby Wells and Associates (South Africa) (Pty) Ltd.) and declare that neither I nor Digby Wells and Associates (South Africa) (Pty) Ltd. have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of Pamish Investments No. 39 (Pty) Ltd, other than fair remuneration for work performed, specifically in connection with the proposed Magnetite mine.

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Full name: Wayne Jackson

Title/ Position: Soil Scientist

Qualification(s): BSc. Soil Science & Hydrology

Experience (years): 7 years