Soil and Waste Characterisation Desk Study

Calingiri Copper-Molybdenum Project
Caravel Minerals

Revision No 1
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Report

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Synopsis:	This document details a soil and waste characterisation desk study assessment of the tenements of the Calingiri Copper-Molybdenum Project and the immediate surrounds. This assessment is intended to detail the characteristics of the *in situ* soils and potential mine wastes and to provide a preliminary insight into potential impacts pertaining to soils and mine wastes during development of a mine as well as its rehabilitation and closure.

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Executive Summary

Scope of Work

Pendragon Environmental Solutions was engaged by Caravel Minerals to undertake a desk study characterisation of soils and potential mine wastes for the Calingiri Copper-Molybdenum Project. This assessment forms one component of the Pre-Feasibility Study (PFS) and is intended to provide:

- Details pertaining to the *in situ* characteristics of soils and mine wastes.
- A preliminary insight into potential impacts pertaining to soils and mine wastes during development of a mine as well as its subsequent rehabilitation and closure.

The Calingiri Copper Project entails the simultaneous development of four open pits with associated waste rock dumps, a processing plant and tailings storage facility.

Lake Ninan and the township of Wongan Hills are 3.2km and 13.3km north-east of the processing plant. Access is from the Calingiri-Wongan Hills sealed road immediately north of the processing plant.

Objectives

The objectives of this preliminary desk study assessment, in the absence of soil sampling and detailed mine and rehabilitation plans, were to obtain a global characterisation of soils pertaining to their physical, hydraulic and chemical properties with the view to ascertain:

- Requirements for mine planning particularly to minimise erosion and environmental impacts offsite and whether there are any soils which could be problematic during mining and/or closure to construct stable land forms e.g. tailings storage facilities (TSFs), waste rock dumps (WRDs) and stockpiles consistent with the proposed final land use.
- The requirements for further sampling and analysis to ascertain the physical, hydraulic and chemical properties of the soils and mine wastes.

Methodology of Soil and Waste/Ore Characterisation

The soil characterisation desk study assessment employed published reports and maps and soil analytical data by NRM and the Western Australian Department of Agriculture and Food.

The mine waste desk study characterisation used assay data provided by Caravel Minerals which included soils and rock that may not necessarily be disturbed during future mining, potential mine wastes and ore.

Conclusions and Recommendations

Soils across the Calingiri Project comprise sand and sandy loams having low natural nutrition with induced subsoil acidity and salinity related to rising water tables. This may have implications with regard to rehabilitation and mobilisation of metals in surface drainage. Soil Nitrogen supply, pH and density parameters have moderate to high risks which require further investigations into management options.

The assay data used in this assessment contained samples with elevated (>0.25%S) concentrations of Sulphur with a number of samples exceeding 1.0%. Concentrations in excess of 1% are considered materials with a high potential for acid generation. However, the overall impression is sporadic occurrences of elevated concentrations of Sulphur at varying depths but generally deeper than 50m within an ore body containing primarily low sulphur concentrations. The samples contain elevated concentrations of some heavy metals which coupled with elevated concentrations of Sulphur warrant further investigation and assessment.

Consideration should be given to undertake soil and waste/ore sampling and analysis in accordance with Section 4.2 of this document.

1. Introduction

1.1 Scope of Works

Pendragon Environmental Solutions was engaged by Caravel Minerals to undertake a desk study characterisation of soils and wastes for the Calingiri Copper-Molybdenum Project and its immediate surrounds. This assessment forms one component of the Pre-Feasibility Study (PFS) and is intended to provide:

- Details pertaining to the in situ characteristics of soils and mine wastes within the project area.
- A preliminary insight into potential impacts pertaining to soils and mine wastes during development of a mine as well as its subsequent rehabilitation and closure.

The project or area referred to throughout this report comprises the collective of tenements that make up the Calingiri Project (Figure 1.1). The project area extends from immediately south-west of the Wongon Hills townsite, to north-east of Bolgart.

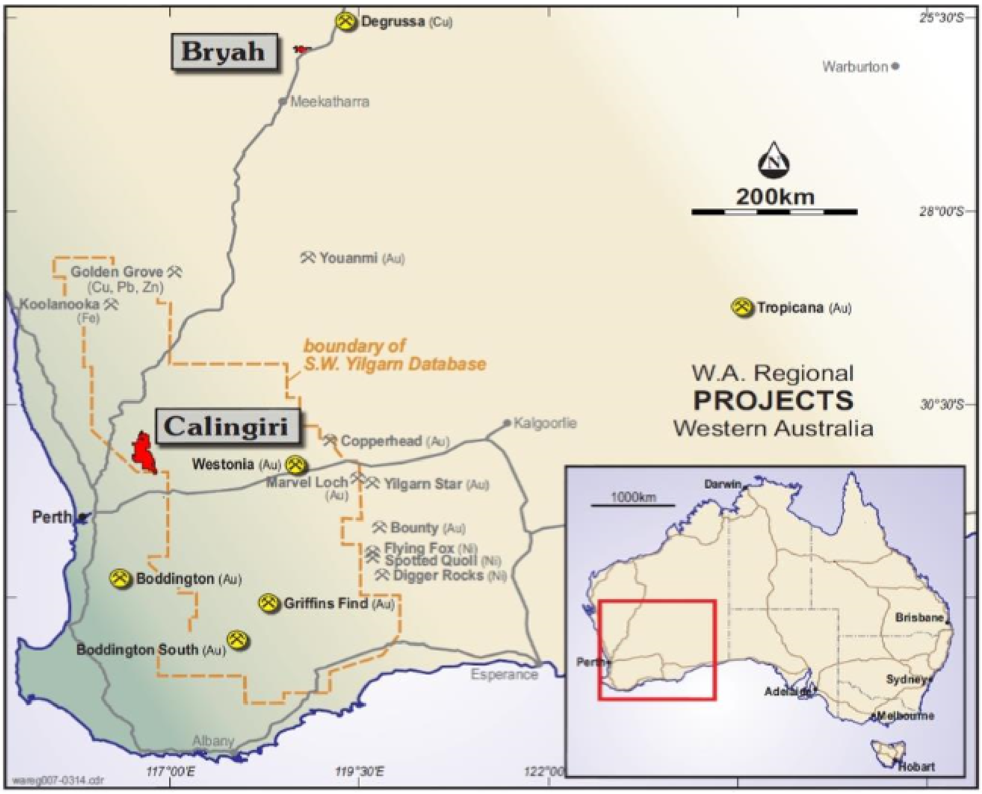

Figure 1.1: Location of the Calingiri Copper-Molybdenum Project.

1.2 Objectives

The objectives of this preliminary desk study assessment, in the absence of soil sampling and detailed mine and rehabilitation plans, were to obtain a global characterisation of soils pertaining to their physical, hydraulic and chemical properties with the view to ascertain:

- Requirements for mine planning particularly to minimise erosion and environmental impacts offsite and whether there are any soils which could be problematic during mining and/or closure to construct stable land forms e.g. tailings storage facilities (TSFs), waste rock dumps (WRDs) and stockpiles consistent with the proposed final land use.

- The requirements for further sampling and analysis.

1.3 Brief Project Description

The Calingiri Copper Project entails the simultaneous development of four open pits with associated waste rock dumps (Figure 1.2) on Tenements 7003674 (two open pits and waste rock dumps), 7002788 and 7002789. The processing plant and tailings storage facility will be located to the south of the northernmost open pit on Tenement 7002788.

Lake Ninan and the township of Wongan Hills are 3.2km and 13.3km north-east of the processing plant. Access is from the Calingiri-Wongan Hills sealed road immediately north of the processing plant.

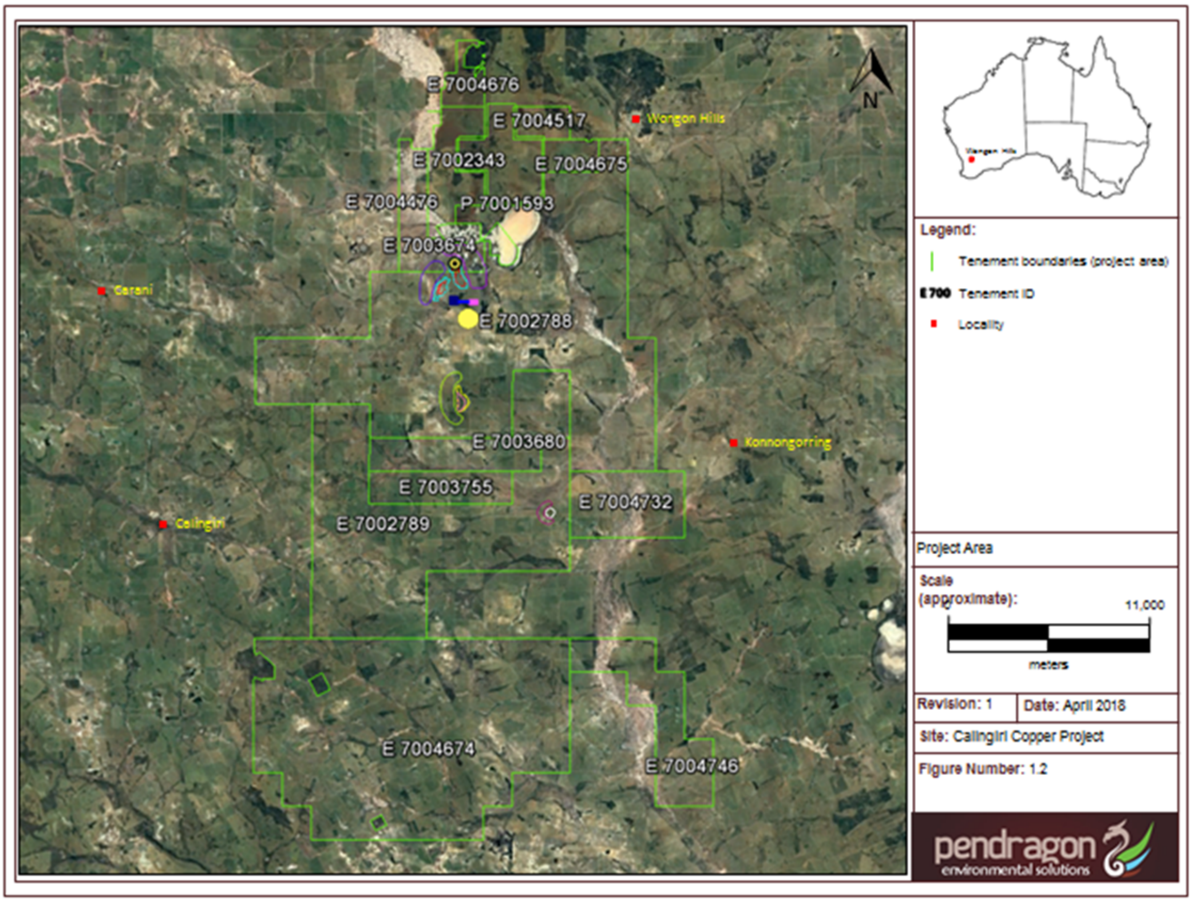

Figure 1.2: Proposed Mine Layout.

Conventional opencast mining will take place at three locations: Bindi, Dasher and Opie (Figure 1.2); these deposits all contain Copper (Cu), Molybdenum (Mo), Silver (Ag) and Gold (Au). Processing will be by means of crushing (with ore stockpiling), grinding and flotation to yield a concentrate for metal recovery. Waste rock will be placed in rock dumps near the open pits. The Calingiri mineralisation is characterised by a relatively simple mineralogy. All the copper is in the form of chalcopyrite with pyrite the only other significant sulphide (cpy: py variable 3:1 to 1:1). All sulphides, including molybdenite, are relatively coarse grained. The gangue is dominantly silicates (quartz, feldspar, epidote, chlorite and garnet) with minor magnetite

The sulphide mineralisation containing the mineral resources is developed within a very consistent fresh gneissic bedrock generally at depths between 5m and 50m beneath a regolith cover of *in situ* weathered saprolitic clays blanketed by a variable 1m to 10m layer of sand and gravel beneath a variable thickness soil horizon comprising sand, clay and laterite:

2. Soil Characterisation

2.1 Soil Landscape Zones

The Calingiri Project falls in the Avon Province Zone 256 (Figure 2.1) which is described as:

- *A laterised plateau (dissected at fringes and with saline drainage lines inland) on a deeply weathered mantle and alluvium over granitic rocks of the Yilgarn Craton.*
- *Sandy duplexes soils and ironstone gravelly soils with loamy earths, loamy duplexes, sandy earths, deep sands and wet soils.*

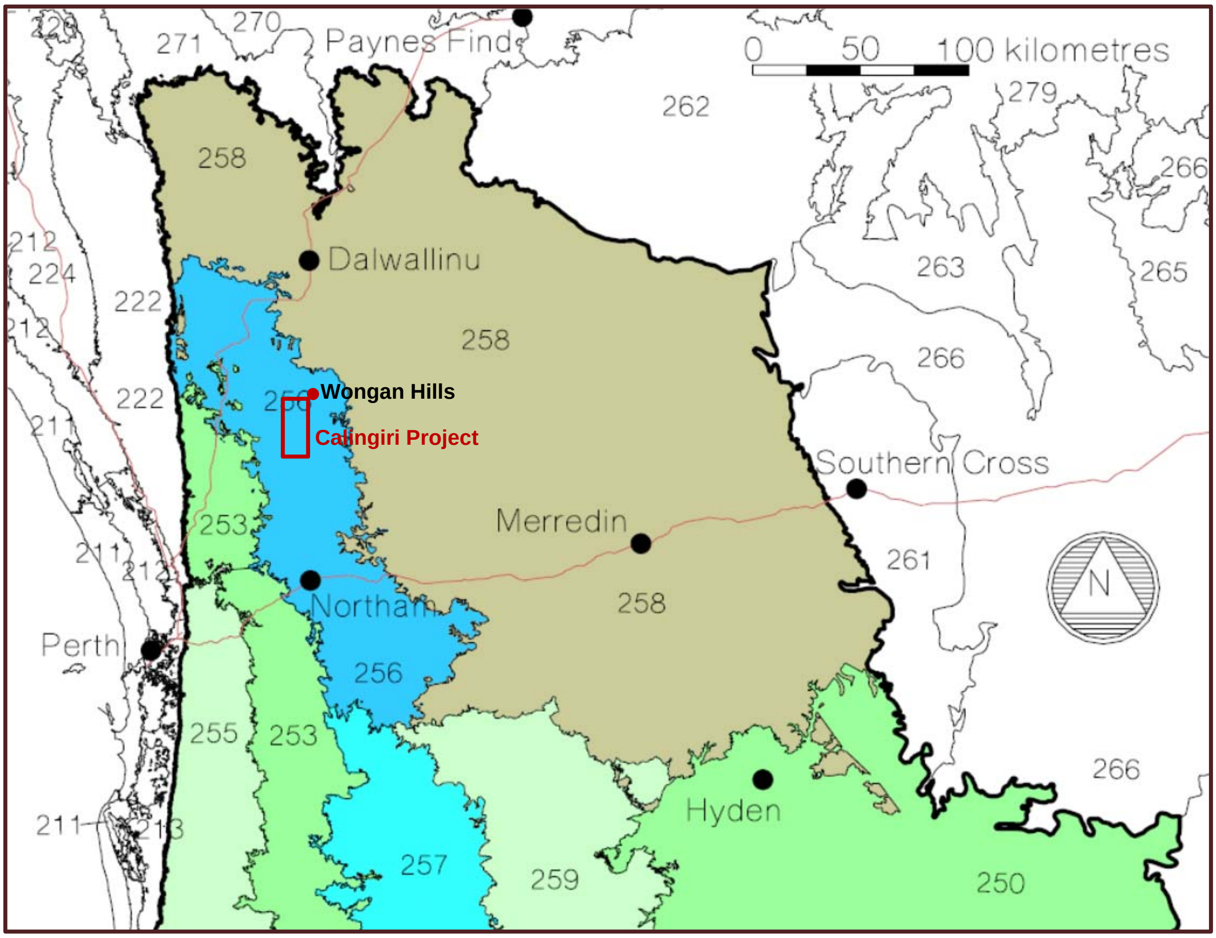

Figure 2.1: Soil-Landscape Zones of the Avon Province.

(after Figure 4.5h, Soil-Landscape Zones of the WA Rangelands and Interior)

The Avon Province occupies about 169,325 km^2, of which the vast bulk (93%) lies in the Agricultural Area (DAFWA, 2006); the Province extends from the eastern Wheatbelt to the south coast near Denmark and Northcliffe, and includes the Darling Range.

The northern part of the Avon Province is a gently undulating terrain (with some sand plains and salt lakes chains) on a deeply (up to 50m) weathered mantle and alluvium over granitic rocks of the Yilgarn Craton. The soils comprises sandy earths (mostly yellow and red), loamy earths (often calcareous), sandy duplexes, loamy duplexes, deep sands and ironstone gravelly soils. Vegetation, although most has been cleared for agriculture, comprises Salmon gum-gimlet-morrel-wandoo-York gum woodlands with mallee scrub (and some acacia-casuarina thickets, scrub-heath and samphire flats).

The bio-climate across the Calingiri Project is described by Beard (1990) as *thermoxeric*. This is a mostly dry to extra dry Mediterranean climate with 5 to 8 dry months. Mean annual rainfall is mostly in the 300mm to 500mm range, tending to fall mainly in the winter months.

Climate impacted on groundwater levels (GHD, 2017). In the decade leading up to 2000, rainfall was above average resulting in rising groundwater levels and increasing salinity risk which was a key driver in the construction of deep drains. From 2001 to 2007 rainfall was well below average and groundwater trends in many valley floors were mostly falling or stable. Acid groundwater is naturally occurring; it is highly variable spatially, although found more frequently in the valley floors of palaeo drainage lines. The hydrolysis of dissolved iron in groundwater (when it is exposed to oxygen in the drain) sometimes results in lower pH in the drainage discharges than in the surrounding groundwater.

2.2 Characteristics of Soils

The primary soil constraints of the central agricultural region include low natural nutrition, production induced subsoil acidity and salinity related to rising water tables (Soil Quality, 2018). Approximately 80% of the topsoil samples are below the target pH level of 5.5 and nearly half of the subsurface soils fall below the target of 4.8.

Soil quality indicators (Tables 2.1 and 2.2) for the sands and loams across the central wheatbelt were obtained by applying a series of critical values relating to impacts on production and/or soil quality in general (Soil Quality, 2018). An indication of high risk identifies the need to investigate management options, a moderate risk should be investigated further, while a low risk requires regular monitoring.

Table 2.1: Soil Quality Indicators.

Soil Quality Indicator	Sand	Loam
Biological		
Total Organic Carbon	Low	Low to Moderate
Soil Nitrogen Supply	Moderate to High	High to Moderate
Chemical		
pH	Moderate to High	Moderate to High
Water Repellency	Low	Low
Electrical Conductivity	Low	Low
Phosphorus	Low	Moderate to Low
Physical		
Bulk Density	Moderate to High	Moderate to High

Table 2.2: Ranges for Soil Quality Indicators.

Soil Quality Indicator	Sand	Loam
Biological		
Total Organic Carbon (mg/kg)	0.5 - 2.2	0.5 - >2.0
Soil Nitrogen Supply (mg/kg)	0.0 - 3.0 very low to high	4 - 60 low to very high
Chemical		
pH (pH units)	4.8 - 5.5	4.8 - 7.5
Electrical Conductivity (dS/m)	<6	<6

Soil Quality Indicator	Sand	Loam
Water Repellency	>75% none to moderate	none
Extractable Sulphur	<5 - 15 average 5 - 10	5 - 15
Potassium (mg/lg)	40 - >120 average 60 - 120	>120
Total Nitrogen (mg/kg)	<0.5	<0.5
Phosphorus (mg/kg)	10 -50	25 - 50
Cation Exchange Capacity (meq/100g)	0 - 5 very low	5 - 20 low to moderate
Physical		
Clay Content (%)	<10	10 - 20 sandy loam
Bulk Density (g/m^3)	1.2 - 1.6 friable to firm	1.2 - 1.6 friable to firm
Gravel Content (%)	0 - 5	0 - 10 5 average

2.2.1 Soil pH

Soil pH affects the soil's physical, chemical, and biological properties and processes as well as plant growth. The nutrition, growth, and yields of most crops decrease where pH is low and increase as pH rises to an optimum level. The optimum pH range for most plants is between 5.5 and 7.0 (Perry, 2003); however, many plants have adapted to thrive at pH values outside this range. The United States Department of Agriculture Natural Resources Conservation Service classifies soil pH ranges as follows (USDA, 1998):

Table 2.3: pH Classification.

Classification	pH Range
Ultra acid	<3.5
Extreme acid	3.5 to 4.4
Very strong acid	4.5 to 5.0
Strong acid	5.1 to 5.5
Moderate acid	5.6 to 6.0
Slight acid	6.1 to 6.5
Neutral	6.6 to 7.3
Slightly alkaline	7.4 to 7.8
Moderately alkaline	7.9 to 8.4
Strongly alkaline	8.5 to 9.0
Very strongly alkaline	>9.0

The pH of sandy soils in the central wheatbelt falls in the category *very strong acidic* to *strong acidic* whilst the pH in the sandy loams fall in the category very strong acidic to neutral. Plants grow best if pH is close to neutral (pH 6.0 to 7.5) although few prefer acidic or alkaline soils. In acidic soils, calcium and magnesium, nitrate, phosphorus, boron, and molybdenum are generally deficient, whereas aluminium and manganese are abundant, sometimes at levels toxic to some plants. Phosphorus, iron, copper, zinc, and boron are frequently deficient in very alkaline soils. Bacterial populations and activity decline at low pH levels, whereas fungi adapt to a large range of pH (acidic and alkaline).

At very acidic or alkaline pH levels, organic matter mineralization slows down or stops because of poor microbial activity linked to bacteria (NRCS, 2011). Nitrification and nitrogen fixation are also inhibited by low pH. The mobility and degradation of herbicides and insecticides, and the solubility of heavy metals are pH dependent. The effects of soil pH on cation availability influence aggregate stability since multivalent cations, such as calcium ions, act as bridges between organic colloids and clays and some plant diseases thrive when the soil is alkaline or acidic.

2.2.2 Chemical Indicators

Further soil sampling is required to ascertain whether the concentrations of Electrical Conductivity, Total Soluble Salts and exchangeable Sodium will render the sands and sandy loams dispersive and/or saline. These factors are to be considered in the choice of plant species for re-vegetation of the final landforms which in itself is an important erosion control measure.

The cation exchange capacity (CEC which is calculated by summing the exchangeable base cations Na^+ , K^+ , Mg^{2+} and Ca^{2+} as well as exchangeable aluminium Al^{3+} and hydrogen H^+) measures the capacity of the soils to retain exchangeable cations including plant nutrients such as potassium, calcium, magnesium and ammonium. The CEC is largely determined by clay content and organic matter. Clay has the greatest ability to hold cations, as it has a very large surface area compared to sand or silt. Organic matter also has a high cation exchange capacity (up to 30 times greater than clay). CEC, as an inherent characteristic which is difficult to alter, is used as a measure of fertility, nutrient retention, and the capacity to protect ground water from cation contamination. Sodicity, as sodic soils are subject to dispersion when wet, is to be determined by the cation exchange capacity (CEC) of major exchangeable cations/bases (Ca^{2+}, Mg^{2+}, Na^+ and K^+). Sandy soils with CECs less than 3 are often low in fertility and susceptible to soil acidification.

In addition, the concentrations of major cations and anions, nutrients and heavy metals are to be determined to confirm the quality of the sandy soils and sandy loams for rehabilitation. Nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) are the key macronutrients for plant growth and are largely derived from soil and organic matter. Concentrations that may be considered typical for arid zone soils include nitrate and phosphorus concentrations between 5mg/kg and 10mg/kg, potassium between 150mg/kg and 200mg/kg and sulphur at less than 100mg/kg (FMG, 2011).

Concentrations of nitrate (plant available N) less than 8mg/kg is considered to be low; however, nitrate can be readily applied to these soils to boost plant growth. Orthophosphates, $H_2PO_4^-$ and HPO_4^{2-} are the primary forms of phosphorus taken up by plants. When the soil pH is less than 7.0, $H_2PO_4^-$ is the predominate form of phosphate in the soil. Whilst the Phosphorous levels seem high, the low pH of soils with elevated concentrations of aluminium will cause phosphate sorption and consequently less availability of phosphate for plant uptake.

Concentrations of Potassium, one of the essential nutrients and commonly deficient in most soils in WA, between 100mg/kg to 300mg/kg are considered optimal. Where soils have less than 100mg/kg additions of potassium fertiliser could be beneficial. Potassium is commonly found in plants at levels above all other macro nutrients except carbon, oxygen, hydrogen and occasionally nitrogen. Potassium has many functions including the regulation of the opening and closing of stomata which are the breathing holes found on plant leaves and therefore regulate moisture loss from the plant.

2.2.3 Erodibility Index of Soils and Soil Erosion Risk

Erosion caused by wind and seasonal rainfall events is often a significant factor during rehabilitation and closure of a waste landform. While erosion by wind may occur all year around, it is the combination of soil characteristics (particle size, clay content, etc.), topographic features, rainfall intensity, vegetation and wind which determines the likelihood of it occurring.

High to very high potential or risk for erosion prevail usually because of the presence of moderate (>5% to 10%) or significant (20%, 5H:1V, or steeper) slopes and/or readily erodible soil profiles. Soils with relatively high silt and fine sand fractions are most susceptible to erosion, while very fine grained, high plasticity clay soils are least susceptible.

Laboratory tests provide measurements of Inter-rill Erodibility (K_i), Saturated Hydraulic Conductivity (K_{eff}), Rill Erodibility (K_r), and overland flow Critical Shear (t_C) which are the primary inputs for a slope erosion model to predict field-scale erosion rates for a range of potential slope configurations commonly constructed on mine site waste dumps using a 100-yr synthetic climate file from measured climate data.

Since erosion of a particular land form also depends on its design and physical characteristics, laboratory testing and modelling provide a sound base for on-site rehabilitation trials to obtain data that will assist in the refinement of closure objectives and completion criteria. This is particularly important for elements of the mine site where it is difficult for progressive rehabilitation to occur (e.g. large excavations and permanent waste rock dumps). Monitored trials during operations are generally required to develop the most appropriate slope treatments for landforms at a particular mine site and are also important to optimise the success of revegetation.

3. Waste Rock Characterisation

This assessment was undertaken on the data base of assay data as provided by Caravel Minerals and thus includes soils and rock that may not necessarily be disturbed during future mining, potential mine wastes and ore. The intention is to ascertain whether metalliferous mine drainage (acidic, neutral and/or saline but particularly acid mine drainage) requires urgent/immediate attention.

3.1 Preliminary Characterisation

Inspection of two data bases of assay data of the:

- bores drilled for a water supply investigation and intersecting the shallow soils and underlying paleochannel sediments; and
- exploration bores intersecting soils, rock, potential wastes and ores;

revealed the following:

- water supply bores (sample size n = 75):

  Samples contained detectable concentrations of Ag, As, Be, Bi, Ca, Cd, Co, Cr, Cu, Ga, K, La, Mg, Mo, Na, Ni, Pb, S, Sb, Sc, Sr, Th, Ti, Tl, U, V, W, Zn, Cs, Ge, Hf, In, Li, Nb, Se, Sn, Ta and Y but at concentrations below 0.1% and/or 50mg/kg.

  Of particular interest are the absence and/or low concentrations of As, S and Se.

  Samples contained elevated average concentrations of Al (5.2%), Ba (249mg/kg), Fe (1.1%), Mn (94mg/kg), P (90mg/kg), Ce (68mg/kg), Rb (123mg/kg) and Zr (144mg/kg). The potential risks of these metals and particularly aluminium should be investigated further by leaching tests.

- exploration bores (sample size n = 1,299):

  Samples contained detectable concentrations of Au, Ag, As, Be, Bi, Cd, Ce, Co, Cs, Ga, Hf, Ind, La, Li, Mo, Nb, Ni, Pb, Re, S, Sb, Sc, Se, Sn, Ta, Te, Th, Tl, U, W, Y and Zn but at concentrations below 0.1% and/or 50mg/kg.

  Sulphur concentrations vary between 0.01% and 2.42% averaging 0.06% with a standard deviation of 0.14%. Elevated concentrations above 0.25%S occurs at:

Table 3.1: Sulphur Concentrations.

Location/Bore Id	Depth (m)	%S
13CARC005	86 to 88 90 to 94 100 to 104 136 to 138 142 to 144	0.35 0.32 to 0.42 0.33 to 0.36 0.30 0.27
13CARC006	32 to 40 42 to 50	0.31 to 0.88 0.29 to 0.38
13CARC007	82 to 84 96 to 98 108 to 115	0.29 0.30 0.27 to 0.34
15CARC003	0 to 4	0.39 to 0.41
15CARC009	62 to 64	0.58
15CARC010	66 to 68	0.26

Location/Bore Id	Depth (m)	%S
	104 to 106	0.38
16CARC008	56 to 58 58 to 60 60 to 62 62 to 64 96 to 100 102 to 108 114 to 120 122 to 136	0.40 2.42 1.16 0.46 0.27 to 0.42 0.30 to 1.56 0.33 to 0.63 0.27 to 0.54
16CARC009	76 to 78 82 to 84 106 to 110	0.82 0.26 0.26 to 0.37

The overall impression is sporadic occurrences of elevated concentrations of Sulphur at varying depths but generally deeper than 50m within an ore body containing primarily low sulphur concentrations. Commonly used criteria classify materials with Total Sulphur (as S) >1.0% as high potential acid-forming (PAF) materials, those between 0.25% and 1.0% as PAF and those <0.25% as non-acid forming (NAF).

Samples contained apparent elevated average concentrations of Al (69,028mg/kg), Ba (417mg/kg), Ca (13,500mg/kg), Cr (65mg/kg), Cu (267mg/kg), Fe (31,275mg/kg), K (13,550mg/kg), Mg (5,363mg/kg), Mn (331mg/kg), Na (19,418mg/kg), P (302 mg/kg), Rb (76mg/kg), Sr (139mg/kg), Ti (2,915mg/kg), V (71mg/kg) and Zr (114mg/kg). The potential risks of these metals and particularly should be investigated further by laboratory leaching tests to ascertain their bio-availability.

4. Conclusions and Recommendations

4.1 Conclusions

A desk study assessment of soils across the Calingiri Project indicated that sands and sandy loams may possess low natural nutrition with induced subsoil acidity and salinity related to rising water tables. This may have implications with regard to rehabilitation and mobilisation of metals in surface drainage. Soil Nitrogen supply, pH and density parameters have moderate to high risks which require further investigations to determine appropriate management regimes.

The assay data used in this assessment contained samples with elevated (>0.25%S) concentrations of Sulphur. Concentrations of Sulphur vary between 0.01% and 2.42% averaging 0.06% with a standard deviation of 0.14%. The overall impression is sporadic occurrences of elevated concentrations of Sulphur at varying depths but generally deeper than 50m within an ore body containing primarily low sulphur concentrations. Commonly used criteria classify materials with Total Sulphur (as S) >1.0% as high potential acid-forming (PAF) materials, those between 0.25% and 1.0% as PAF and those <0.25% as non-acid forming (NAF). In addition the samples contain elevated concentrations of some heavy metals which coupled with elevated concentrations of Sulphur warrant further investigation and assessment.

4.2 Recommendations

Consideration should be given to:

4.2.1 Soil Sampling and Analysis

Future sampling programs across the footprints of the open pits, waste rock dumps, processing plant and tailings storage facility should include the following analytical parameters:

Soil Physical Analysis

Physical tests should include Particle Size Distribution (PSD), density, porosity, dispersion, Atterburg Limits and field hydraulic conductivity.

Soil Chemical Analysis

Laboratory tests for soils and wastes should include those properties which influence plant growth (pH, salinity, and nutrients), material stability, and tests for elements which may pose problems with water quality such as pH, Electrical Conductivity, Soluble Salts, Cation Exchange Capacity, Total Sulphur, Organic Carbon, Heavy Metals and Nutrients. Once the results of the soil analytical program are available, consideration should be given to undertake leachate testing at pH's 3, 7 and 9 on a selected number of samples (generally a representative set of samples across the range of concentrations) to ascertain the leachability of metals from soils.

Erodibility Index of Soils and Soil Erosion Risk

Bulk samples of soils should be submitted for laboratory testing to provide measurements of Inter-rill Erodibility (K_i), Saturated Hydraulic Conductivity (K_{eff}), Rill Erodibility (K_r), and overland flow Critical Shear (t_C), the primary inputs for a slope erosion model, to be undertaken once the designs for the waste rock and tailings landforms are available, to predict field-scale erosion rates for a range of potential slope configurations.

Sampling Frequency

Samples of soils (one topsoil at <0.1m depth, one of the mid soils between 0.1m and 0.5m depth, and one of the subsoils between 0.5m and 1.0m depth) which to be disturbed and/or stripped during mining are to be obtained:

Table 4.1: Soil Sampling Frequency.

Infrastructure	Location	Sampling Locations	Number of Samples
Open Pits	North	5	15
	Central	3	9
	South	2	6
Waste Rock Dumps	North	10	30
	Central	3	9
	South	2	6
Processing Plant	-	2	6
Tailings Storage Facility	-	2	6
	Total:	**29**	**87**

Samples are to be accompanied by detailed descriptions (soil profile), photographs and coordinates.

All the topsoil samples are to be analysed for all the analytes whilst the mid and sub soils are to be analysed for selective parameters pending their *in situ* characteristics. Once the analytical results of these samples were assessed, and pending their variability and concentrations, further sampling may be undertaken at smaller intervals.

4.2.2 Waste/Ore Sampling

Materials characterisation should aim to prove which materials are benign and identify those materials that could be problematic; the key is to ascertain the impacts and their magnitudes and adopt sensible and appropriate management options to manage and mitigate the impacts (risks) if any.

A phased approach should be applied to further materials characterisation programs:

- Phase 1: Sulfur and elemental assays to define the chemical variability within key representative lithologies and within the deposit; this may include static geochemical (to provide estimates of the total amount of acid generating and neutralising material present) and tests to determine the physical properties of materials.
- Phase 2: further testing informed by the outcomes of Phase 1 which may include leaching tests to identify materials which may cause acid generation and/or metalliferous/saline drainage.
- Phase 3: long term kinetic tests to estimate the geochemical behaviour and potential drainage quality of mined materials, if required.

Representative samples of ore (tailings) and waste are to be obtained. The number of samples and target zones are to be ascertained from an overall NAF/PAF mass balance coupled with a mine block model with the view to refine waste management.

Laboratory Analysis

All samples from each alteration within each weathering profile within each lithology should be analysed for:

- pH, pH_{ox}, Redox Potential, Electrical Conductivity, Cation Exchange Capacity, Total Sulphur, Sulfate-S, Chromium Reducible Sulfur (SCR), Net Acid Generating (NAG) capacity, Acid Neutralizing Capacity (ANC), Total Inorganic Carbon (TIC), bulk density and dispersion.
- Multi-element composition: The metals and metalloid content of the solid phase material will be assessed to identify elements that may be of ecological concern (i.e. exceeding the relevant Ecological Investigation Levels). Using the Geochemical Abundance Index (GAI) the relative enrichment of the various metals is determined. Metals to be assessed will include Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se, Sn, Sr, V and Zn.
- Metal bioavailability: This analysis is required to measure the actual mobility of the various metal and metalloids in the waste materials so that the environmental risks associated with the disturbance of these materials can be accurately identified. The mobility of the metals and metalloids is typically assessed using the standard Australia Standard Leach Procedure (ASLP) under neutral (pH 7), acidic (pH 3 to 4) and alkaline (pH 8 to 9) conditions. Additional analytes should include pH, Eh, EC, Acidity, Alkalinity, major cations and anions and nutrients.

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