Venturex Resources Limited

Sulphur Springs Copper Zinc Project

Soil Resource Assessment

April 2013

Outback Ecology Services
1/71 Troy Terrace
Jolimont WA 6014
Ph: +61 (08) 9388 8799
Fax: +61 (08) 9388 8633
admin@outbackecology.com

Venturex Resources Limited

Sulphur Springs Copper Zinc Project - Soil Resource Assessment

Distribution:

Company	Copies	Contact Name
RMDSTEM Limited (on behalf of Venturex Resources Limited)	1 x electronic	A. Robertson

Document Control for Job Number: SULP-SS-12001

Document Status	Author	Reviewer	Signature	Date of Issue
Draft Report	A. Byrne	M. Braimbridge	MB	25 Jan 2013
		A. Robertson (RMDSTEM Limited)		29 Jan 2013
Final Draft Report V1.0		M. Braimbridge	MB	30 Jan 2013
Final Draft Report V2.0		M. Braimbridge	MB	22 Apr 2013
Final Report		B. Gordon	BG	24 Apr 2013

DISCLAIMER, CONFIDENTIALITY AND COPYRIGHT STATEMENT

This document is confidential. Neither the whole nor any part of this document may be disclosed to any third party without the prior written approval of Outback Ecology and Venturex Resources Limited.

Outback Ecology undertook the work, and prepared this document, in accordance with specific instructions from Venturex Resources Limited to whom this document is addressed, within the time and budgetary requirements of Venturex Resources Limited. The conclusions and recommendations stated in this document are based on those instructions and requirements, and they could change if such instructions and requirements change or are in fact inaccurate or incomplete.

Outback Ecology has prepared this document using data and information supplied to Outback Ecology by Venturex Resources Limited and other individuals and organisations, most of whom are referred to in this document. Where possible, throughout the document the source of data used has been identified. Unless stated otherwise, Outback Ecology has not verified such data and information. Outback Ecology does not represent such data and information as true or accurate, and disclaims all liability with respect to the use of such data and information. All parties relying on this document, do so entirely at their own risk in the knowledge that the document was prepared using information that Outback Ecology has not verified.

This document is intended to be read in its entirety, and sections or parts of the document should therefore not be read and relied on out of context.

The conclusions and recommendations contained in this document reflect the professional opinion of Outback Ecology, using the data and information supplied. Outback Ecology has used reasonable care and professional judgment in its interpretation and analysis of the data. The conclusions and recommendations must be considered within the agreed scope of work, and the methodology used to carry out the work, both of which are stated in this document.

This document was intended for the sole use of Venturex Resources Limited and only for the use for which it was prepared, which is stated in this document. Any representation in the document is made only to Venturex Resources Limited. Outback Ecology disclaims all liability with respect to the use of this document by any third party, and with respect to the use of and reliance upon this document by any party, including Venturex Resources Limited for a purpose other than the purpose for which it was prepared.

Outback Ecology has conducted environmental field monitoring and/or testing for the purposes of preparing this document. The type and extent of monitoring and/or testing is described in the document.

On all sites, there exists varying degrees of non-uniformity of the vertical and horizontal soil and water conditions. Because of this non-uniformity, no monitoring, testing or sampling technique can completely eliminate the possibility that the results/samples obtained through monitoring or testing are not entirely representative of the soil and/or groundwater conditions on the site. Any conclusions based on the monitoring and/or testing only serve as an indication of the environmental condition of the site (including the presence or otherwise of contaminants or emissions) at the time of preparing this document. It should be noted that site conditions, including the exact location, extent and concentration of contaminants, can change with time.

Subject to the limitations imposed by the instructions and requirements of Venturex Resources Limited, the monitoring and testing have been undertaken in a professional manner, according to generally-accepted practices and with a degree of skill and care which is ordinarily exercised by reputable environmental consultants in similar circumstances. Outback Ecology makes no other warranty, express or implied.

Executive Summary

Outback Ecology was commissioned by Venturex Resources Limited (Venturex) to characterise potential soil materials and develop a soil resource inventory for the proposed Sulphur Springs Copper Zinc Project (the Project). The Project is located in the Pilbara Region of Western Australia, situated approximately 110 kilometres (km) south-east of Port Hedland and 57 km west of Marble Bar.

The aim of the soil characterisation programme was to assess topsoil and subsoil resources from the Project area and surrounding areas, which may be available for use as a rehabilitation medium and / or as a component of the cover for the proposed tailings storage facilities (TSFs). A soil resources inventory has been developed and recommendations for the use of available soil resources, as a source of cover materials for the proposed TSFs, have been outlined.

Soils from within the Project area were sampled by Venturex personnel on three separate occasions, in December 2011, November 2012 and February 2013. A summary of the physical and chemical characteristics of the soils is provided in (**Table ES1**).

Soil physical characteristics

The texture of the soil sized fraction (<2 mm) of the soils from the Project area ranged from 'loamy sand' (4.8% clay) to 'sandy clay' (29% clay) (**Table ES1**). The amount of coarse material (>2 mm) present within Project area soils ranged from 11% to 81%. Overall, the Kangaroo Caves, Eastern and Air Strip area soils had comparatively less clay fraction and less coarse material content than the 2011 and 2012 Project area soils.

The degree of clay dispersion in the soils, as measured by the Emerson Aggregate Test, was variable, with Emerson Test Classes of 2, 3a, 3b, 4, 5, 6 and 8 recorded (**Table ES1**). The majority of the soils were considered 'stable' to 'moderately stable', from a clay dispersion perspective.

The saturated hydraulic conductivity, and associated drainage classes, for the majority of soils ranged from 'moderate' to 'moderately rapid' (**Table ES1**), indicating a moderate potential for the soil to accept rainfall and, in combination with the high percentage of coarse material (particularly for the 2011 and 2012 Project area soils), a relatively low potential erodibility for these soils. This, however, comes at the cost of a lower water holding capacity for the soils with a high amount of coarse (competent rock) material. In contrast, the Kangaroo Caves, Eastern and Air Strip area soils have a comparatively lower percentage of coarse material and therefore a greater water holding capacity (**Table ES1**), but are comparatively more prone to erosion.

The majority of Kangaroo Caves, Eastern and Air Strip area soils (<2 mm sized fraction) are considered not prone to hardsetting. However, a number of the 2011 and 2012 Project area soil samples were considered prone to hardsetting, with soil strength values exceeding the 60 kPa value, indicative of hardsetting soils (**Table ES1**).

Soil chemical characteristics

The relatively low EC values (**Table ES1**) of the majority of the soils sampled, indicate that there is a low risk of salinity related issues occurring if the topsoil and sub surface soils are used as a surface rehabilitation medium. The pH of the soils was variable (pH ($CaCl_2$) 4.5 to 8.3), with soil pH unlikely to be a limiting factor to successful vegetation growth of rehabilitated areas.

The majority of the soils (<2 mm sized fraction) from the Project area are considered non-sodic (**Table ES1**) with the exchangeable sodium concentrations being below the level of detection for the majority of samples. The low exchangeable sodium percentages (ESP) correlates to the low degree of clay dispersion observed for the majority of the soils sampled.

The majority of soils from the Project area had 'low' concentrations of organic carbon and 'low' to 'moderate' levels of plant-available nutrients, typical of the surface soils in the Pilbara region (**Table ES1**).

Analysis of total metals (**Table ES1**) indicates that the total metal concentrations of the soil materials sampled are typically low, with some concentrations of total nickel, copper and zinc above their respective Ecological Investigation Levels (EILs). These values are however, seen as a natural occurrence and pose no risk in terms of the use of the material for rehabilitation purposes.

Use of soil resources for the TSF cover

The soil store-release layer of the proposed TSF cover will need to be capable of holding water from the majority of rainfall events and resilient enough to shed water from high intensity rainfall events. The soil store-release component will also need to support the growth of native vegetation which will assist in the release of stored water, as will evaporation from the outer surface. The analyses performed as part of this investigation indicate that, while there is substantial variation in many of the physical and chemical characteristics of the soils present, the majority are likely to be suitable for use as a surface cover / rehabilitation medium.

The 2011 and 2012 Project area soils have a high percentage of coarse rock and a 'moderate' to 'moderately high' drainage capacity, indicating a low inherent erodibility. The water retention characteristics of these soils indicate that, assuming homogenous infiltration and water storage (i.e. no preferential flow), the soils have a USL, on average, of approximately 15% (by volume). This means that a 1.0 m depth of soil will hold approximately 150 mm of rainfall. These characteristics make the 2011 and 2012 Project area soils potentially suitable as component of the outer 'erosion resistant' surface cover.

In contrast, the Kangaroo Caves, Eastern and Air Strip area soils have a lower percentage of coarse rock, indicating they are likely to be more prone to erosion. These soils have a USL, on average, of approximately 23% (by volume). This means that a 1.0 m depth of soil will hold approximately 230 mm of rainfall. These characteristics make the Kangaroo Caves, Eastern and Air Strip area soils potentially suitable as a soil water storage layer situated below the outer 'erosion resistant' cover.

Regional rainfall data indicates that the 1 in 100 year 72 hour rainfall event is 379 mm (BoM 2012). A potential depth of ‘rocky’ soil for the outer ‘erosion resistant’ soil layer has been indicated as 1.0 m which, based on a USL of 15%, would hold approximately 150 mm of rainfall. In addition, a potential depth of soil for the water storage layer has been indicated as 3.0 m, which, based on a USL of 23%, would hold approximately 690 mm of rainfall. This assumes homogenous infiltration of rainfall, a negligible amount of existing water storage in the soil materials and no surface run-off. As the TSF cover will be designed to shed any rainfall which falls at a rate greater than the infiltration capacity of the surface soil materials, the water retention ability of the proposed cover depths is considered likely to be adequate to restrict the downward movement of water from rainfall.

Current data, supplied by Venturex personnel, indicates that further volumes of, as yet, unassessed soil materials within the Airstrip area. These soil resources may potentially provide a source of material suitable or the clay sealing component of the TSF cover. This will require further investigation as the Project develops.

Soil resource inventory

Based on the current soil resources inventory for areas of disturbance within the Project area, a volume of approximately 3,511,155 m^3 of soil has been identified as potentially available for salvage. A soil cover of 3.0 m depth on the final TSF surface at closure would require a volume of soil over 600,000 m^3. This indicates a substantial surplus in the currently available soil resources required for the final cover, rehabilitation and closure of the TSFs. This information is based on approximate soil volume calculations derived from spatial and soil depth information supplied by Venturex personnel.

Recommendations for further investigations

Recommendations for further investigations to refine the proposed TSF cover design include:

- further identification of a suitable source of clay materials from the Airstrip areas, for the clay sealing layer, and geochemical assessment of the compacted permeability of those materials;
- identification of a suitable source of clean competent rock to enhance the geotechnical stability and surface stability (i.e. surface armour) of the TSF cover if required;
- modelling of water balance of the TSF cover, expected runoff, drainage and sediment loss; and
- a commitment to establishment of field trials of TSF cover components, including evaluation of water storage capacity, erodibility and rehabilitation parameters. A conceptual design of the field trials could be established to demonstrate a commitment to evaluation of TSF cover options.

Table ES1: Summary of physical and chemical characteristics of soil samples from the Sulphur Springs Copper Zinc Project area. The figures presented represent average values with broad ratings of good, moderate and poor for each parameter relative to suitability for plant growth and/or overall material stability

Description	Site	Total soil depth (m)	Approx. area of soil present (m^2)	Sample depth (cm)	Physical characteristics						Chemical characteristics					
					Soil texture[1]	Coarse material content (%) [2]	Emerson Class [3]	(Modulus of Rupture (kPa)	Hydraulic conductivity (mm/hr)	Upper storage limit (% vol) [4]	pH ($CaCl_2$)	Salinity class (dS/m)	Organic carbon (%)	Nutrient status	Exchangeable Sodium Percentage (%) [5]	Total metal concentrations [6]
Project area soil 2011	Site A1	-	-	0-5	Sandy loam	67	3b Moderately stable	52.9 Non-hardsetting	-	-	5.5 Neutral	0.021 Non-saline	0.43 Low	Low to medium	BDL Non-sodic	Low (high Zn)
				10-20	Clayey sand	81	3b Moderately stable	72.3 Hardsetting	-	-	5.4 Slightly acidic	0.020 Non-saline	0.18 Low	Low to medium	BDL Non-sodic	-
				40-50	Clayey sand	75	3b Moderately stable	111.5 Hardsetting	52.01 Moderate	-	5.5 Neutral	0.026 Non-saline	0.17 Low	Low to medium	BDL Non-sodic	Low (high Ni, Zn)
	Site A2	-	-	0-5	Clayey sand	63	5 Stable	44.6 Non-hardsetting	-	-	4.8 Moderately acidic	0.036 Non-saline	0.41 Low	Low to medium	BDL Non-sodic	Low
				10-20	Sandy clay loam	77	6 Stable	36.6 Non-hardsetting	-	-	4.6 Moderately acidic	0.016 Non-saline	0.12 Low	Low to medium	BDL Non-sodic	-
				40-50	Clayey sand	71	6 Stable	33.5 Non-hardsetting	18.8 Moderately slow	-	4.5 Moderately acidic	0.014 Non-saline	0.12 Low	Low to medium	BDL Non-sodic	Low
	Site A3	-	-	0-5	Clayey sand	70	2 Unstable	68.8 Hardsetting	-	-	5.9 Neutral	0.069 Non-saline	0.18 Low	Low to medium	8.16* Sodic	Low
				10-20	Clayey sand	71	2 Unstable	115.1 Hardsetting	-	-	6.1 Neutral	0.046 Non-saline	0.12 Low	Low to medium	7.04* Sodic	-
				40-50	Sandy clay loam	71	2 Unstable	146.7 Hardsetting	13.62 Moderately slow	-	6.1 Neutral	0.068 Non-saline	0.15 Low	Low to medium	14.08* Sodic	Low
	Site A4	-	-	0-5	Sandy clay loam	67	2 Unstable	126.8 Hardsetting	-	-	7.3 Moderately alkaline	1.511 Very saline	0.15 Low	Low to medium (high N, S)	2.44 Non-sodic	Low

Description	Site	Total soil depth (m)	Approx. area of soil present (m^2)	Sample depth (cm)	Physical characteristics						Chemical characteristics					
					Soil texture[1]	Coarse material content (%)[2]	Emerson Class[3]	(Modulus of Rupture (kPa)	Hydraulic conductivity (mm/hr)	Upper storage limit (% vol)[4]	pH ($CaCl_2$)	Salinity class (dS/m)	Organic carbon (%)	Nutrient status	Exchangeable Sodium Percentage (%)[5]	Total metal concentrations[6]
				10-20	Clay loam	58	6 Stable	130.2 Hardsetting	-	-	7.3 Moderately alkaline	3.415 Extremely saline	0.23 Low	Low to medium (high N, S)	3.73 Non-sodic	-
				40-50	Sandy loam	43	6 Stable	42.2 Non-hardsetting	13.93 Moderately slow	-	7.5 Moderately alkaline	3.930 Extremely saline	0.22 Low	Low to medium (high N, S)	3.50 Non-sodic	Low
	Site A5	-	-	0-5	Sandy loam	65	3b Moderately stable	57.5 Non-hardsetting	65.77 Moderately rapid	-	4.6 Moderately acidic	0.012 Non-saline	0.51 Low	Low to medium	BDL Non-sodic	Low
				10-20	Sandy loam	59	5 Stable	87.2 Hardsetting	-	-	5.0 Slightly acidic	0.060 Non-saline	0.27 Low	Low to medium	BDL Non-sodic	-
	Site A6	-	-	0-5	Loam	49	5 Stable	23.0 Non-hardsetting	13.95 Moderately slow	-	5.0 Slightly acidic	0.015 Non-saline	0.25 Low	Low to medium	BDL Non-sodic	Low
				10-20	Sandy clay loam	69	5 Stable	72.9 Hardsetting	-	-	5.0 Slightly acidic	0.028 Non-saline	0.18 Low	Low to medium	BDL Non-sodic	-
Project area soil 2012	Site 1	0.7	44,919	0-20	Sandy loam	60	8 Stable	52.5 Non-hardsetting	44.71 Moderate	18.7	8.0 Moderately alkaline	0.098 Non-saline	0.72 Low	Low (high K)	BDL Non-sodic	Low (high Ni)
				40-60	Loamy sand	56	4 Stable	63.7 Hardsetting	69.58 Moderately rapid	16.2	8.2 Strongly alkaline	0.101 Non-saline	0.24 Low	Low	BDL Non-sodic	Low
	Site 2	0.4	52,828	0-20	Sandy clay loam	76	3b Moderately stable	81.9 Hardsetting	23.90 Moderate	6.1	5.8 Neutral	0.034 Slightly saline	0.45 Low	Low	BDL Non-sodic	Low
	Site 3	1.0	15,013	0-20	Clay loam	73	8 Stable	194.3 Hardsetting	86.26 Moderately rapid	11.2	7.4 Moderately alkaline	0.02 Non-saline	0.85 Low	Low	7.38* Sodic	Low
				40-60	Silty loam	28	2 Unstable	394.5 Hardsetting	1.49 Slow	33.8	7.9 Moderately alkaline	0.064 Non-saline	0.10 Low	Low (high S)	24.05* Highly sodic	Low
	Site 4	0.4	16,299	0-20	Sandy clay	57	3a Moderately stable	76.2 Hardsetting	42.71 Moderate	15.0	7.1 Moderately alkaline	0.476 Moderately saline	0.46 Low	Low (high K)	BDL Non-sodic	Low (high Cu, Ni)

Description	Site	Total soil depth (m)	Approx. area of soil present (m^2)	Sample depth (cm)	Physical characteristics						Chemical characteristics					
					Soil texture[1]	Coarse material content (%)[2]	Emerson Class[3]	(Modulus of Rupture (kPa)	Hydraulic conductivity (mm/hr)	Upper storage limit (% vol)[4]	pH ($CaCl_2$)	Salinity class (dS/m)	Organic carbon (%)	Nutrient status	Exchangeable Sodium Percentage (%)[5]	Total metal concentrations[6]
	Site 5	1.2	18,693	0-20	Sandy loam	34	5 Stable	42.4 Non-hardsetting	44.10 Moderate	21.5	7.5 Moderately alkaline	1.764 Very saline	0.95 Low	Low (high K)	BDL Non-sodic	Low (high Cu, Ni, Zn)
				40-60	Silty loam	51	4 Stable	161.1 Hardsetting	27.28 Moderate	18.2	8.3 Strongly alkaline	0.027 Slightly saline	0.20 Low	Low (high K)	BDL Non-sodic	Low (high Cu)
				100-120	Loamy sand	68	5 Stable	23.6 Non-hardsetting	156.21 Rapid	12.1	8.2 Strongly alkaline	0.069 Non-saline	0.24 Low	Low	16.20* Highly sodic	Low (high Cu)
	Site 6	1.0	16,755	0-20	Sandy clay	74	3b Moderately stable	153.3 Hardsetting	90.61 Moderately rapid	11.5	6.6 Neutral	0.042 Non-saline	0.19 Low	Low (high K)	BDL Non-sodic	Low (high Ni)
				40-60	Sandy clay	63	3b Moderately stable	237.3 Hardsetting	53.14 Moderate	12.6	6.7 Neutral	0.148 Non-saline	0.15 Low	Low (high K)	BDL Non-sodic	Low (high Cu, Ni)
TSF Area B footprint soil 2012	Site 7	0.05	47,144	0-5	Sandy loam	61	3b Moderately stable	73.7 Hardsetting	80.43 Moderately rapid	14.8	6.9 Neutral	0.018 Non-saline	0.78 Low	Low (high K)	BDL Non-sodic	Low
	Site 8			0-5	Sandy loam	80	3a Moderately stable	153.8 Hardsetting	10.39 Moderately slow	8.0	5.6 Neutral	0.121 Non-saline	0.92 Low	Low (high K)	BDL Non-sodic	Low
TSF Area A footprint soil 2012	Site 9	0.05	159,055	0-5	Sandy clay loam	71	2 Unstable	135.7 Hardsetting	15.90 Moderately slow	13.0	6.1 Neutral	0.033 Non-saline	0.66 Low	Low (high K)	BDL Non-sodic	Low
	Site 10			0-5	Sandy clay loam	68	2 Unstable	180.9 Hardsetting	26.37 Moderate	12.3	6.5 Neutral	0.199 Slightly saline	1.02 Medium	Low	BDL Non-sodic	Low
	Site 11			0-5	Sandy loam	68	3a Moderately stable	143.8 Hardsetting	20.60 Moderate	14.3	5.5 Neutral	0.054 Non-saline	0.89 Low	Low	BDL Non-sodic	Low
Kangaroo Caves area soil 2013	Site 12	0.3	47,592	0-20	Sandy loam	43	3b Moderately stable	9.9 Non-hardsetting	57.15 Moderate	17.1	5.1 Slightly acidic	0.057 Non-saline	1.24	Low (high K)	BDL Non-sodic	Low
	Site 13	0.3	48,511	0-20	Sandy loam	47	5 Stable	31.9 Non-hardsetting	10.55 Moderately slow	-	6.7 Neutral	0.033 Non-saline	0.66	Low (high K)	BDL Non-sodic	Low (high Ni)

					Physical characteristics						Chemical characteristics					
Description	Site	Total soil depth (m)	Approx. area of soil present (m^2)	Sample depth (cm)	Soil texture[1]	Coarse material content (%)[2]	Emerson Class[3]	(Modulus of Rupture (kPa)	Hydraulic conductivity (mm/hr)	Upper storage limit (% vol)[4]	pH ($CaCl_2$)	Salinity class (dS/m)	Organic carbon (%)	Nutrient status	Exchangeable Sodium Percentage (%)[5]	Total metal concentrations[6]
	Site 14	0.5	33,940	0-20	Sandy loam	13	5 Stable	20.1 Non-hardsetting	54.34 Moderate	30.7	6.6 Neutral	0.092 Non-saline	1.47	Low (high K)	BDL Non-sodic	Low (high Ni)
	Site 15	0.5	20,347	0-20	Sandy loam	22	3b Moderately stable	15.1 Non-hardsetting	26.06 Moderate	-	7.6 Moderately alkaline	0.142 Non-saline	0.82	Low (high K)	BDL Non-sodic	Low (high Ni)
Eastern area soil 2013	Site 16	0.7	No data	0-20	Sandy loam	11	8 Stable	12.1 Non-hardsetting	122.26 Moderately rapid	15.2	6.7 Neutral	0.046 Non-saline	0.62	Low (high K)	BDL Non-sodic	Low (high Ni)
	Site 17	0.7	No data	0-20	Sandy loam	18	4 Stable	11.0 Non-hardsetting	30.05 Moderate	-	7.4 Moderately alkaline	0.059 Non-saline	0.54	Low (high K)	BDL Non-sodic	Low (high Ni)
Airstrip area soil 2013	Site 18	0.4	57,420	0-20	Sandy loam	17	2 Unstable	34.7 Non-hardsetting	61.87 Moderate	-	4.8 Moderately acidic	0.029 Non-saline	0.44	Low (high K)	BDL Non-sodic	Low (high Ni)
	Site 19	2.0	162,974	0-20	Sandy loam	19	2 Unstable	63.8 Hardsetting	53.92 Moderate	19.9	7.0 Neutral	0.029 Non-saline	0.20	Low (high K)	BDL Non-sodic	Low (high Ni)
	Site 20	2.5	1,318,360	0-20	Sandy loam	22	2 Unstable	23.3 Non-hardsetting	69.27 Moderately rapid	18.2	5.5 Neutral	0.017 Non-saline	0.32	Low (high K)	BDL Non-sodic	Low

1. Based on the <2 mm size fraction
2. Determined for all coarse fragments >2 mm in size
3. See Appendix C for Emerson Classes. Potentially dispersive properties may be masked by flocculating effects of high salinity
4. Upper storage limit (USL) (% volume) of total material (<2 mm fraction and coarse material)
5. BDL denotes samples for which exchangeable sodium was below the detectable limit - assumed 'non-sodic' (*eCEC < 3 indicating minimal effect on structural decline)
6. 'Low' metal concentrations indicate results below Ecological Investigation Levels (EILs) (Department of Environment 2010)

TABLE OF CONTENTS

TABLES

FIGURES

PLATES

APPENDICES

1. INTRODUCTION

1.1 Background

Outback Ecology was commissioned by Venturex Resources Limited (Venturex) to characterise soil resource material and develop a soil resource inventory for the proposed Sulphur Springs Copper Zinc Project (the Project). The Project is located in the Pilbara Region of Western Australia and is situated approximately 110 km south-east of Port Hedland and 57 km west of Marble Bar, within three mining leases: M45/494, M45/653, M45/1001 and seven miscellaneous licences L45/166, L45/170, L45/173, L45/179, L45/188, L45/189 and L45/287 (**Figure 1, Figure 2**).

The Project will comprise the underground development of the Sulphur Springs Copper Zinc deposit, processing of ore at an onsite concentrate plant and haulage of concentrate from Sulphur Springs to Port Hedland via road train for export.

Development within the Project area will include a processing plant, Tailings Storage Facility (TSF), evaporation ponds, a ROM Pad, access roads, workshops, a borrow pit, offices, an accommodation village and an air strip.

The transport route to Port Hedland will be via a haul road, currently under construction by Atlas Iron Limited (Atlas), then along the Marble Bar public road and Great Northern Highway to Port Hedland. The haul road will be shared under an existing agreement with the adjoining Atlas Abydos DSO Project and the construction is not part of the Sulphur Springs Mining Proposal. The haul road is a component of the Atlas Iron Mining Proposal and will not require assessment with this Project.

Copper and zinc concentrate will be produced at an onsite concentrator. The operation is expected to produce around 6,200 wet tonnes (t) of copper concentrate and 5,500 wet t of zinc concentrate per month.

It is proposed that the Project life will be extended by mining at the Venturex owned Whim Creek and Mons Cupri Projects, with the intent for this ore to be hauled by road to Sulphur Springs for processing, as part of the Pilbara Copper Zinc Project.

The tailings in the TSF will be dry stacked and compacted, with the proposed cover design incorporating a clay sealing layer, clean competent waste rock for geotechnical stability and a store-release ‘rocky soil’ layer. The soil cover will require enough volume to store water from the majority of rainfall events, but also be resistant to erosion to allow runoff from high intensity rainfall events.

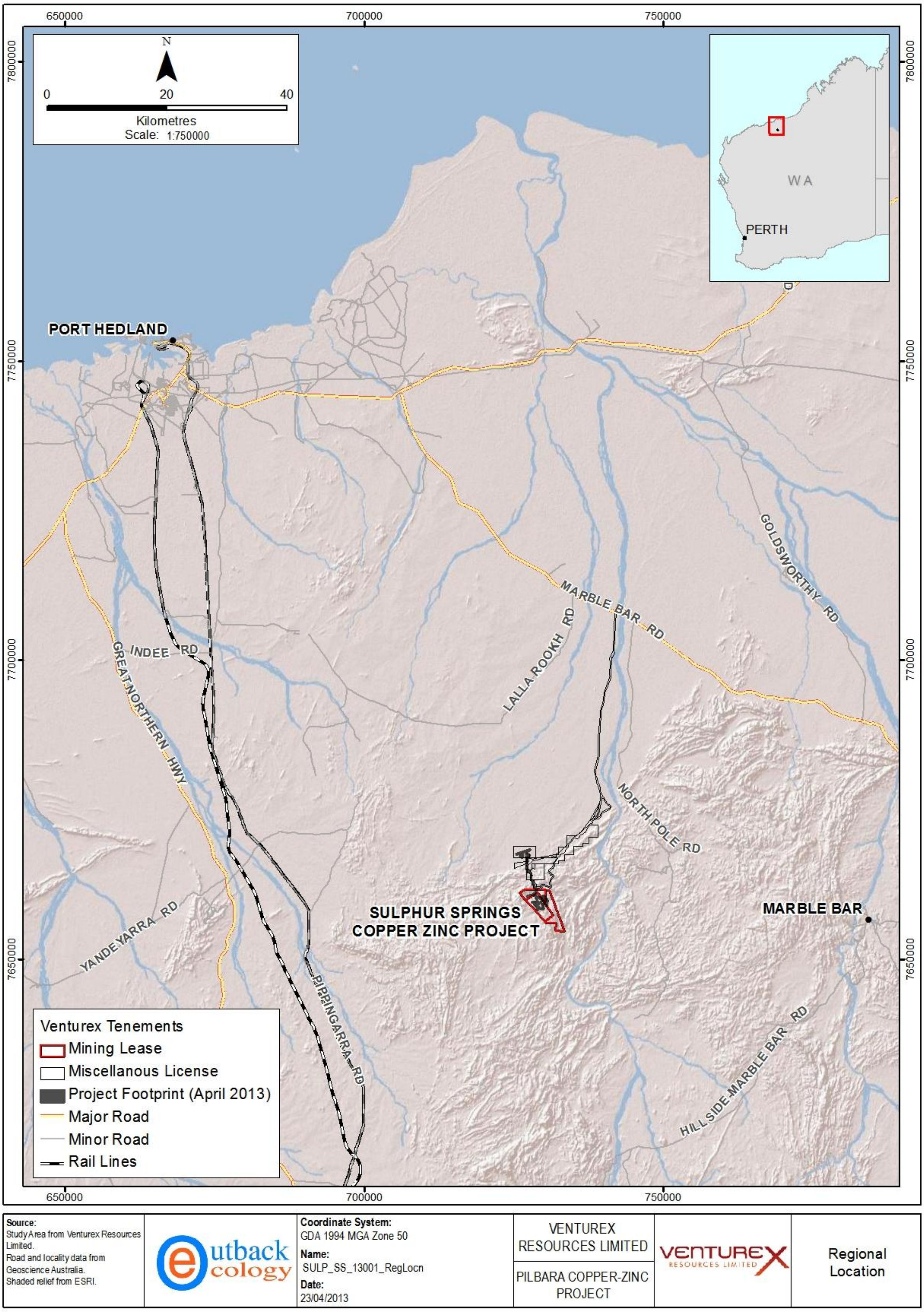


Figure 1: Regional location of the Sulphur Springs Copper Zinc Project

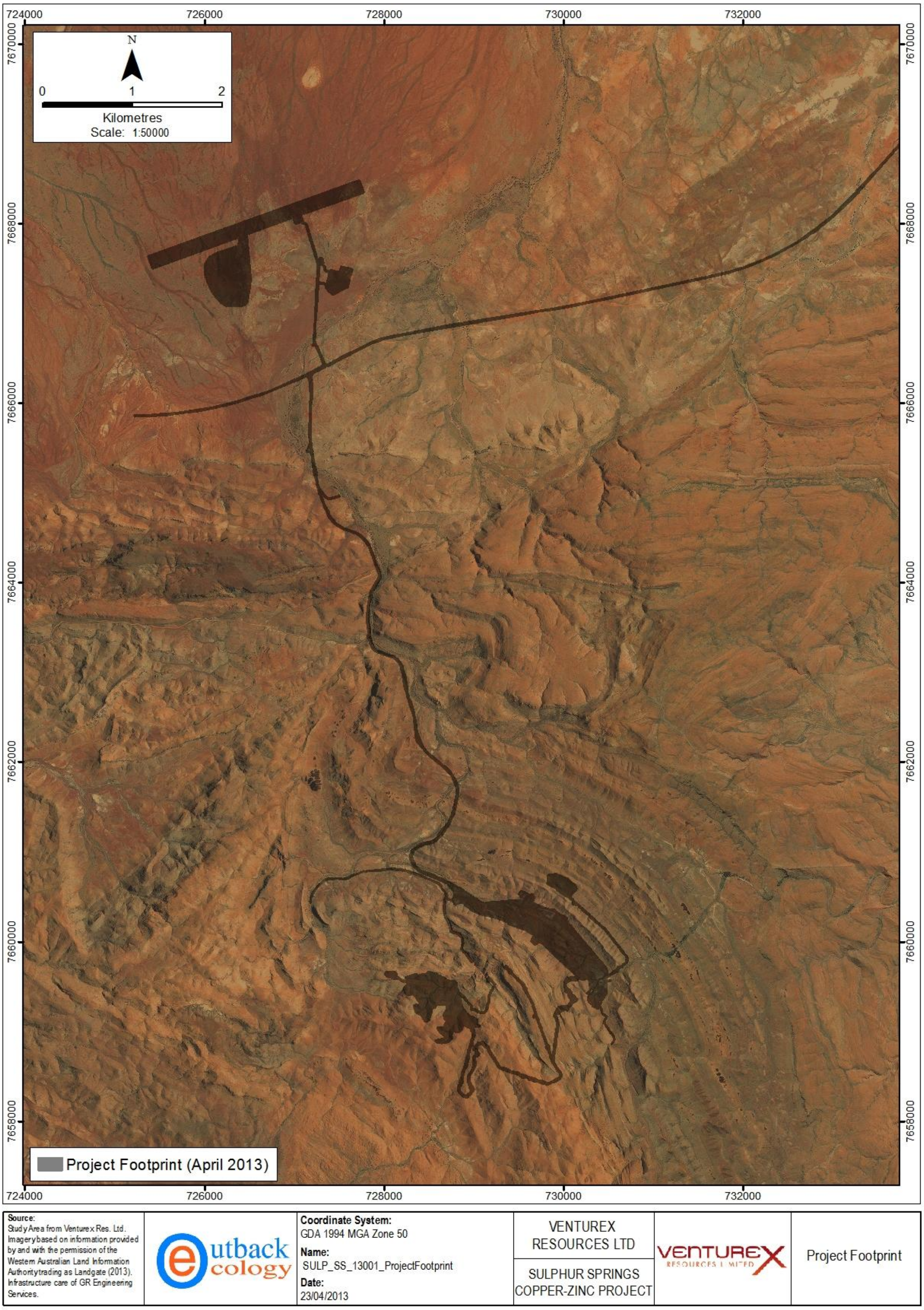


Figure 2: Proposed Project footprint for the Sulphur Springs Copper Zinc Project

1.2 Climate

The Project area is located within the northern section of the Pilbara bioregion, which experiences a semi-desert to tropical climate characterised by hot summers and relatively warm dry winters (Bureau of Meteorology [BoM] 2012). Tropical cyclones can occur between the months of January to April, bringing sporadic drenching rainfall events (How *et al.* 1991).

The nearest Bureau of Meteorology (BOM) weather station to the Project is located at Marble Bar, approximately 57 km to the east of the Project area. Weather data collected from the Marble Bar Meteorological Station indicates rainfall occurs mainly in the first half of the year with a mean average rainfall of approximately 350 mm (BoM 2012) (**Figure 3**). Rainfall within the Project area can be highly localised and unpredictable with substantial fluctuations occurring from year to year (BoM 2012, Leighton 2004).

Marble Bar typically experiences a very hot summer with the mean maximum temperature reaching 41.6°C in December and the minimum temperature averaging 26.7°C in January (**Figure 3**). Marble Bar averages 98 days above 40° each year (Leighton 2004). Winter occurs from June to August when the mean maximum temperature for Marble Bar is 28°C and the mean minimum temperature is 12.8°C (**Figure 3**).

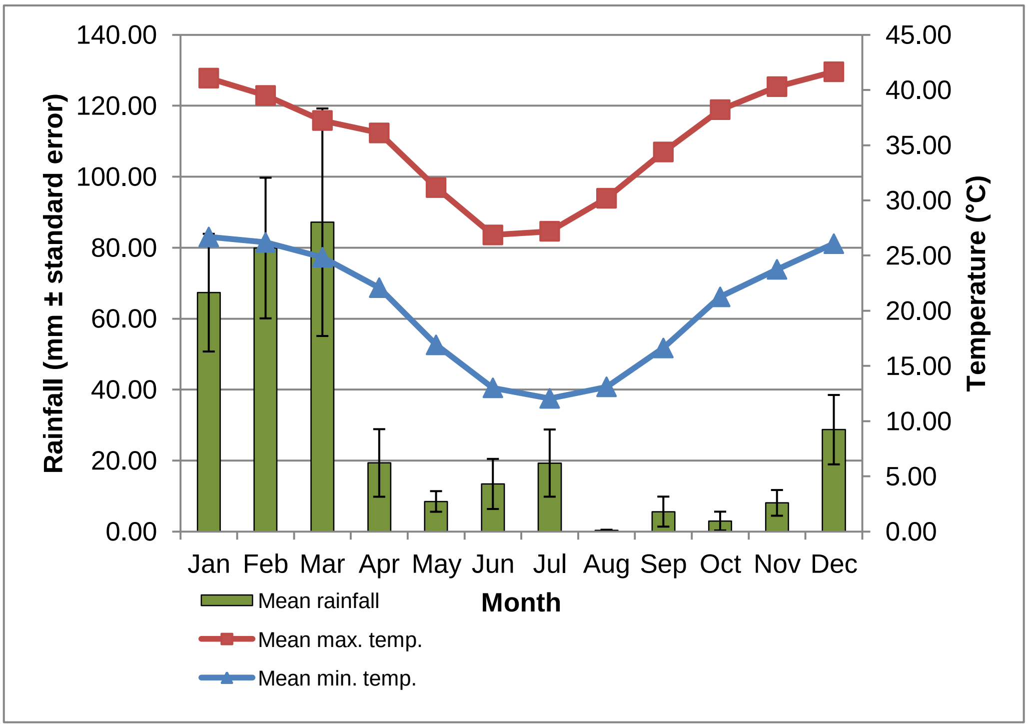


Figure 3: Long term climate data for Marble Bar Weather Station (BoM 2012)

1.2.1 Average Recurrence Interval

The design rainfall intensity for the Project (position approximately 21.125 S 119.200 E) is recorded in **Table 1** and **Figure 4**. The 1 in 100 year 72 hour rainfall event is 379 mm (BoM 2012).

Table 1: Sulphur Springs Copper Zinc Project Average Recurrence Interval rainfall intensity over various time periods (millimetres per hour) (BoM 2012)

Duration	1 year	2 years	5 years	10 years	20 years	50 years	100 years
5 Mins	80.5	107	152	181	218	267	307
6 Mins	74.7	99.8	142	169	203	250	287
10 Mins	61.5	82.4	119	142	171	212	244
20 Mins	46.2	62.3	91.2	110	134	167	194
30 Mins	37.8	51.2	75.8	92.1	113	141	164
1 Hr	25	34.1	51.4	63.0	77.6	98.2	115
2 Hrs	15.1	20.8	32.0	39.7	49.4	63.1	74.3
3 Hrs	11.0	15.1	23.6	29.5	36.9	47.5	56.2
6 Hrs	6.2	8.7	13.8	17.5	22.0	28.7	34.2
12 Hrs	3.6	5.0	8.1	10.4	13.2	17.3	20.8
24 Hrs	2.1	2.3	4.9	6.3	8.0	10.5	12.7
48 Hrs	1.3	1.8	2.9	3.7	4.7	6.2	7.5
72 Hrs	0.9	1.3	2.0	2.6	3.3	4.4	5.3

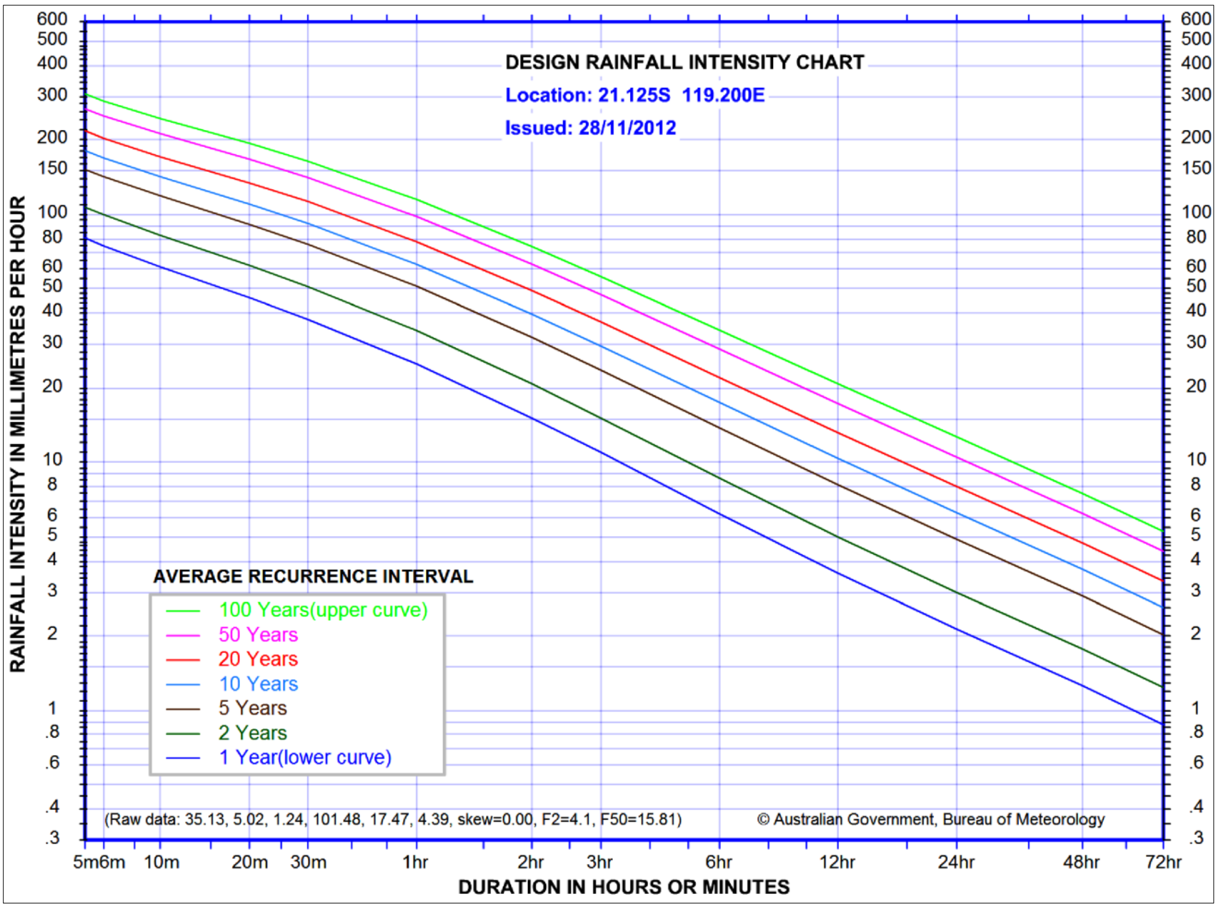


Figure 4: Sulphur Springs Copper Zinc Project rainfall intensity chart (BoM 2012)

1.3 Geomorphology and Land Systems of the Sulphur Springs Copper Zinc Project Area

The geomorphology of the Sulphur Springs Creek Catchment is characterised by numerous rocky hills and gorges that control the flow of surface water. The Sulphur Springs Project area, including the TSF areas, has a diverse landscape, where the differential weathering of the basement rocks has developed sharp local changes in relief around 175 m (range: 200 to 375 m AHD). In this landscape, the competent lithologies tend to form topologically high areas (such as ridge lines). In contrast, zones subjected to greater geological stress may preferentially weather and erode and be associated with valley-floor settings.

A ferruginous duricrust mantles the upland areas to the south, with pisolitic lags (gravel sized material) common constituents in eroded material. Transported cover (colluvial and alluvial sediments) increases in profile thickness from the upland areas through to valley flanks and floors. These materials are dominated by ferruginised clays and minor iron-stained sand lenses. Topsoil development is localised and not extensive in the Project area.

A regional survey was undertaken in the Pilbara between 1995 and 1999 by the Department of Agriculture (now the Department of Agriculture and Food) and the Department of Land Administration (now Landgate) to develop a comprehensive description of the biophysical resources and the vegetation composition and soil condition within the region. This information was used by van Vreeswyk *et al*. (2004) to classify and map the land systems of the Pilbara region based on landform, soil, vegetation, geology and geomorphology.

An assessment of land systems provides an indication of the occurrence and distribution of landforms and vegetation types within, and surrounding, the Project area. The Project footprint is situated on three land systems: Boolgeeda, Capricorn and Rocklea (**Table 2, Figure 5**).

Table 2: Land systems within and surrounding the Project area

Land System	Characteristics	Area in Project Footprint
Boolgeeda	Stony lower slopes and plains below hill systems supporting hard and soft spinifex grasslands or mulga shrublands	63.7 ha (39%)
Capricorn	Hills and ridges of sandstone and dolomite supporting low shrublands or shrubby spinifex grasslands	74.0 ha (46%)
Rocklea	Basalt hills, plateaux, lower slopes and minor stony plains supporting hard spinifex (and occasionally soft spinifex) grasslands	25.0 ha (15%)

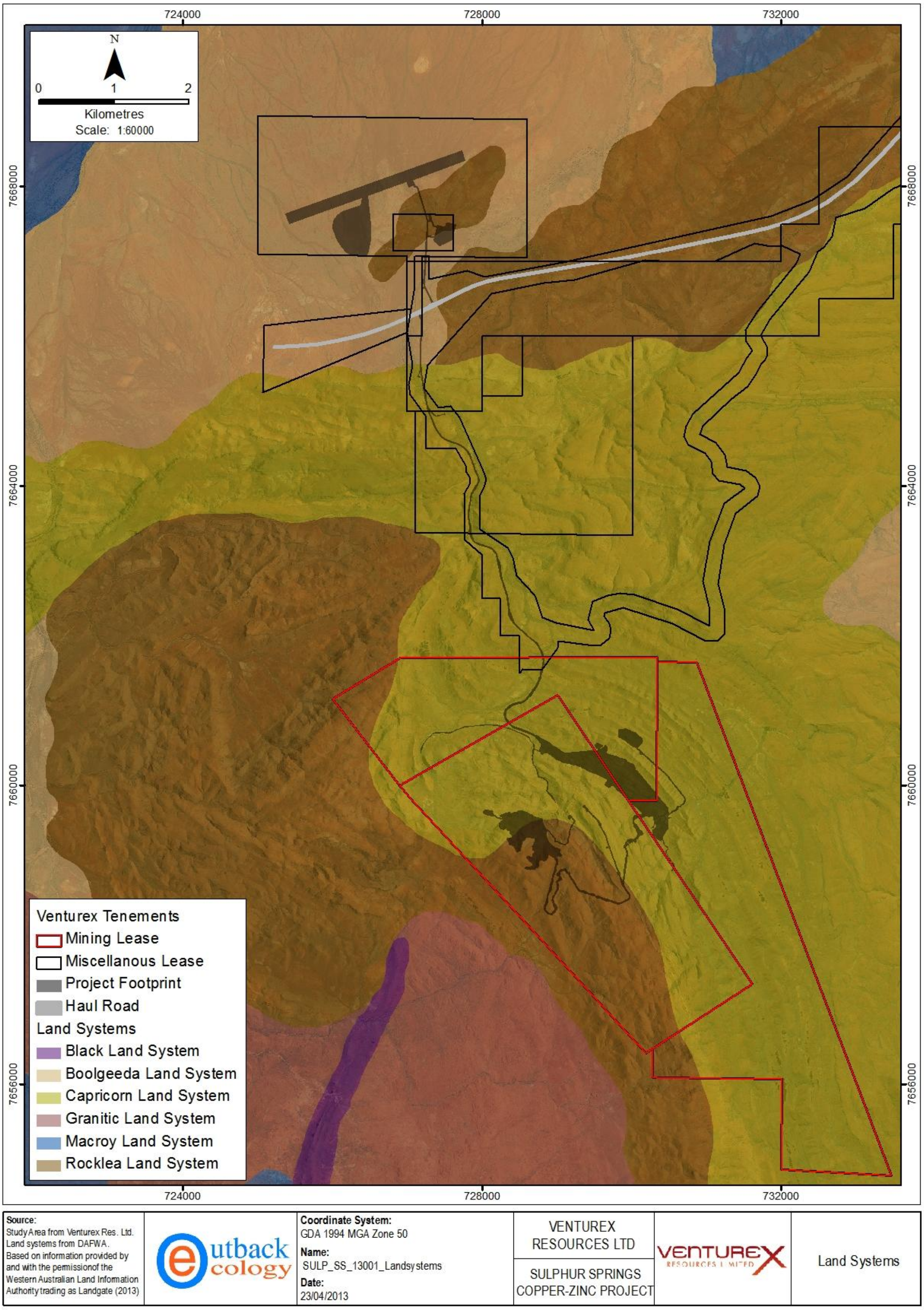


Figure 5: Land Systems within the Sulphur Springs Copper Zinc Project

1.4 Geology

The Sulphur Springs Copper Zinc Project Area is located in the East Pilbara Terrane, the oldest component of the northern Pilbara Craton with a maximum thickness up to 22,000 m. The East Pilbara Terrane is a 'dome-and-basin' granite–greenstone domain in which ovoid granites are flanked by arcuate-shaped volcano-sedimentary packages. Within the Sulphur Springs Copper Zinc Project area, the geology predominantly consists of successions of the Sulphur Springs Group. Sulphur Springs encompasses several deposits of volcanogenic massive sulphide (VMS) copper-zinc mineralisation occurring within a 35 km long belt of mineralised volcanic rocks.

The Sulphur Springs orebody is a strata-bound copper-zinc rich massive sulphide lens extending approximately 500 m east-west along strike, and for a similar distance down dip, and is up to 50 m thick in places. The orebody is underlain by a copper rich stringer zone which is far more variable, though typically it is between 2 m and 50 m thick, dipping moderately towards the north at about 50 degrees. Mineralisation appears to migrate from the felsic volcanic Marker Chert contact in the west and central parts of the deposit to the upper part of the Marker Chert in the east of the deposit. This is interpreted to be a post mineralisation structural phenomenon rather than a primary emplacement feature. Mineralisation is generally zoned from copper dominant at the base, to zinc rich at the top, of the deposit. The contact between the chert and the top of the massive sulphide ore is generally sharply defined while the lower contact to the underlying stringer zone is more gradational (Venturex 2012).

1.5 Report scope and objectives

The aim of the sampling and analysis programme was to assess soil resources from the Project area which may be available for use as a rehabilitation medium and / or as a component of the proposed cover for the TSFs. This report details the physical and chemical characteristics of soil materials within the Project area and discusses their suitability for use as a component of the TSF cover. Also included is a soil resources inventory detailing the locations, characteristics and potential volumes of soil resources identified (by Venturex personnel) within the Project area.

The likely closure design for the TSFs will incorporate a soil cover which is capable of storing water from the majority or rainfall events, but sheds water from high intensity storms. The store- release soil layer therefore needs to be 'rocky' enough to withstand erosional forces during high intensity rainfall events, but have enough soil sized fraction material to hold and release water via evaporation and transpiration.

This report documents the results of the soil characterisation and provides the following:

- descriptions of soil profile morphology, to the maximum depth possible, based on Australian Soil Classification Standards (McDonald *et al.* 1998);
- soil physical parameters
    - soil texture / particle size distribution (PSD);

- % coarse material (>2 mm);
- structural stability assessed via Emerson Aggregate Test;
- hardsetting / strength of disturbed material assessed via modulus of rupture (MOR) test;
- saturated hydraulic conductivity (K_{sat}) (repeated for several wetting / drying cycles); and
- water retention characteristics of selected representative samples.

- soil chemical characteristics
  - soil pH and electrical conductivity (EC);
  - plant-available nutrients (N, P, K, S) and soil organic carbon (C) of selected samples;
  - exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), derivation of exchangeable sodium percentage (ESP), and
  - total metal concentrations (As, Cd, Cr, Cu, Pb, Ni, Zn and Hg).

2. MATERIALS AND METHODS

2.1 Sampling regime

The field surveys were conducted in December 2011, November 2012 and February 2013 by Venturex personnel. Topsoil and subsoil materials were collected from areas identified by Venturex geologists as having potentially substantial soil resources. A total of 41 samples, from 26 sites, were received from site along with photographs and information (2012 and 2013 only) derived from the soil sampling sites.

The sampling undertaken in 2011 provided 16 topsoil and subsoil samples from 6 sites (Sites A1 to A6); the 2012 sampling provided 16 topsoil and subsoil samples from 11 sites (Sites 1 to 11); and the 2013 sampling provided nine topsoil and subsoil samples from nine sites within the Project area. The samples were taken from various depth intervals to a maximum of 250 cm (**Table 3**, **Figure 6**, **Figure 7, Figure 8, Figure 9**) and analysed for chemical and physical parameters. The 2012 and 2013 surface soils were described (soil profile morphology, soil structure, root distribution) based on the Australian Soil and Land Survey Handbook (McDonald *et al.* 1998). The 2012 and 2013 field surveys also included an estimation, by Venturex personnel, of potential soil resource areas and depths of soil located at Sites 1 to 20 (**Figure 6**, **Figure 7, Figure 8, Figure 9**).

Table 3: Summary table of sampling sites and locations for the Sulphur Springs Copper Zinc Project

Description	Site #	Sample ID	Sample depth (cm)	Coordinates (Projection: MGA Zone 50; Datum: GDA94)	
				Easting (mE)	Northing (mN)
Project area soil 2011	Site A1	SSA01	0-5	-	-
		SSA01	10-20	-	-
		SSA01	40-50	-	-
	Site A2	SSA02	0-5	-	-
		SSA02	10-20	-	-
		SSA02	40-50	-	-
	Site A3	SSA03	0-5	-	-
		SSA03	10-20	-	-
		SSA03	40-50	-	-
	Site A4	SSA04	0-5	-	-
		SSA04	10-20	-	-
		SSA04	40-50	-	-
	Site A5	SSA05	0-5	-	-
		SSA05	10-20	-	-
	Site A6	SSA06	0-5	-	-
		SSA06	10-20	-	-
Project area soil 2012	Site 1	SS01	0-20	730335	7659666
		SS01	40-60	730335	7659666
	Site 2	SS02	0-20	729729	7659988
	Site 3	SS03	0-20	729455	7660265
		SS03	40-60	729455	7660265
	Site 4	SS04	0-20	728647	7660639
	Site 5	SS05	0-20	728070	7660962
		SS05	40-60	728070	7660962
		SS05	100-120	728070	7660962
	Site 6	SS06	0-20	728575	7661116
		SS06	40-60	728575	7661116
TSF Area B footprint soil 2012	Site 7	SS07	0-5	728880	7659229
	Site 8	SS08	0-5	728808	7659105
TSF Area A footprint soil 2012	Site 9	SS09	0-5	728728	7659352
	Site 10	SS10	0-5	728566	7659440
	Site 11	SS11	0-5	728385	7659517
Kangaroo Caves area soil 2013	Site 12	SS12	0-20	734025	7651760
	Site 13	SS13	0-20	733791	7653547

Description	Site #	Sample ID	Sample depth (cm)	Coordinates (Projection: MGA Zone 50; Datum: GDA94)	
				Easting (mE)	Northing (mN)
	Site 14	SS14	0-20	733561	7654330
	Site 15	SS15	0-20	732769	7655219
Eastern area soil 2013	Site 16	SS16	0-20	732292	7658966
	Site 17	SS17	0-20	731305	7661016
Airstrip area soil 2013	Site 18	SS18	0-20	726432	7667050
	Site 19	SS19	0-20	727040	7666769
	Site 20	SS20	0-20	726398	7667110

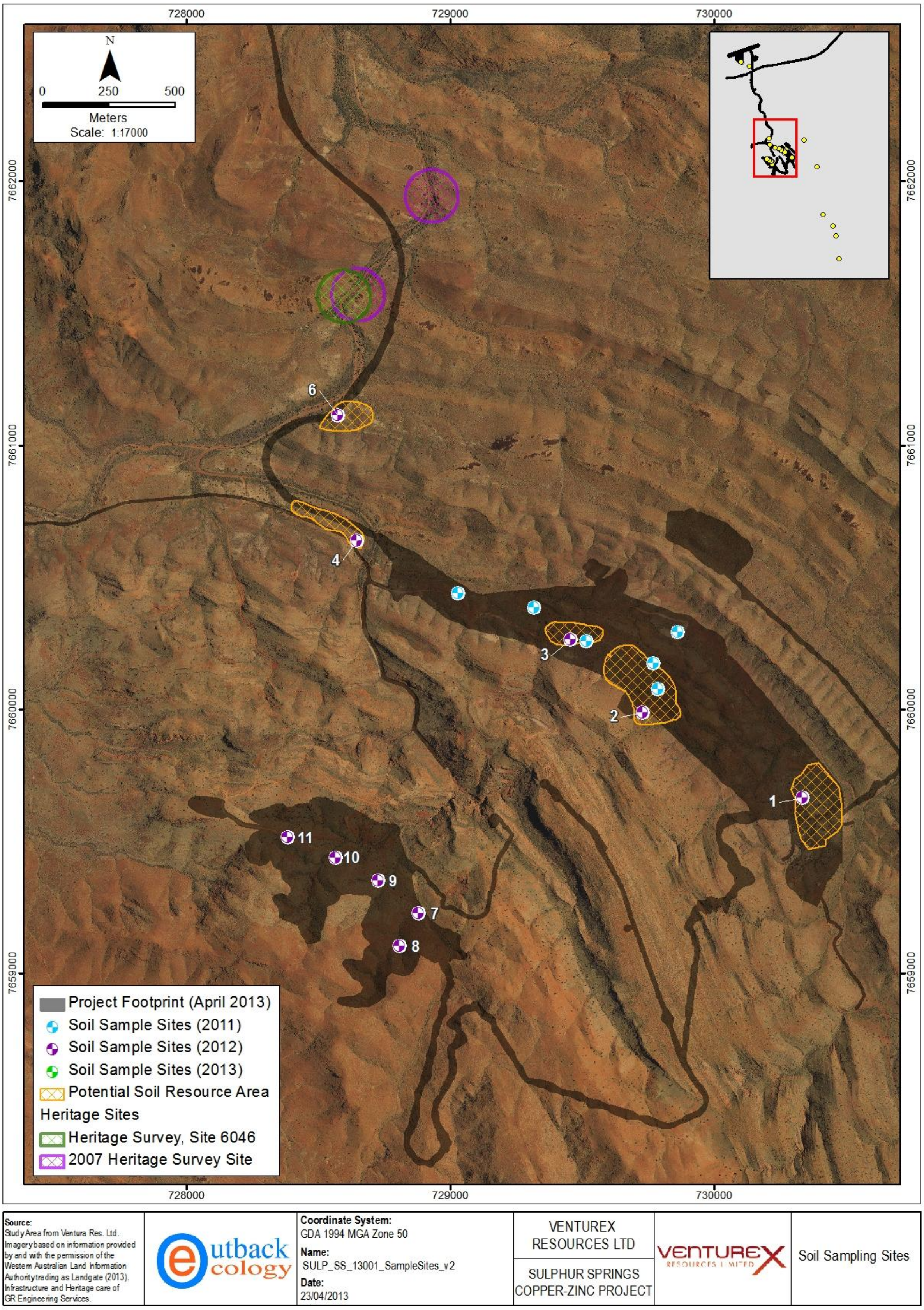
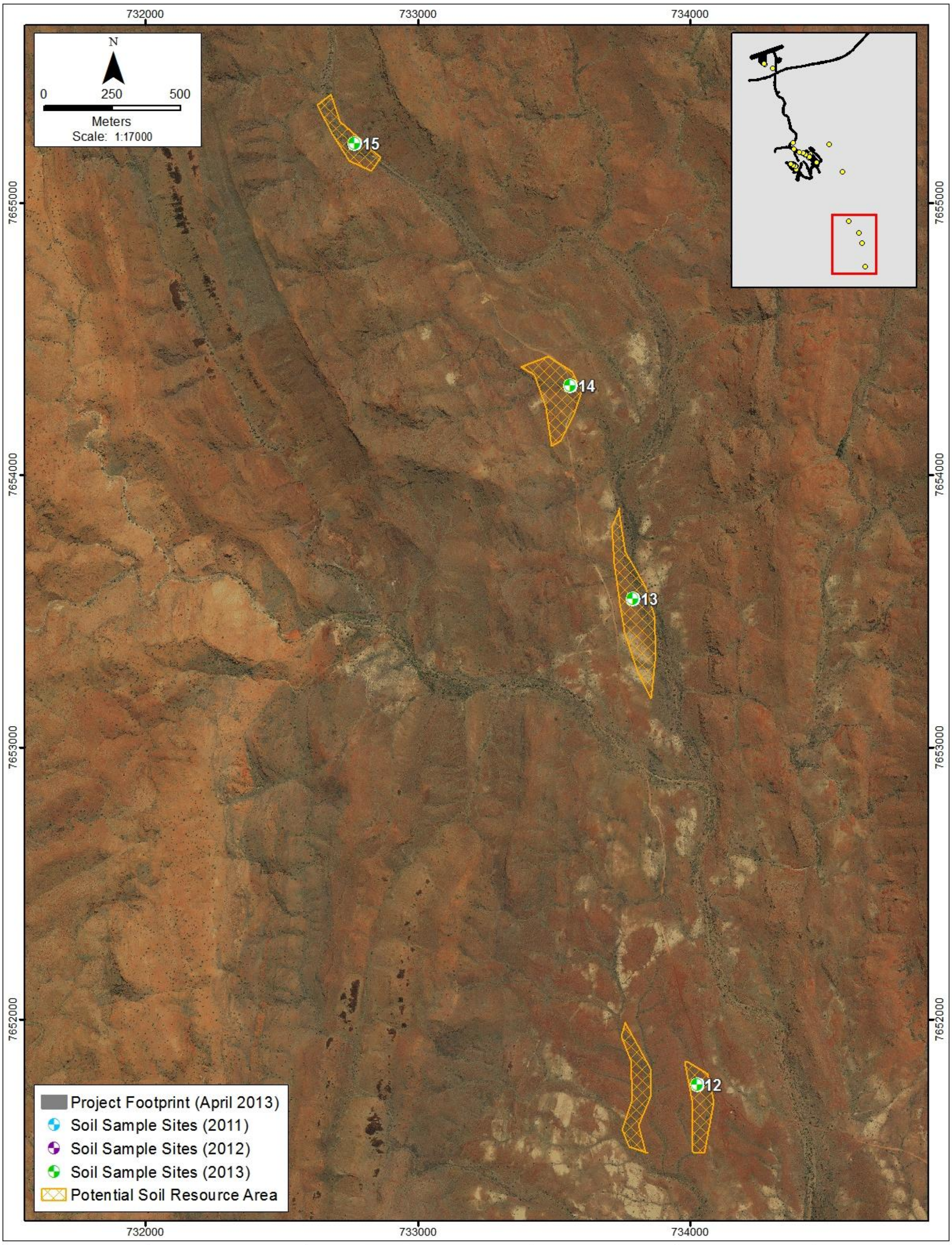


Figure 6: Location of 2011 and 2012 sampling sites and potential soil resources at the Sulphur Springs Copper Zinc Project



Source: StudyArea from Venturex Res. Ltd. Imagery based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2013).	outback ecology	Coordinate System: GDA 1994 MGA Zone 50 Name: SULP_SS_13001_SampleSites_KCaveS Date: 23/04/2013	VENTUREX RESOURCES LTD SULPHUR SPRINGS COPPER-ZINC PROJECT	VENTUREX RESOURCES LIMITED	Soil Sampling Sites: Kangaroo Caves

Figure 7: Location of Kangaroo Caves area 2013 sampling sites and potential soil resources at the Sulphur Springs Copper Zinc Project

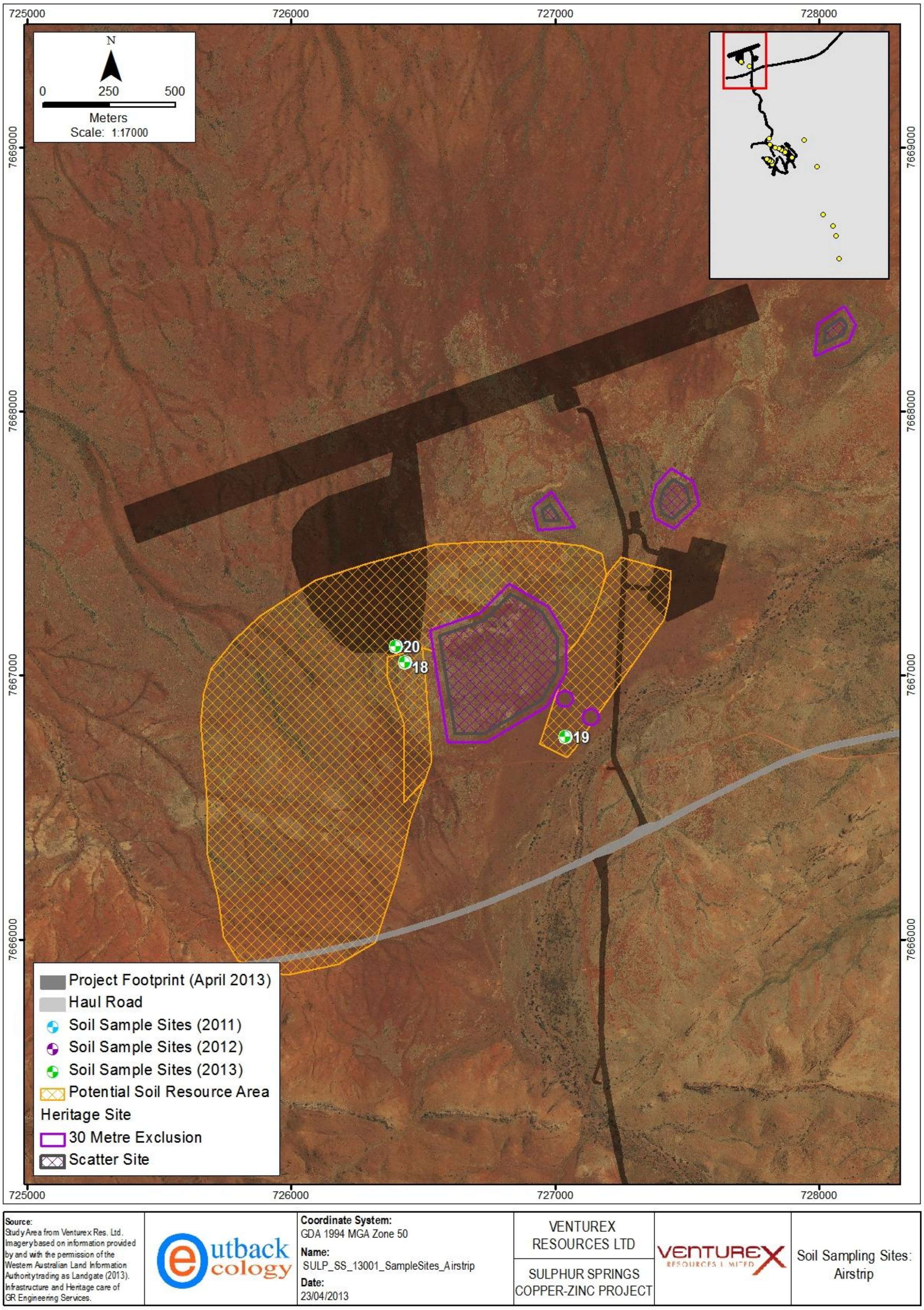


Figure 8: Location of Air Strip area 2013 sampling sites and potential soil resources at the Sulphur Springs Copper Zinc Project

Figure 9: Location of Eastern area 2013 sampling sites at the Sulphur Springs Copper Zinc Project

2.2 Test work and procedures

CSBP Soil and Plant Laboratory conducted analyses on the sampled soils from the 26 sites for ammonium and nitrate (Scarle 1984), plant-available phosphorus and potassium (Colwell 1965, Rayment and Higginson 1992), plant-available sulphur (Blair *et al.* 1991) and organic carbon (Walkley and Black 1934). Measurements of electrical conductivity (1:5 H_2O) and soil pH (1:5 H_2O and 1:5 $CaCl_2$) were conducted using the methods described in Rayment and Higginson (1992). Exchangeable cations Ca^{2+}, Mg^{2+}, Na^+ and K^+ (Rayment and Higginson 1992) and particle size distribution (McKenzie *et al.* 2002) was also assessed on selected samples.

ALS Environmental Laboratory analysed selected samples for total concentrations of metals including arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), zinc (Zn) and mercury (Hg). Cold vapour/ flow injection mercury system (CV/FIMS) method was used to analyse for Hg, while inductively coupled plasma atomic emission spectroscopy (ICP-AES) method was used for the other elements.

Soil texture was assessed by Outback Ecology staff using the procedure described in McDonald *et al.* (1998). A measure of soil slaking and dispersive properties (Emerson Aggregate Test) was conducted as described in McKenzie *et al.* (2002). Soil strength and the resulting tendency of each material to hardset was assessed by OES staff using a modified Modulus of Rupture (MOR) test (Aylmore and Sills 1982, Harper and Gilkes 1994). Saturated hydraulic conductivity of the soils was assessed on ‘loosely’ re-packed samples (Hunt and Gilkes 1992).

The water retention characteristics of all 2012 and 2013 samples were assessed by Outback Ecology using pressure plate apparatus, as described in McKenzie *et al.* (2002). Samples assessed using the pressure plate apparatus were packed to a bulk density likely to be experienced once the materials are disturbed and re-deposited, approximately 75% of the maximum dry bulk density.

Table 4: Soil analyses conducted on soil samples from the Sulphur Springs Copper Zinc Project

Soil parameter	Measurement method	Conducted by	Number of samples analysed	Sample selection criteria
Chemical properties				
Total Metals (As, Cd, Cr, Cu, Pb, Ni and Zn)	Inductively coupled plasma atomic emission spectroscopy (ICP-AES) method	ALS	10 + 16 + 9	Selected 2011 and all 2012 and 2013 samples
Total Metals (Hg)	Cold vapour/ Flow injection mercury system (CV/FIMS) method	ALS	10 + 16 + 9	Selected 2011 and all 2012 and 2013 samples
Soil pH	pH measured in 1:5 soil:water and 1:5 Soil:$CaCl_2$ (Rayment and Higginson 1992)	CSBP	16 + 16 + 9	All samples
Electrical conductivity	Measured in 1:5 soil:water (Rayment and Higginson 1992)	CSBP	16 + 16 + 9	All samples
Plant-available nitrogen (ammonium and nitrate)	Scarle (1984)	CSBP	16 + 16 + 9	All samples
Exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+})	Rayment and Higginson (1992)	CSBP	16 + 16 + 9	All samples
Plant-available phosphorus and potassium	Colwell (1965); Rayment and Higginson (1992)	CSBP	16 + 16 + 9	All samples
Plant-available sulphur	Blair *et al.* (1991)	CSBP	16 + 16 + 9	All samples
Organic carbon percentage	Walkley and Black (1934)	CSBP	16 + 16 + 9	All samples
Physical properties				
Particle size distribution	Pipette method (Day, 1965)	CSBP	3 + 16 + 9	Selected 2011 and all 2012 and 2013 samples
Saturated hydraulic conductivity (K_{sat})	Measured on materials packed to their respective field bulk densities, using a constant-head of pressure technique (Hunt and Gilkes 1992)	Outback Ecology	6 + 16 + 9	Selected 2011 and all 2012 and 2013 samples
Soil slaking and dispersive properties	Emerson Aggregate Test (McKenzie *et al.*, 2002)	Outback Ecology	16 + 16 + 9	All samples
Soil strength	Modified Modulus of Rupture test (Aylmore and Sills 1982; Harper and Gilkes 1994)	Outback Ecology	16 + 16 + 9	All samples
Soil texture	McDonald *et al.* (1998)	Outback Ecology	16 + 16 + 9	All samples

Soil parameter	Measurement method	Conducted by	Number of samples analysed	Sample selection criteria
Soil colour	Determined using a Munsell® soil colour chart	Outback Ecology	16 + 16 + 9	All samples
Water retention characteristics	Using pressure plate apparatus (McKenzie *et al.* 2002)	Outback Ecology	16 + 9	All 2012 and 2013 samples

3. RESULTS AND DISCUSSION

3.1 Soil profile descriptions

Photographs of the 2011 Project area sites (Site A1 to A6) were provided by Venturex personnel (**Section 3.1.1** to **3.1.6**). A description of the soil profile morphology and vegetation at each of the sites, sampled in 2012 and 2013, has been documented from photographs and information supplied by Venturex personnel (**Section 3.1.7** to **3.1.26**). Individual physical and chemical characteristics of all soil samples are then discussed in further detail (**Sections 3.2** to **3.5**).

3.1.1 Site A1 (2011 soil sampling)

Plate 1: Vegetation and soil surface at Site A 1

3.1.2 Site A2 (2011 soil sampling)

Plate 2: Vegetation and soil surface at Site A 2

3.1.3 Site A3 (2011 soil sampling)

Plate 3: Vegetation and soil surface at Site A 3

3.1.4 Site A4 (2011 soil sampling)

Plate 4: Vegetation and soil surface at Site A 4

3.1.5 Site A5 (2011 soil sampling)

Plate 5: Vegetation and soil surface at Site A 5

3.1.6 Site A6 (2011 soil sampling)

Plate 6: Vegetation and soil surface at Site A 6

3.1.7 Site 1 (2012 soil sampling)

Plate 7: Soil profile at Site 1

Soil profile description

0 – 20 cm: Approximately 20% angular coarse siltstone fragments, 20 to 30 mm in size. Aggregates present. Root abundance classified as 'few'.

20 – 70 cm: Approximately 50% angular coarse siltstone fragments, 20 to 150 mm in size. Root abundance classified as 'few'.

70 cm: Siltstone bedrock.

Plate 8: Vegetation at Site 1

Soil surface: Approximately 60% coarse shale fragments. No crusting, leaf litter or erosion.

Vegetation: Burnt spinifex and shrubs.

3.1.8 Site 2 (2012 soil sampling)

Plate 9: Soil profile at Site 2

Soil profile description

0 – 40 cm: Approximately 50% rounded coarse sandstone fragments, 30 to 150 mm in size. Root abundance classified as ‘few’.

40 cm: Sandstone bedrock.

Plate 10: Vegetation at Site 2

Soil surface: Approximately 60 % coarse sandstone fragments. No crusting, leaf litter or erosion.

Vegetation: Burnt spinifex.

3.1.9 Site 3 (2012 soil sampling)

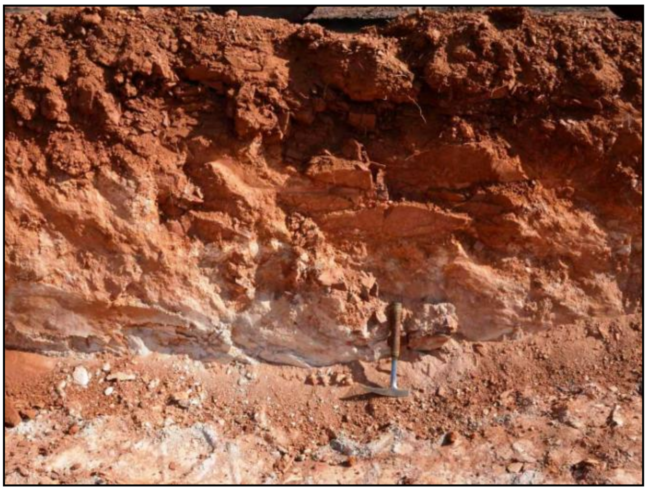


Plate 11: Soil profile at Site 3

Soil profile description

0 – 30 cm: Approximately 10% angular coarse siltstone fragments, 20 to 30 mm in size. Aggregates present. Root abundance classified as 'common'.

30 – 100 cm: Approximately 10% angular coarse siltstone fragments, 30 to 50 mm in size. Aggregates present. Root abundance classified as 'few'.

100 cm: Siltstone bedrock.

Plate 12: Vegetation at Site 3

Soil surface: Approximately 60% coarse siltstone and sandstone fragments. No crusting, leaf litter or erosion.

Vegetation: Burnt spinifex.

3.1.10 Site 4 (2012 soil sampling)

Plate 13: Soil profile at Site 4

Soil profile description

0 – 40 cm: Approximately 50% angular coarse chert and sandstone fragments, 30 to 100 mm in size. Aggregates present. Root abundance classified as 'few'.

40 cm: Chert and sandstone bedrock.

Plate 14: Vegetation at Site 4

Soil surface: Approximately 50% coarse sandstone and siltstone fragments. No crusting, leaf litter or erosion.

Vegetation: Burnt spinifex and shrubs.

3.1.11 Site 5 (2012 soil sampling)

Plate 15: Soil profile at Site 5

Soil profile description

0 – 40 cm: Approximately 10% rounded coarse siltstone and sandstone fragments, 30 to 40 mm in size. Aggregates present. Root abundance classified as ‘many’.

40 – 110 cm: Approximately 10% rounded coarse siltstone and sandstone fragments, 30 to 40 mm in size. Aggregates present. Root abundance classified as ‘few’.

110 – 120 cm: Approximately 50% angular coarse dolerite fragments, 50 to 150 mm in size. Aggregates present. Root abundance classified as ‘none’.

120 cm: Dolerite bedrock.

Plate 16: Vegetation at Site 5

Soil surface: Approximately 10% coarse sandstone and siltstone fragments. No crusting or leaf litter. Drainage line present.

Vegetation: Burnt spinifex and gumtrees.

3.1.12 Site 6 (2012 soil sampling)

Plate 17: Soil profile at Site 6

Soil profile description

0 – 100 cm: Approximately 50% angular coarse siltstone fragments, 20 to 50 mm in size. Aggregates present. Root abundance classified as 'few'.

100 cm: Siltstone bedrock.

Plate 18: Vegetation at Site 6

Soil surface: Approximately 90% coarse siltstone fragments. No crusting, leaf litter or erosion.

Vegetation: Burnt spinifex and small trees.

3.1.13 Site 7 (2012 soil sampling)

Plate 19: Soil profile at Site 7

Soil profile description

0 – 5 cm: Approximately 40% angular coarse dacite fragments, 30 to 100 mm in size. Root abundance classified as 'few'.

5 cm: Dacite bedrock

Soil surface: No crusting, leaf litter or erosion.

Vegetation: Spinifex

3.1.14 Site 8 (2012 soil sampling)

Plate 20: Soil profile at Site 8

Soil profile description

0 – 5 cm: Approximately 70% angular coarse dacite fragments, 20 to 100 mm in size. Root abundance classified as 'few'.

5 cm: Dacite bedrock

Soil surface: No crusting, leaf litter or erosion..

Vegetation: Spinifex and shrubs.

3.1.15 Site 9 (2012 soil sampling)

Plate 21: Soil profile at Site 9

Soil profile description

0 – 5 cm: Approximately 70% angular coarse dacite fragments, 20 to 50 mm in size. Aggregates present. Root abundance classified as 'few'.

5 cm: Dacite bedrock

Soil surface: No crusting, leaf litter or erosion..

Vegetation: Spinifex and small trees.

3.1.16 Site 10 (2012 soil sampling)

Plate 22: Soil profile at Site 10

Soil profile description

0 – 5 cm: Approximately 80% angular coarse dacite fragments, 20 to 30 mm in size. Aggregates present. Root abundance classified as 'few'.

5 cm: Dacite bedrock

Soil surface: No crusting, leaf litter or erosion.

Vegetation: Burnt spinifex and trees.

3.1.17 Site 11 (2012 soil sampling)

Plate 23: Soil profile at Site 11

Soil profile description

0 – 5 cm: Approximately 80% angular coarse dacite and rhyolite fragments, 20 to 100 mm in size. Root abundance classified as 'none'.

5 cm: Dacite bedrock

Soil surface: No crusting, leaf litter or erosion.

Vegetation: None.

3.1.18 Site 12 (2013 soil sampling)

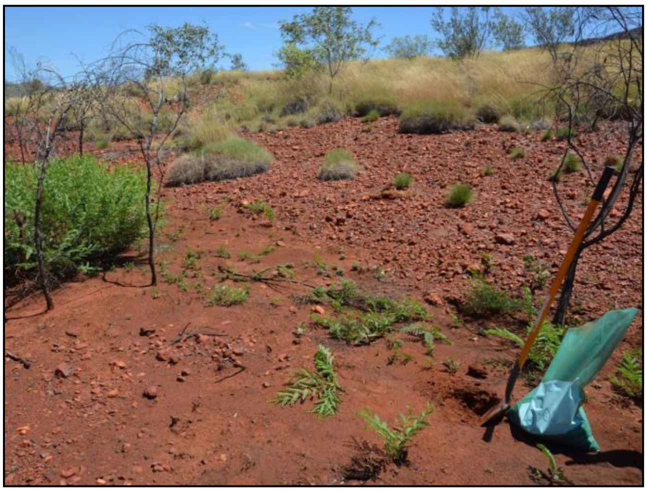


Plate 24: Soil profile at Site 12

Soil profile description

0 – 20 cm: Approximately 40% angular coarse fragments, 20 to 30 mm in size. Aggregates present. Root abundance classified as 'few'.

20 – 30 cm: Unknown

Soil surface: Approximately 50% coarse fragments. No crusting or leaf litter. Creek bed erosion evident.

Vegetation: Spinifex and small trees.

3.1.19 Site 13 (2013 soil sampling)

Plate 25: Soil profile at Site 13

Soil profile description

0 – 20 cm: Approximately 45% angular coarse fragments, 20 to 30 mm in size. Aggregates present. Root abundance classified as ‘few’.

20 – 30 cm: Unknown

Soil surface: Approximately 50% coarse fragments. No crusting, leaf litter or erosion.

Vegetation: Abundant spinifex.

3.1.20 Site 14 (2013 soil sampling)

Plate 26: Soil profile at Site 14

Soil profile description

0 – 20 cm: Approximately 10% coarse fragments. Aggregates present. Root abundance classified as ‘few’.

20 – 50 cm: Unknown

Soil surface: Approximately 20% coarse fragments. No crusting, leaf litter or erosion.

Vegetation: Spinifex and small trees.

3.1.21 Site 15 (2013 soil sampling)

Plate 27: Soil profile at Site 15

Soil profile description

0 – 20 cm: Approximately 20% coarse fragments. Aggregates present. Root abundance classified as 'few'.

20 – 50 cm: Unknown

Soil surface: Approximately 30% coarse fragments. No crusting or leaf litter. Erosion evident in possible water course.

Vegetation: Spinifex and small trees.

3.1.22 Site 16 (2013 soil sampling)

Plate 28: Soil profile at Site 16

Soil profile description

0 – 20 cm: Approximately 10% coarse fragments. Aggregates present. Root abundance classified as 'few'.

20 – 70 cm: Unknown

Soil surface: Approximately 20% coarse fragments. No crusting or leaf litter. Minor erosion evident.

Vegetation: Small burned trees.

3.1.23 Site 17 (2013 soil sampling)

Plate 29: Soil profile at Site 17

Soil profile description

0 – 20 cm: Approximately 20% coarse fragments. Aggregates present. Root abundance classified as 'few'.

20 – 70 cm: Unknown

Soil surface: Approximately 50% coarse fragments. No crusting or leaf litter. Minor erosion evident.

Vegetation: Small trees and spinifex.

3.1.24 Site 18 (2013 soil sampling)

Plate 30: Soil profile at Site 18

Soil profile description

0 – 20 cm: Approximately 15% coarse fragments. Aggregates present. Root abundance classified as 'few'.

20 – 40 cm: Unknown

Soil surface: Approximately 10% coarse fragments. No crusting leaf litter or erosion.

Vegetation: Small trees.

3.1.25 Site 19 (2013 soil sampling)

Plate 31: Soil profile at Site 19

Soil profile description

0 – 20 cm: Approximately 20% coarse fragments. Aggregates present. Root abundance classified as 'none'.

20 – 200 cm: Unknown

Soil surface: Approximately 5% coarse fragments. No crusting, leaf litter or erosion.

Vegetation: Dispersed small spinifex.

3.1.26 Site 20 (2013 soil sampling)

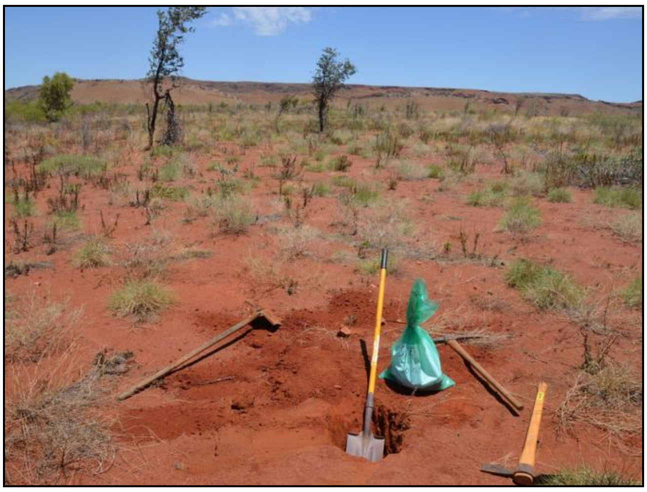


Plate 32: Soil profile at Site 20

Soil profile description

0 – 20 cm: Approximately 20% coarse fragments. Aggregates present. Root abundance classified as 'none'.

20 – 250 cm: Unknown

Soil surface: Approximately 5% coarse fragments. No crusting, leaf litter or erosion.

Vegetation: Dispersed spinifex and grass.

3.2 Soil physical properties – Project area sites - 2011 and 2012

3.2.1 Soil profile morphology

The surface soil profiles investigated within the 2011 and 2012 Project area sites, exhibited some variation in terms of morphological characteristics. All soil profiles present were typically shallow, with fractured / competent bedrock present at all 2012 sites. Fractured bedrock typically occurred within 5 cm of the surface within the TSF footprint sites. The depth to competent rock ranged from approximately 40 to 120 cm at the other 2012 sampling sites.

3.2.2 Soil texture

Soil texture describes the proportions of sand, silt and clay (the particle size distribution) within a soil. The particle size distribution and resulting textural class of soils is an important factor influencing most physical and many chemical and biological properties. Soil structure, water holding capacity, hydraulic conductivity, soil strength, fertility, erodibility and susceptibility to compaction are some of the factors closely linked to soil texture.

Particle size distribution results indicate that the texture of the soil sized fraction (<2 mm) ranged from ‘loamy sand’ to ‘sandy clay’ (**Figure 10**). The clay fraction within the samples was variable, ranging from 4.8% of the soil sized fraction (<2 mm) for the sub surface soils from Site 5, to 29.0% of the soil from Site 6. The amount of coarse material present (>2 mm) within the soil samples was variable, ranging from 28% to 81%, but typically high, with the majority of soils having greater than 50% coarse material content (**Figure 11**).

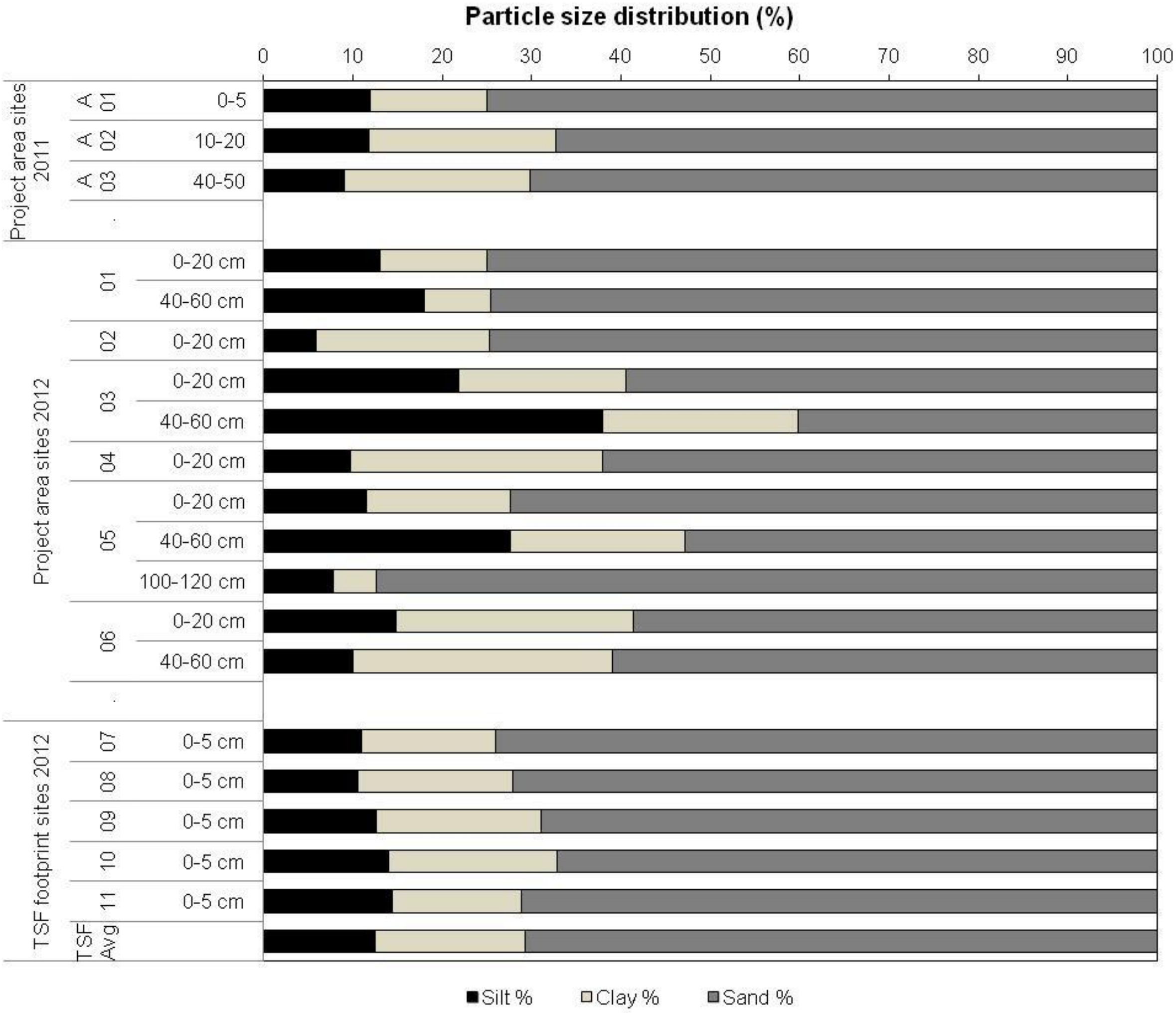


Figure 10: Individual particle size distribution (%) for soil samples (<2 mm fraction) from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites

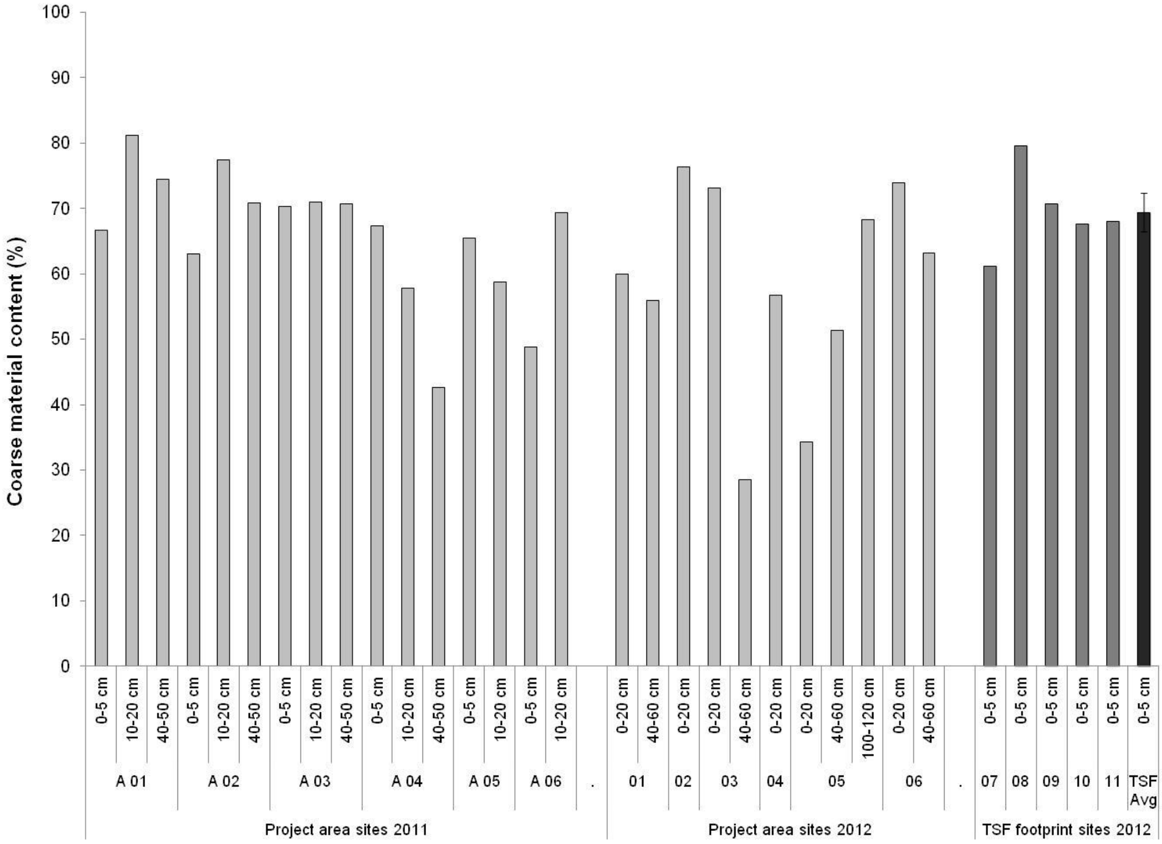


Figure 11: Individual coarse material content (%) (>2 mm fraction) for soil samples from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (error bar represents standard error)

3.2.3 Soil structure

Soil structure describes the arrangement of solid particles and void space in a soil. It is an important factor influencing the ability of soil to support plant growth, store and transmit water and resist erosional processes. A well-structured soil is one with a range of different sized aggregates, with component particles bound together to give a range of pore sizes facilitating root growth and the transfer of air and water.

Soil structure can be influenced by the particle size distribution, chemical composition and organic matter content of a soil, and is often affected by root growth, vehicle compaction, and with respect to reconstructed soil profiles, the methods of soil handling and deposition. When a soil material is disturbed, the breakdown of aggregates into primary particles can lead to structural decline (Needham *et al.* 1998). This can result in hard-setting and crusting at the soil surface and a 'massive' soil structure at depth, potentially reducing the ability of seeds to germinate, roots to penetrate the soil matrix and water to infiltrate to the root zone.

The soils sampled from the proposed TSF footprints were predominantly single grained with abundant angular coarse material. The remaining 2012 Project area soils were predominantly single grained with some weak aggregates and angular to rounded coarse material. No massive soils or physical restrictions to root penetration (apart from coarse materials / competent rock) were identified.

3.2.4 Structural stability

The structural stability of a soil and its susceptibility to structural decline is complex and depends on the net effect of a number of properties, including the amount and type of clay present, organic matter content, soil chemistry and the nature of disturbance. Soil aggregates that slake and disperse indicate a weak soil structure that is easily degraded. These soils should be seen as potentially problematic when used for the reconstruction of soil profiles for rehabilitation, particularly if left exposed at the surface.

The Emerson Aggregate Test (McKenzie *et al.* 2002) identifies the potential slaking and dispersive properties of soil aggregates. The dispersion test identifies the properties of the soil materials under a worst case scenario, where severe stress is applied to the soil material. Generally, samples allocated into Emerson Classes 1 and 2 are those most likely to exhibit clay dispersion and therefore be the most problematic.

The structural stability of the soils from the Project area was variable, with classifications including Emerson Classes 2, 3a, 3b, 4, 5, 6 and 8 (**Table 5**). Clay dispersion within the soil, indicated by Emerson Class 2 and to a lesser degree Emerson Class 3a and 3b, suggests that those soils are potentially prone to structural decline as a result of clay dispersion and may form a surface seal (hard-set) or be considered as erodible if used as a surface rehabilitation material on constructed slopes. Dispersive soils are also more prone to tunnelling and erosion in areas where surface water pools and the underlying soils remain saturated.

These results should, however, be viewed in conjunction with the particle size distribution, percentage coarse fragments, sodicity, hydraulic conductivity and hardsetting results to obtain a full indication of the likely erodibility and suitability for use as a rehabilitation resource, particularly on constructed slopes. Taking the amount of clay and coarse materials into consideration, the majority of the 2011 and 2012 Project area soils are considered ‘moderately stable’ to ‘stable’, from an erodibility perspective.

Table 5: Summary of slaking/dispersion properties (Emerson Test) results for the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites, indicating structural stability. Emerson Test classes are included in Appendix B

Description	Site	Depth (cm)	Emerson class (24 hour)	Description
Project area soil 2011	Site A1	0-5	3b	Slaked, remoulded soil dispersed partially
		10-20	3b	Slaked, remoulded soil dispersed partially
		40-50	3b	Slaked, remoulded soil dispersed partially
	Site A2	0-5	5	Slaked; 1:5 suspension remains dispersed
		10-20	6	Slaked; 1:5 suspension remains flocculated
		40-50	6	Slaked; 1:5 suspension remains flocculated
	Site A3	0-5	2	Slaked, dispersed partially
		10-20	2	Slaked, dispersed partially
		40-50	2	Slaked, dispersed partially
	Site A4	0-5	2	Slaked, dispersed partially
		10-20	6	Slaked; 1:5 suspension remains flocculated
		40-50	6	Slaked; 1:5 suspension remains flocculated
	Site A5	0-5	3b	Slaked, remoulded soil dispersed partially
		10-20	5	Slaked; 1:5 suspension remains dispersed
	Site A6	0-5	5	Slaked; 1:5 suspension remains dispersed
		10-20	5	Slaked; 1:5 suspension remains dispersed
Project area soil 2012	Site 1	0-20	8	Not slaked; not swollen
		40-60	4	Slaked; not dispersed
	Site 2	0-20	3b	Slaked, remoulded soil dispersed partially
	Site 3	0-20	8	Not slaked; not swollen
		40-60	2	Slaked, dispersed partially
	Site 4	0-20	3a	Slaked, remoulded soil dispersed completely
	Site 5	0-20	5	Slaked; 1:5 suspension remains dispersed
		40-60	4	Slaked; not dispersed
		100-120	5	Slaked; 1:5 suspension remains dispersed
	Site 6	0-20	3b	Slaked, remoulded soil dispersed partially
		40-60	3b	Slaked, remoulded soil dispersed partially
TSF Area B footprint soil 2012	SS07	0-5	3b	Slaked, remoulded soil dispersed partially
	SS08	0-5	3a	Slaked, remoulded soil dispersed completely
TSF Area A footprint soil 2012	SS09	0-5	2	Slaked, dispersed partially
	SS10	0-5	2	Slaked, dispersed partially
	SS11	0-5	3a	Slaked, remoulded soil dispersed completely

3.2.5 Soil strength

A modified Modulus of Rupture (MOR) test was conducted on the soil fraction (<2 mm) of all 2011 and 2012 Project area soil samples collected. This test is a measure of soil strength and identifies the tendency of a soil to hard-set as a direct result of soil slaking and dispersion. A modulus of rupture of over 60 kPa has been described as the critical value for distinguishing potentially problematic soils in agricultural scenarios (Cochrane and Aylmore 1997). Restricted root penetration into the soil matrix is a likely consequence of a high modulus of rupture. In reconstructed soil profiles, materials normally deep within the profile that may have a high MOR can often be re-deposited closer to the surface, leading to germination / emergence and root penetration problems.

As this test is conducted on reconstructed soil blocks composed of the <2 mm soil fraction, it does not take into account the effect of gravel content or soil structure on soil strength, nor any degree of compaction that may be present in the field. It does, however, provide insight into the potential for layers to hard-set and compact with repeated wetting and drying cycles, and the ability of roots to fracture the soil and penetrate crack faces.

The soil sized fraction (<2 mm) of the majority of the 201 and 2012 Project area soils sampled exhibited soil strength values above 60 kPa (**Figure 12**) and are therefore considered to be prone to hardsetting. This may have some negative implications for the establishment of vegetation in rehabilitated soils. The majority of the soils however have greater than 50% coarse material content which, to a degree, is likely to counteract the negative influence of the potentially hardsetting soil fraction. Nevertheless, it is recommended that soil stripping operations and associated earthworks are not conducted when the soils are wet, as this can exacerbate the decline in soil structure and potential hardsetting of the soil materials.

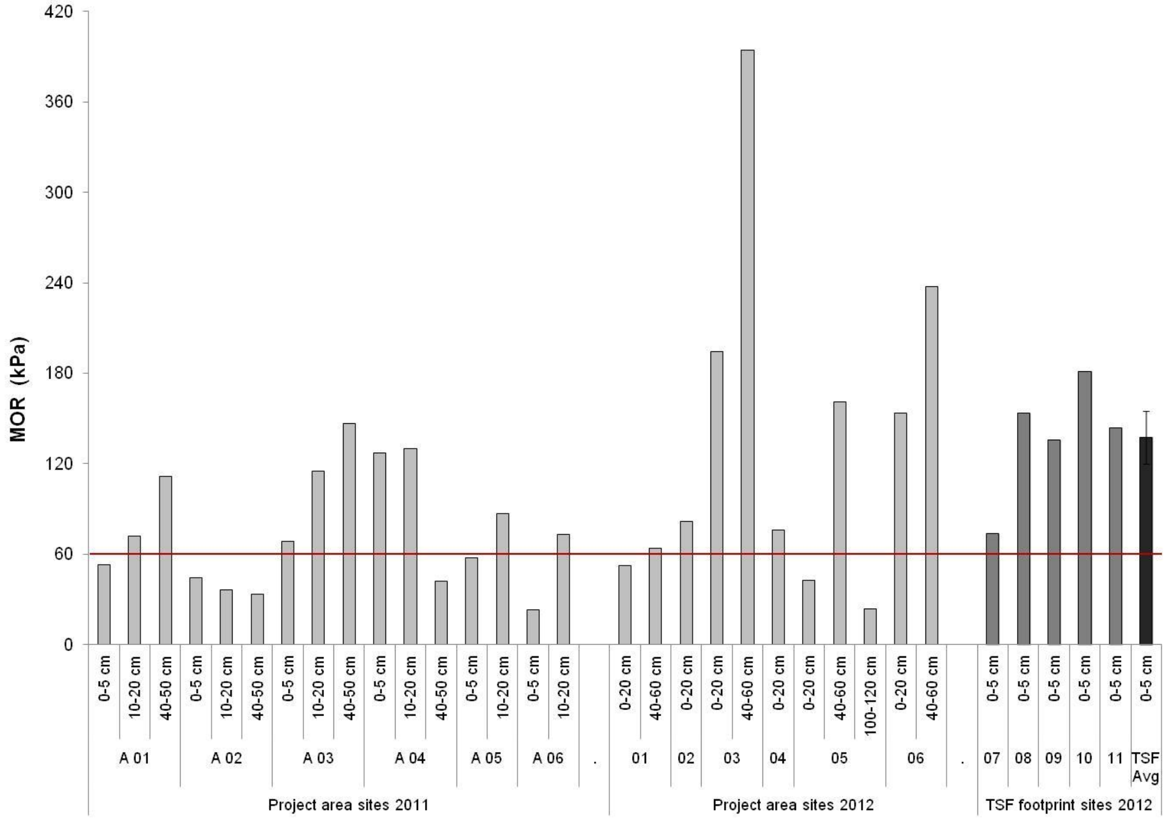


Figure 12: Individual MOR (kPa) values for soil samples from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites. Red line indicates potential restrictions to plant and root development (Cochrane and Aylmore 1997) (error bar represents standard error)

3.2.6 Saturated hydraulic conductivity (K_{sat})

Hydraulic conductivity (K_{sat}) refers to the permeability of soil, or the ability of water to infiltrate and drain through the soil matrix, and is dependent on soil properties such as texture and structure (Hunt and Gilkes 1992; Hazelton and Murphy 2007; Moore 1998). Freely draining soils with high K_{sat} values will generally be less susceptible to surface runoff and erosion. Slow draining soils with low K_{sat} values, are more likely to experience waterlogging, increased surface runoff and erosion.

Saturated hydraulic conductivity refers to the permeability of soil, or the ability of water to infiltrate and drain through the soil matrix, and is dependent on soil properties such as texture and structure (Hunt and Gilkes 1992; Hazelton and Murphy 2007; Moore 1998).

Drainage classes were determined for selected 2011 and all 2012 Project area samples according to their K_{sat} value (Hunt and Gilkes 1992) (**Figure 13**, **Figure 14**, **Table 6**). Soil from Site 3 (40 to 60 cm) was the only sample to exhibit a “slow” drainage class (K_{sat} of 1.49 mm/hr). This soil was a light clay with the lowest coarse material percentage (28%) and a tendency to slake, disperse and hardset. The drainage classes of all other samples ranged from ‘moderately slow’ to ‘rapid’, with K_{sat} values ranging from 10.4 to 156.2 mm/hr (**Table 6**).

Repeated K_{sat} analyses were undertaken after a second and third wetting and drying cycle for each 2012 soil sample (**Figure 14**) to identify the influence of settling / consolidation of the soils on the hydraulic conductivity. Results indicate that while there were some fluctuations in K_{sat} values between wetting / drying cycles, the majority of the soils remained within the same drainage class. This suggests that, from a K_{sat} perspective, the soils will retain a relatively constant ability to accept rainfall over wetting and drying cycles.

The soils with the lower K_{sat} values may be problematic from an erodibility perspective if placed on the surface of rehabilitated slopes due to their low saturated hydraulic conductivity and resulting low potential to accept rainfall. However, with the majority of soils classed as having a 'moderate' and 'moderately rapid' drainage class, this indicates a moderate potential for the soils to accept and transmit water.

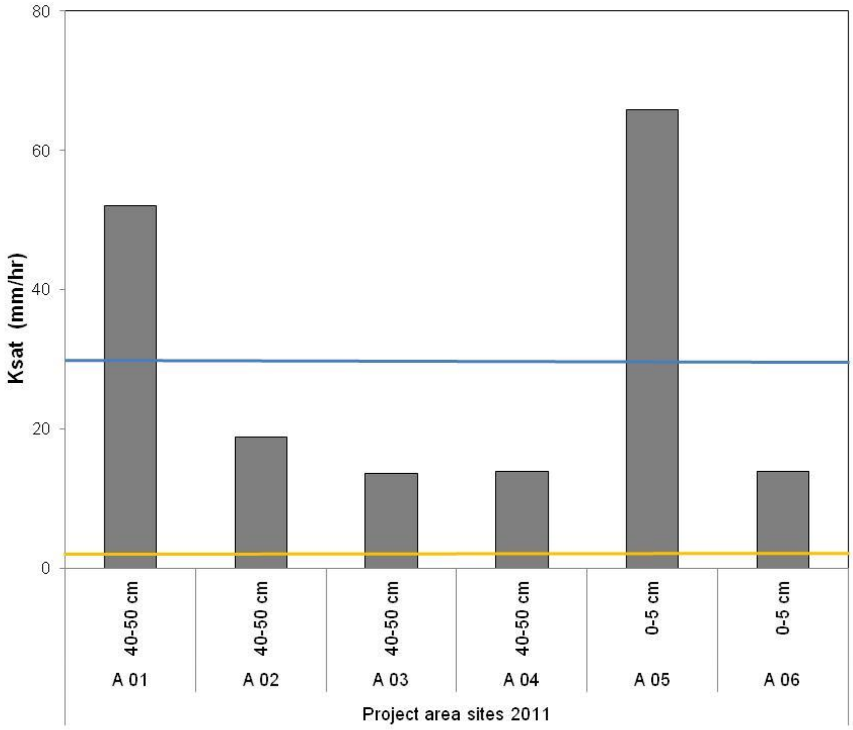


Figure 13: Individual K_{sat} (mm/hr) values for selected soil samples from the Sulphur Springs Copper Zinc Project area 2011 sites. Horizontal lines indicate average drainage class categories – slow, and moderate (Hunt and Gilkes 1992)

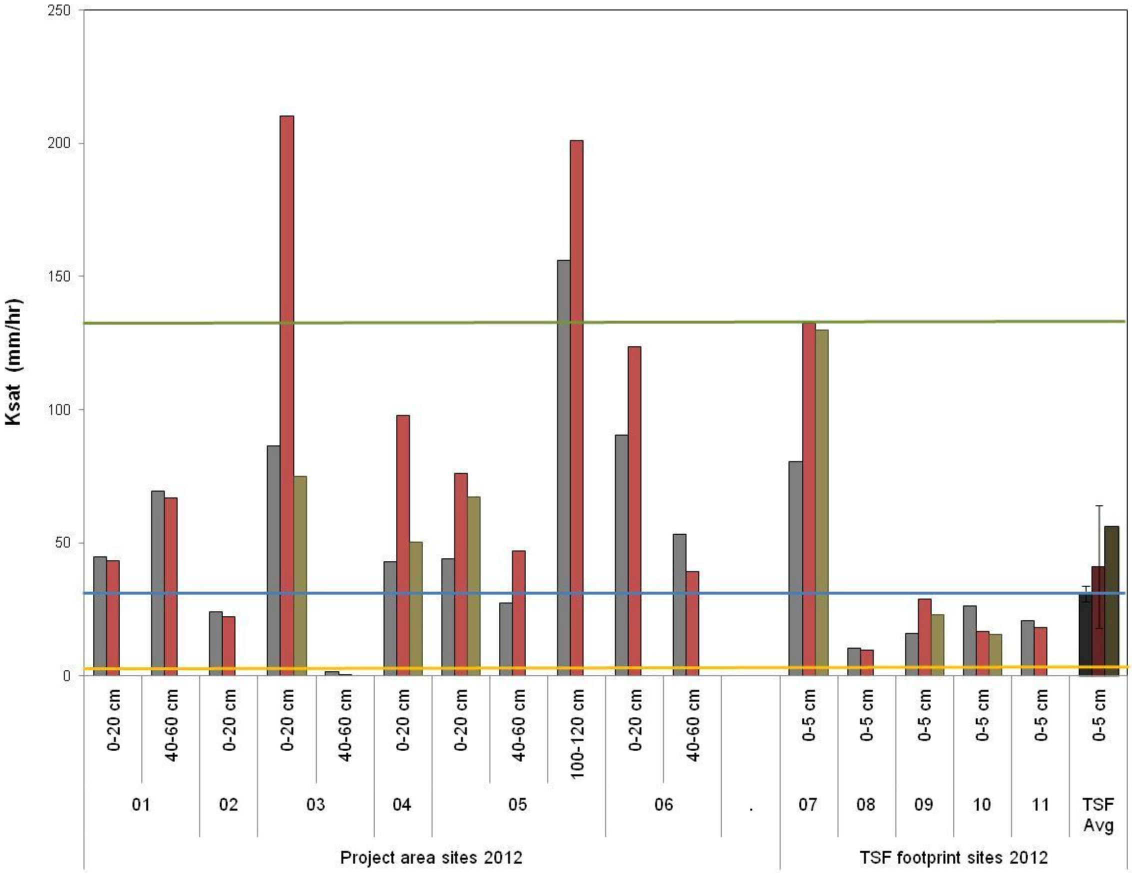


Figure 14: Individual K_{sat} (mm/hr) values for two and three wetting / drying cycles for the Sulphur Springs Copper Zinc Project area 2012 sites. Horizontal lines indicate average drainage class categories – slow, moderate and rapid (Hunt and Gilkes 1992) (error bar represents standard error)

Table 6: Initial saturated hydraulic conductivity (Ksat) values, soil texture, coarse fragment content and drainage class for selected Sulphur Springs Copper Zinc Project area, 2011 and 2012 soil samples

Description	Site	Depth (cm)	Soil texture – PSD (hand texture)	Coarse fragments (%)	Initial k_{sat} (mm/hr)	Initial drainage class
Project area soil 2011	A1	40-50	(Clayey sand)	75	52.01	Moderate
	A2	40-50	(Clayey sand)	71	18.8	Moderately slow
	A3	40-50	Sandy clay loam	71	13.62	Moderately slow
	A4	40-50	(Sandy Loam)	43	13.93	Moderately slow
	A5	0-5	(Sandy loam)	65	65.77	Moderately rapid
	A6	0-5	(Loam)	49	13.95	Moderately slow
	A6	10-20	(Sandy clay loam)	69	44.71	Moderate
Project area soil 2012	SS01	0-20	Sandy loam	60	69.58	Moderately rapid
	SS01	40-60	Loamy sand	56	23.90	Moderate
	SS02	0-20	Sandy clay	76	86.26	Moderately rapid
	SS03	0-20	Sandy clay loam	73	1.49	Slow
	SS03	40-60	Sandy clay loam	28	42.71	Moderate
	SS04	0-20	Clay loam	57	44.10	Moderate
	SS05	0-20	Silty loam	34	27.28	Moderate
	SS05	40-60	Sandy clay	51	156.21	Rapid
	SS05	100-120	Sandy loam	68	90.61	Moderately rapid
	SS06	0-20	Sandy clay	74	53.14	Moderate
	SS06	40-60	Sandy loam	63	80.43	Moderately rapid
TSF Area B footprint soil 2012	SS07	0-5	Sandy loam	61	10.39	Moderately slow
	SS08	0-5	Silty loam	80	15.90	Moderately slow
TSF Area A footprint soil 2012	SS09	0-5	Sandy loam	71	26.37	Moderate
	SS10	0-5	Loamy sand	68	20.60	Moderate
	SS011	0-5	Sandy clay loam	68	44.71	Moderate

3.2.7 Soil water retention

The water retention properties of the soils within the Project area are an important factor in determining the amount of water that the soils are able to store, and the amount of water available for plant growth when soil materials are re-deposited and rehabilitated. In low-nutrient environments, such as that of the Project area, the amount of water available to plants is often the most limiting factor to vegetation establishment and growth. The water retention or water holding capacity of a soil is influenced by a number of factors, with the particle size (and pore space) distribution, soil structure and organic matter content being the most influential.

All 2012 soil samples from the Project area were selected for analysis of water retention properties on the <2 mm fraction. The water holding capacity of the soil samples was relatively low (**Figure 16**), but typical of analogue soils with the range of soil textures exhibited. This observation is based on the results from other analyses conducted by Outback Ecology of surface soils from similar landforms in the Pilbara region. The water retention curves were relatively similar (**Figure 15**), reflecting the relative similarity in soil textures present (**Figure 16**). As the water pressure increases the amount of water that is held within the pores of the soil materials is reduced (**Figure 16**). The soil water (% volume) at 10 kPa is considered to be the field capacity of the soil (upper storage limit) and 1500 kPa is considered to be the wilting point (lower storage limit) of the soil. Field capacity is the percentage of water remaining in a soil two or three days after it has been saturated and free drainage has practically ceased. Wilting point is the percentage of water in the soil at which plants wilt and fail to recover.

The upper storage limit of the samples (<2 mm fraction) ranged from 25.7% to 47.3% (volumetric) (**Table 7**). This means that when the soil samples are at field capacity, 25.7% to 47.3% of the volume is comprised of water. The lower storage limit of the surface soils ranged from 13.1% to 26.8% (volumetric). This means that when the soil samples are at wilting point, 13.1% to 26.8% of the volume is comprised of water. The plant-available water (PAW), which is the upper storage limit minus lower storage limit of the soil fraction (<2 mm), ranged from 12.6% to 29.5% (volumetric).

Taking the percentage of coarse material into consideration, the upper storage limit of both the soil and coarse fractions combined (the ‘total’ material) is substantially reduced, ranging from 6.1 to 33.8% (volumetric). The PAW of the total material ranged from 3.0% to 14.7% (volumetric) (**Table 7**). These are relatively low PAW values, but are typical of weathered surface soils in the region, particularly those with high gravel / coarse material contents.

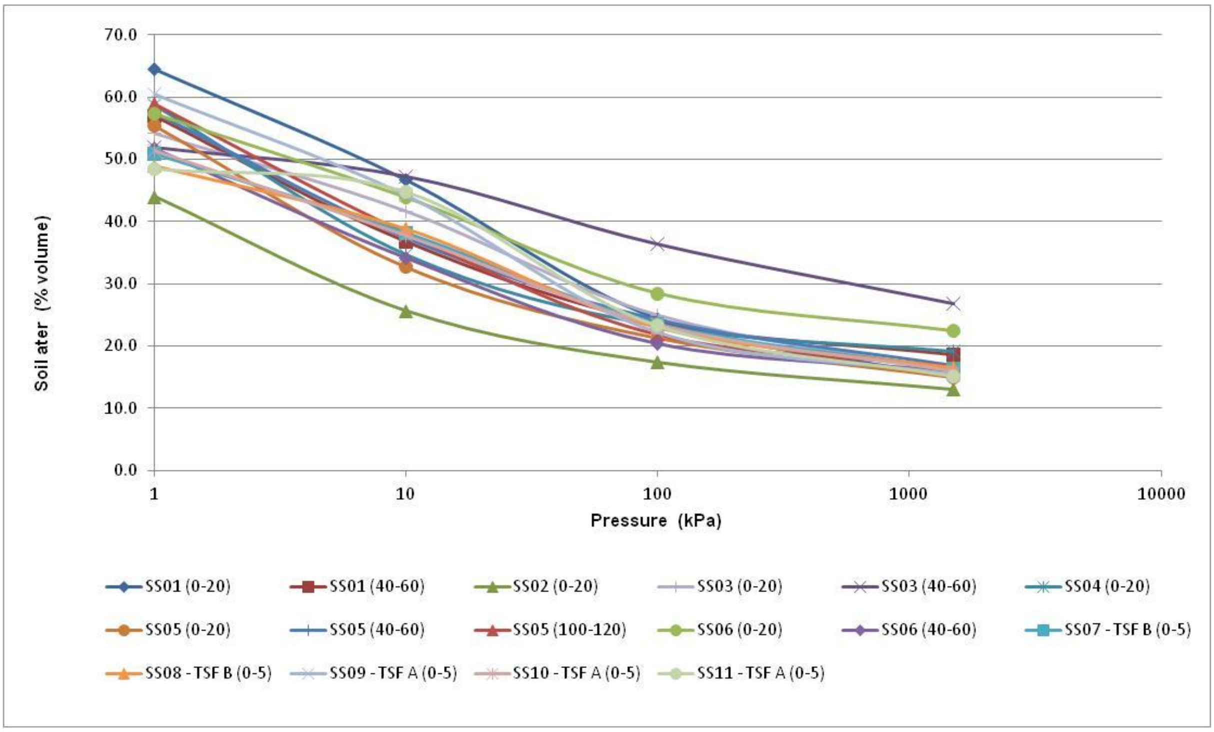


Figure 15: Water retention curves for selected soils from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites

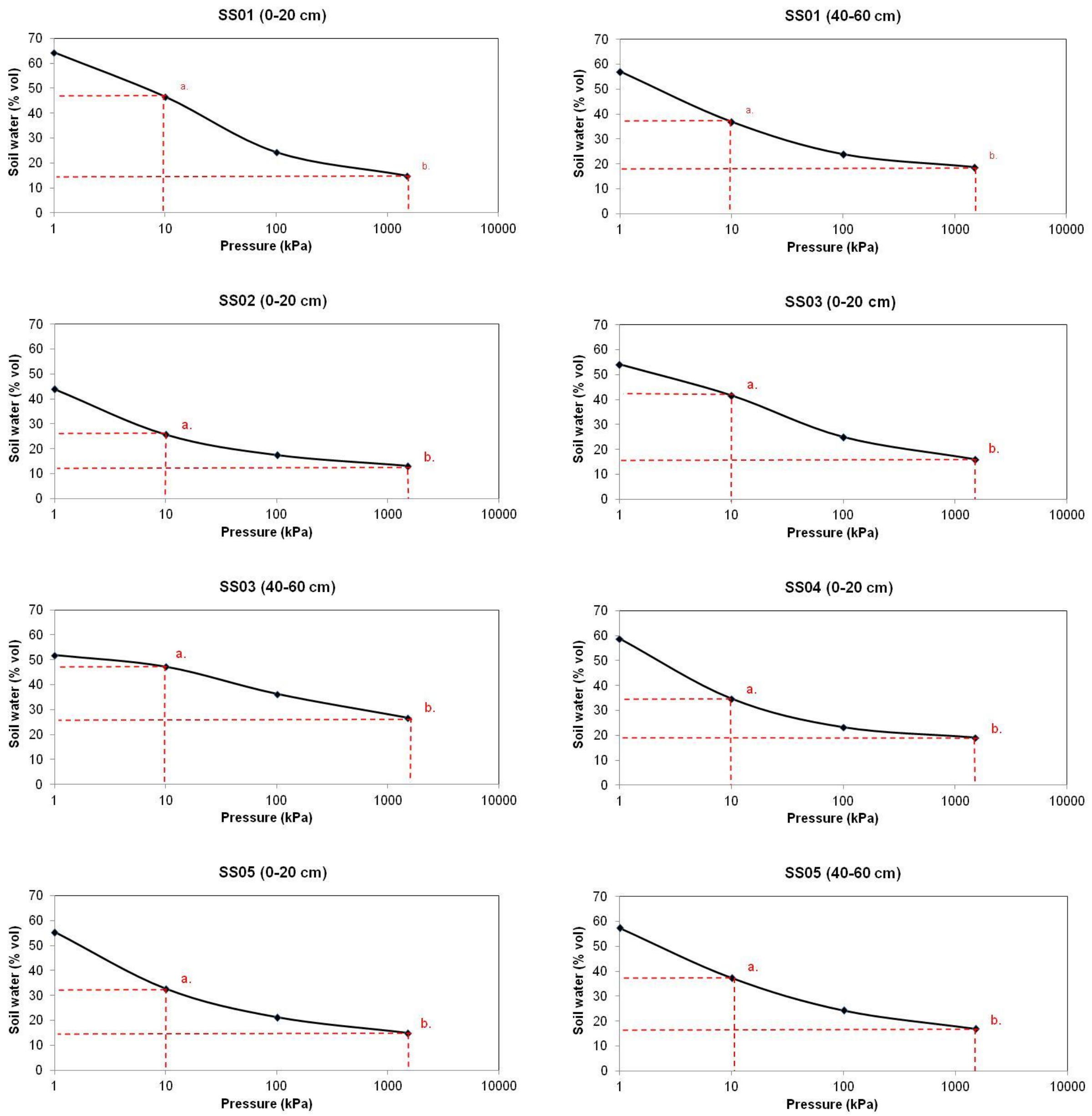


Figure 16: Water retention curves for individual soils from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (Water content at point a. is the upper storage limit and point b. is the lower storage limit. The difference in water content between a. and b. is the PAW)

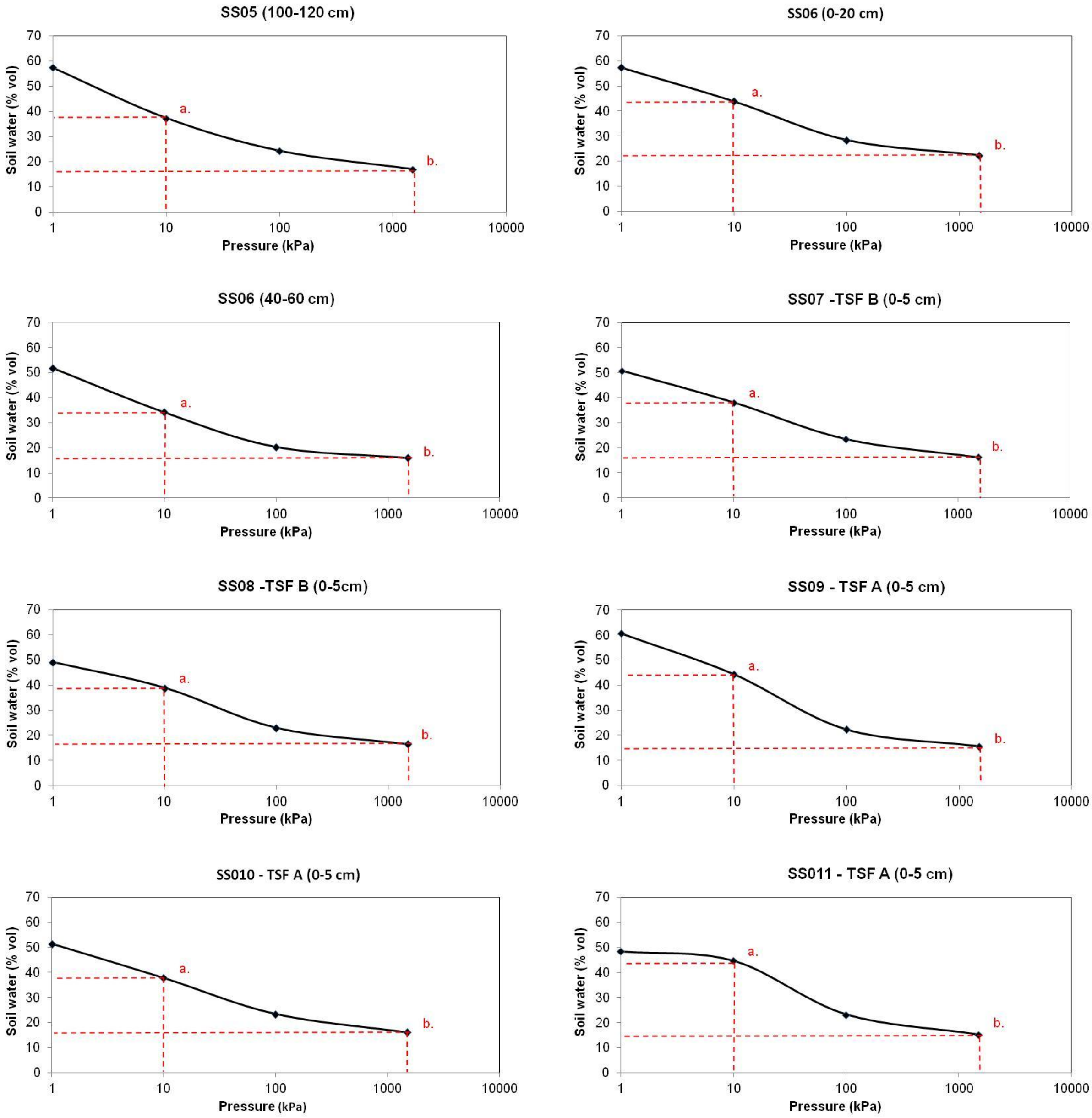


Figure 17: continued. Water retention curves for individual selected soil samples from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (Water content at point a. is the upper storage limit and point b. is the lower storage limit. The difference in water content between a. and b. is the PAW)

Table 7: Water retention and availability characteristics for soils from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites

			<2 mm fraction			Total material [2]	
Description	**Site**	**Depth interval (m)**	**Upper storage limit[1] (% volume)**	**Lower storage limit[1] (% volume)**	**Plant available water (PAW) (% volume)**	**Upper storage limit (% vol)**	**Plant available water (PAW) (% vol)**
Project area soil 2012	SS01	0-20	46.7	15.0	31.7	18.7	12.7
	SS01	40-60	36.8	18.6	18.2	16.2	8.0
	SS02	0-20	25.7	13.1	12.6	6.1	3.0
	SS03	0-20	41.7	16.0	25.6	11.2	6.9
	SS03	40-60	47.3	26.8	20.5	33.8	14.7
	SS04	0-20	34.7	19.1	15.6	15.0	6.7
	SS05	0-20	32.7	15.0	17.7	21.5	11.6
	SS05	40-60	37.4	16.9	20.5	18.2	9.9
	SS05	100-120	38.2	16.8	21.4	12.1	6.8
	SS06	0-20	43.9	22.4	21.5	11.5	5.6
	SS06	40-60	34.1	16.0	18.2	12.6	6.7
TSF Area B footprint soil 2012	SS07	0-5	38.2	16.3	21.9	14.8	8.5
	SS08	0-5	38.9	16.5	22.4	8.0	4.6
TSF Area A footprint soil 2012	SS09	0-5	44.2	15.5	28.8	13.0	8.4
	SS10	0-5	37.8	16.1	21.7	12.3	7.0
	SS11	0-5	44.7	15.2	29.5	14.3	9.4

1. Upper storage limit taken at 10 kPa (pF 2), Lower storage limit taken at 1500 kPa (pF 5.5).
2. Taking gravel / coarse material (>2 mm) for each material into account. This assumes water holding capacity of >2 mm coarse fraction is negligible.

3.3 Soil physical properties – Kangaroo Caves, Eastern and Airstrip areas - 2013

3.3.1 Soil profile morphology

The surface soil profiles investigated within the Kangaroo Caves, Eastern and Air Strip areas exhibited some variation in terms of morphological characteristics. The depth of soil ranged from approximately 30 to 250 cm at the sites.

3.3.2 Soil texture

Particle size distribution results indicate that the texture of the soil sized fraction (<2 mm) of the all the Kangaroo Caves, Eastern and Air Strip area soils was 'sandy loam' (**Figure 18**). The clay fraction within the samples was consistent with an average of 13%. The amount of coarse material present (>2 mm) within the soil samples was variable, ranging from 11% to 47% (**Figure 19**). Overall, the Kangaroo Caves, Eastern and Air Strip area soils had comparatively less clay fraction and less coarse material content than the 2011 and 2012 Project area soils.

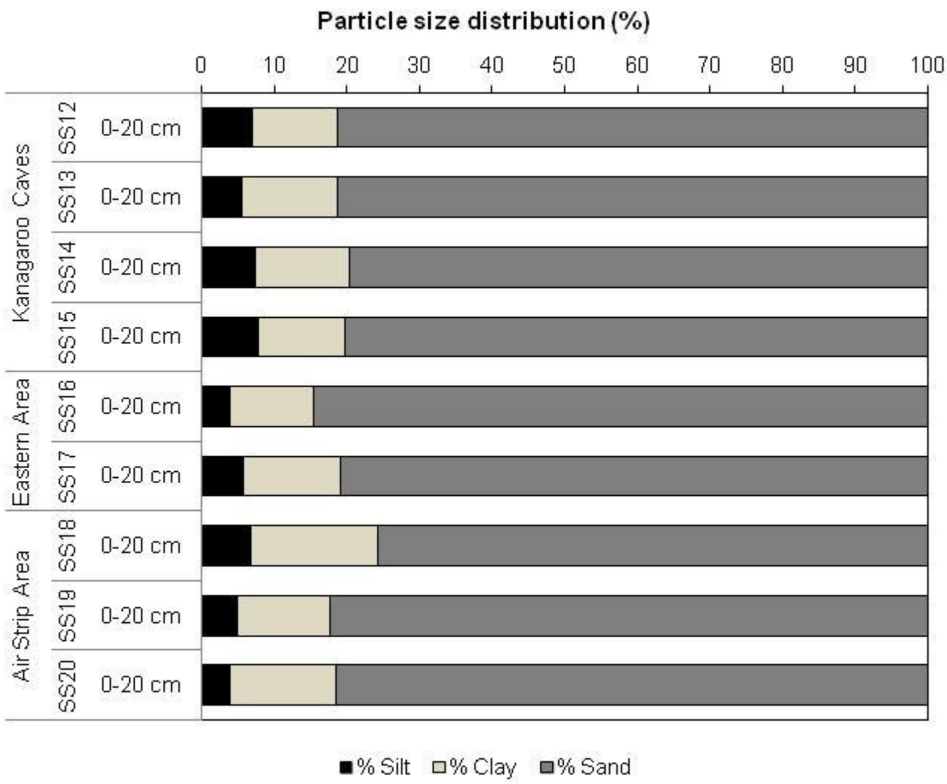


Figure 18: Individual particle size distribution (%) for soil samples (< 2 mm fraction) from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area

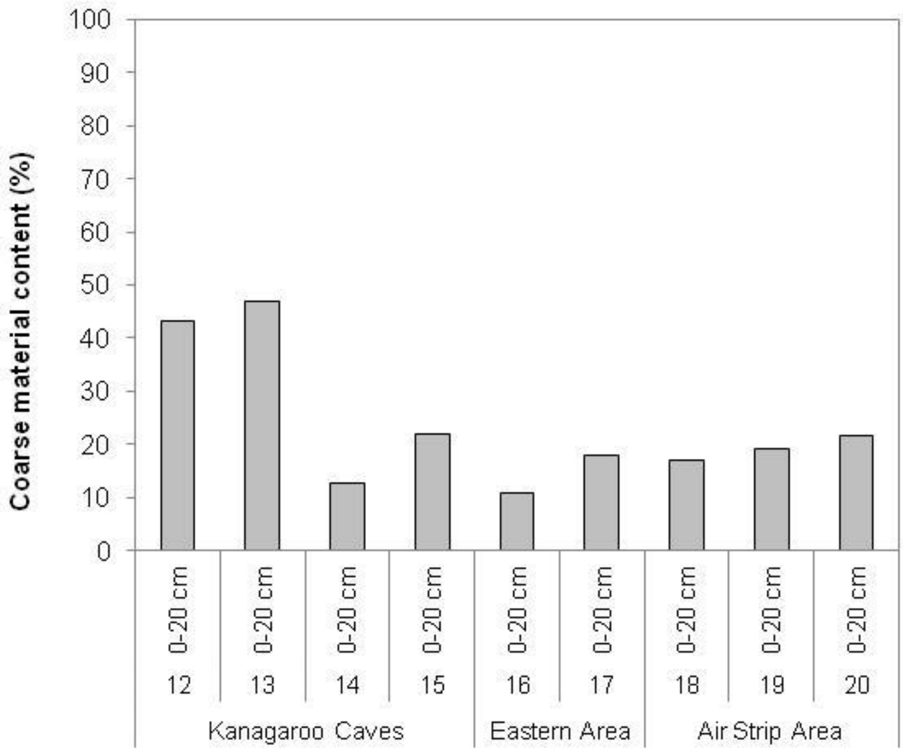


Figure 19: Individual coarse material content (%) (>2 mm fraction) for soil samples from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area

3.3.3 Soil structure

The soils sampled from the Kangaroo Caves and Air Strip areas were predominantly single grained with aggregates and coarse material. No massive soils or physical restrictions to root penetration were identified.

3.3.4 Structural stability

The structural stability of the soils from the Kangaroo Caves, Eastern and Air Strip areas was variable, with classifications including Emerson Classes 2, 3b, 4, 5 and 8 (**Table 8**). Clay dispersion within the soil, indicated by Emerson Class 2 and to a lesser degree Emerson Class 3b, suggests that those soils are potentially prone to structural decline as a result of clay dispersion and may form a surface seal (hard-set) or be considered as erodible if used as a surface rehabilitation material on constructed slopes. Dispersive soils are also more prone to tunnelling and erosion in areas where surface water pools and the underlying soils remain saturated.

These results should, however, be viewed in conjunction with the particle size distribution, percentage coarse fragments, sodicity, hydraulic conductivity and hardsetting results to obtain a full indication of the likely erodibility and suitability for use as a rehabilitation resource, particularly on constructed slopes.

The majority of the Kangaroo Caves, Eastern and Air Strip area soils are considered ‘moderately stable’ to ‘stable’, from an erodibility perspective, as were the 2011 and 2012 Project area soils.

Table 8: Summary of slaking/dispersion properties (Emerson Test) results, indicating structural stability. Emerson Test classes are included in Appendix B

Description	Site	Depth (cm)	Emerson class (24 hour)	Description
Kanagaroo Caves area soil 2013	SS12	0-20	3b	Slaked, remoulded soil dispersed partially
	SS13	0-20	5	Slaked; 1:5 suspension remains dispersed
	SS14	0-20	5	Slaked; 1:5 suspension remains dispersed
	SS15	0-20	3b	Slaked, remoulded soil dispersed partially
Eastern area soil 2013	SS16	0-20	8	Not slaked; not swollen
	SS17	0-20	4	Slaked; not dispersed
Air Strip area soil 2013	SS18	0-20	2	Slaked, dispersed partially
	SS19	0-20	2	Slaked, dispersed partially
	SS20	0-20	2	Slaked, dispersed partially

3.3.5 Soil strength

A modified Modulus of Rupture (MOR) test was conducted on the soil fraction (<2 mm) of all the Kangaroo Caves, Eastern and Air Strip soil samples collected. The majority of the soils exhibited soil strength values below 60 kPa (**Figure 20**) and are therefore considered not prone to hardsetting. This is in contrast to the 2011 and 2012 Project area sites where the majority of the soils were considered to be hardsetting. Nevertheless, it is recommended that soil stripping operations and associated earthworks are not conducted when the soils are wet, as this can exacerbate the decline in soil structure and potential hardsetting of the soil materials.

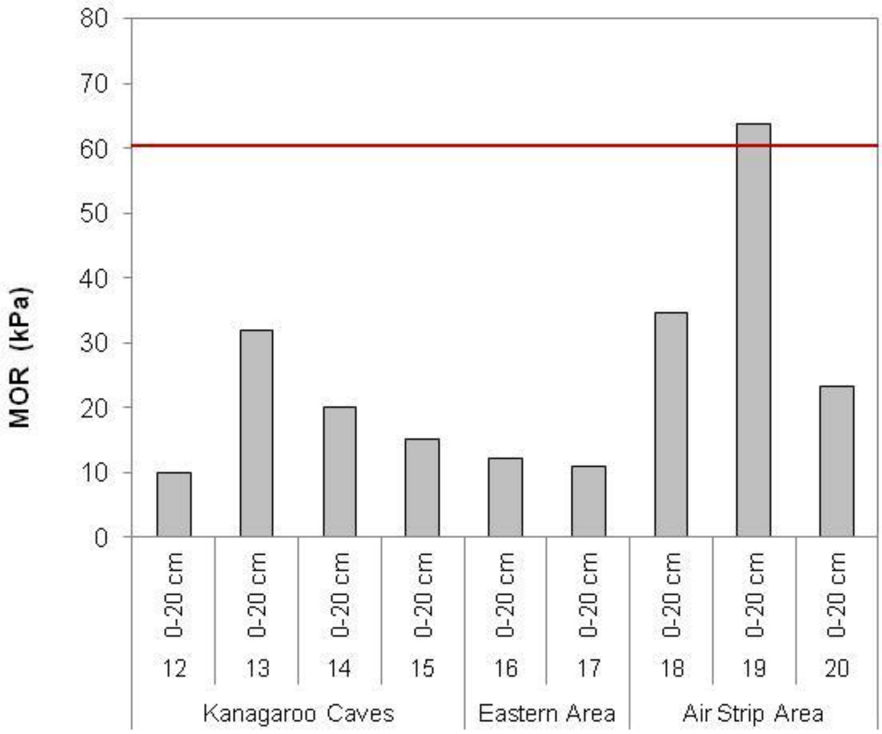


Figure 20: Individual MOR (kPa) values for soil samples from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area. Red line indicates potential restrictions to plant and root development (Cochrane and Aylmore 1997)

3.3.6 Saturated hydraulic conductivity (K_{sat})

Drainage classes were determined for all Kangaroo Caves, Eastern and Air Strip area samples according to their K_{sat} value (Hunt and Gilkes 1992) (**Figure 21**, **Table 9**). The drainage classes of all samples ranged from 'moderately slow' to 'moderately rapid', with K_{sat} values ranging from 10.6 to 122.3 mm/hr (**Table 9**). These drainage classes are similar to those for the 2011 and 2012 Project area surface soils.

The soil with the lowest K_{sat} value (Site 13) may be problematic from an erodibility perspective if placed on the surface of rehabilitated slopes due to the low saturated hydraulic conductivity and resulting low potential to accept rainfall. However, with the majority of soils classed as having a 'moderate' and 'moderately rapid' drainage class, which is similar to the 2011 and 2012 Project area site soils, this indicates a moderate potential for the soils to accept and transmit water.

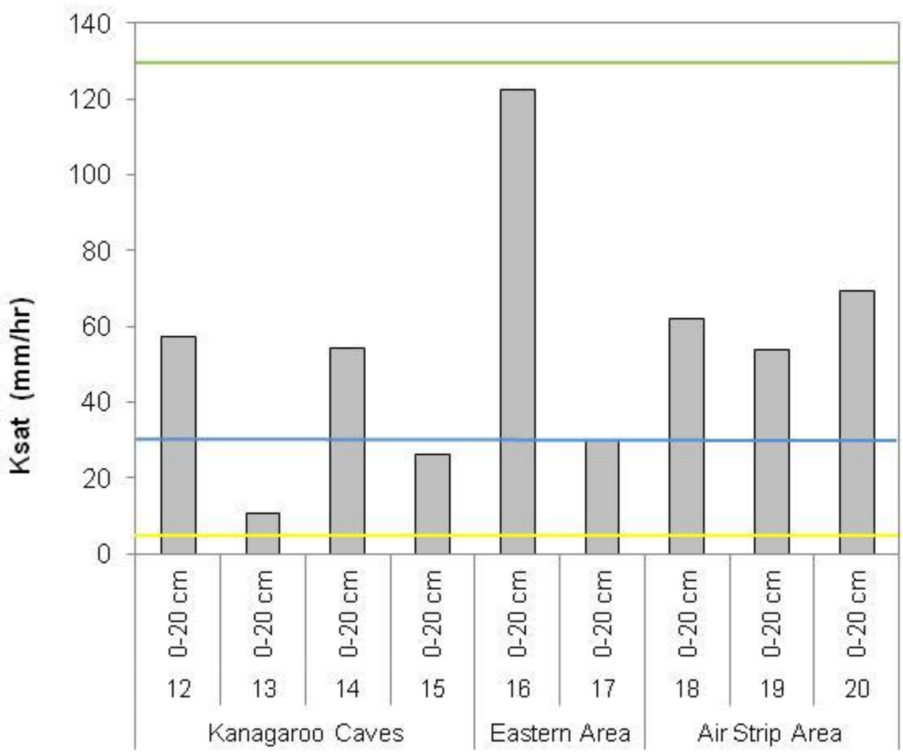


Figure 21: Individual K_{sat} (mm/hr) values for soil samples from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area. Horizontal lines indicate average drainage class categories – slow, moderate and rapid (Hunt and Gilkes 1992)

Table 9: Initial saturated hydraulic conductivity (Ksat) values, soil texture, coarse fragment content and drainage class for Kangaroo Caves, Eastern and Air Strip area soil samples of the Sulphur Springs Copper Zinc Project area

Description	Site	Depth (cm)	Soil Texture (PSD)	Coarse fragments (%)	k_{sat} (mm/hr)	Initial drainage class
Kanagaroo Caves area soil 2013	SS12	0-20	Sandy loam	43	57.15	Moderate
	SS13	0-20	Sandy loam	47	10.55	Moderately slow
	SS14	0-20	Sandy loam	13	54.34	Moderate
	SS15	0-20	Sandy loam	22	26.06	Moderate
Eastern area soil 2013	SS16	0-20	Sandy loam	11	122.26	Moderately rapid
	SS17	0-20	Sandy loam	18	30.05	Moderate
Air Strip area soil 2013	SS18	0-20	Sandy loam	17	61.87	Moderate
	SS19	0-20	Sandy loam	19	53.92	Moderate
	SS20	0-20	Sandy loam	22	69.27	Moderately rapid

3.3.7 Soil water retention

A selection of 2013 soil samples from the Project area were analysed for water retention properties on the <2 mm fraction. The water holding capacity of the soil samples was relatively low (**Figure 23**), but typical of analogue soils with the range of soil textures exhibited. This observation is based on the results from other analyses conducted by Outback Ecology of surface soils from similar landforms in the Pilbara region. The water retention curves were relatively similar (**Figure 22**), reflecting the relative similarity in soil textures present (**Figure 23**). As the water pressure increases the amount of water that is held within the pores of the soil materials is reduced (**Figure 23**).

The upper storage limit of the samples (<2 mm fraction) ranged from 23.2% to 35.2% (volumetric) (**Table 10**). This means that when the soil samples are at field capacity, 23.2% to 35.2% of the volume is comprised of water. The lower storage limit of the surface soils ranged from 11.5% to 16.2% (volumetric). This means that when the soil samples are at wilting point, 11.5% to 16.2% of the volume is comprised of water. The plant-available water (PAW), which is the upper storage limit minus the lower storage limit of the soil fraction (<2 mm), ranged from 11.7% to 19.0% (volumetric).

Taking the percentage of coarse material into consideration, the upper storage limit of both the soil and coarse fractions combined (the ‘total’ material) is reduced, ranging from 17.1 to 30.7% (volumetric). The PAW of the total material ranged from 9.2% to 16.6% (volumetric) (**Table 10**). These are low to medium PAW values, but are typical of weathered surface soils in the region, particularly those with low gravel / coarse material contents.

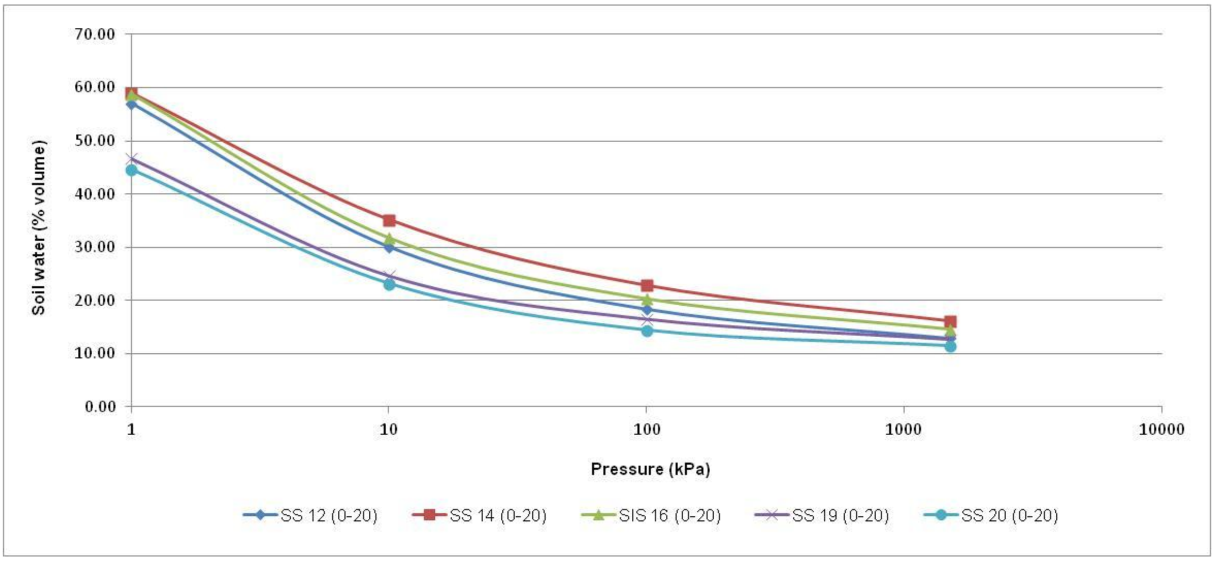


Figure 22: Water retention curves for selected soils from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area.

(Note: Logarithmic scale)

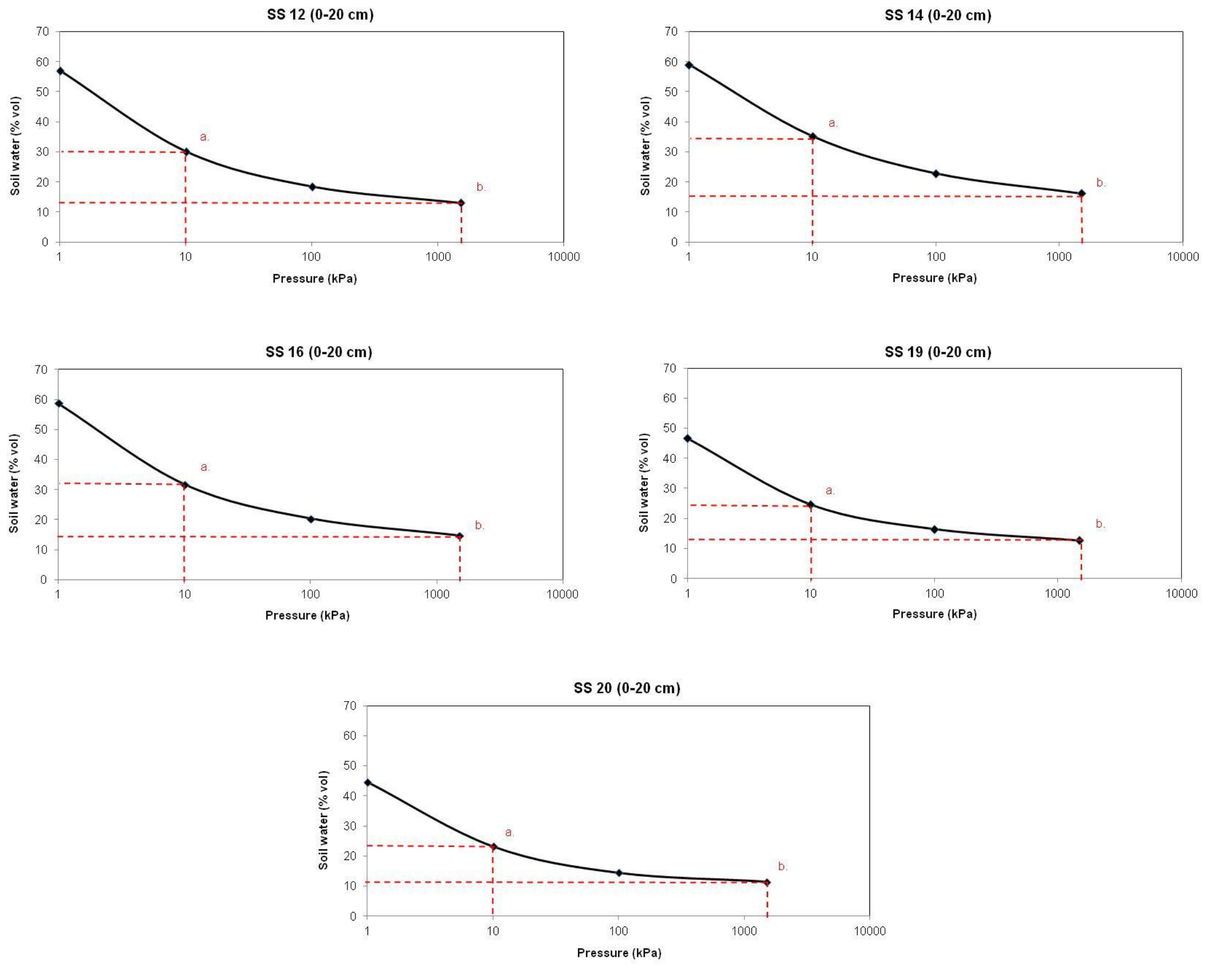


Figure 23: Water retention curves for individual soils from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area (Water content at point a. is the upper storage limit and point b. is the lower storage limit. The difference in water content between a. and b. is the PAW)

(Note: Logarithmic scale)

Table 10: Water retention and availability characteristics for soils from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project

Description	Site	Depth interval (m)	<2 mm fraction			Total material [2]	
			Upper storage limit[1] (% volume)	Lower storage limit[1] (% volume)	Plant available water (PAW) (% volume)	Upper storage limit (% vol)	Plant available water (PAW) (% vol)
Kanagaroo Caves area soil 2013	SS12	0-20	30.1	13.0	17.2	17.1	9.7
	SS14	0-20	35.2	16.2	19.0	30.7	16.6
Eastern area soil 2013	SS16	0-20	31.8	14.7	17.1	28.3	15.2
Air Strip area soil 2013	SS19	0-20	24.7	12.7	12.0	19.9	9.7
	SS20	0-20	23.2	11.5	11.7	18.2	9.2

1. Upper storage limit taken at 10 kPa (pF 2), Lower storage limit taken at 1500 kPa (pF 5.5).
2. Taking gravel / coarse material (>2 mm) for each material into account. This assumes water holding capacity of >2 mm coarse fraction is negligible.

3.4 Soil chemical properties – Project area sites – 2011 and 2012

3.4.1 Soil pH

The soil pH gives a measure of the soil acidity or alkalinity, with ratings determined by pH range and analysis method (Van Gool *et al*. 2005). The ideal pH range for plant growth of most agricultural species is considered to be between 5.0 and 7.5 (Moore 1998). Outside this range, the plant-availability of some nutrients is affected, while various metal toxicities (e.g. Al and Mn) can become limiting at low pH. For native species, which are known to be tolerant of wider ranges in soil pH, preferred pH ranges are best inferred from the soil in which they are observed to occur.

Soil pH measured in 0.01 M calcium chloride ($CaCl_2$) is considered a more accurate measurement of hydrogen ion concentration ($[H^+]$), closer to that of the natural soil solution which is taken up by plants (Hunt and Gilkes 1992). As a result, soil pH measured in $CaCl_2$ is lower than pH measured in water, however both measurements are taken for a complete assessment.

There was a range of soil pH values recorded for the soils sampled from the Project area. Soil pH ($CaCl_2$) ranged from ‘strongly acidic’ (pH 4.5) to ‘strongly alkaline’ (pH 8.3) (**Figure 24**). Soil pH (H_2O) also ranged from ‘strongly acidic’ (pH 5.4) to ‘strongly alkaline’ (pH 9.2) (**Figure 25**). The 2011 Project area samples, overall, had a lower soil pH than the TSF footprint and 2012 Project area samples.

The majority of the soil pH values were within the optimum range for plant growth of Pilbara plant species, with soil pH unlikely to be a limiting factor to successful vegetation growth of rehabilitated areas.

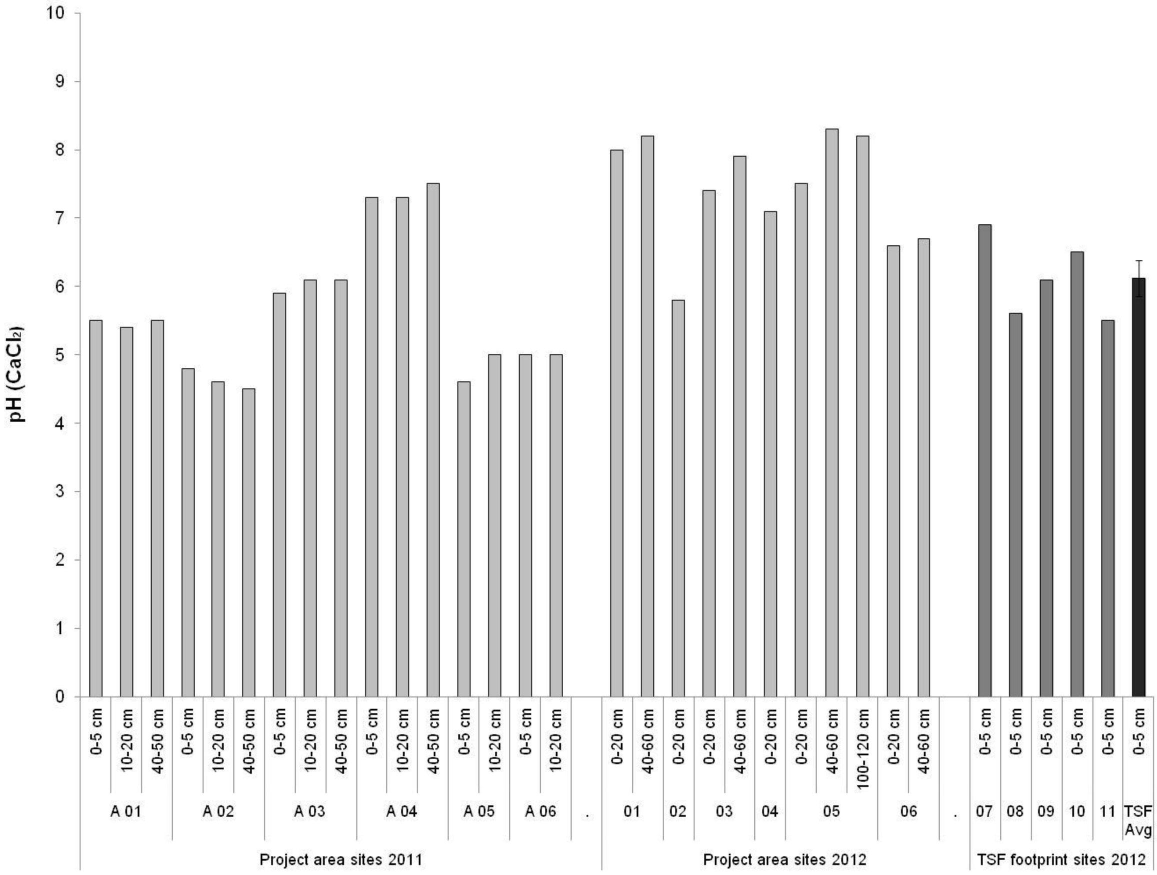


Figure 24: Individual soil pH ($CaCl_2$) values for soil samples from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (error bar represents standard error)

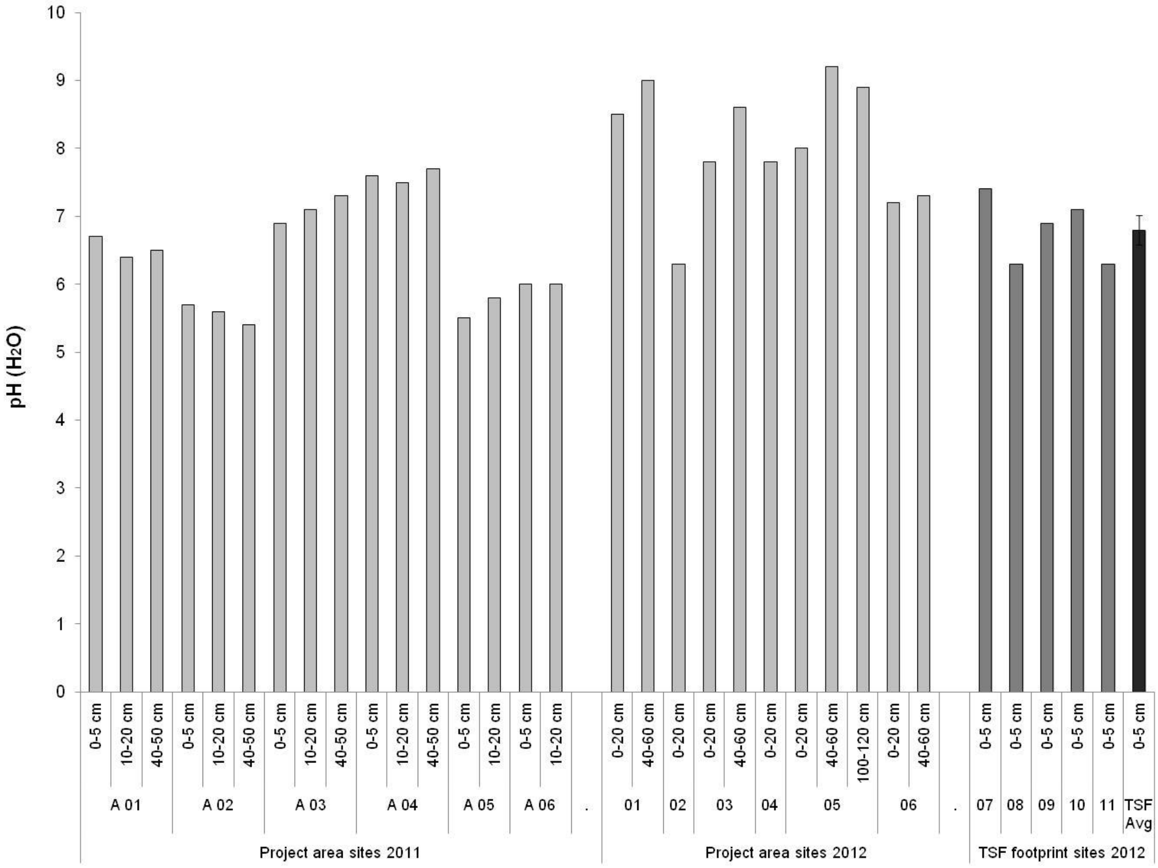


Figure 25: Individual soil pH (H_2O) values for soil samples from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (error bar represents standard error)

3.4.2 Electrical conductivity

Electrical conductivity (EC) is a measurement of the soluble salts in soils or water. The amount of salt in the soil determines its ability to conduct an electric current. High levels of soluble salts lower the osmotic potential of the soil water, making it more difficult for roots to remove water from the soil (Brady and Weil 2002).

The EC values of the soils sampled ranged from 0.018 to 3.930 dS/m (**Figure 26**), with the majority of samples classified as 'non-saline' based on the standard USDA and CSIRO categories (**Appendix B**). Soils from Site A4 and Site 3 (40 to 60 cm) were classified as 'very saline' to 'extremely saline'.

The relatively low EC values, except for Site A4 and Site 3 (40 to 60 cm), indicate that there is a very low risk of salinity related issues occurring if the soils are stripped, stockpiled and used as a surface rehabilitation medium.

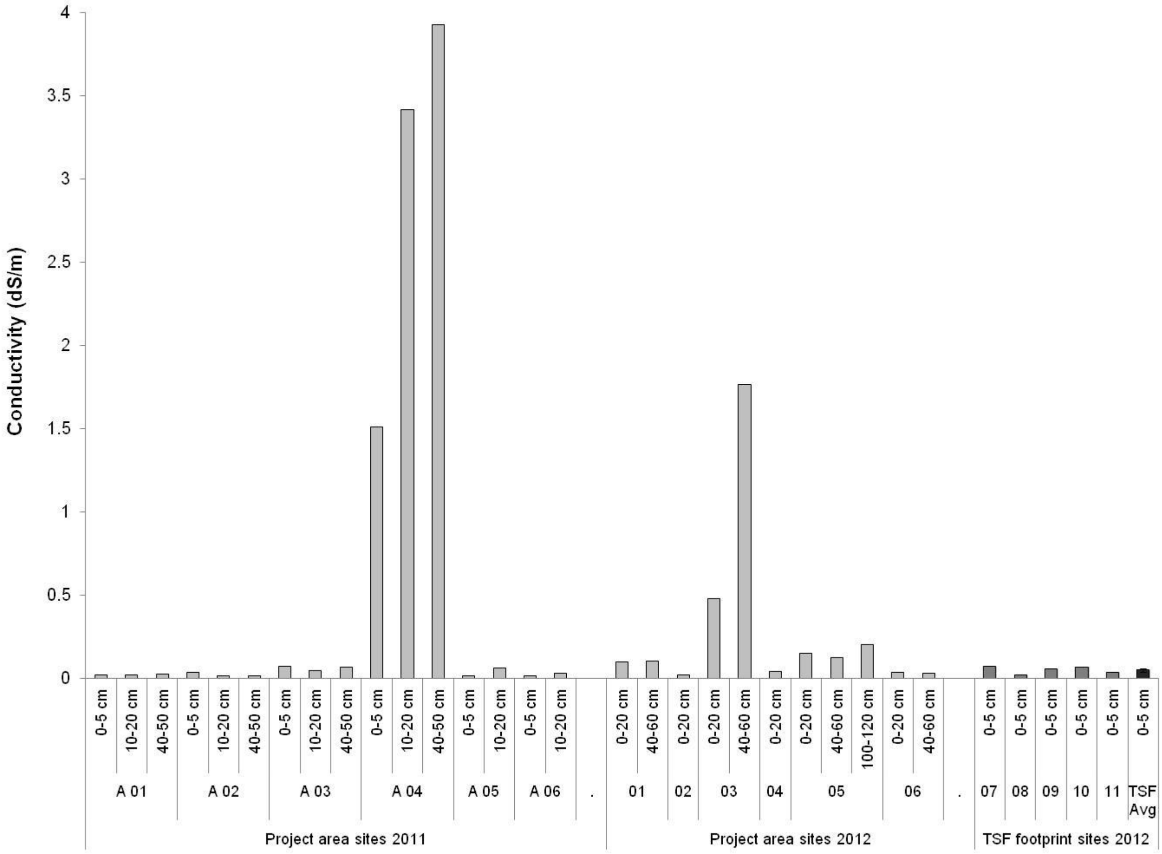


Figure 26: Individual electrical conductivity (EC 1:5 H_2O) values for soil samples from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (error bar represents standard error)

3.4.3 Soil organic carbon

The organic matter content of soil is an important factor influencing many physical, chemical and biological soil characteristics. Directly derived from plants and animals, its functions in soil include supporting the micro and macro fauna and flora populations in the soil, increasing the water retention capacity, buffering pH and improving soil structure. The organic matter content of the soils within the study area was determined as a measure of the soil organic carbon percentage (SOC%).

The SOC% within the majority of the Project area soils was low (<1% SOC) (Moore 1998), as is the case in most natural Western Australian arid land soils, with individual values ranging between 0.10% and 1.02% (**Figure 27**). As would be expected, the highest organic carbon values were generally measured in the topsoil (0 to 20 cm) with the TSF footprint soils having the overall highest values.

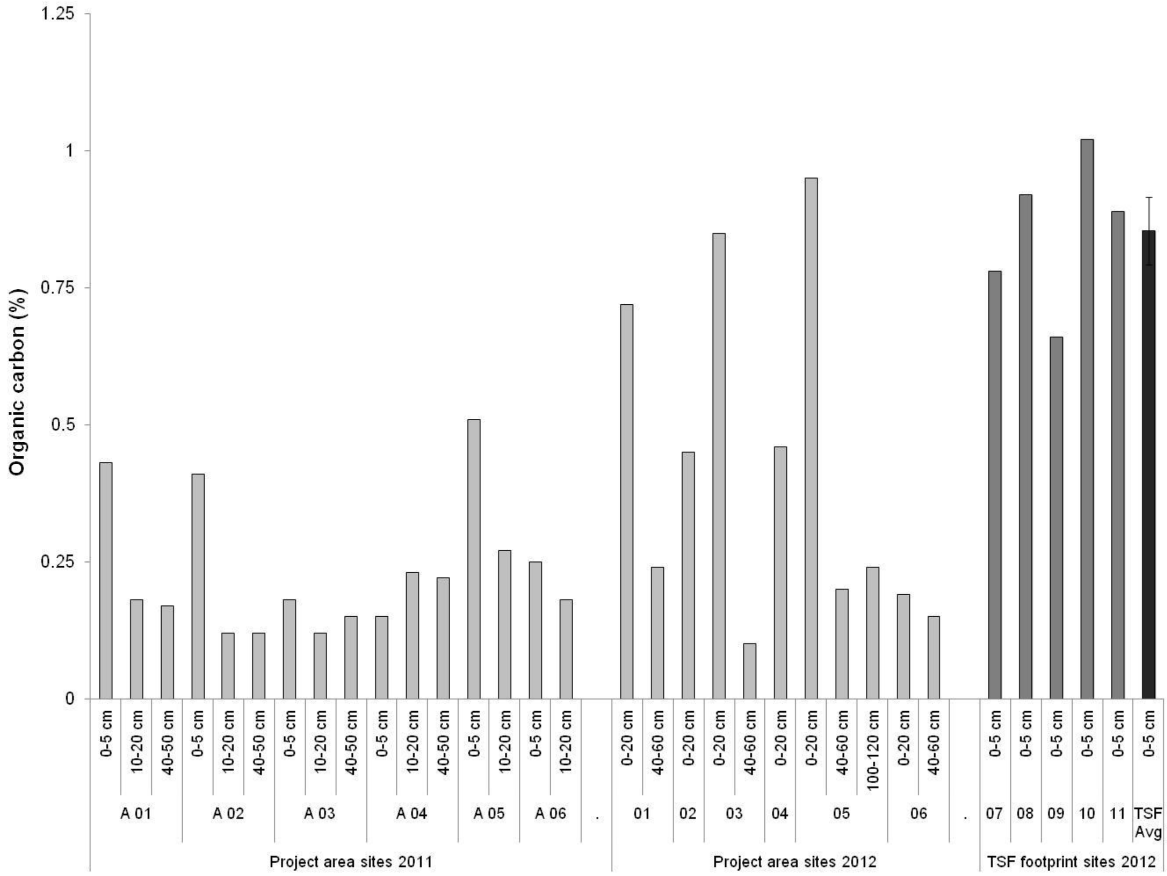


Figure 27: Individual soil organic carbon (%) values for soils from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (error bars represent standard error)

3.4.4 Exchangeable cations and exchangeable sodium percentage (ESP)

Exchangeable cations held on clay surfaces and within organic matter are an important source of soil fertility and can influence the physical properties of soil. Generally, if cations such as Ca^{2+}, Mg^{2+} and K^{+} are dominant on the clay exchange surfaces, the soil will typically display increased physical structure and stability, leading to increased aeration, drainage and root growth (Moore 1998). If Na cations (Na^{+}) are dominant on exchange surfaces and exceed more than 6% of the total exchangeable cations, then the soil is considered to be *sodic*, which can lead to poor physical properties (i.e. dispersion, hard-setting and erosion in clay-rich soils).

If the ESP exceeds more than 15%, then the soil is considered to be *highly sodic* (Moore 1998). Sodic soils have an increased tendency to disperse upon wetting and are therefore more prone to hardsetting at the soil surface, and erosion when placed on the slopes of constructed landforms.

The majority of soil samples (soil sized fraction) from within the Project area were classified as 'non-sodic' with ESP values less than 6% or exchangeable sodium values below the level of detection (**Table 11**). Site A3 and Site 3 recorded ESP values between 6.57% and 14.08% indicating 'sodic' soils. However, all these samples had low effective cation exchange capacity (eCEC) values (< 3 meq/100g) indicating that the dispersive effect of high sodicity is likely to be minimal. This is evidenced by the relatively low amounts of clay dispersion identified by the Emerson Aggregate Test (**Section 3.2.4**). In summary, the majority of the soils from the Project area are considered unlikely to be problematic from a clay dispersion and derived erodibility perspective. Care should be taken, however, to minimise the handling of the soil materials where possible, particularly when wet.

Table 11: Individual exchangeable sodium percentage (ESP) (%) and effective cation exchange capacity (eCEC) values for the soil sized fraction (< 2 mm) of the Sulphur Springs Copper Zinc Project area 2011 and 2012 surface soil samples

Description	Site	Depth (cm)	ESP (%)[1]	eCEC (meq/100g)
Project area soil 2011	Site A1	0-5	BDL	3.35
		10-20	BDL	2.90
		40-50	BDL	3.57
	Site A2	0-5	BDL	1.49
		10-20	BDL	1.58
		40-50	BDL	1.60
	Site A3	0-5	8.16	1.47
		10-20	7.04	2.13
		40-50	14.08	1.42
	Site A4	0-5	2.44	7.39
		10-20	3.73	9.91
		40-50	3.50	13.13
	Site A5	0-5	BDL	1.22
		10-20	BDL	1.70
	Site A6	0-5	BDL	2.46
		10-20	BDL	3.23
Project area soil 2012	Site 1	0-20	BDL	3.35
		40-60	BDL	2.90
	Site 2	0-20	BDL	3.57
	Site 3	0-20	2.06	1.49
		40-60	6.57	1.58
	Site 4	0-20	BDL	1.60
	Site 5	0-20	BDL	1.47
		40-60	BDL	2.13
		100-120	2.43	1.42
	Site 6	0-20	BDL	7.39
		40-60	BDL	9.91
TSF Area B footprint soil 2012	SS07	0-5	BDL	13.13
	SS08	0-5	BDL	1.22
TSF Area A footprint soil 2012	SS09	0-5	BDL	1.70
	SS10	0-5	BDL	2.46
	SS11	0-5	BDL	3.23

1. BDL: Exchangeable sodium below detection limit, assumed non-sodic.

3.4.5 Plant-available soil nutrients

The most important macronutrients for plant growth are nitrogen (N), phosphorus (P), potassium (K), and sulphur (S). These nutrients are largely derived from the soil mineral component and organic matter.

Native plant species have a number of physiological adaptations that enable them to be productive in areas where the supply of macronutrients is limited. There is limited information available which details the specific nutritional requirements for native plant species in the semiarid zone of WA. Therefore, the use of analogue sites is an effective way to baseline the soil nutritional requirements of native plant species within the Project area.

3.4.5.1 Plant-available nitrogen

A significant proportion of soil nitrogen is held in organic matter and it is not immediately available for plant uptake (Hazelton and Murphy 2007). The nitrogen that is readily available to plants is generally measured as nitrate. Nitrogen is an integral component of many essential plant compounds. It is a major part of all amino acids, which are the building blocks of all proteins, including the enzymes which effectively control all biological processes (Brady and Weil 2002). A good supply of nitrogen stimulates root growth and development, and enhances the uptake of other nutrients (Brady and Weil 2002).

Plant-available nitrogen was typically low, ranging from <1 (below the detectable limit) to 8 mg/kg (**Figure 28**). Site A4 had relatively high plant-available nitrogen values ranging from 29 mg/kg to 57 mg/kg.

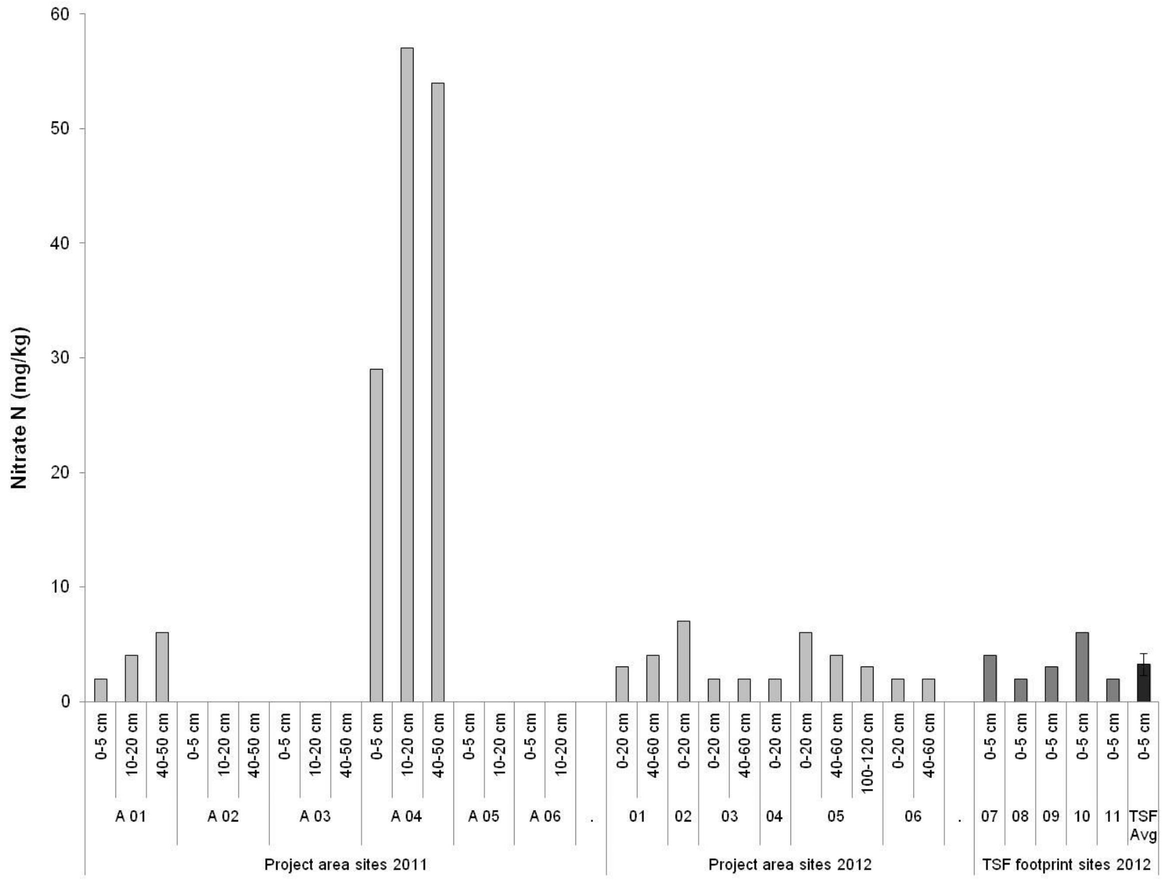


Figure 28: Individual plant-available nitrogen (nitrate N) (mg/kg) values for soils from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (error bar represents standard error)

3.4.5.2 Plant-available phosphorus

Phosphorus is essential for the growth of plants and animals as it plays a key role in the formulation of energy producing organic compounds. Adequate phosphorus nutrition enhances many aspects of plant physiology, including the fundamental processes of photosynthesis, nitrogen fixation, flowering, fruiting (including seed production), and maturation (Brady and Weil 2002).

Plant-available phosphorus for all samples was classed as 'low' (<10 mg/kg) to 'medium' (10 to 30 mg/kg) (Moore 1998) with individual concentrations ranging from <2 (below the detectable limit) to 10 mg/kg (**Figure 29**).

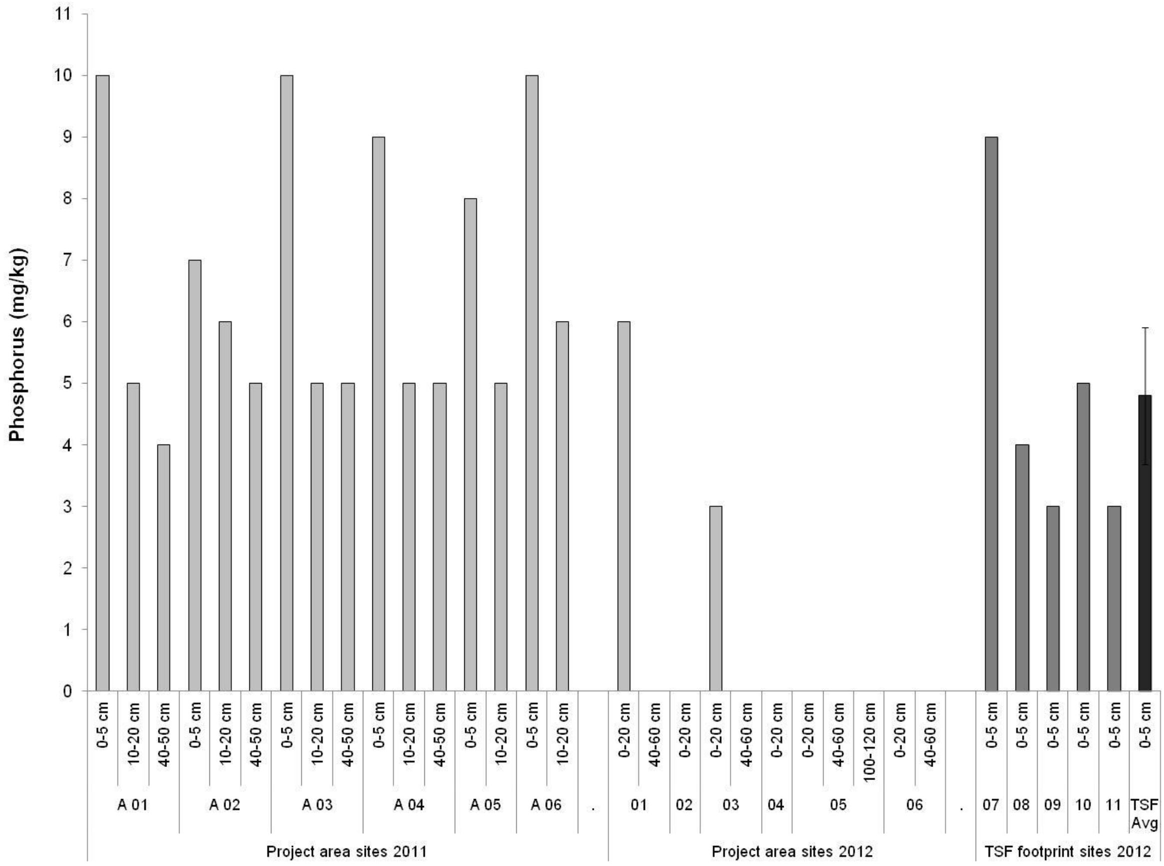


Figure 29: Individual plant-available phosphorus (P) (mg/kg) values for soil samples from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (error bars represent standard error)

3.4.5.3 *Plant-available potassium*

Potassium (K) plays a critical role in a number of plant physiological processes. Adequate amounts of K have been linked to improved drought tolerance, improved winter hardiness, better resistance to certain fungal diseases, and greater tolerance to insect pests. Potassium can also improve the structural stability of plants (Brady and Weil 2002).

Plant-available potassium within all soils sampled was classed as 'low' to 'high' (Moore 1998) ranging from <15 (below the detectable limit) to 404 mg/kg (**Figure 30**).

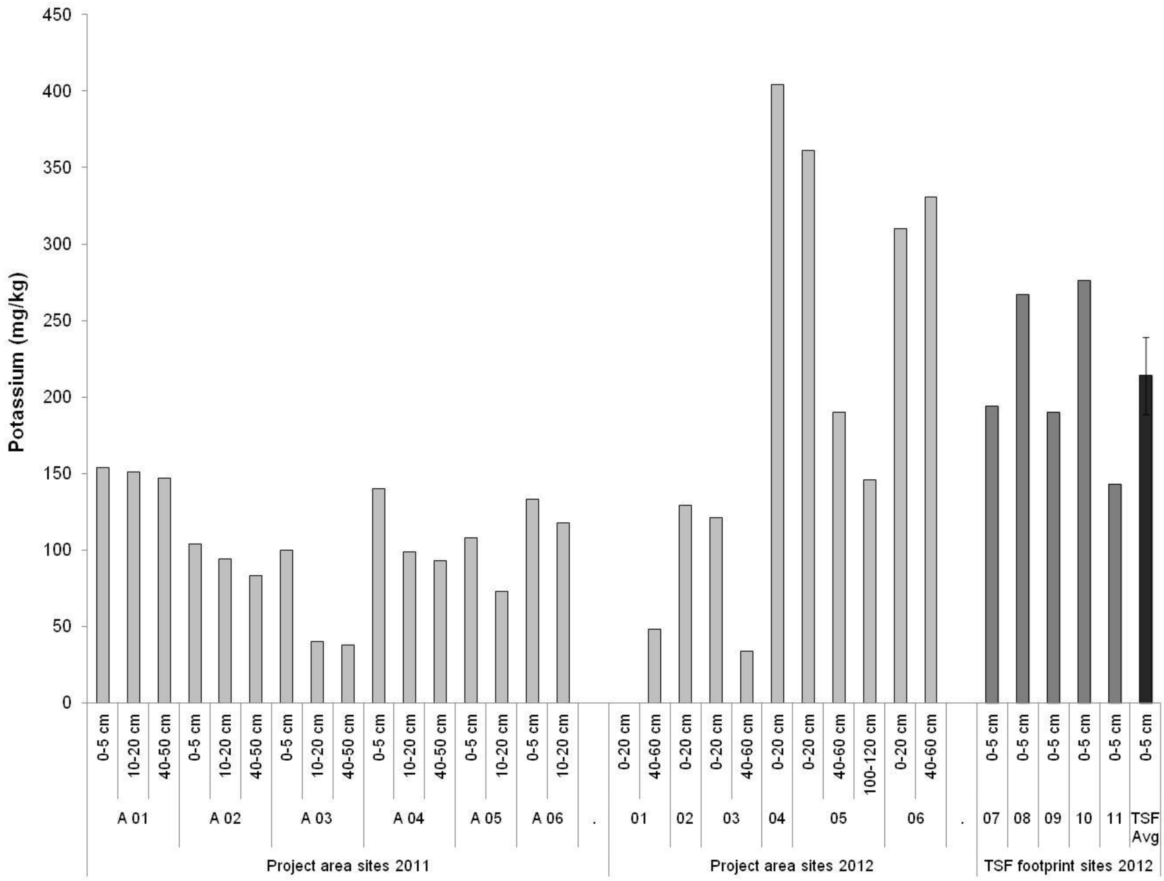


Figure 30: Individual plant-available potassium (K) (mg/kg) values for soils from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (error bars represent standard error)

3.4.5.4 Plant-available sulphur

Sulphur is a constituent of many protein enzymes that regulate activities such as photosynthesis and nitrogen fixation (Brady and Weil 2002). Symptoms of sulphur deficiency are similar to those associated with nitrogen deficiency. Plants deficient in sulphur tend to become spindly and develop thin stems and petioles. Plant growth will be slowed, and maturity may be delayed. The plants will also develop a light green or yellow appearance. Sulphur is relatively immobile in the plant, so chlorosis (light-green shading) develops first on the youngest leaves as sulphur supplies are gradually depleted (Brady and Weil 2002).

Plant-available sulphur concentration for the majority of the soils was below 20 mg/kg (**Figure 31**). Relatively high values were recorded (up to 1645.7 mg/kg) at Site A4 and Site 3.

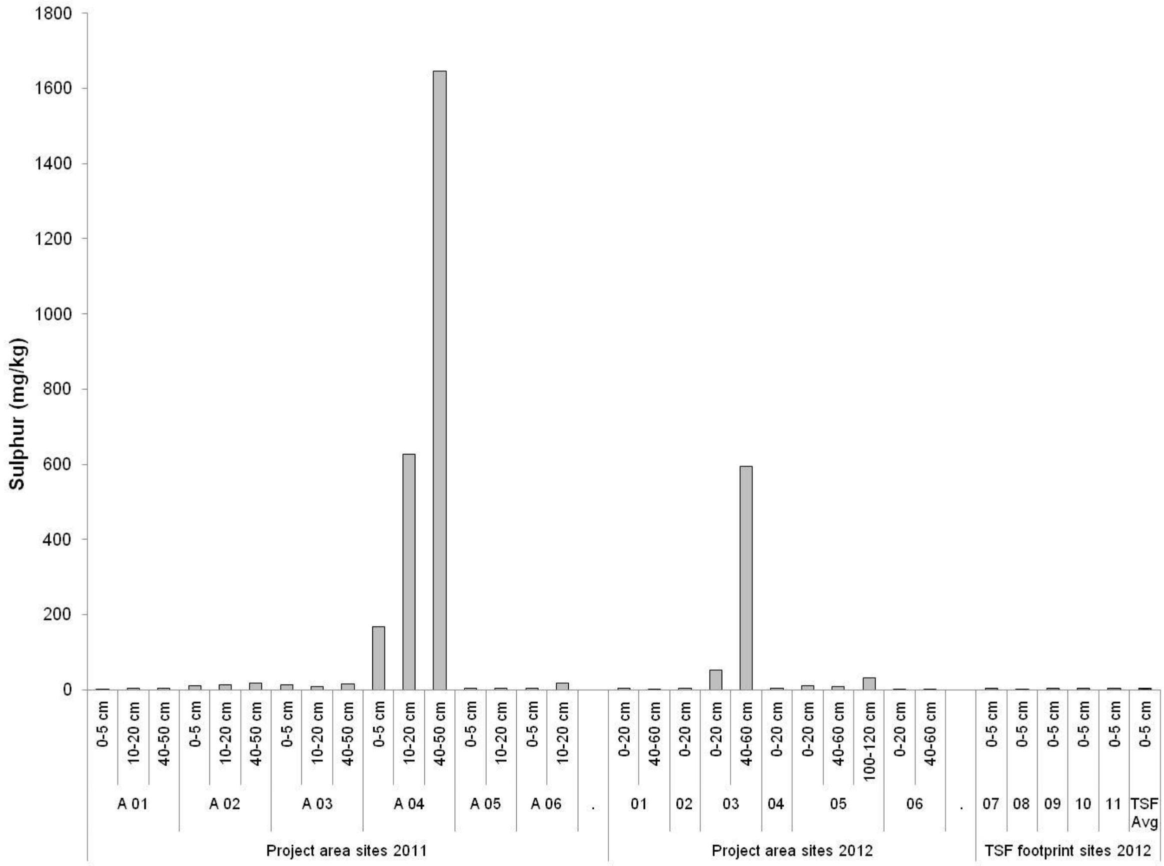


Figure 31: Individual plant-available sulphur (S) (mg/kg) values for soil samples from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (error bar represents standard error)

3.4.6 Total metal concentrations

Measurements of total metal concentrations of the soil samples indicated that variable levels of Cr, Cu, Ni, and Zn were present (**Table 12**). Most materials sampled were below the detectable limit of reporting (LOR) for As and Hg, and often below the LOR for Cd. Concentrations of Cr, Cu, Pb, Ni and Zn were regularly detected at a reportable level (**Table 12**).

All results were compared with 'Ecological Investigation Levels' (EILs) for soils (DEC 2010). The EILs are intended as a guide only, as higher EIL values may be acceptable for some metal concentrations, such as As, Cr, Cu, Ni, Pb and Zn, in areas where soils naturally have high background concentrations of these substances (DEC 2010). The levels of Cu, Ni and Zn were measured above the default EILs for soils (DEC 2010) in some samples from the Project area (**Table 12**).

Table 12: Individual total metal values (mg/kg) and limits of reporting (LOR) for soil samples from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites

Description	Site	Depth (cm)	Analyte (mg/kg)							
			Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Mercury
Project area soil 2011	Site A1	0-5	<5	**3**	**76**	**23**	**7**	**47**	**202**	<0.1
		40-50	<5	**3**	**93**	**32**	**12**	**73**	**262**	<0.1
	Site A2	0-5	<5	**2**	**83**	**30**	**22**	**27**	**39**	<0.1
		40-50	<5	**2**	**73**	**19**	**12**	**20**	**24**	<0.1
	Site A3	0-5	<5	**2**	**54**	**14**	**6**	**15**	**34**	<0.1
		40-50	<5	**2**	**56**	**18**	**7**	**31**	**43**	<0.1
	Site A4	0-5	<5	**2**	**73**	**32**	**8**	**42**	**52**	<0.1
		40-50	<5	<1	**39**	**30**	**5**	**40**	**44**	<0.1
	Site A5	0-5	<5	**1**	**71**	**21**	**23**	**19**	**46**	<0.1
	Site A6	0-5	<5	**2**	**186**	**32**	**8**	**44**	**58**	<0.1
Project area soil 2012	Site 1	0-20	<5	<1	**72**	**35**	**8**	**66**	**110**	<0.1
		40-60	<5	**1**	**56**	**24**	**9**	**52**	**110**	<0.1
	Site 2	0-20	<5	<1	**36**	**12**	**6**	**11**	**19**	<0.1
	Site 3	0-20	<5	<1	**41**	**19**	**10**	**30**	**73**	<0.1
		40-60	<5	<1	**15**	**10**	**7**	**16**	**63**	<0.1
	Site 4	0-20	<5	**2**	**528**	**383**	**18**	**141**	**172**	<0.1
	Site 5	0-20	<5	**1**	**131**	**119**	**12**	**65**	**260**	<0.1
		40-60	<5	<1	**88**	**110**	**7**	**39**	**59**	<0.1
		100-120	<5	<1	**76**	**106**	**7**	**33**	**59**	<0.1
	Site 6	0-20	<5	<1	**168**	**85**	**15**	**174**	**126**	<0.1
		40-60	<5	<1	**245**	**104**	**11**	**240**	**110**	<0.1
TSF Area B footprint soil 2012	Site 7	0-5	<5	<1	**18**	**41**	**5**	**12**	**71**	<0.1

Description	Site	Depth (cm)	Analyte (mg/kg)							
			Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Mercury
	Site 8	0-5	<5	<1	**29**	**13**	**5**	**12**	**26**	<0.1
TSF Area A footprint soil 2012	Site 9	0-5	<5	<1	**26**	**16**	**6**	**9**	**18**	<0.1
	Site 10	0-5	<5	<1	**17**	**6**	<5	**7**	**17**	<0.1
	Site 11	0-5	<5	<1	**20**	**10**	<5	**7**	**15**	<0.1
LOR (mg/kg)			**5**	**1**	**2**	**5**	**5**	**2**	**5**	**0.1**
EIL (mg/kg)			**20**	**3**	**1* / 400^**	**100**	**600**	**60**	**200**	**1**

Note: Values in bold indicate levels detected above Limits of Reporting (LOR), levels above the Ecological Investigation Levels (EIL) (DEC 2010) are highlighted in orange.
* = EIL for Chromium VI
^ = EIL for Chromium III

3.5 Soil chemical properties – Kangaroo Caves and Airstrip areas - 2013

3.5.1 Soil pH

There was a range of soil pH values recorded for the soils sampled from the Kangaroo Caves, Eastern and Air Strip area. Soil pH ($CaCl_2$) ranged from 'moderately acidic' (pH 4.8) to 'moderately alkaline' (pH 7.6) (**Figure 32**). Soil pH (H_2O) also ranged from 'moderately acidic' (pH 5.8) to 'moderately alkaline' (pH 8.4) (**Figure 33**). The 2011 and 2012 Project area samples, overall, had a greater range of soil pH values than the Kangaroo Caves, Eastern and Air Strip area samples.

The majority of the soil pH values were within the optimum range for plant growth of Pilbara plant species, with soil pH unlikely to be a limiting factor to successful vegetation growth of rehabilitated areas.

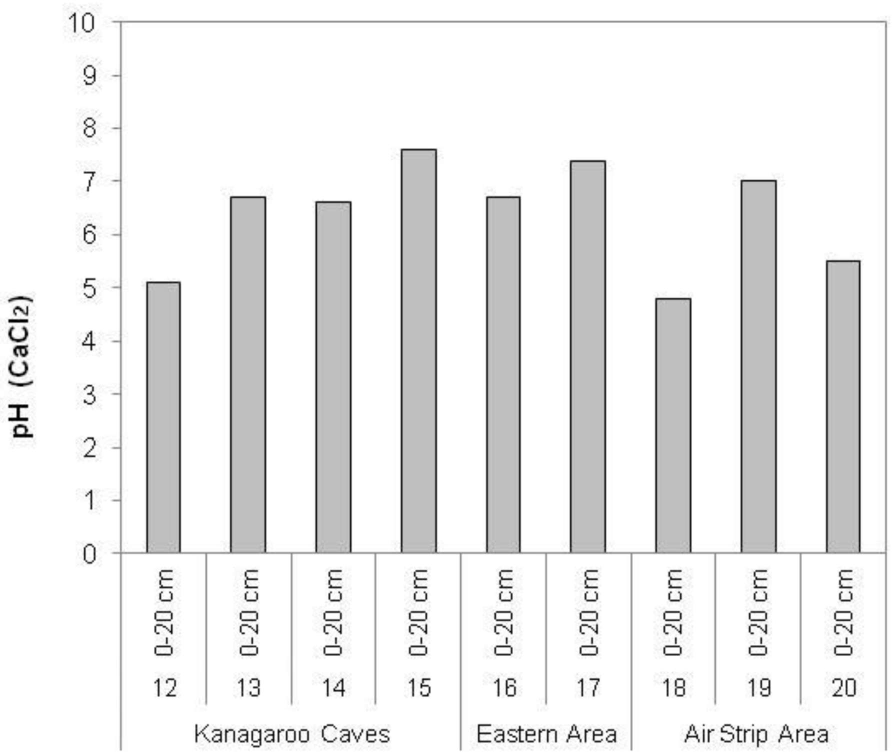


Figure 32: Individual soil pH ($CaCl_2$) values for soil samples from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area

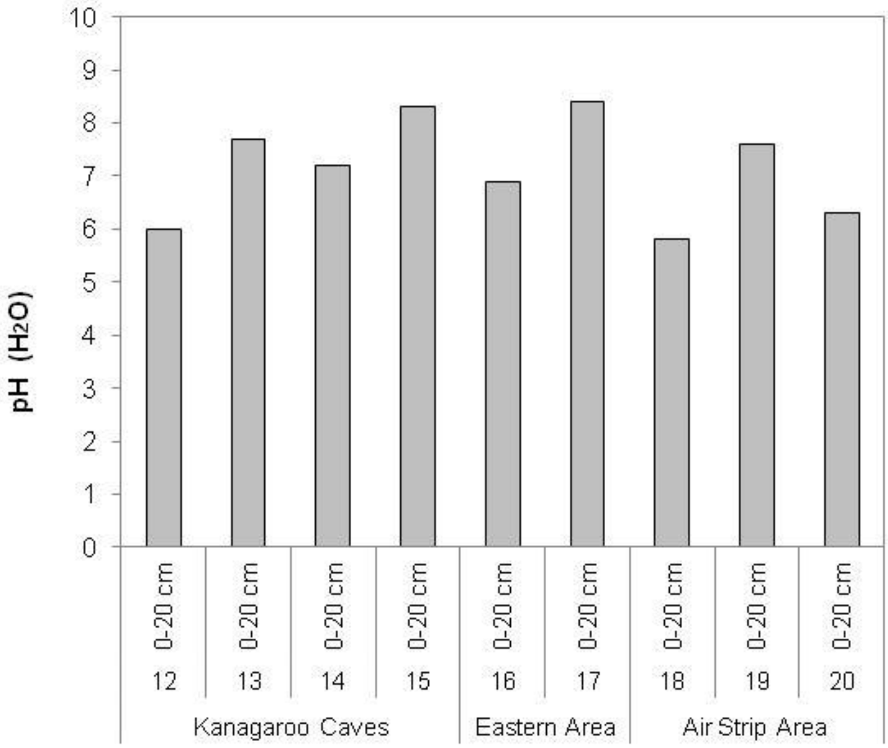


Figure 33: Individual soil pH (H_2O) values for soil samples from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area

3.5.2 Electrical conductivity

The EC values of the soils sampled from the Kangaroo Caves, Eastern and Air Strip area ranged from 0.017 to 0.142 dS/m (**Figure 34**), with all samples classified as 'non-saline' based on the standard USDA and CSIRO categories (**Appendix B**). The majority of the 2011 and 2012 Project area soils were also 'non-saline'.

The low EC values indicate that there is a very low risk of salinity related issues occurring if the soils are stripped, stockpiled and used as a surface rehabilitation medium.

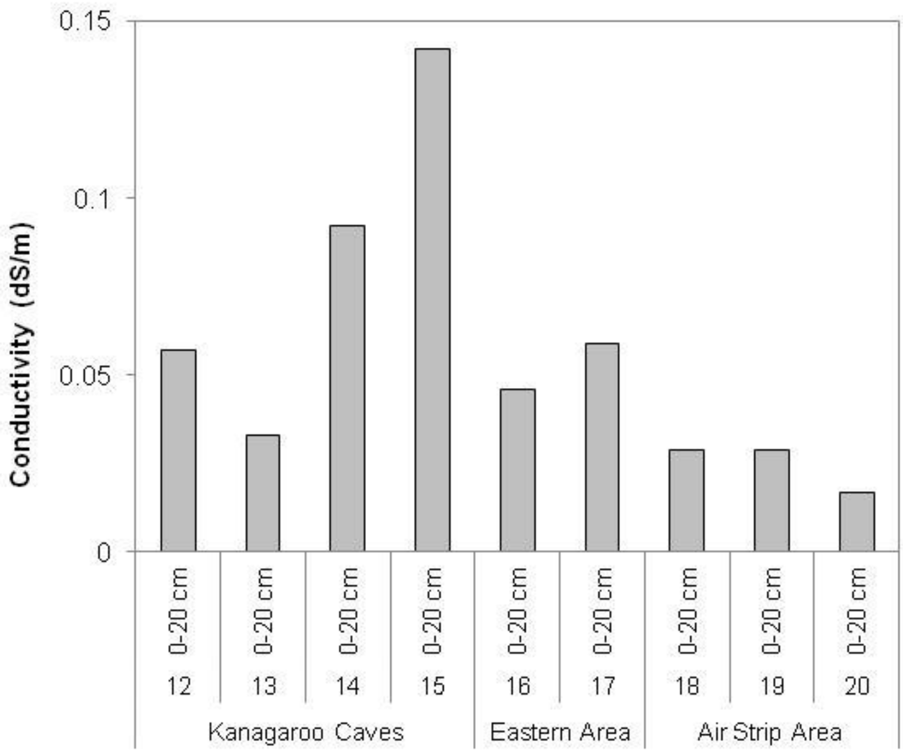


Figure 34: Individual electrical conductivity (EC 1:5 H_2O) values for soil samples from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area

3.5.3 Soil organic carbon

The SOC% within the majority of the Kangaroo Caves, Eastern and Air Strip area soils was low (<1% SOC) (Moore 1998), as is the case in most natural Western Australian arid land soils, with individual values ranging between 0.20% and 1.47% (**Figure 35**). The organic carbon percentage for the 2011 and 2012 Project area soils was, overall, lower than that of the Kangaroo Caves, Eastern and Air Strip area soils.

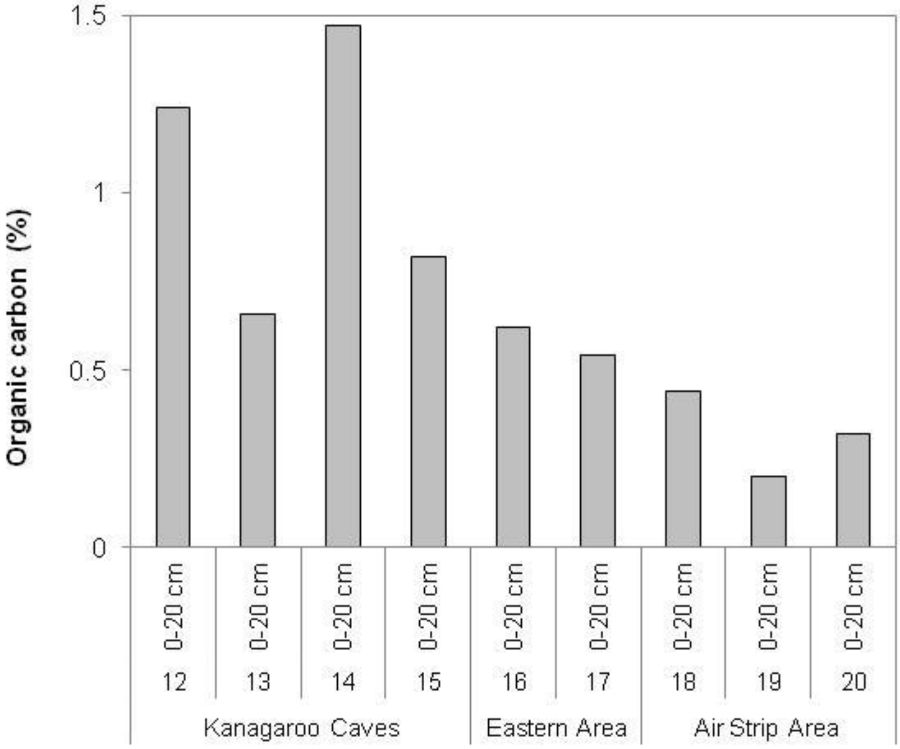


Figure 35: Individual soil organic carbon (%) values for soils from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area

3.5.4 Exchangeable cations and exchangeable sodium percentage (ESP)

All the soil samples (soil sized fraction) from within the Kangaroo Caves, Eastern and Air Strip area were classified as 'non-sodic' with exchangeable sodium values below the level of detection (**Table 13**). This indicates that the soils from the Kangaroo Caves, Eastern and Air Strip area are considered unlikely to be problematic from a clay dispersion and derived erodibility perspective. Care should be taken, however, to minimise the handling of the soil materials where possible, particularly when wet. The majority of the 2011 and 2012 Project area soils were also classified as 'non-sodic'.

Table 13: Individual exchangeable sodium percentage (ESP) (%) and effective cation exchange capacity (eCEC) values for the soil sized fraction (<2 mm) of the Kangaroo Caves, Eastern and Air Strip areas of the Project area surface soil samples

Description	Site	Depth (cm)	ESP (%)[1]	eCEC (meq/100g)
Kanagaroo Caves area soil 2013	SS12	0-20	BDL	3.09
	SS13	0-20	BDL	10.95
	SS14	0-20	BDL	12.07
	SS15	0-20	BDL	11.08
Eastern area soil 2013	SS16	0-20	BDL	10.34
	SS17	0-20	BDL	9.94
Air Strip area soil 2013	SS18	0-20	BDL	2.92
	SS19	0-20	BDL	5.19
	SS20	0-20	BDL	3.11

1. BDL: Exchangeable sodium below detection limit, assumed non-sodic.

3.5.5 Plant-available soil nutrients

3.5.5.1 Plant-available nitrogen

Plant-available nitrogen values from the Kangaroo Caves, Eastern and Air Strip area soils was ranged from low (4 mg/kg) to relatively high (29 mg/kg) (**Figure 36**). The majority of the 2011 and 2012 Project area soils exhibited low plant-available nitrogen values.

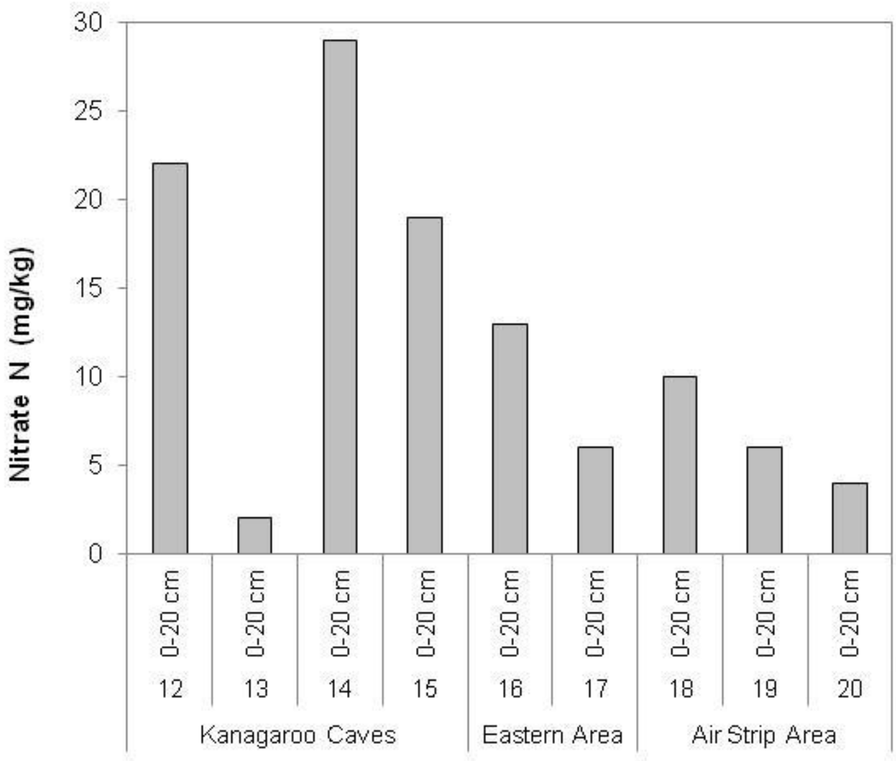


Figure 36: Individual plant-available nitrogen (nitrate N) (mg/kg) values for soils from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area

3.5.5.2 Plant-available phosphorus

Plant-available phosphorus for all samples from the Kangaroo Caves, Eastern and Air Strip area was classed as 'low' (<10 mg/kg) (Moore 1998) with individual concentrations ranging from 3 mg/kg to 6 mg/kg (**Figure 37**). The 2011 and 2012 Project area soils also exhibited low plant-available phosphorus values.

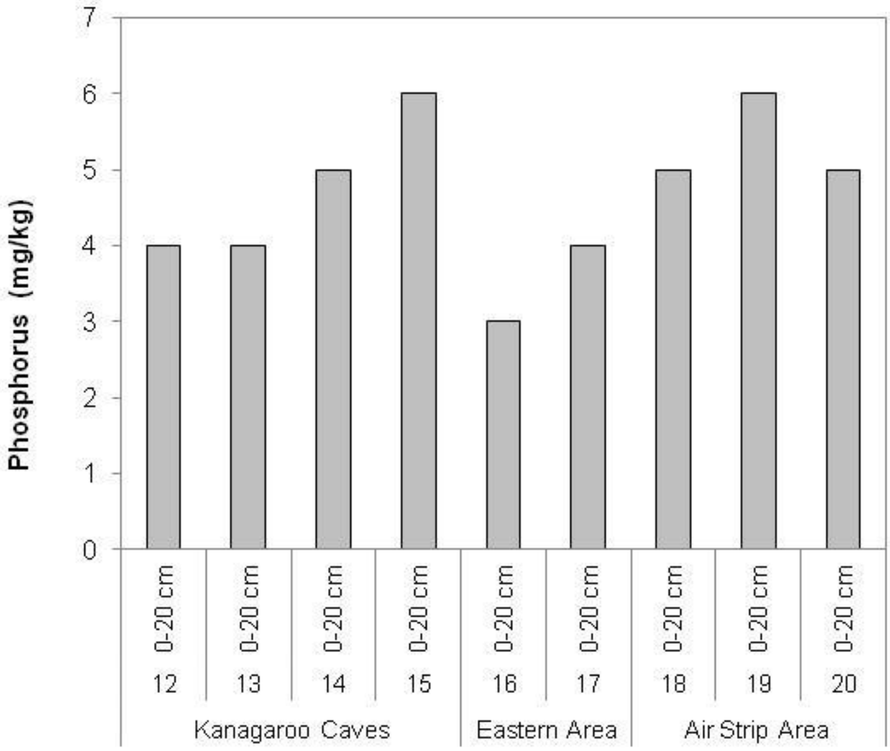


Figure 37: Individual plant-available phosphorus (P) (mg/kg) values for soil samples from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area

3.5.5.3 Plant-available potassium

Plant-available potassium within all soils sampled from the Kangaroo Caves, Eastern and Air Strip area was classed as 'high' (<200 mg/kg) (Moore 1998) ranging from 249 mg/kg to 553 mg/kg (**Figure 38**). The 2011 and 2012 Project area soils exhibited 'low' to 'high' plant-available potassium values.

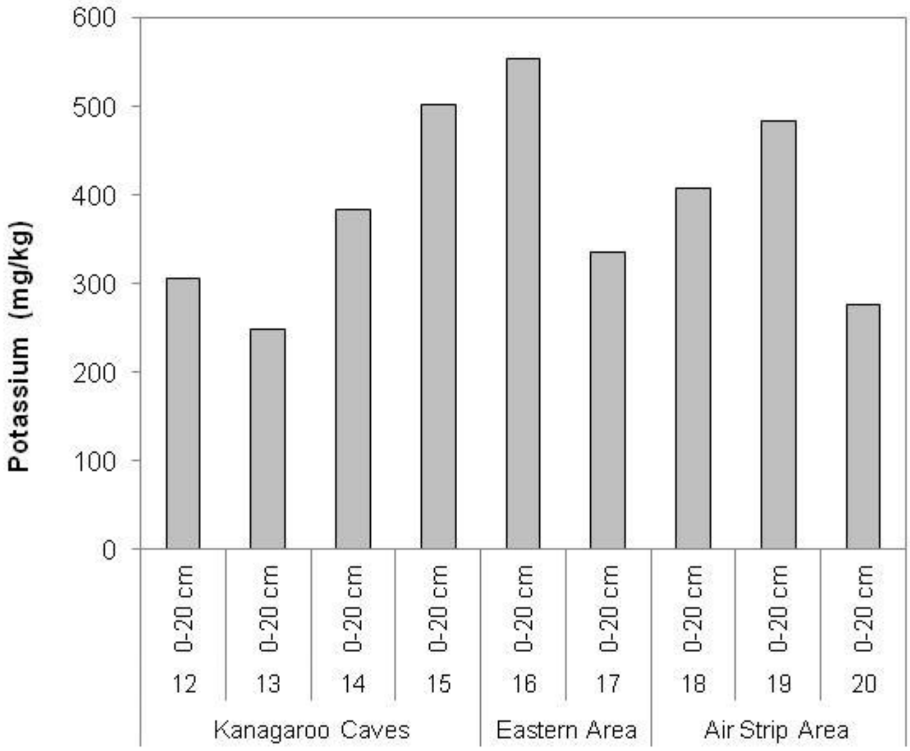


Figure 38: Individual plant-available potassium (K) (mg/kg) values for soils from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area

3.5.5.4 Plant-available sulphur

Plant-available sulphur concentrations of the Kangaroo Caves, Eastern and Air Strip area soils were below 14 mg/kg (**Figure 39**). The plant-available sulphur values for the majority of the 2011 and 2012 Project area soils were below 20 mg/kg.

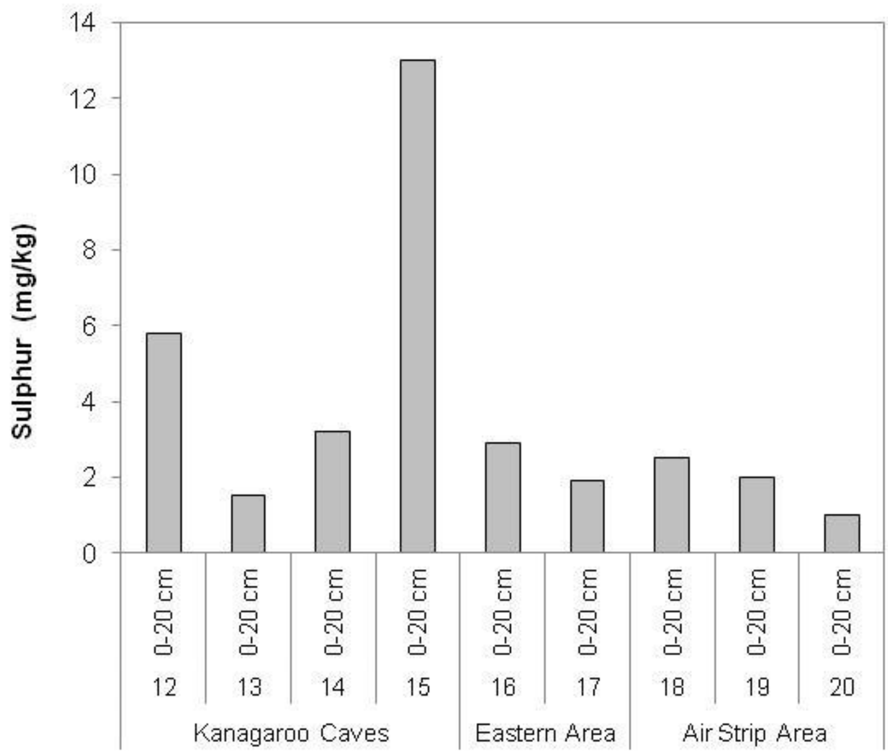


Figure 39: Individual plant-available sulphur (S) (mg/kg) values for soil samples from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area

3.5.6 Total metal concentrations

Measurements of total metal concentrations of the Kangaroo Caves and Air Strip area soil samples indicated that variable levels of Cr, Cu, Ni, and Zn were present (**Table 14**). Most materials sampled were below the detectable limit of reporting (LOR) for As, Cd and Hg, and often below the LOR for Pb. Concentrations of Cr, Cu, Ni, Pb and Zn were regularly detected at a reportable level (**Table 14**).

All results were compared with 'Ecological Investigation Levels' (EILs) for soils (DEC 2010). The EILs are intended as a guide only, as higher EIL values may be acceptable for some metal concentrations, such as As, Cr, Cu, Ni, Pb and Zn, in areas where soils naturally have high background concentrations of these substances (DEC 2010). The levels of Ni were measured above the default EILs for soils (DEC 2010) in the majority of samples from the Kangaroo Caves and Air Strip areas (**Table 14**).

Table 14: Individual total metal values (mg/kg) and limits of reporting (LOR) for soil samples from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area

Description	Site	Depth (cm)	Analyte (mg/kg)							
			Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Mercury
Kangaroo Caves area soil 2013	SS12	0-20	<5	<1	**128**	**20**	**6**	**52**	**42**	<0.1
	SS13	0-20	<5	<1	**211**	**45**	<5	**171**	**129**	<0.1
	SS14	0-20	**7**	<1	**454**	**56**	<5	**243**	**127**	<0.1
	SS15	0-20	<5	<1	**266**	**42**	<5	**195**	**130**	<0.1
Eastern area soil 2013	SS16	0-20	<5	<1	**279**	**40**	<5	**190**	**142**	<0.1
	SS17	0-20	<5	<1	**399**	**45**	<5	**192**	**54**	<0.1
Air Strip area soil 2013	SS18	0-20	<5	<1	**127**	**50**	**9**	**60**	**50**	<0.1
	SS19	0-20	<5	<1	**137**	**65**	**6**	**112**	**97**	<0.1
	SS20	0-20	<5	<1	**106**	**30**	**6**	**51**	**34**	<0.1
LOR (mg/kg)			**5**	**1**	**2**	**5**	**5**	**2**	**5**	**0.1**
EIL (mg/kg)			**20**	**3**	**1* / 400^**	**100**	**600**	**60**	**200**	**1**

Note: Values in bold indicate levels detected above Limits of Reporting (LOR), levels above the Ecological Investigation Levels (EIL) (DEC 2010) are highlighted in orange.
* = EIL for Chromium VI
^ = EIL for Chromium III

4. SOIL RESOURCE INVENTORY

An inventory of potentially available soil resources has been calculated from the approximate soil depth and spatial 'soil area' information supplied by Venturex personnel (**Table 15**).

The volume of soil associated with Site 5 (2012) has been removed from the soil resources inventory as the site occurs over a locally significant vegetation association (Outback Ecology 2013) and is also within close proximity of a short range endemic species pseudoscorpion *Feaella* PSE007 (Outback Ecology 2012).

Table 15: Potential soil resources available within the Sulphur Springs Copper Zinc Project area

Description	Site	Approx. soil depth (m) [1]	Potential area of soil resources (m^2) [2]	Approximate volume of soil resources available (m^3) [3]
Project area soil 2012	Site 1	0.7	44,919	31,443
	Site 2	0.4	52,828	21,131
	Site 3	1.0	15,013	15,013
	Site 4	0.4	16,299	6,520
	Site 5 *	1.2	18,693	-
	Site 6	1.0	16,755	16,755
TSF Area B soil 2012	Sites 7, 8	0.05	47,592	2,356
TSF Area A soil 2012	Sites 9, 10, 11	0.05	159,055	7,952
Kangaroo Caves area soil 2013	Site 12	0.3	47,592	14,278
	Site 13	0.3	48,511	14,553
	Site 14	0.5	33,940	16,970
	Site 15	0.5	20,347	10,174
Eastern area soil 2013	Site 16	0.7	no data	no data
	Site 17	0.7	no data	no data
Air Strip area soil 2013	Site 18	0.4	57,420	22,968
	Site 19	2.0	157,731	315,462
	Site 20	2.5	1,206,232	3,015,579
TOTAL				**3,511,155**

1. Approximate depth of soil data supplied by Venturex personnel
2. Approximate area of soil as delineated in Figures 6, 7 & 8 (information supplied by Venturex)
3. Calculated from approximate depth of soil indicated

* Site 5 soil volume removed from inventory due to location in a sensitive area

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of soil characteristics

This section provides a summary of the characteristics of potential soil resources within the Sulphur Springs Copper Zinc Project area.

The physical and chemical characteristics of the 2011 and 2012 project area surface soils were:

- Soil textures ranging from ‘loamy sand’ to ‘sandy clay’ (5% to 29% clay);
- approximately 28% to 81% coarse material (>2 mm) with the majority >50%;
- ‘stable’ to ‘moderately stable’ from a structural stability perspective, although some partially dispersive soils identified;
- potentially hardsetting soils;
- predominantly ‘moderate’ to ‘moderately rapid’ drainage class;
- low water retention capacity;
- predominantly ‘non-saline’;
- ‘moderately acidic’ to ‘strongly alkaline’ pH;
- mostly “non-sodic”;
- predominantly ‘low’ organic carbon percentage;
- variable concentrations of plant-available nutrients (typical of regional soils); and
- variable concentrations of total metals (typical of regional soils).

The physical and chemical characteristics of the Kangaroo Caves, Eastern and Air Strip area surface soils were:

- Soil textures were all ‘sandy loam’ (13% to 15% clay);
- approximately 11% to 47% coarse material (>2 mm)
- ‘stable’ to ‘moderately stable’ from a structural stability perspective, although some partially dispersive soils identified;
- non-hardsetting soils;
- predominantly ‘moderate’ to ‘moderately rapid’ drainage class;
- low to medium water retention capacity;
- predominantly ‘non-saline’;
- ‘moderately acidic’ to ‘strongly alkaline’ pH;
- mostly “non-sodic”;
- predominantly ‘low’ organic carbon percentage;
- variable concentrations of plant-available nutrients (typical of regional soils); and
- variable concentrations of total metals (typical of regional soils).

The investigations into the soil resources present within the Project area indicates that, while there is substantial variation in many of the physical and chemical characteristics of the soils present, the majority are likely to be suitable for use as a component of the TSF cover / rehabilitation medium.

5.2 Use of soil resources as a component of the TSF cover

The proposed TSF cover design will incorporate a clay sealing layer above the compacted, dry-stacked tailings, a soil 'water storage' layer of and an outer 'erosion resistant' layer of rocky soil. The outer surface of the cover will be sloped to promote runoff of surface water during high intensity rainfall events.

Of primary interest to the Project is the availability of suitable soil materials for use as the store-release component of the proposed TSF cover system. The soil store-release layer of the TSF cover will need to be capable of holding water from the majority of rainfall events and resilient enough to shed water from high intensity rainfall events. The soil store-release component will also need to support the growth of native vegetation which will assist in the release of stored water, as will evaporation from the outer surface. The key characteristics of the soils are therefore their ability to accept and store rainfall, resist erosion by surface water flow and support vegetation.

The high coarse fragment content of the majority of soils from the 2011 and 2012 Project area, in combination with the 'moderate' to 'moderately rapid' drainage class and low levels of clay dispersion, indicate that the majority of these soils should be relatively resistant to erosion, provided that surface water flow is not concentrated in any areas of the surface cover. The water retention characteristics of these soils indicate that, assuming homogenous infiltration and water storage (i.e. no preferential flow), the soils have a USL, on average, of approximately 15% (by volume). This means that a 1.0 m depth of soil will hold approximately 150 mm of rainfall. These characteristics make the 2011 and 2012 Project area soils potentially suitable as an outer 'erosion resistant' soil cover layer.

In contrast, the Kangaroo Caves, Eastern and Air Strip area soils have a lower percentage of coarse rock, indicating they are likely to be more prone to erosion. These soils have a USL, on average, of approximately 23% (by volume). This means that a 1.0 m depth of soil will hold approximately 230 mm of rainfall. These characteristics make the Kangaroo Caves, Eastern and Air Strip area soils potentially suitable as a soil water storage layer situated below the outer, more rocky soils.

Regional rainfall data indicates that the 1 in 100 year 72 hour rainfall event is 379 mm (BoM 2012). A depth of soil for the outer rocky soil cover has been indicated as 1.0 m which, based on a USL of 15%, would hold approximately 150 mm of rainfall. In addition, a depth of soil for the water storage layer soil has been indicated as 3.0 m, which, based on a USL of 23%, would hold approximately 690 mm of rainfall. This assumes homogenous infiltration of rainfall, a negligible amount of existing water storage in the soil materials and no surface run-off. As the TSF cover will be designed to shed any rainfall which falls at a rate greater than the infiltration capacity of the surface soil materials, the indication of the required depth of soil is likely to be adequate.

Current data, supplied by Venturex personnel, indicates that further volumes of, as yet, unassessed soil materials within the Airstrip area. These soil resources may potentially provide a source of material suitable or the clay sealing component of the TSF cover. This will require further investigation as the Project develops.

The volume of soil materials which would potentially be required for the TSF covers at closure is detailed in **Table 16**. The data presented is for a 3.0 m depth of soil cover for each TSF.

Table 16: Volume of soil potentially required for rehabilitation and closure of the Sulphur Springs Copper Zinc Project TSF areas

Rehabilitation area	Surface area (m^2)	Volume of soil required for 3.0 m cover depth (m^3)
TSF Area A		
Upper surface	111,131	333,392
Sloped surface	47,924	143,771
TSF Area B		
Upper surface	34,175	102,526
Sloped surface	12,939	38,816
	Total	**618,505**

The current soil resources inventory for the Project area has identified an available volume of soil in the vicinity of 3,511,155 m^3 (**Section 4**), based on information supplied by Venturex personnel. There is therefore a surplus in the currently identified available soil resources required for the final cover, rehabilitation and closure of the TSFs.

5.3 Recommendations for further investigations

It is likely that further investigations will be required to potentially refine the proposed TSF cover design, rehabilitation protocols and associated mine closure criteria. Recommendations for further investigations include:

- further identification of a suitable source of clay materials, for the clay sealing layer, and geochemical assessment of the compacted permeability of those materials;
- identification of a suitable source of clean competent rock to enhance the armouring capacity and outer stability of the TSF cover;
- modelling of water balance of the TSF cover, expected runoff, drainage and sediment loss; and

- a commitment to establishment of field trials of TSF cover components, including evaluation of water storage capacity, erodibility and rehabilitation parameters (**Section 5.4** below).

A conceptual design of the field trials could be established to demonstrate a commitment to evaluation of TSF cover options.

5.4 Potential TSF cover field trial parameters

Potential cover parameters to be investigated at a 'field scale' could include:

- water infiltration and store-release characteristics of available soil cover materials;
- erodibility of outer layer soil / rock combinations;
- effectiveness of cover material combinations in reducing infiltration of water into underlying materials; and
- ability of outer soil cover materials to support vegetation growth.

The field trial would have to be established at a suitably large scale (i.e. over several hectares) to identify 'realistic' information on water storage and erodibility parameters. The cover treatments could be established on an existing slope, with monitoring of the soil water content (via sensors / loggers) through the constructed cover profiles, and surface soil loss (i.e. erodibility) from each treatment combination. The trial should be conducted for a number of years, to take as many climatic variables as possible into consideration.

6. REFERENCES

Aylmore, L. A. G. and Sills, I. D. (1982) Characterisation of soil structure and stability using modulus of rupture – ESP relationships. *Australian Journal of Soil Research* 62: 213-224.

Blair, G. J., Chinoim, N., Lefroy, R. D. B., Anderson, G. C. and Crocker, G. J. (1991) A soil sulphur test for pastures and crops. *Australian Journal of Soil Research* 29: 619-626.

BOM: Bureau of Meteorology. (2012) *Climate Data Online.* Available online at http://www.bom.gov.au/climate/data/?ref=ftr. Accessed on 26 October 2012.

Brady, N. and Weil, R. 2002, *The Nature and Properties of Soils - Thirteenth Edition*, Prentice Hall, Upper Saddle River, New Jersey.

Cochrane, H. R. and Aylmore, L. A. G. (1997) *Assessing management induced changes in the structural stability of hardsetting soils*. *Soil & Tillage Research*.

Colwell, J. D. (1965) An automated procedure for the determination of phosphorus in sodium hydrogen carbonate extracts of soils. *Chemistry and Industry* May: 893-895.

Day, P.R. (1965) Particle fraction and particle-size analysis. Methods of soil analysis, Part 1. *Agronomy* 9:545-567.

Department of Environment and Conservation (DEC) (2010). Assessment Levels for Soil, Sediment and Water. Contaminated Sites Management Series. Version 4, Revision 1, February 2010.

Department of Resources, Energy and Tourism (DRET) (2006) *Leading Practice Sustainable Development Program for the Mining Industry; A Guide to Leading Practice Sustainable Development in Mining.* Australian Centre for Sustainable Mining Practices, July 2011.

Department of Mines and Petroleum (DMP) formerly Department of Industry and Resources (DoIR) (2006) *Guidelines for Mining Proposals in Western Australia.* February 2006

Harper, R. J. and Gilkes, R. J. (1994) Hardsetting in the Surface Horizons of Sandy Soils and its Implications for Soil Classification and Management. *Australian Journal of Soil Research*.

Hazelton, P. and Murphy, B. (2007) *Interpreting soil test results, what do all the numbers mean?* NSW Department of Natural Resources. CSIRO Publishing, Collingwood, Victoria.

Hunt, N. and Gilkes, R. (1992) *Farm monitoring handbook, a practical down-to-earth manual for farmers and other land users.* The University of Western Australia, Perth.

How, R., Dell, J. and Cooper, N. K. (1991) Ecological Survey of Abydos-Woodstock Reserve, Western Australia: Vertebrate Fauna. *Records of the Western Australia Museum Supplement* 37: 78-125.

Leighton, K. A. (2004) Climate. In: A.M.E. van Vreeswyk, A.L. Payne, K.A.Leighton and P.Hennig (eds) *An Inventory and Condition Survey of the Pilbara Region, Western Australia*. Technical Bulletin No. 92, Western Australia Department of Agriculture, Perth, W.A.

Lindsay, W. L. and Norvell, W. A. (1978) Development of DTPA test for zinc, iron, manganese, and copper. Soil Sci. Soc. Amer. J. 41:421-428.

McDonald, R. C., Isbell, R. F., Speight, J. G., Walker, J. and Hopkins, M. S. (1998) *Australian soil and land survey - field handbook.* CSIRO Land and Water, Canberra.

McKenzie, N., Coughlan, K. and Cresswell, H. (2002) *Soil physical measurement and interpretation for land evaluation.* CSIRO Publishing, Canberra.

Moore, G. (1998) *Soilguide.* A handbook for understanding and managing agricultural soils, Agriculture Western Australia. Bulletin No. 4343.

Needham, P., Moore, G. and Scholz., G. (1998) Soil structure decline. In: G. Moore (ed) *Soil guide - a handbook for understanding and managing agricultural soils*, vol Bulletin No. 4343. Agriculture Western Australia, Perth, Western Australia, pp 64 - 79

Outback Ecology. (2012) Sulphur Springs Copper Zinc Project Targeted Terrestrial SRE Invertebrate Fauna Assessment. Report prepared for Venturex Resources Limited. November 2012.

Outback Ecology. (2013) Pilbara Copper Zinc Project Level 1 Vegetation and Flora Survey, Report prepared for Venturex Resources Limited, Perth, Western Australia. December 2012.

Peverill, K. I., Sparrow, L. A. and Reuter, D.J. (1999) Soil analysis: an interpretation manual. CSIRO Publishing, Collingwood, Australia.

Rayment, G. E. and Higginson, F. R. (1992) *Australian Laboratory Handbook of Soil and Chemical Methods.* Inkata Press,

Scarle, P. L. (1984) *Analyst* 109: 549-568.

Schwertmann, U. (1993) Relations between iron oxides, soil colour and soil formation. *Soil Science Society of America Special Publication* 31: 51-71.

Shen, Y.W. and Jasper, D. A. (2002) Defining soil properties for revegetation of iron ore tailings in the Pilbara region of Western Australia. Metallurgical Mine Tailings Rehabilitation, Attachment 5 - Research Report by Y. W. Shen and D. A. Jasper. Australian Centre for Geomechanics.

Van Gool, D., Tille, P. and Moore, G. (2005) Land evaluation standards for land resource mapping. Third edition. Resource Management Technical Report 298, December 2005. Department of Agriculture, Western Australia.

Van Vreeswyk, A. M. E., Payne, A. L., Leighton, K. A. and Hennig, P. (2004) *An Inventory and Condition Survey of the Pilbara Region of Western Australia.* WA Department of Agriculture Technical Bulletin No, 92.,

Walkley, A. and Black, I. A. (1934) An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic and titration method. *Soil Science* 37: 29-38.

Appendix A

Glossary of terms

Glossary of terms

Aggregate (or ped)	A cluster of primary particles separated from adjoining peds by natural planes of weakness, voids (cracks) or cutans.
Bulk density	Mass per unit volume of undisturbed soil, dried to a constant weight at 105°C.
Clay	The fraction of mineral soil finer than 0.002 mm (2 µm).
Coarse fragments	Particles greater than 2 mm in size.
Consistence	The strength of cohesion and adhesion in soil.
Dispersion	The process whereby the structure or aggregation of the soil is destroyed, breaking down into primary particles.
Electrical conductivity	How well a soil conducts an electrical charge, related closely to the salinity of a soil.
Hydrophobicity	Description of hydrophobic or water repellent characteristics in soil. Primarily caused by hydrophobic organic residues derived from decomposing plant materials, which alter the contact angle between water droplets and the soil surface, in turn affecting the ability of water to infiltrate into the soil.
Massive soil structure	Coherent soil, no soil structure, separates into fragments when displaced. Large force often required to break soil matrix.
Modulus of Rupture (MOR)	This test is a measure of soil strength and identifies the tendency of a soil to hard-set as a direct result of soil slaking and dispersion.
Organic carbon	Carbon residue retained by the soil in humus form. Can influence many physical, chemical and biological soil properties. Synonymous with organic matter (OM).
Plant-available water	The ability of a soil to hold that part of the water that can be absorbed by plant roots. Available water is the difference between field capacity and permanent wilting point.

Regolith	The unconsolidated rock and weathered material above bedrock, including weathered sediments, saprolites, organic accumulations, soil, colluvium, alluvium and aeolian deposits.
Single grain structure	Loose, incoherent mass of individual particles. Soil separates into individual particles when displaced.
Slaking	The partial breakdown of soil aggregates in water due to the swelling of clay and the expulsion of air from pore spaces.
Soil horizon	Relatively uniform materials that extend laterally, continuously or discontinuously throughout the profile, running approximately parallel to the surface of the ground and differs from the related horizons in chemical, physical or biological properties.
Soil pH	The negative logarithm of the hydrogen ion concentration of a soil solution. The degree of acidity or alkalinity of a soil expressed in terms of the pH scale, from 2 to 10.
Soil structure	The distinctness, size, shape and arrangement of soil aggregates (or peds) and voids within a soil profile. Can be classed as *'apedal'*, having no observable peds, or *'pedal'*, having observable peds.
Soil strength	The resistance of a soil to breaking or deformation. '*Hardsetting'* refers to a high soil strength upon drying.
Soil texture	The size distribution of individual particles of a soil.
Subsoil	The layer of soil below the topsoil or A horizons, often of finer texture (i.e. more clayey), denser and stronger in colour. Generally considered to be the 'B-horizon' above partially weathered or un-weathered material.
Topsoil	Soil consisting of various mixtures of sand, silt, clay and organic matter; considered to be the nutrient-rich top layer of soil – The 'A-horizon'.

Appendix B

Outback Ecology soil analysis methods

Soil texturing

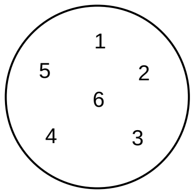
Soils were worked by hand, and the texture, shearing capacity, particle size and ribbon length were observed according to methods described in McDonald *et al.* (1998) as follows.

Texture grade	Behaviour of moist bolus	Approximate clay content	Code
Sand	Nil to very slight coherence; cannot be moulded; single sand grains adhere to fingers	<5 %	S
Loamy sand	Slight coherence; can be sheared between thumb and forefinger to give minimal ribbon of about 5 mm	5 %	LS
Clayey sand	Slight coherence; sticky when wet; many sand grains stick to fingers; discolours fingers with stain; forms minimal ribbon of 5 – 15 mm	5 - 10 %	CS
Sandy loam	Bolus coherent but very sandy to touch; dominant sand grains of medium size and readily visible ; ribbon of 15 – 25 mm	10 – 20 %	SL
Loam	Bolus coherent and rather spongy; no obvious sandiness or silkiness; forms ribbon of about 25 mm	25 %	L
Sandy clay loam	Strongly coherent bolus; sandy to touch; ribbon of 25 – 40 mm	20 - 30 %	SCL
Clay loam	Coherent plastic bolus, smooth to touch, ribbon of 25 mm to 40 mm	30 – 35 %	CL
Clay loam, sandy	Coherent plastic bolus, sand grains visible in finer matrix, ribbon of 40 - 50 mm; sandy to touch	30 - 35 %	CLS
Light clay	Plastic bolus, smooth to touch; slight resistance to shearing; ribbon of 50 – 75 mm	35 – 40 %	LC
Light medium clay	Ribbon of about 75 mm, slight to moderate resistance to ribboning shear	40 - 45 %	LMC
Medium clay	Smooth plastic bolus, handles like plasticine and can be moulded into rods without fracture; moderate resistance to ribboning shear, ribbon of 75 mm or longer	45 – 55 %	MC
Medium heavy clay	Ribbon of 75 mm or longer, handles like plasticine, moderate to firm resistance to ribboning shear	>50 %	MHC
Heavy clay	Handles like stiff plasticine; firm resistance to ribboning shear, ribbon of 75 mm or longer	>50 %	HC

Emerson dispersion test

Emerson dispersion tests were carried out on all samples according to the following procedure:

1. A petri dish was labelled 1 to 6. eg.



2. The petri dish was filled with DI water.
3. A 3-5mm soil aggregate is taken from each sample and gently placed into the labelled petri dish (3 per dish).
4. Additional aggregates, remoulded by hand, are placed into the labelled petri dish (3 per dish).
5. Observations are made of the dispersivity or slaking nature of the sample according to the following table:

Emerson Aggregate test classes (Moore 1998)

Class	Description
Class 1	Dry aggregate slakes and completely disperses
Class 2	Dry aggregate slakes and partly disperses
Class 3a	Dry aggregate slakes but does not disperse; remoulded soil disperses completely
Class 3b	Dry aggregate slakes but does not disperse; remoulded soil partly disperses
Class 4	Dry aggregate slakes but does not disperse; remoulded soil does not disperse; carbonates and gypsum are present
Class 5	Dry aggregate slakes but does not disperse; remoulded soil does not disperse; carbonates and gypsum are absent; 1:5 suspension remains dispersed
Class 6	Dry aggregate slakes but does not disperse; remoulded soil does not disperse; carbonates and gypsum are absent; 1:5 suspension remains flocculated
Class 7	Dry aggregate does not slake; aggregate swells
Class 8	Dry aggregate does not slake; aggregate does not swell

The samples were left in the dish for a 24 hour period, after which the samples were observed again and rated according to the above Table.

Soil electrical conductivity classes

(Based on standard USDA and CSIRO categories)

EC (1:5) (dS/m)						
Salinity class	**Sand**	**Sandy loam**	**Loam**	**Clay loam**	**Light / medium clay**	**Heavy clay**
Non-saline	<0.13	<0.17	<0.20	<0.22	<0.25	<0.33
Slightly saline	0.13-0.26	0.17-0.33	0.20-0.40	0.22-0.44	0.25-0.50	0.33-0.67
Moderately saline	0.26-0.52	0.33-0.67	0.40-0.80	0.44-0.89	0.50-1.00	0.67-1.33
Very saline	0.52-1.06	0.67-1.33	0.80-1.60	0.89-1.78	1.00-2.00	1.33-2.67
Extremely saline	>1.06	>1.33	>1.60	>1.78	>2.00	>2.67

Root abundance scoring

Root abundance is scored on a visual basis within the categories defined by McDonald *et al.* 1998:

Score	Roots per 10 cm^2	
	Very fine and fine roots	*Medium and coarse roots*
0 – No roots	0	0
1 – Few	1 - 10	1 or 2
2 – Common	10 - 25	2 – 5
3 – Many	25 - 200	>5
4 - Abundant	>200	>5

General soil pH ratings

These ratings area based on the Land Evaluation Standards for Land Resource Mapping categories, (Van Gool *et. al*. 2005).

The pH of a soil measures its acidity or alkalinity. The standard method for measuring pH in WA is 1:5 0.01M $CaCl_2$ (pH_{Ca}). However, in most land resource surveys it has been measured in a 1:5 soil:water suspension (pH_w). It is preferable to record actual data rather than derived data, therefore pH should be recorded according to the method used. The pH measured using different methods should not be compared directly for site investigations. For general land interpretation purposes, the relationship between pH_w and pH_{Ca} can be estimated by the equation:

$$pH_{Ca} = 1.04\ pH_w - 1.28$$ (Van Gool *et. al*. 2005)

The most widely available pH measurement is for the surface layer. However, the pH of the topsoil varies dramatically, and based on a comparison of map unit and soil profile data, estimated mean values for topsoil pH is commonly underestimated. Hence it is suggested that only an estimate of subsoil pH should be attempted. Even for subsoil the value can only be used as an indicator because pH varies dramatically with land use and minor soil variations.

Soil depth

The pH should be recorded for each soil group layer. It is then reported at the following predefined depths:

- 0 - 10 cm (the surface layer);
- 20 cm (used for assessing subsoil acidity); and
- 50 - 80 cm. If there is a layer boundary within this depth use the higher value (used for assessing subsoil alkalinity).

	Soil pH rating						
	Very strongly acid (Vsac)	Strongly acid (Sac)	Moderately acid (Mac)	Slightly acid (Slac)	Neutral (N)	Moderately alkaline (Malk)	Strongly alkaline (Salk)
pH_w	< 5.3	5.3 - 5.6	5.6 - 6.0	6.0 - 6.5	6.5 - 8.0	8.0 - 9.0	> 9.0
pH_{Ca}	< 4.2	4.2 - 4.5	4.5 - 5.0	5.0 - 5.5	5.5 - 7.0	7.0 - 8.0	> 8.0

Appendix C

Outback Ecology soil analysis results

Summary of Outback Ecology results for hand texture, coarse fraction content, Emerson Class and soil strength (Modulus of Rupture)

Description	Site	Sample depth interval (cm)	Hand texture (<2 mm fraction)	% Coarse material (>2 mm)	Emerson Test Class	MOR (kPa)
Project area soil 2011	Site A1	0-5	Clayey sand	67	3b	52.9
		10-20	Clayey sand	81	3b	72.3
		40-50	Clayey sand	75	3b	111.5
	Site A2	0-5	Clayey sand	63	5	44.6
		10-20	Clayey sand	77	6	36.6
		40-50	Clayey sand	71	6	33.5
	Site A3	0-5	Clayey sand	70	2	68.8
		10-20	Clayey sand	71	2	115.1
		40-50	Clayey sand	71	2	146.7
	Site A4	0-5	Sandy clay loam	67	2	126.8
		10-20	Clay loam	58	6	130.2
		40-50	Sandy loam	43	6	42.2
	Site A5	0-5	Sandy loam	65	3b	57.5
		10-20	Sandy loam	59	d	87.2
	Site A6	0-5	Loam	49	5	23.0
		10-20	Sandy clay loam	69	5	72.9
Project area soil 2012	Site 1	0-20	Sandy clay loam	60	8	52.5
		40-60	Clay loam sandy	56	4	63.7
	Site 2	0-20	Sandy clay loam	76	3b	81.9
	Site 3	0-20	Clay loam sandy	73	8	194.3
		40-60	Light clay	28	2	394.5
	Site 4	0-20	Light clay	57	3a	76.2
	Site 5	0-20	Sandy loam	34	5	42.4
		40-60	Clay loam sandy	51	4	161.1
		100-120	Sand	68	5	23.6
	Site 6	0-20	Clay loam sandy	74	3b	153.3
		40-60	Clay loam sandy	63	3b	237.3
TSF Area B footprint soil 2012	Site 7	0-5	Sandy clay loam	61	3b	73.7
	Site 8	0-5	Sandy clay loam	80	3a	153.8
TSF Area A footprint soil 2012	Site 9	0-5	Sandy clay loam	71	2	135.7
	Site 10	0-5	Clay loam sandy	68	2	180.9
	Site 11	0-5	Clay loam sandy	68	3a	143.8

Description	Site	Sample depth interval (cm)	Hand texture (<2 mm fraction)	% Coarse material (>2 mm)	Emerson Test Class	MOR (kPa)
Kangaroo Caves area soil 2013	SS12	0-20	-	43	3b	9.9
	SS13	0-20	-	47	5	31.9
	SS14	0-20	-	13	5	20.1
	SS15	0-20	-	22	3b	15.1
Eastern area soil 2013	SS16	0-20	-	11	8	12.1
	SS17	0-20	-	18	4	11.0
Air Strip area soil 2013	SS18	0-20	-	17	2	34.7
	SS19	0-20	-	19	2	63.8
	SS20	0-20	-	22	2	23.3

Appendix D

CSBP analysis results

Table D1: Summary of CSBP analyses

Sample ID	Depth (cm)/ Group	Texture	Gravel (%)	Ammonium Nitrogen	Nitrate Nitrogen	Phosphorus Colwell	Potassium Colwell	Sulphur	Organic Carbon	Conductivity	pH Level ($CaCl_2$)	pH Level (H_2O)	Particle size distribution					Exchangeable cations			
													% Clay	% Course Sand	% Fine Sand	% Sand	% Silt	Prewash exch. Ca	Prewash exch. K	Prewash exch. Mg	Prewash exch. Na
				mg / kg	mg / kg	mg / kg	mg / kg	mg / kg	%	dS / m	pH	pH	%	%	%	%	%	meq / 100g	meq / 100g	meq / 100g	meq / 100g
A SS01	0-5	2.5	25-30	< 1	2	10	154	2.6	0.43	0.021	5.5	6.7	13.13	45.69	29.30	74.99	11.88	1.83	0.17	1.35	<0.10
A SS01	10-20	3.0	45-50	< 1	4	5	151	5.2	0.18	0.020	5.4	6.4	-	-	-	-	-	1.47	0.19	1.24	<0.10
A SS01	40-50	3.0	35-40	< 1	6	4	147	4.6	0.17	0.026	5.5	6.5	-	-	-	-	-	1.83	0.19	1.55	<0.10
A SS02	0-5	3.0	35-40	< 1	< 1	7	104	10.2	0.41	0.036	4.8	5.7	-	-	-	-	-	0.71	0.11	0.67	<0.10
A SS02	10-20	3.0	45-50	1	< 1	6	94	13.3	0.12	0.016	4.6	5.6	20.92	43.82	23.45	67.27	11.81	0.80	0.12	0.66	<0.10
A SS02	40-50	3.0	25-30	1	< 1	5	83	18.2	0.12	0.014	4.5	5.4	-	-	-	-	-	0.79	0.11	0.70	<0.10
A SS03	0-5	3.0	25-30	1	< 1	10	100	14	0.18	0.069	5.9	6.9	-	-	-	-	-	0.46	0.11	0.78	0.12
A SS03	10-20	3.0	25-30	< 1	< 1	5	40	7.7	0.12	0.046	6.1	7.1	-	-	-	-	-	0.35	0.68	0.95	0.15
A SS03	40-50	3.0	35-40	1	< 1	5	38	14.7	0.15	0.068	6.1	7.3	20.69	46.22	24.00	70.22	9.08	0.20	0.04	0.98	0.20
A SS04	0-5	3.0	15-20	2	29	9	140	167.3	0.15	1.511	7.3	7.6	-	-	-	-	-	2.82	0.18	4.21	0.18
A SS04	10-20	3.0	15-20	4	57	5	99	626.7	0.23	3.415	7.3	7.5	-	-	-	-	-	3.75	0.12	5.67	0.37
ASS04	40-50	3.0	5-10	3	54	5	93	1645.7	0.22	3.930	7.5	7.7	-	-	-	-	-	7.73	0.11	4.83	0.46
A SS05	0-5	3.0	35-40	< 1	< 1	8	108	3.6	0.51	0.012	4.6	5.5	-	-	-	-	-	0.56	0.08	0.58	<0.10
A SS05	10-20	3.0	35-40	1	< 1	5	73	3.2	0.27	0.060	5.0	5.8	-	-	-	-	-	0.65	0.08	0.97	<0.10
A SS06	0-5	3.0	5-10	3	< 1	10	133	3.5	0.25	0.015	5.0	6.0	-	-	-	-	-	1.02	0.15	1.29	<0.10
A SS06	10-20	3.0	15-20	1	< 1	6	118	16.9	0.18	0.028	5.0	6.0	-	-	-	-	-	1.18	0.17	1.88	<0.10
SS01	0-20	2	0	3	< 1	6	< 15	4.7	0.72	0.098	8.0	8.5	11.96	57.40	17.62	75.02	13.02	7.58	0.13	3.23	<0.10
SS01	40-60	2	0	4	< 1	< 2	48	1.3	0.24	0.101	8.2	9.0	7.52	39.34	35.18	74.52	17.97	4.07	0.04	4.38	<0.10

													Particle size distribution					Exchangeable cations			
Sample ID	Depth (cm)/ Group	Texture	Gravel (%)	Ammonium Nitrogen	Nitrate Nitrogen	Phosphorus Colwell	Potassium Colwell	Sulphur	Organic Carbon	Conductivity	pH Level ($CaCl_2$)	pH Level (H_2O)	% Clay	% Course Sand	% Fine Sand	% Sand	% Silt	Prewash exch. Ca	Prewash exch. K	Prewash exch. Mg	Prewash exch. Na
				mg / kg	mg / kg	mg / kg	mg / kg	mg / kg	%	dS / m	pH	pH	%	%	%	%	%	meq / 100g	meq / 100g	meq / 100g	meq / 100g
SS02	0-20	1.5	0	7	< 1	< 2	129	3.5	0.45	0.02	5.8	6.3	19.47	56.53	18.15	74.68	5.86	0.73	0.08	0.43	<0.10
SS03	0-20	2.5	0	2	2	3	121	52.9	0.85	0.476	7.4	7.8	18.79	25.59	33.80	59.38	21.82	2.06	0.1	3.07	0.11
SS03	40-60	2.5	0	2	2	< 2	34	594.8	0.10	1.764	7.9	8.6	21.92	16.67	23.46	40.14	37.94	1.98	0.04	3.38	0.38
SS04	0-20	3	0	2	3	< 2	404	3.6	0.46	0.042	7.1	7.8	28.24	34.82	27.19	62.01	9.75	5.85	0.46	3.80	<0.10
SS05	0-20	3.5	0	6	5	< 2	361	11.1	0.95	0.148	7.5	8.0	16.21	40.05	32.26	72.31	11.48	5.05	0.32	2.13	<0.10
SS05	40-60	3	0	4	3	< 2	190	9.5	0.20	0.121	8.3	9.2	19.64	30.04	22.76	52.80	27.56	3.56	0.17	4.69	<0.10
SS05	100-120	3	0	3	3	< 2	146	31.8	0.24	0.199	8.2	8.9	4.83	54.73	32.64	87.37	7.80	2.76	0.17	6.29	0.23
SS06	0-20	3	0	2	2	< 2	310	1.5	0.19	0.034	6.6	7.2	26.62	32.77	25.80	58.57	14.81	2.63	0.34	2.15	<0.10
SS06	40-60	3	0	2	2	< 2	331	1.0	0.15	0.027	6.7	7.3	29.02	31.60	29.35	60.95	10.03	4.48	0.36	3.29	<0.10
SS07	0-5	3	0	4	8	9	194	3.7	0.78	0.069	6.9	7.4	14.98	42.18	31.81	74.00	11.02	2.47	0.11	1.17	<0.10
SS08	0-5	3	0	2	4	4	267	1.5	0.92	0.018	5.6	6.3	17.31	40.13	31.95	72.08	10.61	2.59	0.20	1.09	<0.10
SS09	0-5	3	0	3	7	3	190	3.2	0.66	0.054	6.1	6.9	18.43	31.81	37.11	68.92	12.65	1.67	0.15	1.15	<0.10
SS10	0-5	3	0	6	5	5	276	3.6	1.02	0.064	6.5	7.1	18.87	29.55	37.64	67.19	13.94	2.75	0.17	1.20	<0.10
SS11	0-5	2.5	0	2	7	3	143	3.9	0.89	0.033	5.5	6.3	14.40	34.54	36.61	71.15	14.45	1.07	0.09	1.05	<0.10
SS12	0-20	2.0	0	14	22	4	306	5.8	1.24	0.057	5.1	6.0	11.81	62.30	18.97	81.27	6.92	1.65	0.31	1.13	<0.10
SS13	0-20	2.0	5-10	2	2	4	249	1.5	0.66	0.033	6.7	7.7	13.10	59.10	22.15	81.24	5.66	8.65	0.23	2.07	<0.10
SS14	0-20	2.0	0	3	29	5	383	3.2	1.47	0.092	6.6	7.2	12.95	58.92	20.68	79.60	7.45	8.89	0.32	2.86	<0.10
SS15	0-20	2.0	5	8	19	6	502	13.0	0.82	0.142	7.6	8.3	11.76	61.66	18.68	80.34	7.91	8.23	0.45	2.40	<0.10
SS16	0-20	2.0	0	5	13	3	553	2.9	0.62	0.046	6.7	6.9	11.57	73.12	11.42	84.54	3.89	7.16	0.36	2.82	<0.10

Sample ID	Depth (cm)/ Group	Texture	Gravel (%)	Ammonium Nitrogen	Nitrate Nitrogen	Phosphorus Colwell	Potassium Colwell	Sulphur	Organic Carbon	Conductivity	pH Level ($CaCl_2$)	pH Level (H_2O)	Particle size distribution					Exchangeable cations			
													% Clay	% Course Sand	% Fine Sand	% Sand	% Silt	Prewash exch. Ca	Prewash exch. K	Prewash exch. Mg	Prewash exch. Na
				mg / kg	mg / kg	mg / kg	mg / kg	mg / kg	%	dS / m	pH	pH	%	%	%	%	%	meq / 100g	meq / 100g	meq / 100g	meq / 100g
SS17	0-20	2.0	5	3	6	4	336	1.9	0.54	0.059	7.4	8.4	13.31	48.61	32.33	80.94	5.75	8.59	0.24	1.11	<0.10
SS18	0-20	2.5	25-30	3	10	5	407	2.5	0.44	0.029	4.8	5.8	17.50	61.35	14.33	75.68	6.82	1.67	0.39	0.86	<0.10
SS19	0-20	2.5	5	2	6	6	483	2.0	0.20	0.029	7.0	7.6	12.84	67.59	14.60	82.20	4.96	2.07	0.36	2.76	<0.10
SS20	0-20	2.5	5-10	2	4	5	277	1.0	0.32	0.017	5.5	6.3	14.64	69.36	12.09	81.45	3.92	1.62	0.24	1.25	<0.10

Appendix E

ALS Certificates of Analysis

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EP1200088**	Page	: 1 of 4
Client	: **OUTBACK ECOLOGY SERVICES**	Laboratory	: Environmental Division Perth
Contact	: ANNE BYRNE	Contact	: Scott James
Address	: 1/71 TROY TERRACE JOLIMONT WA, AUSTRALIA 6014	Address	: 10 Hod Way Malaga WA Australia 6090
E-mail	: anna.byrne@outbackecology.com	E-mail	: perth.enviro.services@alsglobal.com
Telephone	: +61 08 93888799	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 93888633	Facsimile	: +61-8-9209 7600
Project	: WHIM-SS-11002	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: OES 2807		
C-O-C number	: ----	Date Samples Received	: 06-JAN-2012
Sampler	: AB	Issue Date	: 12-JAN-2012
Site	: ----		
		No. of samples received	: 16
Quote number	: EP/615/11	No. of samples analysed	: 10

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Canhuang Ke	Metals Instrument Chemist	Perth Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

Analytical Results

Sub-Matrix: **SOIL**

Compound	CAS Number	LOR	Unit	WIVXR01 0-5	WIVXR01 40-50	WIVXR02 0-5	WIVXR02 40-50	WIVXR03 0-5
Client sampling date / time				[06-JAN-2012]	[06-JAN-2012]	[06-JAN-2012]	[06-JAN-2012]	[06-JAN-2012]
				EP1200088-001	EP1200088-003	EP1200088-004	EP1200088-006	EP1200088-007
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	<1.0	1.7	<1.0	2.9	<1.0
EG005T: Total Metals by ICP-AES								
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	<5	<5
Cadmium	7440-43-9	1	mg/kg	3	3	2	2	2
Chromium	7440-47-3	2	mg/kg	76	93	83	73	54
Copper	7440-50-8	5	mg/kg	23	32	30	19	14
Lead	7439-92-1	5	mg/kg	7	12	22	12	6
Nickel	7440-02-0	2	mg/kg	47	73	27	20	15
Zinc	7440-66-6	5	mg/kg	202	262	39	24	34
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: **SOIL**			Client sample ID	WIVXR03 40-50	WIVXR04 0-5	WIVXR04 40-50	WIVXR05 0-5	WIVXR06 0-5
			Client sampling date / time	[06-JAN-2012]	[06-JAN-2012]	[06-JAN-2012]	[06-JAN-2012]	[06-JAN-2012]
Compound	*CAS Number*	*LOR*	*Unit*	**EP1200088-009**	**EP1200088-010**	**EP1200088-012**	**EP1200088-013**	**EP1200088-015**
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	**1.9**	<1.0	**3.6**	<1.0	<1.0
EG005T: Total Metals by ICP-AES								
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	<5	<5
Cadmium	7440-43-9	1	mg/kg	**2**	**2**	<1	**1**	**2**
Chromium	7440-47-3	2	mg/kg	**56**	**73**	**39**	**71**	**186**
Copper	7440-50-8	5	mg/kg	**18**	**32**	**30**	**21**	**32**
Lead	7439-92-1	5	mg/kg	**7**	**8**	**5**	**23**	**8**
Nickel	7440-02-0	2	mg/kg	**31**	**42**	**40**	**19**	**44**
Zinc	7440-66-6	5	mg/kg	**43**	**52**	**44**	**46**	**58**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

CERTIFICATE OF ANALYSIS

Work Order	: **EP1210107**	Page	: 1 of 6
Client	: **OUTBACK ECOLOGY SERVICES**	Laboratory	: Environmental Division Perth
Contact	: ANNE BYRNE	Contact	: Scott James
Address	: 1/71 TROY TERRACE JOLIMONT WA, AUSTRALIA 6014	Address	: 10 Hod Way Malaga WA Australia 6090
E-mail	: anna.byrne@outbackecology.com	E-mail	: perth.enviro.services@alsglobal.com
Telephone	: +61 08 93888799	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 93888633	Facsimile	: +61-8-9209 7600
Project	: SULP-SS-12001	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: OES 3531		
C-O-C number	: ----	Date Samples Received	: 04-DEC-2012
Sampler	: VENTUREX REWSOURCES	Issue Date	: 11-DEC-2012
Site	: ----		
		No. of samples received	: 16
Quote number	: EP-180-10 BQ	No. of samples analysed	: 16

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Canhuang Ke	Metals Instrument Chemist	Perth Inorganics
Scott James	Laboratory Manager	Perth Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	SS01 0-20	SS01 40-60	SS02 0-20	SS03 0-20	SS03 40-60
			Client sampling date / time	[04-DEC-2012]	[04-DEC-2012]	[04-DEC-2012]	[04-DEC-2012]	[04-DEC-2012]
Compound	CAS Number	LOR	Unit	EP1210107-001	EP1210107-002	EP1210107-003	EP1210107-004	EP1210107-005
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	2.0	5.8	<1.0	1.4	5.2
EG005T: Total Metals by ICP-AES								
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	<5	<5
Cadmium	7440-43-9	1	mg/kg	<1	1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	72	56	36	41	15
Copper	7440-50-8	5	mg/kg	35	24	12	19	10
Lead	7439-92-1	5	mg/kg	8	9	6	10	7
Nickel	7440-02-0	2	mg/kg	66	52	11	30	16
Zinc	7440-66-6	5	mg/kg	110	110	19	73	63
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	SS04 0-20	SS05 0-20	SS05 40-60	SS05 100-120	SS06 0-20
Client sampling date / time				[04-DEC-2012]	04-DEC-2012 09:00	[04-DEC-2012]	[04-DEC-2012]	[04-DEC-2012]
				EP1210107-006	EP1210107-007	EP1210107-008	EP1210107-009	EP1210107-010
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	4.3	2.6	4.6	7.6	4.4
EG005T: Total Metals by ICP-AES								
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	<5	<5
Cadmium	7440-43-9	1	mg/kg	2	1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	528	131	88	76	168
Copper	7440-50-8	5	mg/kg	383	119	110	106	85
Lead	7439-92-1	5	mg/kg	18	12	7	7	15
Nickel	7440-02-0	2	mg/kg	141	65	39	33	174
Zinc	7440-66-6	5	mg/kg	172	260	59	59	126
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**SS06 40-60**	**SS07 0-5**	**SS08 0-5**	**SS09 0-5**	**SS10 0-5**
			Client sampling date / time	[04-DEC-2012]	[04-DEC-2012]	[04-DEC-2012]	[04-DEC-2012]	[04-DEC-2012]
Compound	*CAS Number*	*LOR*	*Unit*	**EP1210107-011**	**EP1210107-012**	**EP1210107-013**	**EP1210107-014**	**EP1210107-015**
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	**6.9**	<1.0	**1.6**	**1.1**	**1.3**
EG005T: Total Metals by ICP-AES								
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	<5	<5
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**245**	**18**	**29**	**26**	**17**
Copper	7440-50-8	5	mg/kg	**104**	**41**	**13**	**16**	**6**
Lead	7439-92-1	5	mg/kg	**11**	**5**	**5**	**6**	<5
Nickel	7440-02-0	2	mg/kg	**240**	**12**	**12**	**9**	**7**
Zinc	7440-66-6	5	mg/kg	**110**	**71**	**26**	**18**	**17**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	SS11 0-5	----	----	----	----
			Client sampling date / time	[04-DEC-2012]	----	----	----	----
				EP1210107-016	**----**	**----**	**----**	**----**
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	<1.0	----	----	----	----
EG005T: Total Metals by ICP-AES								
Arsenic	7440-38-2	5	mg/kg	<5	----	----	----	----
Cadmium	7440-43-9	1	mg/kg	<1	----	----	----	----
Chromium	7440-47-3	2	mg/kg	**20**	----	----	----	----
Copper	7440-50-8	5	mg/kg	**10**	----	----	----	----
Lead	7439-92-1	5	mg/kg	<5	----	----	----	----
Nickel	7440-02-0	2	mg/kg	**7**	----	----	----	----
Zinc	7440-66-6	5	mg/kg	**15**	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	----	----	----	----

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EP1301249**	Page	: 1 of 4
Client	: **OUTBACK ECOLOGY SERVICES**	Laboratory	: Environmental Division Perth
Contact	: ANNE BYRNE	Contact	: Scott James
Address	: 1/71 TROY TERRACE JOLIMONT WA, AUSTRALIA 6014	Address	: 10 Hod Way Malaga WA Australia 6090
E-mail	: anna.byrne@outbackecology.com	E-mail	: perth.enviro.services@alsglobal.com
Telephone	: +61 08 93888799	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 93888633	Facsimile	: +61-8-9209 7600
Project	: SULP-SS-13001	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: OES 3634		
C-O-C number	: ----	Date Samples Received	: 20-FEB-2013
Sampler	: ----	Issue Date	: 27-FEB-2013
Site	: ----		
		No. of samples received	: 9
Quote number	: EP-180-10 BQ	No. of samples analysed	: 9

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Scott James	Laboratory Manager	Perth Inorganics
Scott James	Laboratory Manager	Perth Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EG005T: Poor matrix spike recovery due to sample heterogeneity. Confirmed by re-extraction and re-analysis.**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Site 12	Site 13	Site 14	Site 15	Site 16
Client sample ID				Site 12	Site 13	Site 14	Site 15	Site 16
Client sampling date / time				[20-FEB-2013]	[20-FEB-2013]	[20-FEB-2013]	[20-FEB-2013]	[20-FEB-2013]
				EP1301249-001	**EP1301249-002**	**EP1301249-003**	**EP1301249-004**	**EP1301249-005**
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	**2.3**	**3.0**	**6.9**	**3.8**	**3.8**
EG005T: Total Metals by ICP-AES								
Arsenic	7440-38-2	5	mg/kg	<5	<5	**7**	<5	<5
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**128**	**211**	**454**	**266**	**279**
Copper	7440-50-8	5	mg/kg	**20**	**45**	**56**	**42**	**40**
Lead	7439-92-1	5	mg/kg	**6**	<5	<5	<5	<5
Nickel	7440-02-0	2	mg/kg	**52**	**171**	**243**	**195**	**190**
Zinc	7440-66-6	5	mg/kg	**42**	**129**	**127**	**130**	**142**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Site 17	Site 18	Site 19	Site 20	----
			Client sampling date / time	[20-FEB-2013]	[20-FEB-2013]	[20-FEB-2013]	[20-FEB-2013]	----
Compound	CAS Number	LOR	Unit	EP1301249-006	EP1301249-007	EP1301249-008	EP1301249-009	----
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	3.5	1.9	3.7	3.6	----
EG005T: Total Metals by ICP-AES								
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	<5	----
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	----
Chromium	7440-47-3	2	mg/kg	399	127	137	106	----
Copper	7440-50-8	5	mg/kg	45	50	65	30	----
Lead	7439-92-1	5	mg/kg	<5	9	6	6	----
Nickel	7440-02-0	2	mg/kg	192	60	112	51	----
Zinc	7440-66-6	5	mg/kg	54	50	97	34	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	----