Barrambie Vanadium Project

Baseline Soil and Landforms Survey

September 2007

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Soil and landforms survey of the proposed Barrambie Mine

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Executive Summary

Outback Ecology Services (OES) was commissioned by Reed Resources Limited to conduct a baseline survey of the surface soils and landforms at the proposed Barrambie Mine. The objectives of this study were to establish baseline levels of a range of physical and chemical soil parameters; to develop a greater understanding of potential correlations between soil properties and landforms units; and to identify potentially problematic soil materials for future rehabilitation requirements.

The investigation of soil properties was conducted within the proposed mine area, comprising the mine site, camp and tailings storage facility (TSF). Shallow soil pits were excavated at fourteen locations across the survey area, including the proposed mine camp site, orebody, plant area, TSF and airstrip. The surface soil profile was described (profile morphology, structure, root distribution) based on the Australian Soil Classification Standards. Samples were taken from consistent depth intervals within each profile for analyses of chemical and physical parameters.

The greatest variations in soil profile morphology appear to be between soils from contrasting positions within the landscape. Sample sites at the proposed air strip, TSF, plant area and camp site locations were located in lower lying, flat areas. The low hill / slope and orebody sites were located on low foothills immediately west of the major ridges.

Soil Physical Characteristics

Soil surface characteristics differed mostly in terms of coarse fragment / gravel content, the presence / absence and degree of surface crust and cryptogam cover. Soil texture classifications ranged from clayey sands to medium heavy clays with little correlation to landform unit or depth within the soil profile, although soils with higher fines (clay) contents were generally identified at sites lower in the landscape. Gravel contents were variable, but were higher at sites located on low hill / slope areas and within the proposed plant area.

Soil structure was predominantly single-grained with some weak aggregates in the surface horizon. One site exhibited massive, structure-less soil material below 10 cm depth. Soil structural stability testing did not identify any highly dispersive soils at any locations, though moderately dispersive properties were observed for samples from the lower lying and foothill / sloped areas. Root growth was commonly observed to be sparse and generally decreased rapidly with depth.

Soil Chemical Characteristics

Soil pH values were mostly moderate to strongly acidic, with some mildly alkaline samples found at sites lower within the landscape. Electrical conductivities were found to be predominantly non-saline

to slightly saline, with some moderately saline soils at the proposed airstrip and low hill / slope areas. The soil sampled from within the minor drainage line was classed as extremely saline.

As would be expected, soil organic matter content was extremely low overall. Nitrate levels were highest in the low hill/slope areas in both the upper 0 – 5 and lower 10 – 20 cm sample depths. Phosphorus levels ranged between 3 and 19 mg/kg, and were generally highest in the upper 0 – 5 cm depth interval. Potassium levels ranged between 42 and 313 mg/kg, and were highest at Site 11 (proposed TSF area). Sulphur levels were notably highest at Site 5, located within a minor drainage line, with values of 547 and 974 mg/kg of extractable sulphur. All other sulphur contents fell below 119 mg/kg.

Conclusions

Soils that are disturbed and brought to the surface during mining operations can behave differently than in their natural setting. For soils within the Barrambie survey area, physical properties such as gravel content, clay content and structural stability are likely to be the most important to consider if soil materials are to be used for specific purposes. There will inevitably be a degree of mixing of soil materials with differing properties from within specific areas.

For revegetation purposes, soils with high salinity may be limited in use as topsoil unless salt tolerant species are planted. Other chemical properties of the materials sampled, suggest that the local vegetation would be well adapted to high soil acidity and low soil fertility / nutrient availability, and that these properties could be considered less limiting.

Potentially problematic soils in the survey area include those that are vulnerable to structural degradation, particularly when the soils are disturbed. Susceptibility of some soils to structural decline was observed, with materials from the proposed camp site, plant area and low hill / slope areas exhibiting dispersive properties, which may be considered as potentially problematic. Other problematic materials include soil from within the minor drainage line, which was found to be extremely saline.

Further investigation of soil and regolith materials below 20 cm depth would be beneficial in understanding the properties and potential behaviour of deeper materials as the project develops.

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1.0 INTRODUCTION

Outback Ecology was commissioned by Reed Resources Limited to conduct a baseline survey of surface soils and landforms at the proposed Barrambie Vanadium Project. This information is required to develop a greater understanding of soil properties within the proposed disturbance area, and identify any correlations that may exist between soils and landform or vegetation units, for future rehabilitation requirements.

The primary objectives of this investigation included;

- the establishment of baseline levels for a range of physical and chemical soil parameters in the study area, for future rehabilitation requirements,
- identifying potentially problematic surface soil materials, and
- identifying potentially different soil properties between landforms / areas of proposed disturbance.

Many natural regolith and waste rock materials, once disturbed and brought to the surface during mining operations, will behave differently to how they would in their natural setting. Such materials often have intrinsic properties that make their management and incorporation into rehabilitation designs difficult. The difficulties faced in the restoration of functioning ecosystems on such landforms, often under extreme ranges of temperature and rainfall, can be exacerbated by the properties of the materials. The way in which these materials are likely to weather and develop over time should also be taken into account when planning final landform designs.

Representative sites were chosen for each landform and / or vegetation unit within the survey area. Soils were classified, where applicable, based on the Australian Soil Classification Standards, detailing soil profile morphology (of surface soils), soil structure and texture. Samples from each site were collected for basic chemical analyses, including soil pH, electrical conductivity, available nutrients and organic carbon.

It must be remembered that the findings presented within this report are based on samples from a limited number of sites. Further investigations may be required if different materials are used in the future to assist revegetation of problematic areas.

1.1 Land Systems of the Study Area

A regional inventory and condition survey of the Sandstone, Yalgoo, Paynes Find area was undertaken between 1992 and 1993 by the Department of Agriculture and the Department of Land Administration(Payne *et al*. 1998). The purpose of the survey was to develop a comprehensive description of the biophysical resources and an assessment of the condition of the soils and the vegetation of the region. A component of the survey was the mapping of land types and associated land systems. The Barrambie Project Area occurs over 5 Land Types and 6 associated Land Systems (Table 1).

Table 1 Land Types and Land Systems occurring over the study area (adapted from Payne *et al*. 1998)

Land Types		Land Systems		
1	Hills with acacia shrublands	3	Gabanintha	Ridges and rounded hills of basalt, dolerite, jaspilite, and greenstone
		5	Naluthanna	Rough hills. Or fields and slopes of gabbro with restricted lower stony plains and gilgaied drainage floors
5	Breakaways and alluvial plains with predominantly saline soils and halophytic shrublands	21	Hootanui	Breakaways, hills and ridges on weathered greenstone and felsic extrusive rocks with extensive gravelly lower alluvial plains
7	Irregular plains and low rises supporting mulga, bowgada, and some halophytic shrublands	27	Violet	Undulating plains with stony and gravelly mantles and low rises with limonite
13	Wash plains on hardpan with mulga shrubland	42	Jundee	Level to very gently inclined wash plains with mantles of fine ironstone gravels
17	Alluvial plains with saline soils and predominantly halophytic shrublands	66	Steer	Alluvial plains with gravelly mantles and scattered small circular drainage foci

2.0 MATERIALS AND METHODS

2.1 Sampling regime

The investigation of soil properties was conducted within the proposed mine area, comprising the ore body, proposed plant area, mine camp, tailings storage facility and airstrip. Shallow soil pits were excavated by hand at fourteen locations (Table 1, Figure 1).

The surface soil profile was described (soil profile morphology, soil structure, root distribution) based on the Australian Soil and Land Survey Handbook (McDonald *et al.* 1998). Samples were taken from two consistent depth intervals within each profile for analyses of chemical and physical parameters.

Table 2 Summary table of sampling sites and locations.

Site #	Location	Coordinates (Projection: UTM Zone 50J, Datum GDA 94:)		Elevation (m)
		Eastings	Northings	
1	Camp site	711493	6961983	549
2	Camp site	711440	6962121	550
3	Orebody	710389	6961263	529
4	Orebody	710613	6960694	532
5	Minor drainage line	709978	6961940	524
6	Low hill / slope	709544	6963336	536
7	Low hill / slope	709416	6963741	534
8	Low hill / slope	709275	6964527	541
9	Plant area	708245	6965401	525
10	Plant area	708119	6965622	523
11	Tailings Storage Facility	707818	6965371	521
12	Air strip	706362	6964680	518
13	Tailings Storage Facility	709428	6963627	530
14	Tailings Storage Facility	709163	6964433	530

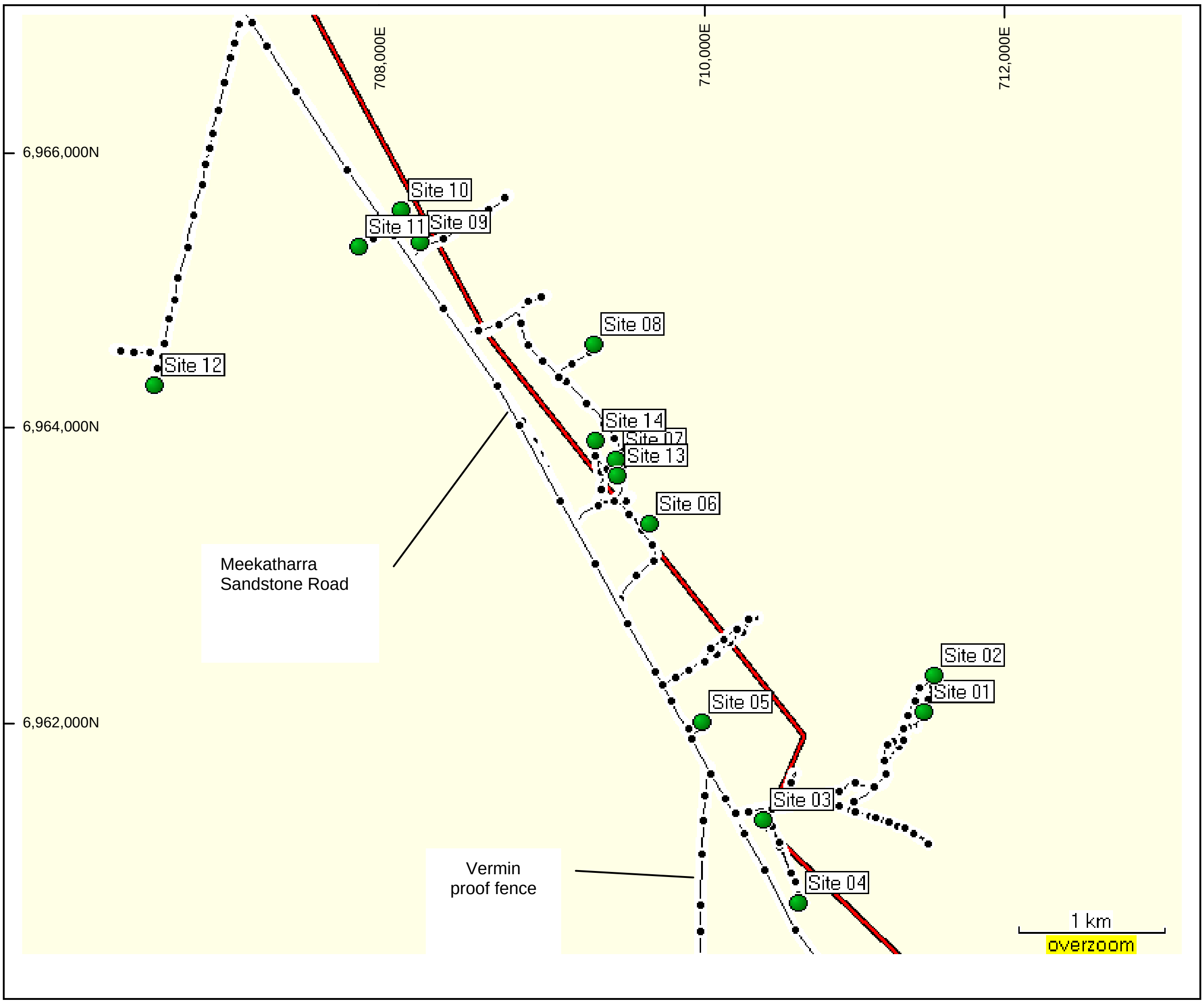

Figure 1 Location of soil sampling sites within the Project Area

2.2 Test work and procedures

CSBP Soil and Plant Laboratory conducted analyses on the sampled soils from the fourteen sites for ammonium and nitrate (Scarle 1984), extractable phosphorus and potassium (Colwell 1965; Rayment and Higginson 1992), extractable sulphur (Blair *et al*. 1991), total phosphorus (Allen and Jeffery 1990), and organic carbon (Walkley and Black 1934). Measurements of electrical conductivity (1:5 H_2O), soil pH (1:5 H_2O and 1:5 $CaCl_2$), were conducted using the methods described in Rayment and Higginson (1992). 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).

3.0 RESULTS AND DISCUSSION

3.1 Soil Profile Descriptions

A description of the surface soil profile morphology at each site has been documented, with a summary of the measured physical, chemical and morphological parameters tabulated for each site (Sections 3.1.1 – 3.1.14). Individual soil characteristics are then discussed in further detail (Sections 3.2 – 3.3).

3.1.1 Site 1

Site Details: Proposed Camp Site

Plate 1 Vegetation at Site 1

Soil surface: Approximately 90 % cover of pisolitic gravel, with approximately 10 % cryptogam cover and 5 % litter cover on soil surface.

0 – 5 cm: Single grained structure. Approximately 50 % sub-angular and sub-rounded coarse fragments, 2 to 10 mm in size. Root growth classed as ‘common’.

10 – 20 cm: Single grained structure. Approximately 50 % sub-angular and sub-rounded coarse fragments, 2 to 10 mm in size. Roots ‘common’.

Table 3 Soil physical and chemical characteristics for Site 1

Depth Interval (cm)	Soil Structure	Textural class	Root score[1.]	Soil pH (H_2O)	EC (dS/m)	Emerson Test Class[2.]	Gravel content (%)	% Organic Carbon	Available nutrients				
									Nitrate N (mg/kg)	Ammonium N (mg/kg)	Avail. P (mg/kg)	Avail. K (mg/kg)	Avail. S (mg/kg)
0-5	Single grained	Fine sandy loam	2	5.7	0.02	4-6	49.0	0.26	1	1	4	60	10.3
10-20	Single grained	Fine sandy loam	2	5.3	0.02	4-6	50.8	0.25	1	1	4	71	18.6

1. See Appendix F for root growth scoring categories.
2. See Appendix B for Emerson Test class categories.

3.1.2 Site 2

Site Details: Proposed Camp Site

Plate 2 Vegetation at Site 2

Soil surface: Weak surface crust with approximately 25 % cryptogam cover. Approximately 75 % cover of pisolitic gravel.

0 – 5 cm: Predominantly single grained structure, some weak polyhedral aggregates. Approximately 50 % sub-angular and sub-rounded coarse fragments, 2 to 10 mm in size. Roots growth classed as ‘common’.

10 – 20 cm: Single grained structure. Approximately 50 % sub-angular and sub-rounded coarse fragments, 2 to 10 mm in size. Roots ‘common’.

Table 4 Soil physical and chemical characteristics for Site 2

.

Depth Interval (cm)	Soil Structure	Textural class	Root score[1.]	Soil pH (H_2O)	EC (dS/m)	Emerson Test Class[2.]	Gravel content (%)	% Organic Carbon	Available nutrients				
									Nitrate N (mg/kg)	Ammonium N (mg/kg)	Avail. P (mg/kg)	Avail. K (mg/kg)	Avail. S (mg/kg)
0-5	Predomnantly single grained, some weak aggregates	Fine sandy loam	2	5.3	0.01	3b	18.1	0.22	1	1	5	42	12.2
10-20	Single grained	Fine sandy loam	2	5.2	0.03	4-6	21.8	0.23	1	1	3	76	14.4

1. See Appendix F for root growth scoring categories.
2. See Appendix B for Emerson Test class categories.

3.1.3 Site 3

Site Details: Orebody

Plate 3 Vegetation at Site 3

Soil surface: Weak surface crust in top 5 mm. Approximately 75 % cover of coarse fragments, mostly pisolitic gravel with some quartz. Less than 5 % cryptogam cover with approximately 5 % litter cover.

0 – 5 cm: Firm to strong aggregates to approximately 5 – 10 cm depth. Approximately 50 % sub-angular and sub-rounded coarse fragments, 2 to 40 mm in size. Root abundance classed as 'few', observed to be dependant on proximity to plants.

10 – 20 cm: Predominantly massive structure. Approximately 25 % sub-angular and sub-rounded coarse fragments, 2 to 40 mm in size. 'Few' roots.

Table 5 Soil physical and chemical characteristics for Site 3

.

Depth Interval (cm)	Soil Structure	Textural class	Root score[1.]	Soil pH (H_2O)	EC (dS/m)	Emerson Test Class[2.]	Gravel content (%)	% Organic Carbon	Available nutrients				
									Nitrate N (mg/kg)	Ammonium N (mg/kg)	Avail. P (mg/kg)	Avail. K (mg/kg)	Avail. S (mg/kg)
0-5	Firm to strong aggregates	Sandy clay loam	1	5.6	0.05	3b	33	0.35	9	3	19	195	8.4
10-20	Massive structure	Sandy clay loam	1	5.7	0.03	2	30.8	0.23	4	1	7	148	6.3

1. See Appendix F for root growth scoring categories.
2. See Appendix B for Emerson Test class categories.

3.1.4 Site 4

Site Details: Orebody

Plate 4 Vegetation at Site 4

Soil surface: Weak surface crust, with approximately 75 % cover of pisolitic gravel and other coarse fragments (including quartz), 2 – 40 mm in size. Approximately 20 % cryptogam cover, with < 5 % litter cover.

0 – 5 cm: Weak polyhedral aggregates to 10 cm depth. Approximately 50 % sub-angular and sub-rounded coarse fragments, 2 to 40 mm in size. Root abundance classed as 'few'.

10 – 20 cm: Predominantly single grained. Approximately 50 % sub-angular and sub-rounded coarse fragments, 2 to 50 mm in size. 'Few' roots.

Table 6 Soil physical and chemical characteristics for Site 4

.

Depth Interval (cm)	Soil Structure	Textural class	Root score[1.]	Soil pH (H_2O)	EC (dS/m)	Emerson Test Class[2.]	Gravel content (%)	% Organic Carbon	Available nutrients				
									Nitrate N (mg/kg)	Ammonium N (mg/kg)	Avail. P (mg/kg)	Avail. K (mg/kg)	Avail. S (mg/kg)
0-5	Weak aggregates	Sandy clay loam	1	5.5	0.04	4-6	35.2	0.19	1	1	5	105	17.7
10-20	Single grained	Sandy clay loam	1	5.3	0.09	4-6	39.9	0.15	3	1	4	87	51.8

1. See Appendix F for root growth scoring categories.
2. See Appendix B for Emerson Test class categories.

3.1.5 Site 5

Site Details: Minor drainage line

Plate 5 Vegetation at Site 5

Soil surface: Weak to moderate strength surface crust over approximately 25 % of surface. Approximately 25 % cover of colluvial material and coarse fragments. No cryptogam cover. Approximately 5 % litter cover. Single grained material in minor drainage channel.

0 – 5 cm: Predominantly single grained structure. Variable abundance (0 - 75 %) of sub-angular and sub-rounded coarse fragments, 2 to 20 mm in size. Root growth classed as 'common'.

10 – 20 cm: Predominantly single grained structure. Variable abundance (0 - 75 %) of sub-angular and sub-rounded coarse fragments, 2 to 20 mm in size. Roots 'common'.

Table 7 Soil physical and chemical characteristics for Site 5

.

Depth Interval (cm)	Soil Structure	Textural class	Root score[1.]	Soil pH (H_2O)	EC (dS/m)	Emerson Test Class[2.]	Gravel content (%)	% Organic Carbon	Available nutrients				
									Nitrate N (mg/kg)	Ammonium N (mg/kg)	Avail. P (mg/kg)	Avail. K (mg/kg)	Avail. S (mg/kg)
0-5	Weak to moderate crust, single grained below	Sandy loam	2	5.4	2.34	4-6	16.2	0.34	3	9	8	143	547
10-20	Single grained	Sandy clay loam	2	5.6	2.98	No aggregates	20	0.27	4	4	9	152	974

1. See Appendix F for root growth scoring categories.
2. See Appendix B for Emerson Test class categories.

3.1.6 Site 6

Site Details: Low hill / slope

Plate 6 Vegetation at Site 6

Soil surface: Approximately 90 % cover of pisolitic gravel and larger fragments, 2 – 300 mm in size. Less than 5 % cryptogam cover, with approximately 5 % litter cover.

0 – 5 cm: Predominantly single grained structure. Approximately 50 % sub-angular and sub-rounded coarse fragments, 2 to 40 mm in size. Root abundance classed as 'few'.

10 – 20 cm: Predominantly single grained structure. Approximately 75 % sub-angular and angular coarse fragments, 2 to 75 mm in size. 'Few' roots.

Table 8 Soil physical and chemical characteristics for Site 6

.

Depth Interval (cm)	Soil Structure	Textural class	Root score[1.]	Soil pH (H_2O)	EC (dS/m)	Emerson Test Class[2.]	Gravel content (%)	% Organic Carbon	Available nutrients				
									Nitrate N (mg/kg)	Ammonium N (mg/kg)	Avail. P (mg/kg)	Avail. K (mg/kg)	Avail. S (mg/kg)
0-5	Single grained	Clay loam	1	5.5	0.83	4-6	35.5	0.28	25	4	5	166	103
10-20	Single grained	Sandy clay loam	1	5.6	1.01	4-6	43.2	0.33	40	4	5	191	119

1. See Appendix F for root growth scoring categories.
2. See Appendix B for Emerson Test class categories.

3.1.7 Site 7

Site Details: Low hill / slope

Plate 7 Vegetation at Site 7

Soil surface: Approximately 90 % cover of coarse fragments, 2 – 200 mm in size. Less than 5 % litter cover, with no cryptogams.

0 – 5 cm: Predominantly single grained, some weak aggregates. Approximately 50 % sub-angular and angular coarse fragments, 2 to 50 mm in size. Root growth classed as ‘common’.

10 – 20 cm: Single grained structure. Approximately 75 % sub-angular and angular coarse fragments, 2 to 50 mm in size. ‘Few’ roots.

Table 9 Soil physical and chemical characteristics for Site 7

.

Depth Interval (cm)	Soil Structure	Textural class	Root score[1.]	Soil pH (H_2O)	EC (dS/m)	Emerson Test Class[2.]	Gravel content (%)	% Organic Carbon	Available nutrients				
									Nitrate N (mg/kg)	Ammonium N (mg/kg)	Avail. P (mg/kg)	Avail. K (mg/kg)	Avail. S (mg/kg)
0-5	Predominantly single grained, some weak aggregates	Clay loam	2	6.4	0.12	3b	58.2	0.5	4	1	7	145	5.2
10-20	Single grained	Clay loam	1	6.3	0.04	2	62.7	0.3	4	1	3	114	7.8

1. See Appendix F for root growth scoring categories.
2. See Appendix B for Emerson Test class categories.

3.1.8 Site 8

Site Details: Low hill / slope

Plate 8 Vegetation at Site 8

Soil surface: Weak surface crust, with approximately 5 % cryptogam cover and <5 % litter cover. Approximately 90 % pisolitic gravel and other coarse fragment cover, 2 – 100 mm in size.

0 – 5 cm: Predominantly single grained, some weak aggregates. Approximately 50 % sub-angular and sub-rounded coarse fragments, 2 to 30 mm in size. Root abundance classed as ‘few’.

10 – 20 cm: Single grained structure. Approximately 75 % sub-rounded, sub-angular and angular coarse fragments, 2 to 50 mm in size. ‘Few’ roots.

Table 10 Soil physical and chemical characteristics for Site 8

.

Depth Interval (cm)	Soil Structure	Textural class	Root score[1.]	Soil pH (H_2O)	EC (dS/m)	Emerson Test Class[2.]	Gravel content (%)	% Organic Carbon	Available nutrients				
									Nitrate N (mg/kg)	Ammonium N (mg/kg)	Avail. P (mg/kg)	Avail. K (mg/kg)	Avail. S (mg/kg)
0-5	Predominantly single grained, some weak aggregates	Fine sandy loam	1	5.8	0.05	4-6	29	0.23	15	2	6	100	1409
10-20	Single grained	Fine sandy loam	1	5.7	0.05	No aggregates	38.5	0.24	14	2	11	180	18.6

1. See Appendix F for root growth scoring categories.
2. See Appendix B for Emerson Test class categories.

3.1.9 Site 9

Site Details: Proposed Plant Area

Plate 9 Vegetation at Site 9

Soil surface: Approximately 90 % coarse fragments 2 – 100 mm in size. Approximately 10 % cryptogam cover and 5 % litter cover on soil surface.

0 – 5 cm: Single grained structure. Approximately 75 % sub-angular and sub-rounded coarse fragments, 2 to 40 mm in size. Root abundance classed as ‘few’.

10 – 20 cm: Single grained structure. Approximately 75 % sub-angular and sub-rounded coarse fragments, 2 to 75 mm in size. ‘Few’ roots.

Table 11 Soil physical and chemical characteristics for Site 9

.

Depth Interval (cm)	Soil Structure	Textural class	Root score[1.]	Soil pH (H_2O)	EC (dS/m)	Emerson Test Class[2.]	Gravel content (%)	% Organic Carbon	Available nutrients				
									Nitrate N (mg/kg)	Ammonium N (mg/kg)	Avail. P (mg/kg)	Avail. K (mg/kg)	Avail. S (mg/kg)
0-5	Single grained	Light clay	1	6.5	0.04	3b	62.9	0.34	2	2	7	143	7.5
10-20	Single grained	Light medium clay	1	7	0.11	3b	61.2	0.54	7	2	6	118	10

1. See Appendix F for root growth scoring categories.
2. See Appendix B for Emerson Test class categories.

3.1.10 Site 10

Site Details: Proposed Plant Area

Plate 10 Vegetation at Site 10

Soil surface: Approximately 5 % cryptogam cover and < 5 % litter cover. Approximately 95 % pisolitic gravel and coarse fragments to 75 mm in size.

0 – 5 cm: Predominantly single grained, some weak aggregates. Approximately 50 % sub-angular and sub-rounded coarse fragments, 2 to 30 mm in size. Root abundance classed as 'few'.

10 – 20 cm: Predominantly single grained, some weak aggregates. Approximately 75 % sub-angular and sub-rounded coarse fragments, 2 to 50 mm in size. 'Few' roots.

Table 12 Soil physical and chemical characteristics for Site 10

.

Depth Interval (cm)	Soil Structure	Textural class	Root score[1.]	Soil pH (H_2O)	EC (dS/m)	Emerson Test Class[2.]	Gravel content (%)	% Organic Carbon	Available nutrients				
									Nitrate N (mg/kg)	Ammonium N (mg/kg)	Avail. P (mg/kg)	Avail. K (mg/kg)	Avail. S (mg/kg)
0-5	Predominantly single grained, some weak aggregates	Medium clay	1	6.6	1.61	2	47.4	0.19	1	2	11	97	39.7
10-20	Predominantly single grained, some weak aggregates	Medium heavy clay	1	6.7	1.86	2	49.6	0.21	1	2	10	109	51.8

1. See Appendix F for root growth scoring categories.
2. See Appendix B for Emerson Test class categories.

3.1.11 Site 11

Site Details: Proposed Tailings Storage Facility Area

Plate 11 Vegetation at Site 11

Soil surface: Weak surface crust, with approximately 20 % cryptogam cover and 5 % litter cover. Approximately 25 % cover of pisolitic gravel and coarse fragments 2 – 50 mm in size.

0 – 5 cm: Weak aggregates below weak surface crust. Approximately 25 % sub-angular and sub-rounded coarse fragments, 2 to 30 mm in size. Root growth classed as ‘common’.

10 – 20 cm: Weak to moderate strength polyhedral aggregates, 5 to 20 mm in size. Approximately 25 % sub-angular and sub-rounded coarse fragments, 2 to 40 mm in size. ‘Few’ roots.

Table 13 Soil physical and chemical characteristics for Site 11

.

Depth Interval (cm)	Soil Structure	Textural class	Root score[1.]	Soil pH (H_2O)	EC (dS/m)	Emerson Test Class[2.]	Gravel content (%)	% Organic Carbon	Available nutrients				
									Nitrate N (mg/kg)	Ammonium N (mg/kg)	Avail. P (mg/kg)	Avail. K (mg/kg)	Avail. S (mg/kg)
0-5	Weak aggregates	Light medium clay	2	7.4	0.25	3b	13.4	0.47	3	1	13	280	12.2
10-20	Weak aggregates	Medium clay	1	7.5	0.32	4-6	6.7	0.39	5	1	7	313	6

1. See Appendix F for root growth scoring categories.
2. See Appendix B for Emerson Test class categories.

3.1.12 Site 12

Site Details: Proposed Air Strip Area

Plate 12 Vegetation at Site 12

Soil surface: Weak surface crust, with approximately 25 % cryptogam cover and 5 % litter cover on soil surface. Approximately 50 % cover of quartz coarse fragments.

0 – 5 cm: Predominantly single grained, some weak aggregates. Approximately 20 % sub-angular coarse fragments, 5 to 50 mm in size. Root growth classed as ‘common’.

10 – 20 cm: Predominantly single grained. Approximately 10 % sub-angular coarse fragments, 2 to 25 mm in size. ‘Few’ roots.

Table 14 Soil physical and chemical characteristics for Site 12

Depth Interval (cm)	Soil Structure	Textural class	Root score[1.]	Soil pH (H_2O)	EC (dS/m)	Emerson Test Class[2.]	Gravel content (%)	% Organic Carbon	Available nutrients				
									Nitrate N (mg/kg)	Ammonium N (mg/kg)	Avail. P (mg/kg)	Avail. K (mg/kg)	Avail. S (mg/kg)
0-5	Predominantly single grained, some weak aggregates	Sandy loam	2	7.4	0.29	3b	14.8	0.31	1	1	6	144	6.8
10-20	Single grained	Sandy clay loam	1	7.6	0.58	2	5.5	0.39	1	1	6	168	14.2

1. See Appendix F for root growth scoring categories.
2. See Appendix B for Emerson Test class categories.

3.1.13 Site 13

Site Details: Proposed Tailings Storage Facility Area

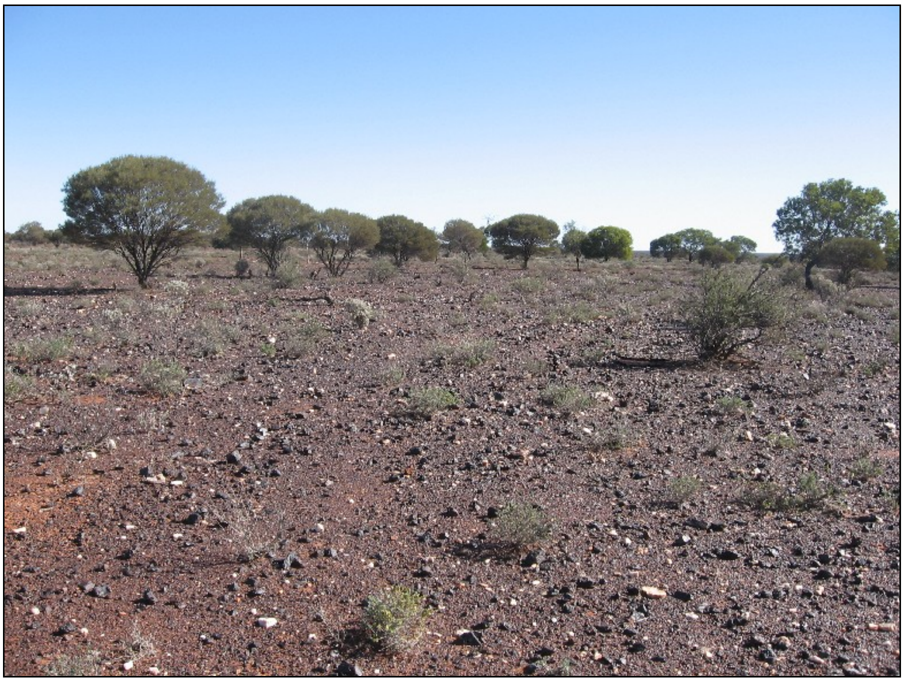

Plate 13 Vegetation at Site 13

Soil surface: Approximately 90 % coarse fragments, 2 – 75 mm in size.

0 – 5 cm: Predominantly single grained. Approximately 50 % sub-angular and sub-rounded coarse fragments, 2 to 30 mm in size. Root abundance classed as ‘few’.

10 – 20 cm: Predominantly single grained. Approximately 50 % sub-angular and sub-rounded coarse fragments, 2 to 50 mm in size. ‘Few’ roots.

Table 15 Soil physical and chemical characteristics for Site 13

Depth Interval (cm)	Soil Structure	Textural class	Root score[1.]	Soil pH (H_2O)	EC (dS/m)	Emerson Test Class[2.]	Gravel content (%)	% Organic Carbon	Available nutrients				
									Nitrate N (mg/kg)	Ammonium N (mg/kg)	Avail. P (mg/kg)	Avail. K (mg/kg)	Avail. S (mg/kg)
0-5	Predominantly single grained, some weak aggregates	Light clay	1	7.5	0.12	2	52.9	0.22	3	2	8	158	5.5
10-20	Predominantly single grained, some weak aggregates	Light clay	1	7	0.26	3a	42.4	0.3	8	3	4	75	10.4

1. See Appendix F for root growth scoring categories.
2. See Appendix B for Emerson Test class categories.

3.1.14 Site 14

Site Details: Proposed Tailings Storage Facility Area

Plate 14 Vegetation at Site 14

Soil surface: Variable cover of coarse fragments, ranging from 10 - 90 %, 2 – 150 mm in size. Approximately 10 – 20 % cryptogam cover, with 5 % litter cover.

0 – 5 cm: Predominantly single grained, some weak aggregates. Approximately 25 % sub-angular and sub-rounded coarse fragments, 2 to 20 mm in size. Root abundance classed as ‘few’.

10 – 20 cm: Single grained structure. Approximately 50 % sub-angular and sub-rounded coarse fragments, 2 to 40 mm in size. ‘Few’ roots.

Table 16 Soil physical and chemical characteristics for Site 14

.

Depth Interval (cm)	Soil Structure	Textural class	Root score[1.]	Soil pH (H_2O)	EC (dS/m)	Emerson Test Class[2.]	Gravel content (%)	% Organic Carbon	Available nutrients				
									Nitrate N (mg/kg)	Ammonium N (mg/kg)	Avail. P (mg/kg)	Avail. K (mg/kg)	Avail. S (mg/kg)
0-5	Predominantly single grained, some weak aggregates	Clayey sand	1	6.9	0.14	No aggregates	25.8	0.16	1	1	8	65	25
10-20	Predominantly single grained, some weak aggregates	Sandy loam	1	5.5	0.26	4-6	33.2	0.25	1	2	6	119	79.5

1. See Appendix F for root growth scoring categories.
2. See Appendix B for Emerson Test class categories.

3.2 Soil physical properties

3.2.1 Soil profile morphology

The surface soil profiles within the study area exhibited a large degree of variation in terms of morphological characteristics. Many subtle differences, such as soil aggregation and gravel content were present over relatively short distances. As this study was restricted to the upper soil horizons (0 – 20 cm), the physical and chemical properties, as well as any changes in morphological features of the soil profile below this depth are unknown.

Soil surface characteristics were variable, with the majority of sites dominated by a high percentage of coarse fragment cover (75 - 95 %), mostly consisting of pisolitic gravel. Sites 3 and 4 (within proposed orebody area) and Site 12 (air strip area) also had a high percentage of quartz fragment cover. Cryptogam cover was variable, ranging from 0 – 25 %, and was often associated with weak surface crusts. Site 5, located in a minor drainage line, exhibited a weak to moderate strength crust with no cryptogam cover and low coarse fragment cover. Litter cover was observed to be low (< 5 %) for all sites across the survey area.

3.2.2 Soil texture

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.

Field texture classifications indicated a range of soil textures throughout the survey area and within the individual soil profiles, ranging from clayey sands (approximately 5 - 10 % clay) to medium heavy clays (>50 % clay) (Appendix C). The majority of soil materials were classed as sandy loams (10 – 20 % clay) or sandy clay loams (20 – 30 % clay), with little correlation between soil texture and depth of sample. Most sandy loams were additionally classified as *fine* sandy loams on account of a very fine sand fraction. Heavier textured soils, classed between light clays and medium heavy clays, were found at Sites 9 and 10 (proposed plant area) and Site 11 (proposed TSF area).

The percentage of coarse material (> 2 mm) was also inconsistent with depth (Figure 2). The majority of samples had a percentage of coarse fragments (including gravels) classed as moderately abundant (20 – 50 %), to very abundant (50 – 90%) (McDonald *et al.* 1998). Samples from the low hill/slope and plant areas (Site 7 and Site 9) had the highest gravel content, while samples from the minor drainage line (Site 5), the air strip (Site 12) and one location within the proposed TSF area (Site 11) had the lowest.

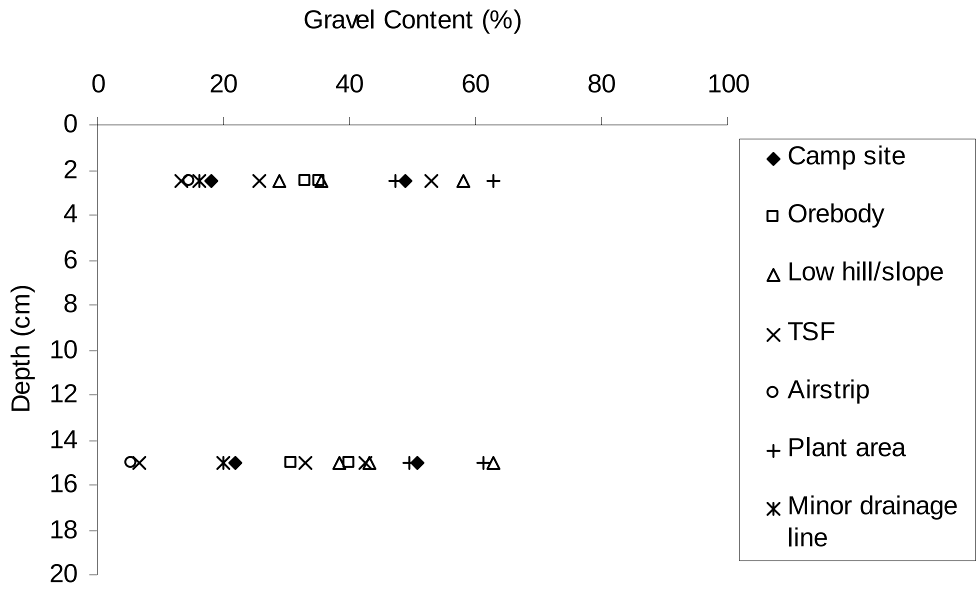

Figure 2 Gravel content (%) with corresponding depth for all samples from 14 sites across the survey area

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.

Soils within the Barrambie survey area, were observed to be predominantly single grained materials at most sites, often with weak polyhedral aggregates in the upper 0 – 5 cm horizon. Site 3, located within the proposed orebody area, was found to have strongly aggregated material in the upper horizon, grading into massive, structure-less material with depth.

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.

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 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 dispersive properties and therefore be the most problematic.

The Emerson test was only performed for samples from which aggregates were retrievable (Appendix C). A sufficient number of aggregates were found for the majority of samples with the exception of Site 5 and Site 8 (10 – 20 cm), and Site 14 (0 – 5 cm). Moderate to highly dispersive properties (Emerson Classes 2, 3a and 3b) were observed for Site 3 (orebody), Site 7 (low hill/slope), Site 9 and 10 (plant area), Site 11 and 13 (TSF area) and from Site 12 (air strip). Samples from Site 1, Site 10 and subsoil (10 – 20 cm) from Site 7 increased in dispersive behaviour over time, suggesting susceptibility to increased soil structure degradation under saturated, or waterlogged conditions. No samples were classed as very highly dispersive (Class 1).

Some of the soils exhibited dispersion upon re-moulding, indicating a potential to become dispersive and problematic following severe disturbance. Care should be taken to minimise the handling of soil materials where possible, particularly when wet, to avoid structural degradation which may impact upon the behavioural properties of these materials when used for rehabilitation.

3.2.5 Root growth

Root abundance was classed as ‘few’ at the majority of sites, and was generally dependant on proximity to plants. Higher root densities (classed as ‘common’) were observed at Sites 1 and 2 (camp site area) and Site 5 in the minor drainage line site. Generally, root abundance decreased rapidly with depth in most profiles. The full extent of root penetration and growth behaviour into the underlying soil / regolith profile, beyond the depth of the soil pits (20 cm), is unknown.

3.3 Soil chemical properties

3.3.1 Soil pH

The soil pH gives a measure of the soil acidity or alkalinity. The ideal pH range for plant growth of most agricultural species is considered to be between 5.0 and 7.5 (Moore 1998). Outside of 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, although many native species are known to be tolerant of wider ranges in soil pH.

Samples from the fourteen sites exhibited pH (H_2O) values that ranged between 5.2 and 7.6., (Figure 3). Sites 11, 12 and 13 (TSF and airstrip areas) had the highest pH (H_2O) values, classed as mildly alkaline, while Sites 1, 2, 4 and 6 (camp site, orebody and low hill/slope areas) had the lowest, classed as moderately to strongly acidic (Hazelton and Murphy 2007).

Some soils from the camp site, orebody and low hill/slope areas fell below pH 5 when measured in 1:5 $CaCl_2$ (Figure 4). 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.

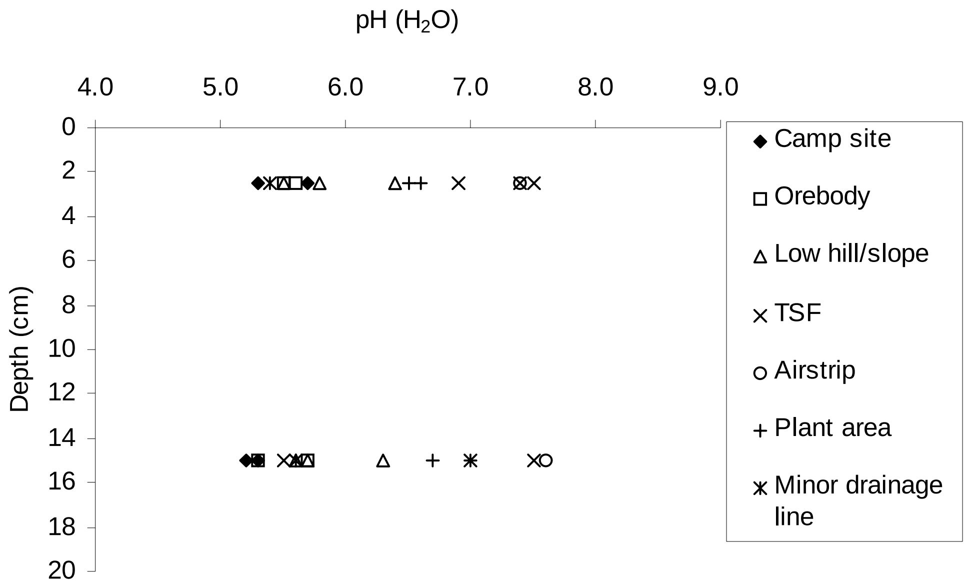

Figure 3 Soil pH (H_2O) with corresponding depth for all samples from 14 sites across the survey area

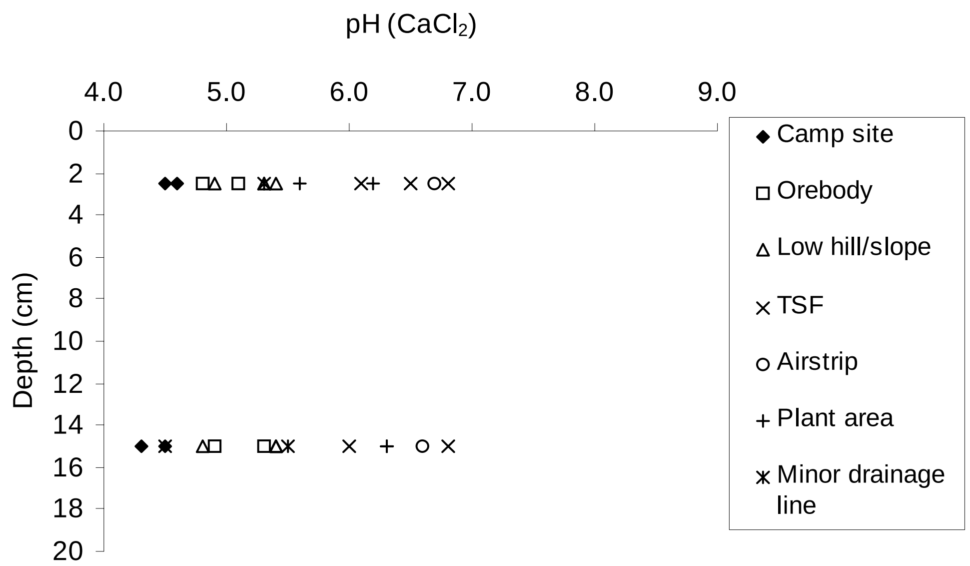

Figure 4 **Soil pH ($CaCl_2$) with corresponding depth for all samples from 14 sites across the survey area**

3.3.2 Electrical conductivity

The electrical conductivity (EC) of the majority of materials sampled throughout the survey area (Figure 5), is considered to be non-saline (0 – 0.2 dS/m) to slightly saline (0.2 – 0.5 dS/m), based on the standard USDA and CSIRO categories (Appendix E). Samples from Site 12 (air strip) were classed as moderately saline, while samples from Site 6 (low hill/slope) were classed as moderately to very saline. The highest salinities were found at Site 10 (proposed plant area), classed as very saline, and at Site 5 (minor drainage line), classed as extremely saline with EC values of 2.34 and 2.98 dS/m.

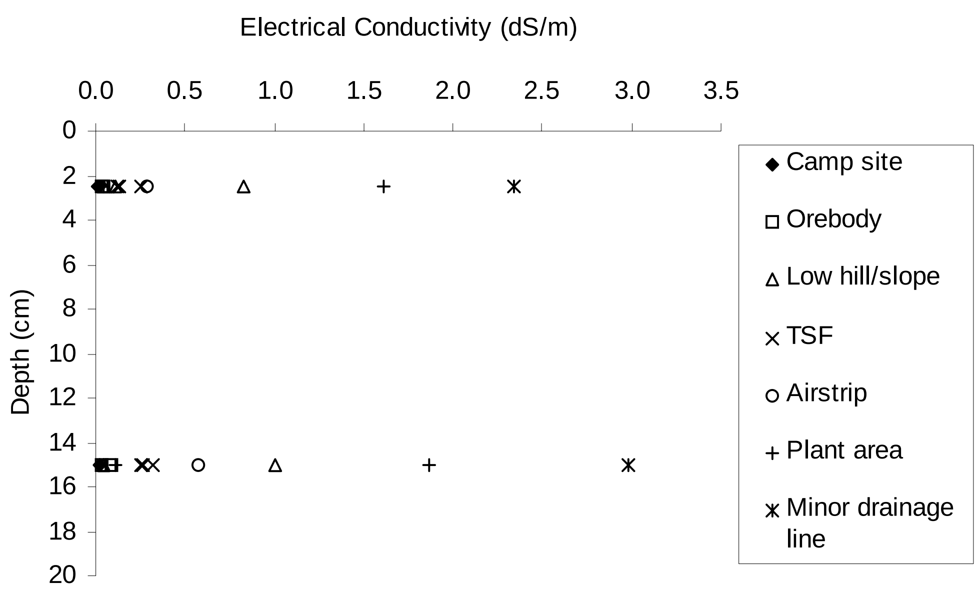

Figure 5 **Electrical conductivity (EC 1:5 H_2O) with corresponding depth for all samples from 14 sites across the survey area**

3.3.3 Soil organic matter

The amount of organic carbon within the majority of the soils sampled was low, as is the case in many natural Western Australian soils (Figure 6). Samples from many sites exhibited organic carbon percentages which are classed as extremely low (< 0.4 %) (Hazelton and Murphy 2007).

The organic matter content of a soil is an important factor influencing many physical, chemical and biological soil characteristics. Of particular relevance to rehabilitation activities is the ability of organic matter to bind soil particles together and improve soil structure. These levels of organic carbon are often associated with eroded or degraded surface soils of poor structure and structural stability, as well as subsoils.

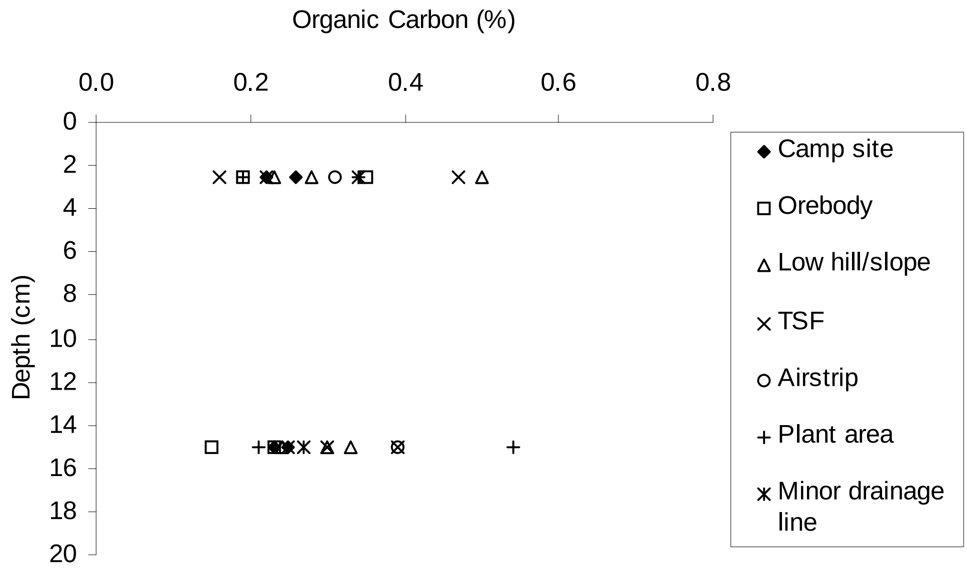

Figure 6 Soil organic carbon (%) with corresponding depth for all samples from 14 sites across the survey area.

3.3.4 Soil nutrients

The amount of nutrients held within the soils sampled were generally low, which is a characteristic typically associated with native soils. Plant available, or extractable forms of nutrients were tested for all samples. Nitrate levels (Figure 7) were highest in the low hill/slope areas (Sites 6 and 8) in both the upper 0 – 5 and lower 10 – 20 cm sample depths. Phosphorus levels (Figure 8) ranged between 3 and 19 mg/kg, and were generally highest in the upper 0 – 5 cm horizon. Potassium levels (Figure 9) ranged between 42 and 313 mg/kg, and were highest at Site 11 (proposed TSF area). Sulphur levels (Figure 10) were notably highest at Site 5, located within a minor drainage line, with values of 547 and 974 mg/kg of extractable sulphur. All other sulphur contents fell below 119 mg/kg.

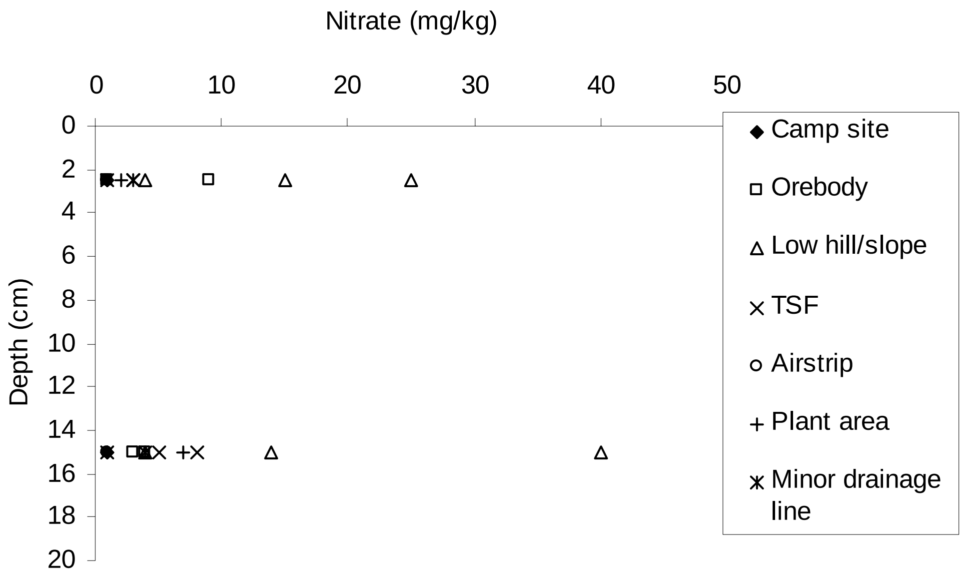

Figure 7 **Extractable nitrate (N) (mg/kg) with corresponding depth for all samples from 14 sites across the survey area**

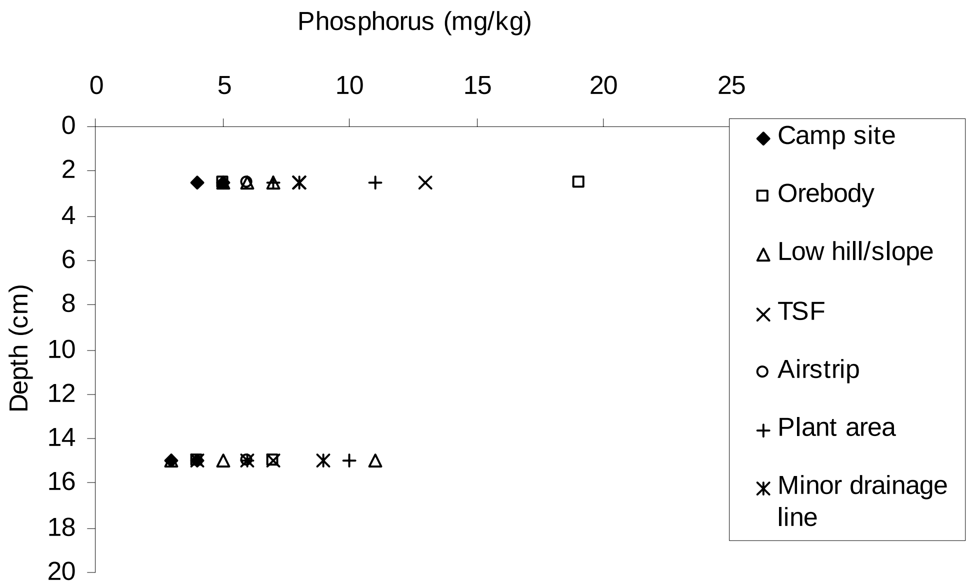

Figure 8 **Extractable phosphorus (P) (mg/kg) with corresponding depth for all samples from 14 sites across the survey area**

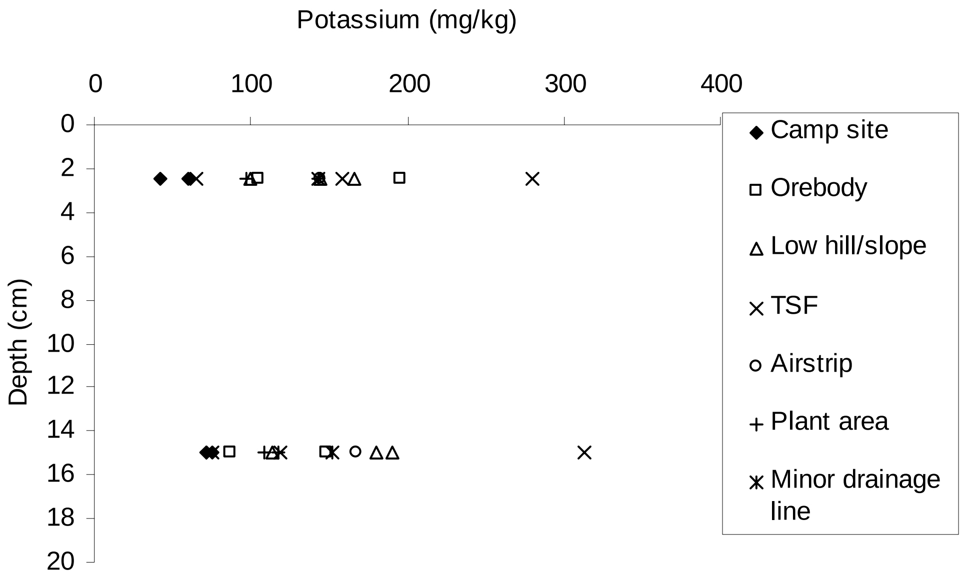

Figure 9 **Extractable potassium (K) (mg/kg) with corresponding depth for all samples from 14 sites across the survey area**

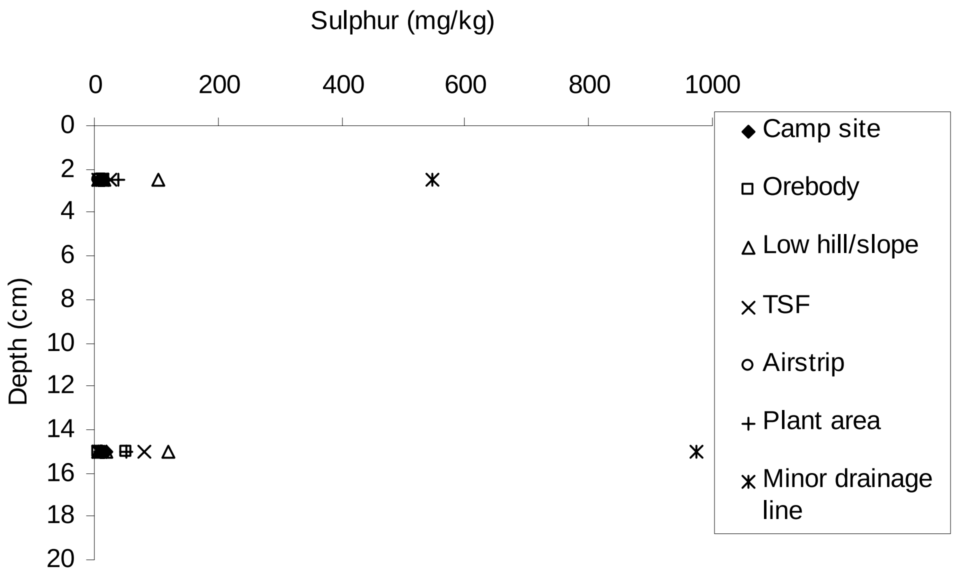

Figure 10 **Extractable sulphur (S) (mg/kg) with corresponding depth for all samples from 14 sites across the survey area**

4.0 CONCLUSIONS

From the investigations into soil profile characteristics at the fourteen sites within the study area, it is apparent that a significant degree of variation exists in soil profile morphology and properties, both within and between the areas sampled. As would be expected, the greatest variations in soil profile morphology appear to be between soils from contrasting positions within the landscape. Sampling sites at the proposed air strip, TSF, plant area and camp site locations were located in lower lying, flat areas. The low hill / slope and orebody sites were located on low foothills west of the major ridgelines.

4.1 Differences in soil properties between landform units

4.1.1 Physical properties

Soil surface characteristics mostly differed in terms of coarse fragment / gravel, surface crust and cryptogam cover. Surface coarse fragment cover was mostly pisolitic gravel, with exceptions being at the proposed orebody and airstrip sites which had quartz fragments present on the soil surface. The minor drainage line site had a stronger surface crust than sites at other locations, but low gravel coverage and no cryptogam cover.

Soil texture classifications ranged from clayey sands to medium heavy clays with little correlation to landform unit or depth within the soil profile. However, soils with heavier textures (higher clay contents) were generally identified at sites in the lower lying, flat areas. Gravel contents were variable, but were higher at sites located on low hill / slope areas and on the proposed plant area, and lowest at the proposed TSF and the minor drainage line sites.

Soil structure was predominantly single-grained with some weak aggregates found within the 0 – 5 cm horizon. One site located on the orebody area exhibited strong aggregates grading into massive, structure-less soil material with depth. Structural stability testing did not identify any highly dispersive properties at any locations, though moderately dispersive properties were observed for samples from a number of areas, including the lower lying and foothill / sloped areas.

Root growth was observed to be sparse and often decreased with depth. The extent of root abundance, or any restrictions to root growth below 20 cm is unknown.

4.1.2 Chemical properties

Soil pH values were mostly moderate to strongly acidic, with some mildly alkaline samples found in the lower lying, flat areas. The most strongly acidic soils were located at the proposed campsite, orebody and low hill /slope areas. Electrical conductivities were found to be predominantly non-saline to slightly saline, however moderately saline soils were found at the proposed airstrip and low hill / slope areas. Soils sampled from within the minor drainage line site were classed as extremely saline.

As would be expected soil organic matter content was extremely low overall. Some samples from the TSF, plant and low hill / slope areas had slightly higher organic carbon contents, but were still classed as very low. Nutrient contents varied, though were also very low overall. Of the individual nutrients, nitrate was highest in the low hill / slope areas,and available potassium was highest in samples from the flat, low lying TSF area. A particularly high available sulphur content was found at the minor drainage line site. There was little trend in available phosphorus between sites.

4.2 Surface soil properties related to future rehabilitation requirements

Soil management for future rehabilitation requirements is important to consider in terms of soil properties. The separate collection, stockpiling and re-application of both topsoil and subsoil materials is an important component to the successful rehabilitation of target vegetation communities. Differences in soil properties and profile characteristics between areas constituting different habitats or landforms, complicate the requirements for material handling and their potential use for rehabilitation.

It is likely that the separate collection and stockpiling of topsoil materials from across the areas proposed for mining will be required as areas are progressively disturbed. This would preserve the seed store, and the chemical, physical and biological attributes of the soil profiles on which the individual vegetation communities in these areas are located. Small variations in topsoil and soil profile properties identified from individual sites, are generally on too small a scale to be dealt with separately. There would inevitably be a degree of mixing of soil materials with differing properties from within individual areas.

Soils with different properties can behave differently once disturbed and brought to the surface during mining operations. For soils within the Barrambie survey area, physical properties such as gravel content, clay content and structural stability are likely to be the most important to consider if soil materials are to be used for specific purposes. The way in which these materials are likely to weather and develop over time should be taken into account when planning final landform designs.

For revegetation purposes, soils with high salinity may be limited in use as topsoil unless salt tolerant species are planted. Other chemical properties of the materials sampled, suggest that the local vegetation would be well adapted to high soil acidity and low soil fertility / nutrient availability, and that these properties could be considered less limiting.

4.3 Potentially problematic surface soil materials

Soil structure can be vulnerable to degradation, particularly when soils are disturbed. During the Emerson Test for soil structural stability, some susceptibility to structural decline over time and after disturbance was observed for some samples. Materials from the proposed camp site, proposed plant area and low hill / slope areas exhibited some dispersive properties which may be considered as potentially problematic for their use in rehabilitation requirements.

Other problematic materials include soil from within the minor drainage line, which was found to be extremely saline.

4.3.1 Further work

The rooting depth of vegetation and physical / chemical characteristics of deeper soil and regolith profile materials have only been partially evaluated, as soil pit excavation was limited to 20 cm depth. Further investigation of materials below this depth would be advantageous in understanding the properties and likely behaviour of deeper materials, and the extent of root growth throughout the profile. This information could be used to better inform future rehabilitation requirements and strategies.

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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.
Clay	The fraction of mineral soil finer than 0.002 mm (2 µm).
Coarse fragments	Particles greater than 2 mm in size.
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.
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 exhibited 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

Summary of methods of soil analyses used by Outback Ecology

1. Soil texturing

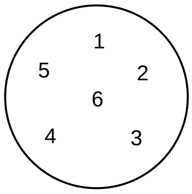
Soils were worked by hand, and the texture, shearing capacity, particle size and ribbon length were observed according to methods described in McDonald *et al.* (1998) as follows.

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 5mm	5%	LS
Clayey sand	Slight coherence; sticky when wet; many sand grains stick to fingers; discolours fingers with stain; forms minimal ribbon of 5-15mm	5-10%	CS
Sandy loam	Bolus coherent but very sandy to touch; dominant sand grains of medium size and readily visible ; ribbon of 15-25mm	10-20%	SL
Loam	Bolus coherent and rather spongy; no obvious sandiness or silkiness; forms ribbon of about 25mm	25%	L
Sandy clay loam	Strongly coherent bolus; sandy to touch; ribbon of 25-40mm	20-30%	SCL
Clay loam	Coherent plastic bolus, smooth to touch, ribbon of 25mm to 40mm	30-35%	CL
Clay loam, sandy	Coherent plastic bolus, sand grains visible in finer matrix, ribbon of 40-50mm; sandy to touch	30-35%	CLS
Light clay	Plastic bolus, smooth to touch; slight resistance to shearing; ribbon of 50-75mm	35-40%	LC
Light medium clay	Ribbon of about 75mm, 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 75mm or longer	45-55%	MC
Medium heavy clay	Ribbon of 75mm 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 75mm or longer	>50%	HC

2. 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.

Appendix C

Summary of Outback Ecology soil analysis results

Summary of Outback Ecology results for field texture, Emerson Test (slaking and dispersion), and gravel content. Shaded cells indicate samples with no aggregates sufficient for Emerson Test.

Site #	Depth (cm)	Emerson class (24 hour)	Field Texture	Gravel Content (%)
Site 1	0-5	4-6	F SL	49.0
	10-20	4-6	F SL	50.8
Site 2	0-5	3b	F SL	18.1
	10-20	4-6	F SL	21.8
Site 3	0-5	3b	SCL	33.0
	10-20	2	SCL	30.8
Site 4	0-5	4-6	SCL	35.2
	10-20	4-6	SCL	39.9
Site 5	0-5	4-6	SL	16.2
	10-20		SCL	20.0
Site 6	0-5	4-6	CL	35.5
	10-20	4-6	SCL	43.2
Site 7	0-5	3b	CL	58.2
	10-20	2	CL	62.7
Site 8	0-5	4-6	F SL	29.0
	10-20		F SL	38.5
Site 9	0-5	3b	LC	62.9
	10-20	3b	LMC	61.2
Site 10	0-5	2	MC	47.4
	10-20	2	MHC	49.6
Site 11	0-5	3b	LMC	13.4
	10-20	4-6	MC	6.7
Site 12	0-5	3b	SL	14.8
	10-20	2	SCL	5.5
Site 13	0-5	2	LC	52.9
	10-20	3a	LC	42.4
Site 14	0-5		CS	25.8
	10-20	4-6	SL	33.2

Appendix D

Summary of CSBP analyses

ANALYSIS REPORT

CSBP LIMITED ABN: 81 008 668 371

UNITS		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg	dS/m	pH	pH
SAMPLE_ID	COLOUR	NITRATE N	AMMONIUM	PHOSPHORUS	POTASSIUM	SULPHUR	ORGANIC CARBON	IRON	EC	PH_CACL2	PH_H2O
1 0-5	BROR	1	1	4	60	10.3	0.26	645	0.02	4.6	5.7
1 5-10	BROR	1	1	4	71	18.6	0.25	786	0.02	4.5	5.3
2 0-5	BROR	1	1	5	42	12.2	0.22	678	0.01	4.5	5.3
2 5-10	BROR	1	1	3	76	14.4	0.23	640	0.03	4.3	5.2
3 0-5	BROR	9	3	19	195	8.4	0.35	775	0.05	5.1	5.6
3 5-10	BROR	4	1	7	148	6.3	0.23	847	0.03	5.3	5.7
4 0-5	BROR	1	1	5	105	17.7	0.19	612	0.04	4.8	5.5
4 5-10	BROR	3	1	4	87	51.8	0.15	590	0.09	4.9	5.3
5 0-5	BRRD	3	9	8	143	547	0.34	784	2.34	5.3	5.4
5 5-10	BRRD	4	4	9	152	974	0.27	727	2.98	5.5	5.6
6 0-5	BROR	25	4	5	166	103	0.28	470	0.83	5.3	5.5
6 5-10	BROR	40	4	5	191	119	0.33	419	1.01	5.4	5.6
7 0-5	BR	4	1	7	145	5.2	0.5	628	0.12	5.4	6.4
7 5-10	BR	4	1	3	114	7.8	0.3	746	0.04	5.4	6.3
8 0-5	BROR	15	2	6	100	14.9	0.23	522	0.05	4.9	5.8
8 5-10	BROR	14	2	11	180	18.6	0.24	592	0.05	4.8	5.7
9 0-5	BROR	2	2	7	143	7.5	0.34	434	0.04	5.6	6.5
9 5-10	BROR	7	2	6	118	10	0.54	401	0.11	6.3	7
10 0-5	BROR	1	2	11	97	39.7	0.19	411	1.61	6.2	6.6
10 5-10	BROR	1	2	10	109	51.8	0.21	376	1.86	6.3	6.7
11 0-5	BROR	3	1	13	280	12.2	0.47	217	0.25	6.8	7.4
11 5-10	BROR	5	1	7	313	6	0.39	252	0.32	6.8	7.5
12 0-5	BROR	1	1	6	144	6.8	0.31	272	0.29	6.7	7.4
12 5-10	BROR	1	1	6	168	14.2	0.39	370	0.58	6.6	7.6
13 0-5	BROR	3	2	8	158	5.5	0.22	592	0.12	6.5	7.5
13 5-10	BROR	8	3	4	75	10.4	0.3	453	0.26	6	7
14 0-5	BROR	1	1	8	65	25	0.16	537	0.14	6.1	6.9
14 5-10	BROR	1	2	6	119	79.5	0.25	565	0.26	4.5	5.5

Appendix E

Soil Electrical Conductivity (EC) classes

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 / Med 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

Appendix F

Root scoring categories

Scoring of root abundance

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